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UNITED STATES DEPARTMENT OF THE INTERIOR

THE MOHAVE DESERT REGION CALIFORNIA

A GEOGRAPHIC, GEOLOGIC, AND HYDROLOGIC RECONNAISSANCE

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 578

UNITED STATES DEPARTMENT OF THE INTERIOR
Ray Lyman Wilbur, Secretary

GEOLOGICAL SURVEY
George Otis Smith, Director

Water-Supply Paper 578

THE MOHAVE DESERT REGION
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A GEOGRAPHIC, GEOLOGIC, AND HYDROLOGIC RECONNAISSANCE

BY

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PREFACE

By O. E. Meinzer

Among the duties of the United States Geological Survey are those of "determining the water supply of the United States, the investigation of underground currents and artesian wells, and the preparation of reports upon the best methods of utilizing the water resources." In the performance of this duty, the Geological Survey has investigated the water resources of 30 to 40 areas in the arid portion of the country. (See pl. 1.)

In addition to the usual appropriation for the investigation of water resources, on August 21, 1916, Congress passed an act authorizing the survey, marking, and protection of desert watering places, for which purpose the sum of $10,000 became available on July 1, 1917. With this money, supplemented by an allotment from the usual appropriation, four field parties were organized, and a survey was made during the year from July 1, 1917, to June 30, 1918, of about 60,000 square miles of the desert region in southeastern California and southwestern Arizona. Signs directing travelers to water were erected at 305 localities, 167 of them in California and 138 in Arizona. Maps were made in the field showing the location of the principal roads and watering places, and many samples of water were collected and analyzed in the water-resources laboratory of the Geological Survey. The maps, together with logs of the roads and brief notes on the watering places have been published as Water-Supply Papers 490–A to 490–D, Routes to desert watering places in California and Arizona.[1]

In connection with the survey of desert watering places a large amount of information was obtained in regard to the geography, geology, and hydrology of the region covered. This information, supplemented by data from other sources, has been used in the preparation of a series of four reconnaissance reports, each covering the part of the region studied by one of the survey parties. The large

[1] Brown, J. S., Routes to desert watering places in the Salton Sea region, Calif.: U. S. Geol. Survey Water-Supply Paper 490–A, pp. i–v, 1–86, pls. 1–7, 1920. Thompson, D. G., Routes to desert watering places in the Mohave Desert region, Calif.: U. S. Geol. Survey Water-Supply Paper 490–B, pp. i–vii, 1–4, 87–269, pls. 1–4, 8–18, 1921. Ross, C. P., Routes to desert watering places in the lower Gila region, Ariz.: U. S. Geol. Survey Water-Supply Paper 490–C, pp. i–iv, 1–4, 271–315, pls. 1–3, 19–22, 1922. Bryan, Kirk, Routes to desert watering places in the Papago country, Ariz.: U. S. Geol. Survey Water-Supply Paper 490–D, pp. i–vi, 1–4, 317–429, pls. 1–3, 16, 23–28, 1922.

size of the areas surveyed by each party and the requirements of the work of erecting signposts and collecting data for the guidebooks prevented the study of the regions in as detailed a manner as might be desired, but the reports contain a large amount of new and useful information on this little-known portion of the United States.

The present report on the Mohave Desert region, by David G. Thompson, is the last of these reports to be published.[2] It is based not only on the survey that was made in 1917 and 1918 but also on field work done in the region in 1919, 1920, and 1921. The report was completed by the author in May, 1924, but was not sent to the printer until 1928. The relief maps (pls. 9, 10, 11, 12, and 13) were printed in Water-Supply Paper 490–B in 1921, and have not been revised. Some information in regard to precipitation, stream discharge, water levels in wells, changes in roads, etc., in the period since the report was completed, has been added, but it has not been practicable to add information in regard to all recent developments in the region.

The Mohave Desert region has an area equal to the combined area of Massachusetts, Rhode Island, Connecticut, and New Jersey, but it would be difficult to conceive of two regions more strikingly different—one densely populated and teeming with industry, the other in large part virtually uninhabited. Almost equally striking, however, and in some respects of more practical importance is the contrast between this almost undeveloped desert region and the region just across the mountains to the west and southwest, including the valley of southern California and other valleys nearer the coast, with their exceedingly productive and valuable irrigated lands. As these better-watered valleys nearer Los Angeles have approached the limits of possible development, their enterprising inhabitants have looked more and more earnestly toward the Mohave Desert region and asked the question whether in its vast expanse, with its 50 desert valleys, each occupying a closed drainage basin of its own, there are not opportunities for making irrigation developments similar to those that have been so successful in the coastal region. Many attempts have already been made to develop irrigation districts in different parts of the region, in a few places with considerable success, as in Antelope Valley, but more commonly with complete failure. The interest in the possibilities of irrigation in this region is, however, unabated, and the United States Geological Survey is constantly

[2] The three reports previously published are Brown, J. S., The Salton Sea region, Calif., a geographic, geologic, and hydrologic reconnaissance, with a guide to desert watering places: U. S. Geol. Survey Water-Supply Paper 497, xv, 292 pp., 19 pls., 1923; Ross, C. P., The lower Gila region, Ariz., a geographic, geologic, and hydrologic reconnaissance, with a guide to desert watering places: U. S. Geol. Survey Water-Supply Paper 498, xiv, 237 pp., 23 pls., 1923; Bryan, Kirk, The Papago country, Ariz., a geographic, geologic, and hydrologic reconnaissance, with a guide to desert watering places: U. S. Geol. Survey Water-Supply Paper 499, xviii, 432 pp., 27 pls., 1925.

receiving inquiries in regard to the ground-water conditions of one locality or another in the region.

In spite of this interest in the Mohave Desert region only very inadequate information has been available in regard to its water supplies. Its vast extent and scarcity of inhabitants and watering places has made any comprehensive and thorough survey of its water resources a formidable undertaking. Though necessarily based on deficient information in many respects, the present report is a more comprehensive and accurate description of the region and contains a more critical and reliable discussion of its water resources than has hitherto been published.

THE MOHAVE DESERT REGION, CALIFORNIA

By David G. Thompson

Part I.—GENERAL FEATURES

INTRODUCTION

PURPOSE AND SCOPE OF REPORT

The Mohave Desert region, in southeastern California, is a part of the so-called "Great American Desert," a vast region that covers nearly one-sixth of the area of the United States. (See pl. 1.)

To most persons, until recent years, the word "desert" signified wide expanses of sand dunes, bare of vegetation or other living things. During the early history of the United States the Great American Desert was an unknown region that barred overland travel to the Pacific coast, which was reached at first only by circuitous voyages around South America. Although California was discovered near the middle of the sixteenth century, it was not until the first part of the nineteenth century that trappers penetrated the desert from the east, and it was not until the gold rush of 1848–49 that there was any extensive travel across the desert. At that time, spurred on by the lust for gold, about 40,000 persons braved the desert with its little-known perils to reach the western coast. Without sufficient equipment, unfamiliar with the geography of the region, and unaccustomed to the hardships encountered, scores of travelers perished from thirst and hunger. During that period the desert gained a reputation as a land of danger and of little value to man.

The completion of the first transcontinental railroad in 1869 was a notable step forward in the conquest of the desert. During the last half century untold mineral wealth has been removed from the mountains, and thousands of acres in the valleys have been made to produce valuable crops by irrigation or dry farming. With the advent of the automobile travel across the desert has lost many of its dangers, and an increasing multitude is discovering that the "desert" is not merely a vast waste of sand.

The reclamation of large areas of arid land by irrigation has proved a most interesting and noteworthy phase of the development of the western United States during the last few decades. The movement was given special impetus at the end of the World War by the proposal to settle the returning soldiers upon these desert lands. Colorful word pictures of the successful reclamation of some parts of the arid region have led many persons to believe that it is only a matter of time until the whole of the desert will be productive. Encouraged, perhaps by the belief that, because the Federal Government would give land at a small cost to anyone who complied with certain conditions, the land must therefore be valuable, some of them have applied for homesteads in the desert. Encouraged by visions of the valleys already successfully reclaimed, they have endured hardships and discomfort, but numerous deserted shacks and plots of cleared land showing a second growth of desert vegetation bear evidence that in many places only failure has resulted. In this arid region the one thing that is necessary above all for success is water.

At some of the abandoned places wells, many of them equipped with expensive pumps, show that water has been obtained, but the supply has proved too poor in quality or too small in quantity or too far below the surface to be profitably utilized. At other deserted shacks there are no wells. Many of the owners have laboriously hauled water several miles during the months they have waited for a crop raised by dry-farming methods or to see if a well being drilled by a neighbor proved successful. To a careful observer it becomes increasingly evident that, although thousands of acres can still be reclaimed, the quantity of water available from all sources is not sufficient to irrigate more than a small part of the desert. As the area that can be irrigated is restricted, it is only good economic policy to determine the regions that are most promising. If the favorable areas could have been separated from the unfavorable areas years ago, millions of dollars would have been saved to homesteaders.

The survey of the desert watering places in the Mohave Desert region was accomplished between September 1, 1917, and March 1, 1918. The party consisted of the writer and a nontechnical assistant and was equipped with a Ford automobile and camping outfit. During the work the party traveled all the main roads in the region, and some of them were covered twice. On the first trip detailed logs of the roads were compiled, maps were made showing the location of the roads and watering places, samples of water from wells and springs were collected and shipped to the laboratory of the Geological Survey for analysis, and many data were collected in regard to the watering places visited. The second trip was a rapid one, devoted principally to setting the signposts.

As the primary object of the work was to collect and prepare information that would aid travelers on the desert, the time that could be spent in scientific observations was not great. The study of geologic and hydrologic problems was necessarily secondary to the other work. However, as a natural result of the study of the watering places on the route of travel, the data obtained on the water resources are more complete than those in regard to the geology.

Subsequently the writer spent another season in the field, from October 20, 1919, to February 1, 1920. The work at that time was essentially confined to studies of the occurrence of ground water in several localities where there has been more or less development of the gound-water resources for irrigation. The parts of the regions thus studied were Mohave River valley from Hinkley eastward to Harvard on the north and Newberry Spring on the south; Crucero Valley, near the junction of the Los Angeles & Salt Lake Railroad [1] and the Tonopah & Tidewater Railroad, and Cronise Valley northwest of that place; Indian Wells Valley; and Antelope Valley. Several days were also spent in Antelope Valley in April and May, 1921, when additional data were collected.

In August, 1916, G. A. Waring, of the United States Geological Survey, made a brief study of the occurrence of ground water in the vicinity of Victorville, in Mohave River valley from Victorville to Daggett, in Superior Valley; and in Pahrump, Mesquite, and Ivanpah Valleys. A report was published which describes conditions in the three last-named valleys.[2] The data collected by Waring in the other valleys have been used in the preparation of this paper. In connection with an investigation on the utilization of Mohave River for irrigation near Victorville, the late C. E. Tait, of the Office of Public Roads and Rural Engineering, United States Department of Agriculture, collected data in regard to wells in that region.[3] With a fine spirit of cooperation Mr. Tait made these data available for the present report. A small part of the region shown on the south end of Plates 11 and 12 was surveyed by John S. Brown, of the Geological Survey, and the description of that area was prepared by him.

To present the wealth of information collected in this investigation without wearying one reader or another is a difficult task. To the average reader some parts may seem too technical; to the geologist or other scientific worker many pages may seem unnecessary. In preparing the report the writer has tried to bear in mind the interests of the different classes of readers who may use it—the prospector, the homesteader, the technical investigator, or the casual traveler who desires to learn more about his native land. The most attention, however, is devoted to the occurrence of ground water in the region.

[1] Since this report was written the Los Angeles & Salt Lake Railroad has become a part of the Union Pacific System, and it is now generally known by that name.

[2] Waring, G. A., Ground water in Pahrump, Mesquite, and Ivanpah Valleys, Nev. and Calif.: U. S. Geol. Survey Water-Supply Paper 450, pp. 51–81, pls. 7–11, 1920.

[3] McClure, W. F., Sourwine, G. A., and Tait, C. E., Report on the utilization of Mojave River for irrigation in Victor Valley, Calif.: California Dept. Eng. Bull. 5, 1918. Also published as appendix C in California Dept. Eng. Sixth Bienn. Rept., 1918.

ACKNOWLEDGMENTS

The data in this report have been gathered from many sources, and it is obviously impossible to mention individually everyone who had given information. The writer desires to express his obligations to the many postmasters, merchants, mine officials, ranchers, and prospectors who have given data of one sort or another. He is especially indebted to Mrs. A. Gilham, postmistress at Barstow during the period of his field work, and to the late Mr. E. T. Hillis, of the same town, and their associates for many favors and aid in various ways. Credit for special information is given in many places where such data are used.

The officials of the railroads that pass through the area—the Atchison, Topeka & Santa Fe, the Southern Pacific, the Los Angeles & Salt Lake, and the Tonopah & Tidewater—gave valuable information about sources of water supply along their lines and data in regard to alinements and altitudes at many points. The county surveyors of San Bernardino and Los Angeles Counties furnished data used in compiling the maps. The writer is under obligations to the officials of the Automobile Club of Southern California for cooperation in many ways, particularly for permission to use data from their copyrighted maps.

The work was done under the direction of O. E. Meinzer, of the United States Geological Survey, whose unfailing interest and helpful criticism of this report are greatly appreciated. The analyses of water samples were mostly made under the direction of W. D. Collins, chemist in charge of the division of quality of water of the Geological Survey, and the statements in regard to quality of water have been reviewed by him. The writer is also under special obligation to John S. Brown, Kirk Bryan, and Clyde P. Ross for suggestions and criticisms resulting from their work in the adjoining regions. A number of other members of the Geological Survey, who have done geologic work in one part or another of the region, especially L. F. Noble, G. R. Mansfield, and F. L. Hess, have furnished valuable data.

GEOGRAPHY

LOCATION AND EXTENT OF AREA

The area considered in this report lies in southeastern California and includes all of the desert portion of San Bernardino, Los Angeles, and Kern Counties, a narrow strip across the north side of Riverside County, and a somewhat wider strip of the southern part of Inyo County. (See index map, pl. 2.) A part of Clark County, Nev., is shown on the maps, but very little information is included about that region. In addition, nearly all of the better-watered part of

San Bernardino County and small portions of Riverside and Los Angeles Counties south of the San Bernardino and San Gabriel Mountains are shown on the large relief map. This region south of the mountains forms part of the famous citrus belt of southern California, and no data are given concerning it. The hydrology of this region has been described by Mendenhall.[4] Only main roads in this region are shown on Plate 10.

The total area shown on the maps is nearly 30,000 square miles, of which more than 25,000 square miles may be considered strictly desert country. It is worthy of note that San Bernardino County is the largest county in the United States. Its area is 20,157 square miles, of which about 18,500 square miles is desert. The next largest county is Coconino County, Ariz., which has an area of 18,623 square miles. This county also is mostly desert, although perhaps not as arid as most of San Bernardino County.

NAME OF THE REGION

The region that is described in this report is generally called the Mohave Desert. The exact origin of the name as a geographic term is obscure, but it doubtless was first applied to the region along Mohave River, first called "Mohave River" by Frémont in 1844. (See p. 12.) At that time most of the Mohave Indians lived along Colorado River near Needles, and it was for a long time supposed that the Mohave entered the Colorado near that place. In this way, probably, the name was eventually applied to a larger area. Apparently, however, the Mohave Indians never made their homes along Mohave River but lived near the Colorado.

At present some confusion exists as to just what is included by the Mohave Desert. Loew,[5] one of the earliest scientific workers in the region, referred to the Mohave Desert as "comprising southeastern California and the southwestern corner of Nevada." He also stated that "Lower California, although a portion of Mexico, belongs geographically to the Mohave Desert." He also included in the Mohave Desert certain areas that are not now commonly assigned to that region, as the Coahuila or Coachella Valley in the Salton Sea region, which is frequently known as the Colorado Desert,[6] and Death Valley and Salinas Valley (probably referring to Saline Valley

[4] Mendenhall, W. C., The hydrology of San Bernardino Valley, Calif.: U. S. Geol. Survey Water-Supply Paper 142, 124 pp., 12 pls., 1905; Ground waters and irrigation enterprises in the foothill belt, southern California: U. S. Geol. Survey Water-Supply Paper 219, 180 pp., 9 pls., 1908.

[5] Loew, Oscar, Report on the physical and agricultural features of southern California and especially of the Mohave Desert: U. S. Geol. Surveys W. 100th Mer. Ann. Rept. for 1876, Appendix H 6, pp. 216–218, 1876.

[6] Brown, J. S., The Salton Sea region, Calif., a geographic, geologic, and hydrologic reconnaissance, with a guide to desert watering places: U. S. Geol. Survey Water-Supply Paper 497, 1923.

shown on the Ballarat topographic map) on the north. Abrams[7] has defined the Mohave Desert a little more definitely as follows:

> The Mohave Desert extends from the eastern base of the Sierra Nevada eastward through the Death Valley region to the Virgin River valley, in the extreme southwestern part of Utah and the northwest corner of Arizona. To the southward it spreads out over the great barren wastes of the desert slopes of the San Bernardino Mountains and their eastern spur, the Chuckawalla Mountains.

Some authors have applied the term to a much more restricted area that is bounded approximately on the east by Mohave River between Barstow and Cajon Pass, on the north by mountains that lie north of the Atchison, Topeka & Santa Fe Railway between Barstow and Mojave,[8] and on the south and west by the San Gabriel and Tehachapi Mountains and the Sierra Nevada. The strictest definition is probably that of Baker,[9] as follows:

> The Mohave Desert region comprises the extreme southwestern portion of the Great Basin. It lies entirely within the State of California and includes within its limits portions of the four counties of San Bernardino, Inyo, Kern, and Los Angeles. Its boundaries on the northwest are the southern end of the Sierra Nevada Mountains and the Tehachapi Range; on the southwest are Sawmill Mountain, Liebre Mountain, the Sierra Pelon, with their southeastern continuation to the head of the Santa Clara River, and the San Gabriel Range; on the south are the San Bernardino Range and the Colorado Desert; on the southeast the natural boundary is the divide between the drainage tributary to the Gulf of California and the interior drainage of the Great Basin. The eastern and northern boundaries are difficult to fix, for there the Mohave Desert merges into the Great Basin proper with no marked drainage divides or high bounding ranges. The northwestwardly directed Piute Range, just inside the California border, may perhaps best be chosen as the eastern boundary, north of the divide of the Colorado River drainage. The northern limits of the Mohave Desert will be given as an east-west line connecting Castle, High, and Clarks Peaks, near the Nevada line, and running through Leach's Point and Burnt Rock Mountains to El Paso Peak, north of the mining camps of Randsburg and Johannesburg. That the eastern and northern boundaries as thus outlined are given not without a measure of reason is shown by the fact that they define the limits between the northern Great Basin region of markedly parallel mountain ranges and the southern Mohave Desert region of lower ranges without notable parallel arrangement.

Baker uses the term essentially to designate a physiographic province, and other authors use it more or less vaguely in the same way. To one not a physiographer, the boundaries of the region are not obvious, for the desert features which are most manifest within the region and which to the nontechnical observer apparently characterize it extend far to the north, east, and south, beyond the boundaries of

[7] Abrams, Leroy, The desert and desert floras of the west: Nature and Science on the Pacific Coast, published under auspices of Pacific Coast Committee of the American Association for the Advancement of Science, p. 172, 1915.

[8] By a decision of the United States Geographic Board, the Indian name applied to the desert and river in San Bernardino County is spelled Mohave. The name of the post office in Kern County is spelled Mojave.

[9] Baker, C. L., Notes on the later Cenozoic history of the Mohave Desert region in southeastern California: California Univ. Dept. Geology Bull., vol. 6, p. 335–336, 1911.

the physiographic province. The significance of the term has accordingly suffered by variation in popular usage, and it is doubtful whether this term should any longer be used to designate a physiographic province. It is desirable, however, to have a term by which the entire region described in this report can be designated. For convenience, therefore, the term "Mohave Desert region" is used as applying to the entire region shown on the large maps (pls. 9, 10, 11, 12, and 13) except the settled region south of the San Gabriel and San Bernardino Mountains. The term is used only in a general locational sense like such names as "southern California" and "the Southwest." Certain areas are thus included that have not previously been considered as being strictly part of the Mohave Desert—for instance, the southern part of Death Valley and the part of California that is drained by Colorado River.

The name "Mohave Desert" is occasionally applied to the northwestern part of Arizona. Doubtless this usage has come about because the region is a part of Mohave County. Although there is good reason for considering this the more correct use of the name, it has not been generally adopted.

In physiographic terms, according to present usage of the United States Geological Survey, the area here described lies mostly in the Sonoran Desert section of the Basin and Range province. That part north of latitude 35° 30′ is in the Nevada Basin section of this province.

RELIEF MAPS

The region considered in this report is shown on five relief maps. (See pls. 9, 10, 11, 12, and 13, in pocket.) The relative position of the areas shown on the different maps is indicated on Plate 2.

The relief maps were compiled from many sources. Topographic maps published by the United States Geological Survey were used so far as they were available, but necessary changes and additions in roads were made.[10] In areas for which such maps did not exist the principal roads were mapped in the field. A plane table was used, and locations were made either by triangulation or by a compass traverse. The mountain borders were also shown on these field maps.

For parts of the region that were not visited several sources of information were used in the compilation of the base map, such as maps prepared by the Automobile Club of Southern California, the county surveyor of San Bernardino County, the California Highway Commission, and the California State Mining Bureau. Use has been made of maps that accompany published and unpublished reports of the United States Geological Survey.

[10] An index map of California and Nevada, showing parts of the area considered in this report for which topographic maps have been published, may be obtained free from the Director, U. S. Geol. Survey, Washington, D. C.

The relief shading of the maps was done by John H. Renshawe, of the Geological Survey. Different degrees of shading have been used to indicate the relative altitude of different parts of the valley. In the flatter areas the darkest color represents the lowest elevation and lighter colors the higher elevations. The mountains are shown by shading as if seen under a strong light coming at a low angle from the northwest.

The details of topography and the accuracy of the relief shading necessarily differ from one part of the map to another, according to the information available. In regions that are covered by topographic maps the topography is shown in sufficient detail to permit the identification of many comparatively insignificant features. The mapping of the northeastern part of the area shown on Plate 11, including about half a degree of latitude and longitude, and of the part of the area shown on Plate 10 east of Victorville and near Barstow is based on incomplete topographic field sheets and is comparable in accuracy to mapping of parts of the area covered by published topographic maps. The topography for several miles on each side of the main line of the Atchison, Topeka & Santa Fe Railway is based on topographic maps published in a bulletin of the Geological Survey.[11]

In parts of the area that were mapped by the writer it was not possible to show the relief and other features in as great detail or as accurately as they would be shown on the topographic maps. However, the most prominent indentations in the border of the mountains, the location of the divides, the mountain passes where they are crossed by roads, and other features that should aid the traveler in locating himself were shown as accurately as possible. For some parts of the region, where topographic maps were lacking, the data were obtained from maps of the United States Geographical Surveys West of the One-Hundredth Meridian, published between 1875 and 1880. For other parts recent township plats of the General Land Office give a fair idea of the relief, but for still other parts only the old township plats were available, and these indicated only the mountain boundaries, and some of them not even that much. Altitudes have been obtained from railroad profiles and from barometric readings from a number of sources. The altitudes given on the maps at railroad stations in parts of the region not covered by topographic maps were taken from railroad profiles. A primary level line has been run by the Coast and Geodetic Survey along the Atchison, Topeka & Santa Fe Railway from San Bernardino to Barstow, thence eastward to Goffs, northward along the Searchlight branch to Ivanpah, and northeastward along the Los Angeles & Salt Lake Railroad. The altitudes at stations on this stretch of the Santa Fe as given on the map generally

[11] Darton, N. H., and others, Guidebook of the western United States, Part C, The Santa Fe Route: U. S. Geol. Survey Bull. 613, 1916.

differ by a few feet from the altitudes of bench marks established by the Coast and Geodetic Survey.

Previously published maps of the region have been very much more generalized, both as to the course of the roads and as to the character of the physical features. Many of the recent maps of the area that have been published by private companies or official organizations have been compiled, in part at least, from older maps, and certain errors existing on the older maps have persisted in the newer ones. A number of these inaccuracies have been corrected in the maps that accompany this paper.

Township lines are shown upon the maps, but they may not be located correctly with respect to springs, railroad stations, and other definite geographic points, because very few land corners were found that would permit the land net to be properly tied to points shown on the base map. Most of the townships were surveyed more than 60 years ago. Recent resurveys by the General Land Office in certain parts of the area show that in places great differences exist between the supposed location and the true location of township lines. For example, north of Goffs (pls. 12 and 13), original township corners have been found almost 3 miles from the points where they were supposed to be.[11a] There is reason to believe that great errors in the original land surveys exist in other parts of the area.

HISTORICAL SKETCH

JOURNEYS OF GARCÉS, 1776

The history of the Mohave Desert region is to be gathered piecemeal from the reports of early explorations and tales by travelers and others who have recorded events of their times. The region apparently was situated between the main routes of travel from east to west, for the pioneer records do not seem to be as abundant for this region as for those to the north and south.

The first white man to enter the Mohave Desert region of whom we have any record was a Spanish priest, Padre Fray Francisco Garcés, who came to America from Spain in 1768 and spent the rest of his life among the Indians of the Southwest.[12] After having been some time among the Indians on the lower Colorado and Gila Rivers, on February 14, 1776, he started north from Yuma to visit the "Jamajabs," or the Mohave Indians, as they are now known.[13] He

[11a], On Plate 12 the northern of the two rows of range numbers just south of latitude 35° should be Rs. 15 to 18 E., and on Plate 13 the corresponding row should be Rs. 19 to 22 E.

[12] Bancroft, H. H., History of California, vol. 1, p. 275, San Francisco, A. L. Bancroft & Co., 1884.

[13] Garcés's diary of his journey across the Mohave Desert is given by Elliott Coues, On the trail of a Spanish pioneer, the diary and itinerary of Francisco Garcés, vol. 1, pp. 213–247, 304–308, New York, Francis P. Harper, 1900.

went alone except for two interpreters. From Yuma he went up the California side of Colorado River. He passed through the territory occupied by the Chemebets Indians, now known as the Chemehuevis, and arrived in the territory of the Mohaves in the vicinity of the present town of Needles on February 28. Garcés was not the first white man to travel up Colorado River, for it had been discovered by Hernando de Alarcón in 1540, more than 200 years previously, and Alarcón is supposed to have ascended it for 85 leagues from its mouth. There is doubt, however, that he went as far north as the Mohave territory, and Garcés was probably the first Spaniard to visit this territory. He was received with great acclaim, for although the Mohaves doubtless had met Spaniards outside of their own territory, no white man had previously entered it.

On March 1, 1776, accompanied by several Mohaves and one of his interpreters, Garcés set out from the Mohave villages westward across the desert to go to the San Gabriel Mission, near the present city of Los Angeles. By following the landmarks mentioned in his diary, it seems probable that he went by way of Piute Spring to a pass in the New York-Providence Range and crossed that range near Cedar Canyon. He continued westward, probably across the south end of Soda Lake, until he reached "an arroyo of saltish water" which he called "Arroyo de los Martires." This was the lower end of Mohave River, which was then seen for the first time by a white man. He continued up the river nearly to its head and crossed the San Bernardino Mountains on March 22. He found several "rancherías" of Indians along the river. At one place, probably between the present towns of Victorville and Barstow, he met several Mohave Indians who were returning from trading at the San Gabriel Mission. He arrived safely at San Gabriel Mission and spent some days there.

On leaving San Gabriel Mission Garcés traveled northward into San Joaquin Valley, where he visited other Indian tribes until early in May. On May 11 he ascended the Sierra Nevada or Tehachapi Mountains, probably near Tehachapi Pass, and proceeded eastward across the desert. He followed his former course along Mohave River, but east of Soda Lake probably went a little north of the path of his first journey. He arrived safely again at the Mohave villages on May 30. On his going and returning trip across the Mohave Desert he had traveled in 41 days a total of nearly 500 miles, a distance that now can be covered in about half as many hours. Garcés's journey was remarkable not only because he was the first white man to penetrate the unknown desert but also because he made it with no equipment such as the later explorers had, for he depended entirely upon the hospitality of the Indians.

EARLY AMERICAN EXPLORERS, 1826–1848

The next white man of whom we have any record as crossing the Mohave Desert region is Jedediah S. Smith, a famous American trapper, who was born in New York State. Smith, with a party of 15 men, left Great Salt Lake on August 22, 1826, to explore the country southwest of that place, probably to determine the feasibility of extending the fur trade of his company into that region.[14] He traveled almost due south but a little to the west, until he reached Virgin River, which he followed to Colorado River. He proceeded down the Colorado to the villages of the Mohave Indians, who, he states, called themselves "Ammuchabas." After obtaining supplies and the services of Indian guides he traveled for 15 days across the desert to the coast. He probably followed the same route that Garcés had taken to the San Gabriel Mission. On leaving southern California he traveled northward through San Joaquin Valley until he was due east of San Francisco Bay and then went eastward across the Sierra Nevada and the desert to Great Salt Lake, which he reached in July, 1827. Smith was probably the first American to cross the continent by the southern and the central routes. Lewis and Clark had reached the coast by a northern route 20 years earlier.

Almost immediately after his return to Great Salt Lake Smith started on another trip to join some of his party whom he had left in San Joaquin Valley. He followed the route he had taken on his first journey and arrived at the Mohave villages in August.[15] The Mohaves seemed as friendly as usual, but as his party of 19 men was ferrying across Colorado River on a raft the Indians attacked them and killed 10. He was then obliged to hasten across the desert to the Spanish settlements near San Gabriel. He made the journey this time in nine and one-half days.

In 1829 another party of trappers, headed by Capt. Erving Young and including Kit Carson, who later crossed the desert with Frémont, traveled from Santa Fe, N. Mex., to Colorado River near the Mohave villages and thence to San Gabriel Mission, probably by way of Mohave River.[16] A few months later, on the return trip to New Mexico, hastening to escape imprisonment by the Mexicans, the party traveled from Los Angeles to the Mohave villages in nine days.[17]

There is almost no record of other travelers passing through the Mohave Desert region until J. C. Frémont crossed it on his second expedition in the spring of 1844. Frémont's party had spent a year in exploration in Oregon and northern California and on their home-

[14] Dale, H. C., The Ashley-Smith explorations and the discovery of a central route to the Pacific, 1822–1829, pp. 186–190, Cleveland, Arthur H. Clark Co., 1918.

[15] Dale, H. C., op. cit., pp. 229–231.

[16] Sabin, E. L., Kit Carson days, p. 52, A. C. McClurg & Co., 1914.

[17] Idem, pp. 60–61.

ward journey had traveled from the vicinity of the present city of Sacramento southward in San Joaquin Valley. On April 14, 1844, the party crossed the mountains into the desert,[18] probably at Tehachapi Pass or through Cottonwood Canyon. They moved southward along the foot of the Tehachapi Range and then eastward along the foot of the San Gabriel Mountains until they struck a road a few miles north of Cajon Pass, which was known as the Spanish Trail.

This trail apparently had been used for some years prior to Frémont's journey, but there is practically no record of the travelers. Farnham [19] records a journey by a Doctor Lyman in 1841 from Santa Fe, N. Mex., to California by way of Colorado River, Las Vegas, and Mohave River. He writes:

> By striking off in a westerly direction from a point about one day's march from its [Colorado River] debouncher into the California Gulf, he [Doctor Lyman] arrived at a river of excellent water called the Amajaves. The source of this stream is in the marine range of the California Mountains immediately east of the Pueblo de los Angeles, at a place called the Cajon.

In regard to the Spanish Trail, Frémont [20] states:

> We had struck the great object of our search—the Spanish Trail. * * * Although in California we had met with people who had passed over this trail, we had been able to obtain no correct information about it. * * * We were now careful to take the old camping places of the annual Santa Fe caravans, which, luckily for us, had not yet made their yearly passage. A drove of several thousand horses and mules would entirely have swept away the scanty grass at the watering places.

The Spanish Trail led in a general northeasterly direction across the present San Bernardino County, Calif., to what is now Las Vegas, Nev.; thence, according to an old map of Utah,[21] northeastward and eastward across the south end of Utah, and crossed Colorado River about halfway between the junctions of Green and San Juan Rivers with that stream.

The Spanish Trail led for many miles along Mohave River, which was first given that name by Frémont, who, however, spelled it "Mohahve." [22] The reason why he gave it this name is not entirely clear, for according to the tales of early explorers the Indians who lived along the river were not Mohaves but tribes unfriendly to them. Possibly it was because he met some Mohaves who told him that members of their tribe once lived along the river. Frémont states that the river was also called Rio de las Animas.[23]

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[18] Frémont, J. C., Report of the exploring expedition to the Rocky Mountains and to Oregon and California, 1st ed., pp. 257–265, Washington, 1845.

[19] Farnham, T. J., Life and adventures in California, pp. 312–318, New York, W. H. Graham, 1846.

[20] Frémont, J. C., op. cit., p. 259.

[21] Froiseth's new sectional and mineral map of Salt Lake City, Utah, 1871.

[22] It will be noted above that Farnham, in describing the journey of Doctor Lyman, refers to "Amajaves River," which is evidently a name equivalent to Mohave.

[23] Frémont, J. C., op. cit., p. 260.

At one of the camps on the river two Mexicans arrived with a harrowing tale of the murder of their companions by Indians. One of the Mexicans, with two of Frémont's party, including the famous Kit Carson, pursued the Indians for many miles and avenged the murder of the white men by killing two of the Indians. The expedition turned northeast, away from the river, probably a few miles east of the present town of Yermo, and continued northeastward to a spring called Agua de Tomaso. This spring is shown on several maps, but no watering place in the region is now known by this name. It is probably the spring now called Bitter Spring. (See p. 546.) The party stopped at springs along Amargosa River, probably those now called Salt Springs. At that early date the Amargosa (Spanish for bitter) was known by its present name. From Salt Springs the party proceeded to Resting Springs.[24] The murder of the Mexicans had occurred at these springs, and Frémont named the place Agua de Hernandez after one of the victims. The party proceeded thence to the place now called Stump Spring in Pahrump Valley and on to Las Vegas and thence to Great Salt Lake.

Frémont's expedition was notable not only because he added considerable to the geographic knowledge of the region but also because he collected numerous botanic and geologic specimens. The botanic specimens, which were studied by Dr. John Torrey, contained a number of new species.

Frémont carried back to the Eastern States much information about the Pacific region, and after his expedition through the Mohave Desert travel in that region increased. In 1846 a troop of Mormons who had enlisted to aid the United States against Mexico, forming what was known as the Mormon battalion, marched from Santa Fe to California by way of Yuma. When this battalion was disbanded in 1847, about 25 members of it proceeded from southern California to Salt Lake City across the Mohave Desert. It is said that these men took with them the first wagon that ever went over the Salt Lake Trail.[25]

THE DEATH VALLEY PARTY, 1849

Gold was discovered in northern California in January, 1848, but official word of the discovery did not reach the Atlantic States until the fall of that year. By the spring of 1849 the rush to the gold fields was well along. The fields could be reached from the East by several routes. These routes were by boat, either around Cape Horn, or with a short land journey across the Isthmus of Panama; by land to Salt Lake City, thence westward to Sacramento and San Francisco; by the same route to Salt Lake City and thence southwestward to Los Angeles and northward to San Francisco by land or boat; and by a

[24] Dellenbaugh, F. S., Frémont and '49, p. 252, New York, G. P. Putnam's Sons. 1914.

[25] Roberts, B. H., The Mormon battalion, p. 73, Deseret News, 1919.

southern route by way of Santa Fe and thence to southern California by two or three different routes, the most traveled of which was by way of Yuma. The northern route was probably most used because it was the most direct route from the East. The southern route was used mostly by persons going from Mexico and the Southern States. The route from Salt Lake City to Los Angeles was not advantageous to the gold seekers, for it took them out of their way and made a hard journey over the desert. It did, however, have one advantage in that it was open throughout the winter, when the northern route was closed by deep snow in the Sierra Nevada.

Many of the gold seekers arrived at Great Salt Lake too late in the summer of 1849 to make the passage over the Sierra Nevada on the northern route, and they feared that the provisions at hand were not sufficient to carry them through the winter. They decided to take the route across the desert to southern California and thence to go north to the gold fields. Capt. Jefferson Hunt, who had made the journey before, was engaged to guide them along the old Spanish Trail, which never before had been traveled by wagons, except by the Mormon battalion in 1846. The harrowing experiences that befell some of the members of this party are told by W. L. Manley, one of the travelers, on whose story [26] the following account is based.

Some distance from Great Salt Lake the train under Captain Hunt was joined by another train. The members of this party had a map on which was shown a short-cut route across the desert and the Sierra Nevada. Although Captain Hunt was certain no such route existed, many of the party were in favor of taking it. After much discussion all but 7 of the 107 wagons started westward. Captain Hunt proceeded with the smaller group along the regular trail.

Several days' journey from the point of separation the party on the supposed short cut came to a canyon impassable for the wagons. After several days' search for a feasible pass most of the party turned back to the trail followed by Captain Hunt. But before all had started back a pass was found, and 27 wagons continued westward. The travel became more difficult, and forage for the oxen and horses and water for all became scarcer. Eventually the party broke into smaller groups, each shifting for themselves. Some of the unmarried men, known as the Jayhawkers, started on ahead, leaving the men with families to get along as best they could. Manley traveled with two families by the names of Bennett and Arcane. After days of hardship, which were mild, however, compared to those that followed, the party descended into a long, narrow valley, bordered on the west by a mountain range so high and so steep that, in Manley's words, "nothing could climb it on its eastern side except a bird." The lower part of the valley was covered with immense blocks of rock salt, clear

[26] Manley, W. L., Death Valley in '49, San Jose, Pacific Tree & Vine Co., 1894.

as ice, between which was water that was a strong brine. One of the Jayhawkers described the valley as "the Creator's dumping place where He had left the worthless dregs after making a world, and the devil had scraped these together a little." [27] This was the now famous Valley of Death, as it was named by these emigrants after their harrowing experiences. The valley was probably visited by white people for the first time when the Jayhawkers entered in December, 1849. Evidences of Indian camps on the border of the valley showed that the valley had not been unknown to the Indians.

The several parties had by this time separated, each looking after its own interests, but all of them probably entered the valley by way of Furnace Creek Wash. The Jayhawkers turned northward from that place, seeking a pass which they had seen from a distance. It is likely that they left the valley through Emigrant Pass. Apparently, according to Manley's description, they crossed Panamint Dry Lake and went along the west side of Searles Lake.

The party that included Manley and the Bennett and Arcane families turned southward from Furnace Creek and finally found a good watering place, which is quite likely that now known as Bennetts Wells. It was decided that the party should remain there while Manley and another man should go ahead to locate watering places and try to obtain help at Los Angeles.

The two men apparently crossed the Panamint Range westward through one of the canyons that led across the higher part of the mountains some distance north of Wingate Pass. They seem not to have found that pass but to have gone near the south end of Panamint Dry Lake, climbed over the Slate Range, and then traveled along the north side of Searles Lake and thence across the Argus Range. They continued southwestward across what is now called Indian Wells Valley to Freeman Canyon, the entrance to Walker Pass, and thence to Red Rock Canyon and down it to springs at the south end of Fremont Dry Lake (probably Cane Springs). On this part of the route they caught up with the Jayhawkers, who, like themselves, had suffered greatly on their journey across the dry stretch of Indian Wells Valley. Two of them had died from thirst since leaving Death Valley. From the springs in Fremont Valley Manley and his companion continued on another almost unendurable dry stretch southward to Antelope Valley and to Soledad Pass, where they traveled down the valley now followed by the Southern Pacific Railroad until they came to a Mexican ranch house. There they obtained a supply of food, two horses, and a mule and turned back to bring help to the party that was left in Death Valley, which they found without mishap. The horses had to be abandoned before the camp in Death Valley was reached, so that for the hazardous journey there

[27] Manley, W. L., op. cit., p. 141.

were left for burden bearers only the mule and the oxen brought from the East. The Arcane and Bennett children were placed on the oxen, or the smaller ones at times carried in their fathers' arms. The women walked. Unaccustomed to such toil, with the added agony of thirst, they suffered untold hardships. At times it seemed as if they must die, but finally they reached the well-watered lands south of the San Gabriel Mountains. Most of the Jayhawkers had arrived previously, but several of them died before they reached the edge of the desert.

As a matter of fact, the travelers, at least Manley's party, seem not to have suffered as much in Death Valley as they did after leaving the valley, particularly on the dry stretches in Indian Wells Valley and from the springs in Fremont Valley southward across Antelope Valley. As one looks at the present-day map of the Mohave Desert region, which shows numerous springs, he may wonder why the travelers did not seek and follow an easier route on which they would have encountered less difficulties. Had they but known it, when they began the descent of Furnace Creek Wash to Death Valley the travelers were not more than 50 miles from the Spanish Trail at Resting Springs, or the Archillete, as it was called by Frémont. They doubtless could have followed this route with little difficulty. It would seem that even from Death Valley they might have found an easier route than they did, but it must be remembered that at the time of their journey the country they traveled was entirely unmapped. They left one watering place not knowing where they would next find water. Many of the springs now shown on maps, to say nothing of the wells, have been found or developed only after the territory had been carefully explored by prospectors. Some of the wells have been dug where only a bit of salt grass or other evidence known only to the experienced prospector has shown the presence of water. To-day, even if the breakdown of his automobile forces the traveler to walk for a long distance, with the location of the water holes known, it is difficult to realize how truly remarkable was the journey of the emigrants across Death Valley and the adjoining desert in 1849.

In contrast to the story of the Death Valley party, and equally fascinating, is that of two modern travelers.[28] One need only read this story of a journey of two women through Death Valley and other parts of the Mohave Desert region to realize that desert travel still involves some danger, but the compensation therefor is ample.

EXPLORATIONS AND SETTLEMENT SINCE 1850

In 1851 a party of Mormons traveled from Salt Lake City across the Mohave Desert region and founded a colony at San Bernardino.

[28] Perkins, E. B., The white heart of Mojave, 229 pp., 1 sketch map, illustrations, Boni & Liveright, 1922.

Thereafter travel along the Salt Lake trail became more frequent, and mail was carried between Salt Lake City and southern California at regular intervals. Tales of journeys along this route by Remy [29] and Chandless [30] throw some light on the travel across the desert at this time.

In the fall of 1852 Capt. L. Sitgreaves,[31] of the Corps of Topographical Engineers of the United States Army, conducted an exploring expedition from the pueblo of Zuñi, in New Mexico, to Colorado River near Needles and thence down the river to Yuma, Ariz. This expedition traveled only along the eastern edge of the Mohave Desert region, and except for descriptions of some plants and animals, the report of it yields little of interest in regard to the region.

In the fall of 1853 a party under Lieut. R. S. Williamson,[32] under orders of the War Department to seek a southern railroad route between Mississippi River and the Pacific Ocean, explored several passes between San Joaquin Valley and the desert and then skirted the north slope of the San Gabriel Range to Mohave River. Thence a part of the expedition proceeded down the river to Soda Lake and northward to the Salt Lake road about 5 miles north of Silver Lake.

In the spring of the following year another party in charge of Lieut. A. W. Whipple [33] passed through the region from Colorado River near Needles to San Bernardino. This expedition also was sent out by the War Department to locate a route for a railroad from Mississippi River to the Pacific Ocean. The route followed was practically that of Garcés in 1776, which crossed the Providence-New York Range in the vicinity of the Mid Hills, thence descended to Soda Lake, and followed Mohave River to Cajon Pass. This route was followed probably because Whipple had Mohave Indians for guides, as did Garcés. It is shorter than the route now followed by the Atchison, Topeka & Santa Fe Railway and the National Old Trails Road, and at that time, when the water supplies were still

[29] Remy, Jules, A journey to Great Salt Lake City, London, W. Jeffs, 1861. (On pp. 416–454 is given a description of the journey from Las Vegas, Nev., to San Bernardino, Calif., in 1855.)

[30] Chandless, William, A visit to Salt Lake, London, 1857.

[31] Sitgreaves, L., Report of an expedition down the Zuñi and Colorado Rivers, S. Ex. Doc. 593, 32d Cong., 2d sess., 1853.

[32] Williamson, R. S., and others, Report of explorations in California for railroad routes to connect with the routes near the thirty-fifth and thirty-second parallels of north latitude: U. S. Pacific R. R. Expl., vol. 5, 1855.

[33] Whipple, A. W., Report of explorations for a railway route near the thirty-fifth parallel of north latitude: U. S. Pacific R. R. Expl., vols. 3 and 4, 1856. (The following pages deal with the Mohave Desert region: Part I (vol. 3), Itinerary, pp. 105–136. Part II (vol. 3), Report on the topographical features and character of the country, pp. 39–45. Part III (vol. 3), Report upon the Indian tribes, by Lieut. A. W., Whipple, Thomas Eubank, and W. W. Turner. Numerous scattered references. Part IV (vol. 3), (1), General report upon the geological collections by W. P. Blake, pp. 51–56 and other pages; (2), Résumé and field notes, by Jules Marcou, pp. 161–164. Part V (vol. 4), Report on the botany of the expedition, by J. M. Bigelow and others, pp. 13–16 and other numerous references under description of species. Part VI (vol. 4), Report on the zoology of the expedition, by C. B. R. Kennerly, p. 8 and numerous scattered references. Additional information in regard to the expedition is given by Baldwin Moelhausen in Diary of a journey from the Mississippi to the coasts of the Pacific with a United States Government expedition, translated by Mrs. Percy Sennett, London, Longman, Brown, Green, Longman & Bros., 1858.)

undeveloped, it afforded the best watering places. Under present conditions of travel, with other water supplies developed, Whipple's route is a very difficult one to travel, for the valley on both sides of Soda Lake ("a dry lake") is very sandy and practically impassable for automobiles.

Williamson's trip down Mohave River to Soda Lake and thence north beyond Silver Lake to the Salt Lake road was significant because he proved definitely that Mohave River ended at Soda Lake. Before his trip it was generally supposed that Mohave River was a tributary of Colorado River, although no exploring expedition had found the junction of the two streams. Moelhausen,[34] a member of Whipple's expedition, wrote:

> The friendly Mohaves * * * had given us two of their warriers to accompany us to the "flowing water" of the Mohave, for from their signs and descriptions we made out that, many days' journey from the Colorado, the river loses itself in the sands and joins the Colorado underground.

He also states that Whipple's party, not knowing of Williamson's discovery a few months before, traveled some distance up the Colorado hoping to find the mouth of the Mohave. From earlier reports and maps it seems probable that Piute Wash,[35] which empties into Colorado River a few miles north of Needles, was believed to be Mohave River on account of its size. Frémont, on his trip across the Mohave Desert in 1844, had failed to discover the fact that Mohave River was not a tributary of the Colorado, because he had turned northeastward away from the river 30 miles or more before he reached Soda Lake. When he crossed the large valley north of Silver Lake he did not know that it was a continuation of the same depression in which the river ended.

In 1855 surveyors of the United States General Land Office began to subdivide the land in the Mohave Desert region into townships and sections. This may be said to be the beginning of settlement of the region. In January and February, 1858, a party under Lieut. Joseph C. Ives [36] explored Colorado River from its mouth to the head of navigation at the lower end of Black Canyon. They traveled on a steamboat and thus proved that the river was navigable. This expedition explored only the part of the Mohave Desert region that is immediately adjacent to Colorado River, but as the party included a geologist, Dr. J. S. Newberry, the report of this expedition is of considerable interest.

In the early sixties a number of stock ranchers settled along Mohave River. In 1861 a ferry was established across Colorado River at

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[34] Moelhausen, Baldwin, op. cit., vol. 2, p. 280.

[35] Piute Wash has also been called Sacramento Wash, but Piute Wash has been adopted by the United States Geographic Board.

[36] Ives, J. C., Report upon the Colorado River of the West: 36th Cong., 1st sess., S. Ex. Doc. — and H. Ex. Doc. 90, 1861.

Fort Mohave, Ariz. (now Mohave City, about 15 miles north of Needles), which had been established a short time after Ives's expedition traversed the Colorado, and a regular stage line was established between southern California and Arizona, which carried much freight to mines in Arizona. There was doubtless some mining in the Mohave Desert in the early sixties, but there is practically no record of it. In 1863 J. W. Searles discovered borax in the deposits of a large playa or "dry lake," now known as Searles Lake. The deposits were not worked commercially for nearly 10 years, but beginning in 1874 the borax from Searles Lake became for a short period one of the most valuable mineral products of the country. These deposits lost their commercial value when other deposits were discovered in the Calico Mountains, near Daggett, in 1882. During the seventies, gold and silver mines were opened in the Panamint, Ivanpah, Bonanza King, and Ord districts.

Mining operations and travel during the sixties seem not to have been without danger, for several parties were set upon by the Indians. In 1868 Camp Cady was established on Mohave River in T. 10 N., R. 4 E. San Bernardino meridian, to afford protection to travelers on the road from Wilmington, the port nearest Los Angeles, to northern Arizona. About 100 soldiers were maintained at the camp until 1870.

In the summer of 1875 a party under Lieut. Eric Bergland[37] traveled from Cajon Pass down Mohave River to Soda Lake and thence by way of Halloran[38] Spring, Francis Spring, and Ivanpah[39] to Colorado River. The purpose of this expedition was to determine the feasibility of diverting Colorado River for irrigation. Dr. Oscar Loew,[40] a geologist, was a member of this expedition, and his report contains considerable information on the geography, geology, and other natural features of the region. In the same year another party, under Lieut. R. Birnie, jr., traveled by way of Cajon Pass, Black's ranch, and Pilot Knob to explore the country in the Owens Lake, Panamint, Death Valley, and Amargosa regions. In connection with these surveys during the early seventies topographic relief maps were published for part of the Mohave Desert region.[41]

[37] Bergland, Eric, Preliminary report upon the operations of party No. 3, California section, season of 1875–76, with a view to determine the feasibility of diverting the Colorado River for purposes of irrigation: U. S. Geog. Surveys W. 100th Mer. Ann. Rept. for 1876, appendix B, pp. 109–113, 1876.

[38] Bergland writes it Hallovan.

[39] The original town of Ivanpah was located on the east slope of the Ivanpah Mountains about 6 miles northwest of the present town of that name on the Los Angeles & Salt Lake Railroad, which has also been called Leastalk and South Ivanpah.

[40] Loew, Oscar, U. S. Geog. Surveys W. 100th Mer. Ann. Rept. for 1876, under the following titles: Appendix G 2, Report on the meteorological conditions of the Mohave Desert, pp. 152–157; Appendix H 2, Report on the geological and mineralogical character of southeastern California and adjacent regions, pp. 173–188; Appendix H 3, Report on the alkaline lakes, thermal springs, mineral springs, and brackish waters of southern California and adjacent regions, pp. 188–199; Appendix H 6, Report on the physical and agricultural features of southern California and especially of the Mohave Desert, pp. 214–222; Appendix H 7, Report on the geographical distribution of vegetation in the Mohave Desert, pp. 222–224; Appendix H 15, On the physiological effects of a very hot climate, pp. 328–330.

[41] Topographical atlas to illustrate explorations and surveys west of the one hundredth meridian, Lieut. G. M. Wheeler in charge, U. S. War Dept.

After the explorations of Williamson and Whipple to find a railroad route from Mississippi River to the Pacific several abortive attempts were made to form a company to build a railroad. In August, 1883, the railroad of the Southern Pacific was completed to Colorado River, where it joined a railroad just built by the Atlantic & Pacific Railroad Co., which was then controlled by the Atchison, Topeka & Santa Fe Railway.[42] A year later the road from Mojave to the Colorado was purchased by the Santa Fe, and at the same time arrangements were made for that company to use the tracks of the Southern Pacific across Tehachapi Pass. The line from San Bernardino to Barstow was completed in November, 1885. As an aid in building the road from Mojave to Needles as well as the line from Mojave southward to Los Angeles, the Southern Pacific Co. was granted certain odd-numbered sections of land for a distance of 10 miles on each side of its right of way, exclusive of all mineral rights except those of coal and oil. When the road was sold to the Atchison, Topeka & Santa Fe the Southern Pacific retained these land-grant sections, which it has sold to the public wherever possible.

Besides the building of the railroads, the outstanding feature of the eighties was the great output of the silver mines in the Calico and Providence districts. (See p. 29.)

The first agricultural development in the Mohave Desert region probably began in the early sixties. Rancho Verde, now one of the largest individual holdings located on the Mohave River bottom land south of Victorville, was first occupied about 1867.[43] The first recorded appropriation of water from Mohave River for irrigation was made in 1872.[44] Black's ranch, on Harper Dry Lake, was occupied by cattle ranchers when Lieutenant Birnie's party passed there in 1875. The development of agriculture, however, apparently was gradual and mostly confined to the moist lands along Mohave River.

Early in the eighties it was discovered that flowing wells could be obtained in the lower part of Antelope Valley near Lancaster by drilling to depths of 200 to 500 feet.[45] Hinton states that in 1890 more than 100 wells were in use in the valley, but it is doubtful whether very many of them were used for irrigation. Ground water in Antelope Valley has been greatly developed in recent years, however, until the valley is now the most productive agricultural district in the Mohave Desert region. (See pp. 289–371.)

In the late eighties and early nineties a wave of land-settlement schemes swept over the Western States, and in California conditions

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[42] Bradley, G. D., The story of the Santa Fe, Boston, Richard G. Badger, 1920.

[43] McClure, W. F., and others, Report on the utilization of Mojave River for irrigation in Victor Valley, Calif.: California Dept. Eng. Bull. 5, p. 23, 1918.

[44] Idem, p. 48.

[45] Hinton, R. J., Progress report of irrigation in the United States, U. S. Dept. Agr., p. 50, 1891. Johnson, H. R., Water resources of Antelope Valley, Calif.: U. S. Geol. Survey Water-Supply Paper 278, p. 86, (well 298), 1911.

were made favorable by the passage in 1887 of a law known as the Wright Act. This law "sought to confer on farming communities powers of municipalities in the purchase or construction and the operation of irrigation works." [46] Under this act six irrigation districts were organized in the Mohave Desert region, all of them in the drainage basin of Antelope Valley. The Little Rock Creek district is the only one that can be said to have been entirely successful after a hazardous career. (See p. 291.) During this same period several other plans to provide water for irrigation were started, although not in the form of irrigation districts. Most of these plans provided for the use of water from Mohave River. The most pretentious plan included the construction of several reservoirs on the north slope of the San Bernardino Mountains. One of these reservoirs, known as Little Bear Lake, has been partly constructed, but the rest of the plan has not yet been completed. None of the other schemes were completed as originally planned, and some of them have failed completely. A brief statement of the history of the different projects for using water from Mohave River is given on pages 381–384.

A remarkable event in the recent history of the region was the construction of the Los Angeles aqueduct. The greatest benefit from this development accrues to the area south of the Mohave Desert region, but as the aqueduct traverses the western border of the region from north to south, the story of its building is not out of place.[47]

Prior to 1905 the water supply of the city of Los Angeles was obtained from Los Angeles River and smaller streams near by and from wells which penetrated the porous gravel at the foot of the mountains. As the city and the surrounding country was intensively cultivated by irrigation, the ground-water level of the region was rapidly lowered. The development of a larger supply sufficient for the future wants of the rapidly growing city became imperative. Investigations showed that water might be obtained from the mountains not far distant, but this would further deplete the ground-water supply of the valleys south of the mountains. To decrease the water supply of this fertile region would be to prevent the maximum development of what was to become one of the most intensively worked and productive farming regions in the United States, because the requirements of irrigation demand large quantities of water. It was evident that if the development of Los Angeles and the surrounding country was to continue a water supply must be found which would not in the least affect the resources of the region.

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[46] Adams, Frank, Irrigation districts in California, 1887–1915: California Dept. Eng. Fifth Bienn. Rept., Appendix B, p. 8, 1917. (This report was also published as California Dept. Eng. Bull. 2, 1916.)

[47] The following description is based largely on Los Angeles Dept. Public Service, Complete report on construction of the Los Angeles aqueduct, 1916.

The solution of this perplexing problem was found by Fred Eaton, a former mayor and city engineer of Los Angeles. In traveling through the region of Owens Valley, almost 250 miles nearly due north of Los Angeles, he had been impressed by the vast quantity of good water that was being wasted through running into Owens Lake, a large body of salt water. He had made investigations and was convinced that, as a result of natural conditions of topography, this great supply could be carried to Los Angeles at a cost which, though great, would not be disproportionate to the value of the water to the growing city. After due investigation the city undertook the project of building a large aqueduct from Owens Valley to Los Angeles. Work was begun in October, 1907, and completed in May, 1913, at a cost of slightly less than $25,000,000.

The capacity of the aqueduct is about 420 cubic feet a second (about 188,500 gallons a minute, or 271,000,000 gallons a day). The length of the aqueduct from the intake to the San Fernando Reservoir is 223 miles, and the end of the aqueduct proper is 23 miles north of Los Angeles. The total distance of nearly 250 miles from source to final destination is just about twice as great as the length of the great Catskill aqueduct, which supplies water to the city of New York. The Catskill aqueduct has a greater capacity than the Los Angeles aqueduct and has cost considerably more, but in many ways the feats involved in its construction are not any more wonderful than those involved in building the western waterway. The water is carried to Los Angeles entirely by gravity, there being a difference of about 2,500 feet between the intake and the San Fernando reservoirs. In order that the effect of fall may not be lost and that the need of pumping may be obviated, the water is carried across deep canyons and wide valleys in inverted siphons that have a total length of 12 miles and through 43 miles of tunnels that cut across mountains. It is expected that eventually hydroelectric power to the extent of 400,000 horsepower may be developed at points along the aqueduct. The city is already selling a considerable quantity of electricity.

The difficulty of the transportation of thousands of tons of supplies across miles of desert and of getting huge pipes into place on steep canyon sides was one of the great problems. The branch of the Southern Pacific Railroad from Mohave northward to Owenyo was built primarily for the express purpose of transporting supplies and equipment for the aqueduct. This railroad incidentally has made the northwestern part of the desert much more accessible than it was before the aqueduct project was begun.

Another notable event in the recent history of the Mohave Desert region was the construction in 1912 of the high-power electric transmission line of the Southern Sierras Power Co. from the Owens Valley, north of the northwest corner of the region, southeastward to

San Bernardino. Electricity was thus made available not only for domestic use but also for irrigation, mining, and manufacturing. Branch lines furnish power for irrigation in Indian Wells Valley, in the vicinity of Victorville, and along Mohave River to Barstow. Power is also furnished to the potash plants on Searles Lake and to mines in the Randsburg district. At the time it was constructed the main transmission line, more than 235 miles long, was one of the longest transmission lines in the world. In 1914 the Southern California Edison Co. began furnishing power for irrigation in Antelope Valley, and electric power is now used almost exclusively in that part of the desert.

The more recent history of the Mohave Desert region is found in the development of the agricultural districts and productive mining districts which are described in the other parts of this report.

SETTLEMENTS AND POPULATION

There are several towns in the Mohave Desert region. Mojave, Barstow, Yermo, Ludlow, and Needles are situated at important railroad junctions or division points. Palmdale, Lancaster, Rosamond, Victorville, Hinkley, Daggett, and Inyokern are situated in agricultural districts. All these towns have good stores and other facilities to meet the demands of the traveler and may be considered permanent. Randsburg, Johannesburg, Atolia, and Goodsprings are mining towns. Oro Grande and Amboy depend respectively on cement and gypsum manufacturing plants. Trona, Borosolvay, and Hanksite, on Searles Lake, are maintained by companies that produce potash from the old lake bed.

Supplies may be obtained at a number of other small places. On the main railroads section crews are located every 10 or 15 miles, but many of the stations indicated on the maps are only sidings, where neither help, supplies, nor water can be obtained.

In the mining districts the permanence of the towns is somewhat uncertain. In several places there is now almost no indication of the presence of towns that at one time had populations ranging from several hundred to a few thousand. Perhaps the best example is the famous town of Calico, in the Calico Mountains, 10 miles north of Daggett, which is said to have had in the late eighties a population of more than 5,000. The town was dependent on silver mines in the mountains, and when silver declined in value the population dwindled rapidly, until during the last few years only three or four men have lived among the ruins of the town while they sporadically worked the best ore in abandoned mines. (See pl. 3, *A*.) A town of several hundred persons is said to have arisen at the Bonanza King mine when it was in operation, and another large settlement grew up at Dale. These places have been practically deserted for a number of years. Within the last two years the towns of Atolia and Randsburg might have shared a similar fate, owing to the almost complete shutting down of the tungsten and gold mines, if a rich and unexpected silver strike had not been made at an opportune time. Goodsprings, Nev., is another town whose population is subject to fluctuation. After the reappearance of German potash on the United States market the potash plant at Borosolvay was closed down, and the town was practically deserted.

In 1920 Needles, the only incorporated town in the region, had a population of 2,807.[48] Census data are not obtainable for unincorporated towns, but the population of the judicial townships in 1900, 1910, and 1920 is given in the following table. With few exceptions the names of the townships are the same as the names of the principal towns in them, so that the table gives an approximate idea of the size of the towns.

Population of minor civil divisions in Mohave Desert region in 1920, 1910, and 1900 [a]

Minor civil division	1920	1910	1900
LOS ANGELES COUNTY			
Antelope Township	2,196	1,047	415
Fairmont Township	840	932	427
Total, part of Los Angeles County considered in this report	3,036	1,979	842
SAN BERNARDINO COUNTY			
Atolia Township	150	--------	--------
Bagdad Township	333	--------	--------
Barstow Township	1,538	1,066	--------
Belleville (including towns of Daggett and Newberry)	347	374	972
Calzona Township and part of Colorado River Indian Reservation	122	97	--------
Dale Township	8	41	63
Hesperia Township	590	92	170
Kelso Township	185	136	--------
Ludlow Township	220	255	--------
Needles Township (including Needles city)	2,930	3,067	1,143
Oro Grande Township	395	280	--------
Silver Lake Township	35	135	--------
Trona Township	724	--------	--------
Vanderbilt Township	135	149	329
Victor Township	989	580	645
Yermo Township	215	178	--------
Total, part of San Bernardino County considered in this report	8,916	6,450	3,322
KERN COUNTY			
Township 10 (including town of Mohave)	1,022	([b])	([b])
Township 11 (including towns of Inyokern and Randsburg)	912	([b])	([b])
Total, part of Kern County considered in this report	1,934	([b])	([b])
Part of Inyo County considered in this report	[c] 250	([d])	([d])
Part of Clark County, Nev., considered in this report	[c] 550	([d])	([d])
Grand total, Mohave Desert region	14,686	([d])	([d])

[a] Fourteenth Census, vol. 1, pp. 354, 356, 1921.
[b] Townships redistricted since 1910 census and data for these districts for 1910 and 1900 therefore not comparable.
[c] Estimate furnished by the Director of the Bureau of the Census.
[d] Statistics for 1910 and 1900 not available.

[48] Fourteenth Census, vol. 1, p. 184, U. S. Dept. Commerce, 1921.

The data in these tables are of interest in showing the permanency of the population in some of the districts where conditions are favorable to agriculture and the fluctuations where mining is the principal industry. The decrease in population in Belleville, Dale, Silver Lake, and Vanderbilt Townships is explained by the dying out of short-lived mining "booms." On the other hand, the increase in the population in Hesperia, Victor, and Antelope Townships is due largely to the gradual development of the agricultural resources.

TRANSPORTATION

The region is fairly accessible by railroads, the main lines of three important systems passing through it. The Valley line of the Southern Pacific Co. crosses the west edge of the desert from Palmdale to Mojave and thence goes through Tehachapi Pass. A branch line continues north from Mojave along the east side of the Sierra Nevada. The Trona Railroad is a short line that leads from Searles station on the Southern Pacific to Trona. The main line of the Atchison, Topeka & Santa Fe Railway from Los Angeles to Chicago goes north from San Bernardino through Cajon Pass to Barstow and thence east to Needles. A branch line goes from Barstow to Mojave, connecting there with the Valley line of the Southern Pacific, which the Santa Fe trains to San Francisco use for some distance. An important branch line of the Santa Fe runs southeast from Cadiz to Parker and Phoenix, Ariz., with a connecting line from Rice (formerly Blythe Junction) to Blythe, in Riverside County. A minor branch runs from Kramer to Johannesburg, and another from Goffs to Barnwell and Searchlight, Nev.[48a] The Los Angeles & Salt Lake Railroad (part of the Union Pacific System) uses the tracks of the Santa Fe from San Bernardino to Daggett and thence runs northeastward across the region. The Tonopah & Tidewater Railroad runs from Ludlow nearly due north, and serves a large territory that contains valuable mineral resources.

Much of the local travel in the region is by automobile, and many travelers even from distant parts of the country pass through the region in automobiles. The through travel is mostly confined to three or four routes which are described briefly on pages 141–143.

Although most of the desert roads are not paved or otherwise improved they are generally in fair or good shape. Sometimes heavy storms wash out stretches and make them impassable. On some routes, mostly those that are little traveled, sand may be encountered, but the desert traveler usually learns in a short time how to cope with this difficulty. The greatest hazard in automobile travel on the desert is the fact that places where water and other

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[48a] After the maps in this report were prepared the branch from Goffs to Barnwell and Searchlight was abandoned and the track torn up.

supplies can be obtained are far apart, and some slight trouble, such as a cracked spark plug or a leaky radiator, which in more settled regions might cause only slight discomfort and delay, may easily prove disastrous. A number of suggestions to desert travelers are given on pages 132–140. Notes on watering places on the different roads are given in the descriptions of the different valleys in the region.

MINERAL RESOURCES

STATISTICS OF PRODUCTION

The products of greatest value obtained in the Mohave Desert region come from mineral deposits. Some idea as to their value may be obtained from the statistics of San Bernardino County given in the following tables. Probably at least two-thirds of the mineral production of San Bernardino County comes from the desert part of the county. For several years this county led all others in the State in variety of minerals produced, 25 different substances being produced commercially in 1918, 17 in 1919, and 22 in 1920.[49]

The statistics for the years prior to 1894 are not available except for gold and silver, and these, which are shown in the second table, are of considerable interest because of the fact that the silver production alone amounted to more than a million dollars annually in several of these years. The production of borax amounted to more than $50,000 a year for a number of years prior to 1894.[50]

The statistics for 1894 to 1919 likewise do not show the full value of mineral production in the county for that period, for during the years of 1904 to 1911 the value of borax and cement produced in the county, and perhaps of other products, was not included in the county totals but was given in unapportioned totals for these materials for the entire State. During this period the production of borax probably gradually declined, but, on the other hand, the production of cement gradually increased from a little more than $100,000 in 1903 to nearly $1,000,000 in 1912. The total mineral production of the county has probably amounted to nearly $135,000,000, and that of the desert part of the county to nearly $100,000,000. Of the products listed in the table a large proportion of the limestone and lime, granite and other rocks, and cement was produced in the region south of the San Bernardino Mountains. Certain products, as tungsten, borax, salt, and gypsum, are obtained solely in the desert. In addition there has been considerable mineral production from the parts of the other counties considered in this paper.

[49] Bradley, W. W., California mineral production for 1920: California State Min. Bur. Bull. 90, p. 173, 1921.

[50] Bailey, G. E., The saline deposits of California: California State Min. Bur. Bull. 24, pp. 39–40, 1902.

Value of mineral production from San Bernardino County, Calif., 1894–1925 [a]

Year	Gold	Silver	Copper	Lead	Zinc	Tungsten	Borax	Potash	Salt	Gypsum	Cement	Lime and limestone	Granite and other stones	Gems	Miscellaneous [b]	Annual total
1894	$130,420	$148,243	--------	--------	--------	--------	$726,509	--------	$3,000	--------	$21,600	$38,250	$31,622	--------	--------	$1,099,644
1895	131,360	219,410	--------	--------	--------	--------	555,900	--------	20,101	--------	32,556	117,864	37,672	--------	--------	1,114,863
1896	96,723	130,714	--------	--------	--------	--------	650,500	--------	15,000	--------	27,000	52,477	31,476	--------	--------	1,003,890
1897	100,373	54,407	--------	--------	--------	--------	1,080,000	--------	--------	--------	66,000	12,000	--------	--------	--------	1,312,780
1898	261,512	32,000	--------	--------	--------	--------	1,120,000	--------	--------	--------	150,000	41,600	23,040	--------	$16,000	1,644,152
1899	164,599	125,603	$232,339	--------	--------	--------	1,106,000	--------	--------	--------	180,000	30,910	11,900	--------	8,000	1,859,351
1900	247,949	172,759	297,600	$400	--------	--------	999,350	--------	--------	--------	121,000	40,328	65,757	$20,000	--------	1,965,143
1901	399,693	57,164	7,875	20	--------	--------	898,130	--------	--------	--------	159,842	119,738	166,777	20,000	15,000	1,844,239
1902	394,936	58,972	41,008	2,076	--------	--------	2,198,600	--------	--------	--------	273,600	117,410	208,000	11,600	1,800	3,308,002
1903	381,197	59,199	7,852	504	--------	--------	495,000	--------	--------	--------	157,000	93,305	308,561	10,000	4,000	1,516.618
1904	595,828	13,025	17,270	--------	--------	--------	(c)	--------	--------	--------	(c)	64,075	214,336	--------	17,500	922.034
1905	473,893	19,595	8,206	--------	--------	--------	(c)	--------	--------	--------	(c)	66,135	187,197	65,000	--------	820,026
1906	354,830	33,765	99,207	--------	--------	$5,500	(c)	--------	--------	--------	(c)	53,136	63,476	--------	13,500	623,414
1907	158,676	81,339	102,856	1,822	--------	--------	(c)	--------	--------	--------	(c)	147,788	177,888	--------	15,555	685,924
1908	180,511	35,704	71,079	17,218	--------	--------	(c)	--------	650	$70,000	(c)	97,466	231,742	200	7,350	711,920
1909	40,071	12,570	40,418	13,254	--------	--------	(c)	--------	14,000	43,000	(c)	41,395	298,777	200	11,966	515,651
1910	55,093	10,164	689	5,972	--------	--------	(c)	--------	9,000	70,357	(c)	157,715	95,126	1,120	17,600	422,836
1911	127,367	35,542	83,311	7,260	--------	--------	(c)	--------	13,800	66,505	(c)	177,080	187,143	--------	12,100	710,108
1912	293,900	49,962	319,636	4,268	--------	--------	(d)	--------	12,600	67,000	(d)	97,867	580,824	450	1,550	1,428,057
1913	356,524	44.413	77,167	12,287	--------	--------	(d)	--------	10,573	74,000	(d)	149,320	364,312	550	1,393,954	2,483,100
1914	205,000	40,000	2,536	1,759	--------	--------	(d)	--------	2,892	49,150	(d)	113,980	131,978	--------	1,062,211	1,609,506
1915	416,967	64,165	36,652	7,952	$4,941	840,947	(d)	--------	3,324	(d)	980,000	68,500	178,528	--------	64,716	2,666,692
1916	279,813	67,146	388,164	46,492	94,746	3,915,434	(d)	--------	13,830	(d)	1,246,000	117,803	174,954	1,000	217,265	6,562,647
1917	154,976	88,930	333,157	197,245	3,951	2,447,726	(d)	$2,049,120	--------	(d)	1,672,054	187,571	113,508	--------	157,884	7,406,122
1918	29,225	88,712	390,507	47,426	257	1,911,966	(d)	3,428,443	--------	(d)	1,453,962	13,323	49,261	--------	159,558	7,572,640
1919	25,000	40,000	47,790	5,607	(d)	(d)	(d)	1,670,919	--------	50,154	1,717,998	(d)	183,388	--------	463,337	4,204,193
1920	79,195	1,212,987	991	9,270	(d)	--------	440,411	1,082,037	1,220	(d)	3,051,079	(d)	169,991	--------	336,551	6,383,732
1921	217,568	3,210,706	2,200	1,027	(d)	--------	338,905	211,067	67,782	--------	4,633,437	106,195	145,572	(d)	652,148	9,586,607
1922	125,728	2,374,948	1,816	615	--------	--------	(d)	(d)	54,259	(d)	4,156,430	7,800	(d)	(d)	1,826,304	8,547,900
1923	210,923	2,225,959	1,959	2,413	--------	(d)	(d)	(d)	65,560	(d)	8,478,612	28,324	351,151	(d)	2,412,362	13,777,253
1924	187,573	1,531,598	2,314	2,533	--------	(d)	(d)	(d)	99,791	(d)	7,571,370	45,137	355,946	--------	2,845,536	12,641,798
1925	157,374	1,378,392	888	5,349	--------	(d)	(d)	(d)	101,085	--------	8,828,044	152,015	395,048	--------	3,161,468	14,179,663
	7,034,797	13,718,093	2,615,487	392,769	103,895	9,121,573	10,609,305	8,441,586	508,457	490,166	44,977,584	2,556,507	5,534,951	130,120	14,895,215	121,130,505

[a] Compiled from bulletins of California State Min. Bur. Does not include mineral waters. Where blank spaces are left it is not certain whether there was any production.

[b] Includes, in one year or another, asbestos, barytes, borax, brick, calcium chloride, cement, clay, gems, gypsum, iron, lead, lime, manganese, mineral paint, potash. salt, soapstone, soda, strontium, talc, tungsten, vanadium, and zinc.

[c] Production of borax and cement for 1904–1911 not included in county report but given only in totals for the entire State. (See p. 26.)

[d] Included in miscellaneous.

Value of gold and silver produced in San Bernardino County, Calif., 1880–1893 [a]

Year	Gold	Silver	Total
1880	([b])	([b])	([b])
1881	9,000	100,000	109,000
1882	20,000	150,000	170,000
1883	30,000	1,050,000	1,080,000
1884	[c] 32,000	[c] 2,550,000	[c] 2,582,000
1885	23,000	2,363,436	2,386,436
1886	56,464	1,204,750	1,261,214
1887	27,850	1,133,267	1,161,117
1888	25,000	1,200,000	1,225,000
1889	19,737	824,820	844,557
1890	17,335	795,465	812,800
1891	62,970	711,157	774,127
1892	47,037	67,072	114,109
1893	158,000	447,020	605,020
Total	528,393	12,596,987	13,125,380

[a] Compiled from the annual reports of the Director of the Mint upon the production of the precious metals in the United States.
[b] No official returns.
[c] The report of the Director of the Mint for 1884 gives two estimates. One, by A. M. Lawver, gives the production of gold in San Bernardino County as $40,000, that of silver as $3,706,204, and the total production as $3,746,204 (p. 175). The figures given above seem to be the official estimate (p. 66), although the estimate of Mr. Lawver is used in California State Min. Bur. Bull. 88, California mineral production for 1919.

Mineral production in the Mohave Desert region has been hampered by lack of cheap transportation and lack of water. Many of the mineral properties are 10 to 50 miles from the nearest railroad. The great development of automobile and tractor transportation has reduced the difficulties of transporting ore from the mines to the railroads, but the cost is still great. For example, in 1915 the cost of hauling ore from the Owl Hole manganese mine, in T. 18 N., R. 3 E. San Bernardino meridian, to the Tonopah & Tidewater Railroad, a distance of 35 miles, was 35 cents a ton-mile, or more than $12 a ton for the entire haul. Obviously an ore must be of high grade to warrant such shipping costs.

Where sufficient water can not be obtained for milling, the ore must be shipped in unconcentrated form, thereby increasing the costs. At several of the larger mines water has been piped for a number of miles or hauled in tank cars. The supply for the Yellow Aster mine, at Randsburg, is pumped from the Goler Well, about 5 miles northwest of the mine, with a lift of about 1,000 feet. The water used at the mill of the Atolia Mining Co. was for many years hauled in tank cars from Hinkley, a distance of nearly 50 miles, at a cost in 1909,[51] of $24.30 for a car of 9,400 gallons. The Pacific Mines Corporation hauled water a distance of 40 miles from Water station (Newberry Spring) for use at its mine at Stedman, 8 miles south of Ludlow. In 1917 the Solvay Process Co. obtained water by tank cars from Cantil, a distance of more than 50 miles, for domestic use by its employees at Borosolvay. It is evident that the cost of obtaining water at many of the places where ore deposits

[51] U. S. Geol. Survey Mineral Resources, 1909, pt. 1, p. 577, 1911.

are found may be a leading factor in determining whether the ore may be mined at a profit.

The following paragraphs give a brief summary of the production of some of the more valuable minerals. Much information in regard to the mineral resources of the Mohave Desert region is given in the annual reports of the State Mining Bureau on mineral production, special reports on specific products, and county reports.[52]

METALS

Silver.—The value of silver produced in San Bernardino County has probably been greater than that of any other mineral and amounts to more than $26,000,000. Practically all the silver has come from the desert part of the county. A large part of the silver was produced prior to 1893. After that the production was small for many years until rich deposits were discovered in 1919.

The earliest year for which there is any record of the production of silver in San Bernardino County is 1881, when the recorded production amounted to only $100,000. In that year rich deposits were discovered in the Calico district. By 1883 the production had risen to more than $1,000,000, and the following year it had reached more than $2,500,000. (See footnote *c* to table on p. 28.) The production continued to be more than $1,000,000 each year through 1888. The importance of the production of San Bernardino County during that period is shown by the fact that from 1883 to 1893, except in 1892, the value of the silver produced in the county each year was practically 70 per cent or more of that produced in the entire State, and in two years, 1884 and 1885, it was 85 per cent or more. The production dropped suddenly after the lowering in the price of silver since 1893, and with the exception of four years, until 1920, it was never again as high as $100,000. In 1919 the value of the silver from San Bernardino County was only about 3 per cent of the total for the State. From 1920 to 1925 the production of silver from the newly discovered Rand district ranged from more than $1,200,000 to $3,210,706 annually and aggregated nearly $12,000,000.

During the early periods of great production most of the silver came from two or three districts. The leading district was the Calico district, about 8 miles north of Daggett. Other productive districts were the Grapevine district, a few miles north of Barstow; the Ivanpah district, 10 or 15 miles north of Ivanpah; and the Providence district, 25 miles northwest of Fenner. There has been practically no production in most of these districts for many years. From time to time a few men have mined out some of the richest ore

[52] Boalich, E. S., Catalog of the publications of the California State Mining Bureau, 1880–1917: California State Min. Bur. Bull. 77, 1917. Brief descriptions of the chief mining regions are given in county reports for San Bernardino, Kern, and Inyo Counties, published as chapters of the report of the State mineralogist for 1915–16.

in the Calico district. In the spring of 1919 rich silver deposits were found near Randsburg (see p. 229), and these have been extensively developed. The California Rand mine, in this district, has been the largest single producer in the United States for several years and up to April 1, 1924, had yielded over $10,000,000.[53] The peak production was reached in 1921, and since then there has been a gradual decline.

Gold.—The total production of gold in San Bernardino County since 1880 has amounted to more than $6,500,000, but this is only a small percentage of the total production of the State. Most of the gold mined in San Bernardino County has been obtained from the San Bernardino Mountains, which in this report are not considered a part of the Mohave Desert. Much of the gold has been obtained from placer workings in these mountains.

In the desert the Dale district, in T. 1 S., R. 12 E. San Bernardino meridian, was an important producer several years ago, but it has not been active for some time. The Providence district, northwest of Fenner, has also been one of the larger producers. Considerable active development work was done in the Goldstone district, 30 miles north of Barstow, after the discovery of gold in 1915, but in 1917 the work was stopped, and so far as is known there has been no further activity.

The largest producing district for some time has been the Randsburg district, which, however, is in Kern County. The principal mine here is the Yellow Aster, which up to 1915 is said to have produced $6,000,000.[54] The Randsburg district, including its placers, is said to have produced $10,000,000 up to the same time. Considerable gold has been produced from several mines in the Rosamond Buttes and other buttes south of Mojave.

An interesting phase of gold mining in the desert region has been the working of the so-called "dry placers." Gold has been found at several places in the alluvium that covers so large a part of the region. The scarcity of water makes impracticable the working of the placers in the usual way, and methods of "dry washing" have been developed. Machines called "dry washers" have been contrived which use bellows to blow away the lighter materials. The residue is sometimes "panned" without water, except perhaps in the final stage, when only a very small quantity is used. Some of the most productive dry placer fields have been the Coolgardie field, 19 miles north of Barstow; Goler Wash, northwest of Randsburg; and the Summit Diggings, about 6 miles north of Johannesburg. None of these fields have

[53] Hulin, C. D., Geology and ore deposits of the Randsburg quadrangle: California State Min. Bur. Bull. 95, p. 119, 1925.

[54] Brown, G. C., Mines and mineral resources of Kern County: California State Min. Bur. Rept. State Mineralogist for 1913 and 1914, p. 59, 1915.

been producing much for some time, although a few men have been working them sporadically.

Copper.—Copper is found in many parts of the Mohave Desert region, but the production has amounted to only a little more than $2,500,000. The annual production has varied greatly from year to year, doubtless in part owing to fluctuations in the price obtained for the metal. The greatest production has probably come from mines in the Ivanpah district, especially from the Copper World mine, in T. 16 N., R. 13 E. A copper smelter was operated at Valley Wells, a few miles southwest of the mine. In 1917, after a period of idleness, the smelter was reequipped and considerable ore was smelted, but the furnaces were operated for only a few months. The mine of the Pacific Mines Corporation at Stedman, about 8 miles south of Ludlow, has been one of the largest producers. In recent years copper has been mined in the Whipple Mountain district, in the southeast corner of San Bernardino County. A copper smelter is operated at Needles, but some of its ore is brought from Arizona.

Lead and zinc.—The production of lead and zinc in the Mohave Desert region has been relatively insignificant. Nevertheless, for a number of years San Bernardino County has ranked second or third among the counties of the State as a lead producer, although in only two years since 1907 has the production from the county been as much as 10 per cent of the total for the State. The lead is generally associated with silver.

The production of zinc has been even smaller than that of lead. The county, however, is one of the three counties in the State which make any regular production, the other two being Inyo and Shasta Counties, which are also regular producers of lead. The zinc is associated with the lead and silver.

Tungsten.—Tungsten is one of the most valuable minerals found in the Mohave Desert region. Extensive deposits exist near Atolia. The tungsten-bearing mineral at Atolia is mostly scheelite ($CaWO_4$), and the Atolia deposits are the largest and most productive deposits of scheelite known. Likewise the mine of the Atolia Mining Co., which has produced most of the tungsten in this district, for several years has been the largest tungsten mine in the world.[55] The output of this mine for the 11 years 1908 to 1918 amounted to more than $9,000,000. In addition to this output ore worth many thousands of dollars has been produced by other mines, and much placer tungsten has been dug up in the so-called "spud patch" on the alluvium-covered slopes below the vein deposits. The total output of the Atolia district has probably been more than $10,000,000. The deposits are described briefly on pages 227–228. Some tungsten ore has been shipped from the Clark Mountain and New York Mountain districts,

[55] U. S. Geol. Survey Mineral Resources, 1918, pt. 1, p. 979, 1921.

in the eastern part of San Bernardino County. Tungsten is also reported to occur 15 miles northwest of Victorville and on the north side of the San Bernardino Mountains, 45 miles southeast of Victorville.[56] Since 1918 the production of tungsten in the desert region has been very small, owing to the fact that the product can not compete with imports from Asia, where cheap coolie labor is used. Because of the lack of a protective tariff, in 1920 for the first time since tungsten has been mined in California there was no production in the State.[57] Such a tariff was imposed by the law passed in 1922. Production from the Atolia region was resumed on a small scale in 1923. In 1924 the production of tungsten in the entire State was $446,000, and in 1925 it was $348,475. It may be assumed safely that most of this came from the Atolia district.

Other metals.—In addition to the metals already mentioned, several others have been produced in the Mohave Desert region, or deposits of them are known to exist which may some time be of commercial value.

Iron ore is found at several places, but its mining on a commercial scale has been hindered by the fact that there is no good supply of fuel for smelting close at hand. Deposits that may prove of value are those in Cave Canyon, near Baxter, in T. 11 N., R. 6 E. San Bernardino meridian; the Iron Age deposits, 6 miles east of Dale, in T. 1 S., R. 13 E.; the Iron Mountain deposits, about 10 miles west of Silver Lake; the Vulcan deposits, in the Providence Mountains east of Kelso; and deposits a few miles north of Cadiz.

Manganese is found at a number of places, but ore has been shipped only from the Owl Hole mine, in the Owl or Owlhead Mountains, T. 18 N., R. 3 E. The ore was hauled by tractor to the railroad at Riggs station, a distance of more than 35 miles. This mine has been idle much of the time because of litigation.

Platinum has been mined at the Boss mine, in the Goodsprings district, in T. 24 S., R. 57 E. Mount Diablo meridian, Clark County, Nev., in the northeastern part of the area covered by this report. The occurrence of this rare metal at this place is of special interest in that it is one of the few primary deposits in which metals of the platinum group occur in more than traces, and, with one possible exception, it is the only primary deposit of economic importance in which these metals are the constituents of greatest value.[58] Most of the world's supply of platinum is obtained from placers. The platinum at the Boss mine is associated with gold and palladium, another rare metal of the platinum group.

[56] Hess, F. L., and Larsen, E. S., Contact-metamorphic tungsten deposits of the United States: U. S. Geol. Survey Bull. 725, pp. 261–262, 1921. Surr, Gordon, Tungsten at Victorville: Am. Min. Rev. (Los Angeles), vol. 24, pp. 8–9, July 11, 1908.

[57] Bradley, W. W., California mineral production for 1920: California State Min. Bur. Bull. 90, p. 80, 1921.

[58] Knopf, Adolph, A gold-platinum-palladium lode in southern Nevada, U. S. Geol. Survey Bull. 620, p. 3, 1916.

Vanadium is found in the Signal mining district, about 8 miles north of Goffs, but up to 1919, so far as is known, there had been no commercial production, although some development work had been done. Vanadium has also been reported in the vicinity of Twenty-nine Palms. The mineral has been reported from only one other locality in California.

Minerals containing mercury, molybdenum, and nickel are also found at one or more places in the Mohave Desert region, but so far as is known none of them have been mined on a commercial scale.

NONMETALS

The recorded production of nonmetals in San Bernardino County exceeds that of the metals. A slightly larger proportion of the nonmetallic production has probably come from the nondesert part of the county, but several of the nonmetallic products occur only in the desert, and their presence is largely due to desert conditions.

Borax.—Borax was one of the first minerals produced in the region and it has been one of the most valuable, ranking close to silver. The total value of borax produced in San Bernardino County is several million dollars greater than is given in the table on page 27. The production prior to 1894 was probably more than $4,000,000,[59] and since 1903, the last year for which there are definite figures, the annual production has been large.

Borax was discovered in Searles Lake by J. W. Searles in 1863, but there was no commercial development until 1873. In 1882 rich deposits of colemanite (borate of lime) were found at the east end of the Calico Mountains, north of Daggett, and a few years later practically all the borax produced in the county came from this district, which is known as the Borate district. Later the so-called Death Valley deposits, which consist of colemanite, were found. The Borate deposits were eventually practically abandoned, but in recent years the company has shipped some of the richest ore. When the Borate deposits were being developed to the maximum a large borax mill was erected at Daggett and another one several miles north of the town. The ruins of these mills are silent witnesses of the extent of development of the deposits in bygone days. With the abandonment of the Borate deposits the production of borax in San Bernardino County was greatly lessened. In recent years some borax has been produced from Searles Lake as a by-product in the refining of potash. Borax deposits have recently been discovered about 7 miles northwest of Kramer.[60]

Potash.—Potash has been one of the most valuable mineral products obtained from the Mohave Desert region in recent years. Potash is

[59] Bailey, G. E., The saline deposits of California: California State Min. Bur. Bull. 24, pp. 39-40, 1902.
[60] Noble, L. F., Borate deposits in the Kramer district, Kern County, Calif.: U. S. Geol. Survey Bull. 785, pp. 45-61, 1926.

found in the saline deposits of many playas or "dry lakes" (see p. 109) in the desert, but in most of these it is mixed with much sand and clay and is not sufficiently pure or does not occur in large enough quantities to warrant its extraction. On account of the demand for potash, especially during the war, when the supply from Germany was shut off, very much prospecting has been done, but the results have largely been negative, except at Searles Lake, in the northwestern part of San Bernardino County.

The central part of the Searles Lake playa is a mass of practically pure crystalline salts of potash and sodium that covers about 11 or 12 square miles.[61] The interstices of the crystalline deposit are filled to a level within a few inches of the surface with a saturated potash-bearing brine which is estimated to form more than 25 per cent of the entire saline mass. Three plants for manufacturing commercial potash have been erected along the borders of the playa, and in the last four or five years nearly $10,000,000 worth of potash has been produced. Since the World War the importation of potash from Germany has rapidly increased again, to the disadvantage of American producers, and production from the Seales Lake plants was greatly curtailed in 1921. There has been some production of potash in the country each year since then, but as the figures are lumped with those for other products to avoid disclosing the output of individual producers they can not be given separately.

Salt.—Salt, like potash, is found in the deposits of many of the desert playas, but at only a few places is it pure enough to be produced on a commercial scale. One salt-refining plant is located at the edge of Bristol Dry Lake near Amboy and another at Saltdale, at the edge of a playa in Fremont Valley, in T. 30 S., R. 38 E. Mount Diablo meridian, in Kern County. Salt has also been shipped from the west end of Danby Dry Lake, in T. 2 N., R. 17 E. San Bernardino meridian. Beginning with a great jump in production in 1921 salt has become of increasing importance as a product of the Mohave Desert region.

Gypsum.—Gypsum is found in a number of places in the Mohave Desert region.[62] The only deposit which has been worked in recent years, however, is at Amboy, where the gypsum occurs a few feet below the surface of Bristol Dry Lake. Gypsum has also been shipped from deposits near Palmdale, in the southeastern part of the region, and from deposits near Acme, in T. 19 N., R. 7 E. San Bernardino meridian. Extensive deposits of gypsum are found in T. 18 N.,

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[61] For a description of the occurrence of potash in Searles Lake, see Hicks, W. B., Evaporation of brine from Searles Lake, Calif.: U. S. Geol. Survey Prof. Paper 98, pp. 1–8, 1917, and Gale, H. S., Salines in the Owens, Searles, and Panamint Basins, southeastern California; U. S. Geol. Survey Bull. 580, pp. 265–317, 1914.

[62] For descriptions of the most extensive gypsum deposits in the Mohave Desert region see Hess, F. L., Gypsum deposits of the United States: U. S. Geol. Survey Bull. 697, pp. 63, 73, 75–77, 81–83, 1920.

R. 5 E., on the northeast side of the Avawatz Mountains, and along the playa in Fremont Valley referred to in the paragraph above regarding salt.

Calcium chloride.—Beginning in 1921 calcium chloride was produced from the saline deposits of certain playas in San Bernardino County, and in the 5-year period ending 1925 the production had exceeded $378,000. Calcium chloride has become important through its use in curing newly laid concrete pavements so that they can be opened to traffic in about half the time formerly required.

Cement.—Cement is one of the leading mineral products of San Bernardino County, but a large part of the output is manufactured near Colton, in the non-desert region south of the San Bernardino Mountains. There are, however, two large cement plants on the desert—one at Victorville, which, when constructed in 1915, had a capacity of 300,000 barrels a year, and another at Oro Grande, which has a capacity of about 200,000 barrels a year.[63] A plant with a capacity of 1,250 tons daily was constructed by the city of Los Angeles at Monolith station, in T. 32 S., R. 33 E. Mount Diablo meridian, in Kern County, to supply cement for use in constructing the Los Angeles aqueduct. In recent years it was sold to a private company.

Lime and limestone.—A large quantity of lime and limestone has been produced from San Bernardino County, but much of it has been obtained in the nondesert portion of the region. Considerable limestone has been quarried at Baxter, on the Los Angeles & Salt Lake Railroad, in T. 11 N., R. 6 E. San Bernardino meridian. The rock is used at sugar refineries. Limestone has also been quarried and some of it burned east of Oro Grande and near Victorville, where the cement plants mentioned above also obtain limestone.

Granite and other stone.—Granite has been quarried near Victorville and Oro Grande. Most of the material has been used for paving blocks, but some has been used for building and monuments. A large part of the stone produced in San Bernardino County has come from quarries south of the San Bernardino Mountains, and much of it has been in the form of crushed stone for macadam and concrete. Some marble has been shipped from small quarries in the desert.

Gems.—Gems of several kinds have been obtained from the Mohave Desert region. The leading gem produced, in point of total value, has been turquoise, which has been mined in T. 16 N., Rs. 10 and 11 E., in the Turquoise Mountains, 12 to 15 miles east of the town of Silver Lake.[64] Opals have been found at several places, but not in sufficient abundance to warrant mining. An unusual gem stone found about 45 miles northeast of Johannesburg is myrickite, named

[63] Cloudman, H. C., and others, Mines and mineral resources of San Bernardino County: California State Min. Bur. Rept. State Mineralogist for 1915 and 1916, pp. 84–86, 1917.

[64] Cloudman, H. C., and others, op. cit., pp. 90–94. (In part quoted from Kunz, G. F., Gems, jewelers' materials, and ornamental stones of California: California State Min. Bur. Bull. 37, pp. 107 et seq., 1905.)

after its discoverer, F. M. Myrick, which is a variety of agate that contains brilliant red inclusions, which are said to be cinnabar.

Petroleum.—Several test wells for oil have been drilled in different parts of the Mohave Desert region, but up to the present time no producing wells have been obtained. Prior to 1912 four wells had been drilled north of the Atchison, Topeka & Santa Fe Railway between Kramer and Barstow.[65] "Showings" of oil were reported to have been found in each well, but if oil was actually present it did not occur in large enough quantity to warrant pumping.

Operations at one of the wells, that of the Kramer Consolidated Oil Co., in the NW. ¼ sec. 11, T. 10 N., R. 5 W., about 3 miles north of Hawes station, have been continued intermittently from about 1900 to 1921. From time to time the well has been drilled deeper until in 1921 it was said to be about 3,000 feet deep. (See p. 274.) The operators pumped the well for many months, hoping that if sufficient water were pumped out oil would come into the hole. When the writer visited the well in December, 1917, warm water was being pumped from the well. A whitish scum on the water was said by the pumpers to be paraffin, but this is doubtful. An analysis of the water (p. 278) shows it to be highly mineralized, but there was no trace of petroleum. It is very doubtful if oil in paying quantities will be found in this locality.

The following statement by Pack [66] gives his conclusions after an investigation of the Kramer-Barstow region:

> The writer believes that the northern part of the Mohave Desert between Barstow and the town of Mojave offers practically no promise of becoming a productive oil field and that further drilling will prove but a waste of money. The principal reasons for believing that this land will not prove productive are (1) the lack of strata from which it would seem reasonable to believe that oil might have been formed, especially the lack of thick masses of organic material (diatomaceous and foraminiferal shale), such as those which occur in or near all the oil fields in the southern half of California and in which the oil is believed to have originated; (2) the lack of structural features favorable for the collection of petroleum even if it existed disseminated through the strata.

In 1920 and 1921 drilling was done at several places in Antelope Valley. Oil is said to have been found in one well on the Liebre ranch, at the extreme west end of the valley, but so far as is known there has been no production. There are no indications that oil may be expected here in paying quantities. Gas has been reported in several water wells in the valley, but it is not uncommon to find small quantities of gas, which originate from the decay of buried vegetation, in alluvial formations such as those that fill the basin of Antelope Valley.

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[65] Pack, R. W., Reconnaissance of the Barstow-Kramer region, Calif.: U. S. Geol. Survey Bull. 541, pp. 141–154, 1914.

[66] Idem, p. 152.

Several wells have been drilled near Hesperia and Victorville and in the northeastern part of Los Angeles County and the southeastern part of Kern County.

It has been reported that drilling operations have been undertaken in the Shadow Mountains, northeast of Silver Lake. The exact location is not known, and the geology of that region has not been studied in detail, but the rocks that the writer has observed in these mountains are all either igneous or sedimentary rocks that have been so greatly metamorphosed that it is doubtful whether oil occurs in them.

The California State Mining Bureau [67] reports 19 "wildcat" wells drilled without finding oil between 1914 and 1924, in the part of the region bounded by a line drawn through Randsburg on the north, a line through Victorville on the east, and the Tehachapi, Sierra Pelona, and San Gabriel Mountains; and 5 unsuccessful wells in the region were abandoned in 1925 and 1926. The location and depths of the wells that have been drilled without success are given in the following table:

Location and depth of wildcat wells drilled for oil in Mohave Desert region, 1914–1926

Company	Section	Township	Range	Base and meridian[a]	Date started	Depth (feet)
Hesperia Oil & Gas Co	29	4 N.	4 W.	S. B	1924	3,103
Victor Valley Land Owners Oil & Gas Co	22	5 N.	6 W.	S. B	1924	1,720
Rock Creek Development Co	2	5 N.	11 W.	S. B	1922	--------
Citizens Oil & Land Corporation	36	7 N.	9 W.	S. B	1922	--------
Antelope Oil & Gas Co	11	7 N.	12 W.	S. B	1921	1,640
Great Angelus Oil & Land Co	21	8 N.	9 W.	S. B	1922	--------
LaKern Oil Syndicate (George A. Devison Co.)	24	8 N.	12 W.	S. B	1921	--------
Tejon Ranch Oil Co	14	8 N.	18 W.	S. B	1920	2,163
Kern-Torrance Petroleum Corporation	13	9 N.	10 W.	S. B	1923	--------
Robert Watchhorn	27	9 N.	17 W.	S. B	1919	4,150
Mojave Basin Oil Co	2	10 N.	5 W.	S. B	1924	650
Interstate Oil Corporation	11	10 N.	5 W.	S. B	([b])	2,942
Crusaders Oil Co	21	10 N.	10 W.	S. B	1924	800+
Conway Oil Syndicate	4	11 N.	9 W.	S. B	--------	--------
George A. Parsons	10	31 S.	38 E.	M. D	1924	--------
Fremont Oil Syndicate	22	31 S.	38 E.	M. D	1922	--------
Fremont Oil Corporation	22	31 S.	38 E.	M. D	1925	2,620
Red Rock Oil Association (Charles W. Harlow)	19	30 S.	38 E.	M. D	1924	5,065
Red Rock Oil Co	19	30 S.	38 E.	M. D	1925	2,727

[a] S. B., San Bernardino; M. D., Mount Diablo. [b] Before 1920.

In a recent report of the California State Mining Bureau [68] the possibility of finding oil in the desert region is summarized as follows:

The greater part of the flat desert floor is covered by recent sand deposits. Along the lower foothills of the mountain ranges, particularly in the western and northern portions, there are small areas of Tertiary sedimentary rocks, interbedded with lava flows. These sediments for the most part represent either

[67] Bush, R. D., Results of wildcat drilling in California, 1914–1924, inclusive: Summary of operations California oil fields, California State Min. Bur., vol. 11, No. 1, table V, pp. 12–26, pl. 3, July, 1925; Wildcat wells abandoned in 1925 and 1926: Idem, vol. 12, No. 8, pp. 49–58, February, 1927.

[68] Vander Leck, Lawrence, Petroleum resources of California, with special reference to unproved areas: California State Min. Bur. Bull. 89, pp. 153–154, 1921.

lake or land deposits. The higher ranges of the southern region are composed of crystalline rocks, either granites or pre-Cambrian metamorphics. The high ranges of the northern region are also crystalline in character, being either composed of granites or highly metamorphosed sediments of Paleozoic and Mesozoic age. With two exceptions, which will be noted below, there are no known deposits of sedimentary rocks which may correspond to the oil-bearing formations of California. It is evident from a study of this region that it had a totally different geological history from the oil fields. The various Tertiary seas in which the oil-bearing formations were deposited apparently did not cover any appreciable portion of this area. The two exceptions mentioned above consist of beds of Eocene age, and the only thing they have in common with the oil-field formations is that they were laid down in the same sea and consequently are of the same age as certain Eocene beds which are oil bearing in other portions of the State. One area of Eocene is found along the western border of the Mojave Desert, near Rock Creek, Los Angeles County, and consists, according to Dickerson,[69] of about 5,000 feet of coarse sandstone and shale, belonging to the Martinez formation. This area probably represents the eastward line of the Martinez sea. The second area of Eocene is found in the Elsinore Valley [south of the Mohave Desert region] and consists of small thicknesses of highly colored shales and sands of Tejon age. Neither of these deposits show the slightest indication of petroleum. The rocks that are present, consisting mainly of granites, highly metamorphosed Paleozoic and Mesozoic sediments, Tertiary sediments of land or lake origin, together with lava flows, are all unsuitable for the formation of any appreciable amount of petroleum.

To the best of the writer's knowledge there are no known authentic seepages of oil in this area. * * * Innumerable seepages and indications of oil have been reported from this area and a certain well in the Mojave Desert has been reporting oil for the last 18 years, but it may be noted here that in no case have these reports been verified.

From the above brief description of the geology it is evident that the possibility of obtaining oil in the desert region is extremely small.

Although it is remotely possible that oil may eventually be found in the region, investors should consider that the chances of success of the numerous wildcat wells are very slight and that purchases of stock in the companies drilling such wells are highly speculative. It is significant that none of the large producing companies have done any drilling in the Mohave Desert region.

Nitrates.—Nitrates are found in the deposits of many of the saline playas in the Mohave Desert region and also in a number of other places in the region, notably in Death Valley and the adjoining territory. On account of the usefulness of nitrates in warfare these deposits were examined carefully by the United States Geological Survey in 1917 and 1918.[70] The results of this investigation showed that although thin layers of the beds were high in nitrate, the nitrate content of the deposits as a whole was not sufficiently great to warrant their development.

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[69] Dickerson, R. E., The Martinez, Eocene, and associated formations at Rock Creek: California Univ. Dept. Geology Bull., vol. 8, No. 14, 1914.

[70] Noble, L. F., Mansfield, G. R., and others, Nitrate deposits in the Amargosa region, southeastern California: U. S. Geol. Survey Bull. 724, 1922.

Other nonmetals.—In addition to the few nonmetals already mentioned a number of others are produced on a small scale or, if they have not yet been mined, may sometime be of value.

Asbestos has been found 4 miles west of Hicks station, probably in the southeastern part of T. 9 N., R. 4 W. San Bernardino meridian. None of it has been shipped.

Several deposits of high-grade clay, suitable for fire brick and tile, have been found, but none of them have been developed. A deposit of white silica, talc, and kaolin 3½ miles east of Oro Grande has been worked to produce "whiting," which is used as a paint filler, in sizing paper, and in porcelain work. A small plant for treating the whiting is located at Bryman.

Strontium ore, used in making red signal rockets, has been shipped from deposits about 10 miles north of Barstow (see p. 439) and about 6 miles northwest of Ludlow (see p. 657). Barite is associated with this ore.

Talc has been mined on a small scale near Riggs, on the Tonopah & Tidewater Railroad. The mineral also occurs on Sheep Creek, 20 miles northwest of Silver Lake.

Magnesite has been shipped from a deposit in T. 10 N., R. 11 W., a short distance north of Bissell. This deposit is of interest because it is said to be the only occurrence of magnesite of evident sedimentary origin that has been reported in the United States.[71]

Other minerals which have been found in the Mohave Desert region but which have not been produced commercially or only on a very small scale include feldspar, fluorspar, fuller's earth, infusorial earth, and niter.

AGRICULTURE AND STOCK RAISING

In the Mohave Desert region agriculture has not been as much developed as the mineral industry, although there has been considerable farming in a few small areas where ground water is close enough to the surface and plentiful enough to be used for irrigation.

The greatest development has taken place in Antelope Valley, in the extreme southwestern part of the region. (See pp. 289–371.) In this valley probably between 10,000 and 15,000 acres are under cultivation. The largest area in the valley is devoted to alfalfa, and about 20,000 tons was shipped in 1919. Data as to shipments since that year are unreliable, for increasingly large shipments have been made each year by automobile trucks. Along the higher land on the south side of the valley, particularly around the town of Little Rock and at Valyermo post office, a considerable acreage is devoted to pears and apples. In 1919 about 1,200 tons of pears and 250 tons of apples were shipped from the south end of the valley.

[71] Gale, H. S., Late developments of magnesite deposits in California and Nevada: U. S. Geol. Survey Bull. 540, pp. 512–513, 1914.

In the Mohave River Valley, from the San Bernardino Mountains to a point a few miles east of Daggett, several thousand acres are irrigated. Several hundred acres are being irrigated from wells in Indian Wells Valley, in the northwestern part of the region. Some land is also being irrigated in Fremont Valley.

It is estimated that more than 2,000,000 acres of land in the Mohave Desert region would be suitable for agriculture if water were available.[72] But it is believed that probably not more than about one-twentieth of that area can eventually be irrigated, and only a very small part of the region is adapted to dry farming. Thousands of acres have been patented or applied for under the homestead and desert-land acts. Many of the homesteads have been applied for and some of the patents have eventually been received by persons who have wanted the land only for speculation. This has been true especially in the regions where projects have been proposed to irrigate large areas or where the prospects are otherwise bright for a considerable increase in the value of the land. These persons have not spent any more money on their land than is necessary to obtain patent to it, and after it has passed into their ownership they have ceased to cultivate it. Such neglect of the land tends to hold back the development of the surrounding territory. Many of the homesteaders, after having spent some time and money on their land, have relinquished their claims before obtaining patent to the land. Some of them have relinquished their claims because they did not have sufficient funds to carry them through the period of no returns until their land should be on a paying basis. Others, after they have been on the land for a few months and have come face to face with the problems of ranching in a desert country, discover that the prospect is not as bright as it first seemed; for many of the homesteaders have been persuaded to apply for their land by unscrupulous "land locators" or by persons who have had greater vision than practical experience and knowledge of the possibilities and difficulties of the development of arid lands. Nearly all of the land suitable for irrigation has been patented.

Cattle raising is unimportant in the Mohave Desert region, the total number on the range in the entire region probably being considerably less than 5,000. The most extensive cattle range is in Providence, New York, and Ivanpah Mountains, where possibly as many as two or three thousand head are run. A few hundred head are run on the northeast slopes of the San Bernardino Mountains near Old Woman Spring, and small scattered herds are run in Antelope and Indian Wells Valleys and around Pilot Knob.

The natural conditions in most of the region are unfavorable to raising cattle on the open range, and there seems to be little likelihood

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[72] Tait, C. E., Irrigation resources of southern California: Rept. California Conservation Commission, p. 326, 1912.

that the industry will grow. The principal difficulty is that the supply of natural feed is not sufficient to support the cattle. In the rainy season annual plants that spring up furnish feed, but these quickly die and in most of the region there is no feed for many months. The winter and spring growth of feed might be utilized if high mountains were near to which the cattle could be driven for grazing in the hot and dry months, but most of the mountains in the region are not high enough to provide the proper conditions in summer. Because of the shortness and uncertain length of the wet season it is not feasible to run cattle in most of the region. The problem of water supply for the stock does not seem to limit cattle raising, for probably enough water for stock could be obtained in almost any part of the region if the feed were sufficient.

It is estimated that the average carrying capacity of the region as a whole is less than 5 head to the section. In order to make it profitable to raise cattle a man ought to have at least 25 or 50 head, and it would accordingly be necessary for him to control from 5 to 10 sections of land. It is evident that even though the feed is good over a small area the homesteader who can obtain patent to a single section of land can not hope to succeed in raising cattle alone unless he grows a large amount of feed by irrigation. The few small areas in the region where cattle can be raised on the range came into the control of ranchers long ago.

FLORA

GENERAL FEATURES OF DESERT VEGETATION

Despite the popular impression that the desert is a vast waste where but few living things can exist, it not only contains much life but there is a considerable variety of both plants and animals. The observing traveler finds many interesting things to occupy his attention, even though he may not be especially trained in botany or zoology. The Desert Botanical Laboratory of the Carnegie Institution of Washington [73] has made the most extensive investigations of the plant life of the desert region of America. The occurrence and distribution of plants in the Mohave Desert region are described by Coville [74] and Merriam,[75] of the Death Valley expedition sent out by the United States Department of Agriculture in 1891. In the present

[73] Among the publications of the Carnegie Institution of Washington relating to the flora of the desert the following contain material of general interest: Coville, F. V., and MacDougal, D. T., Desert Botanical Laboratory of the Carnegie Institution: Pub. 6, 1903. MacDougal, D. T., Botanical features of the North American deserts; Pub. 99, 1908. Spalding, V. M., Distribution and movements of desert plants: Pub. 113, 1909. Cannon, W. A., The root habits of desert plants: Pub. 131, 1911. MacDougal, D. T., and others, The Salton Sea, a study of the geography, the geology, the floristics, and the ecology of a desert basin: Pub. 193, 1914.

[74] Coville, F. V., Botany of the Death Valley expedition: Contr. U. S. National Herbarium, vol. 4, 1893.

[75] Merriam, C. H., The Death Valley expedition, a biological survey of parts of California, Nevada, Arizona, and Utah: North Am. Fauna, No. 7, 1893 (report on desert trees and shrubs, pp. 285–343; report on desert cactuses and yuccas, pp. 345–359).

report a technical discussion of plants would be out of place, but some of the facts of general interest about the vegetation of the region are given.

One of the principal conditions that govern the distribution of vegetation is the moisture supply. Except in the highest mountains the rainfall probably does not average more than 5 inches a year—an amount which is insufficient to produce vegetation like that of humid regions but which produces a characteristically desert type of vegetation. In certain parts of the region the water table stands so close to the surface that the ground water is within reach of the plants, and plants similar to those in humid regions are found. In some places where the water table is close to the surface, however, the soil is so impregnated with alkali that only certain species that are especially adapted to withstand the effect of the alkali can grow. Such plants are physiologically like the true desert types of vegetation, because the presence of so much alkali in the water in the soil makes the water unavailable to the plant, even though it is present in abundance.[76] Trees are found in some areas along Mohave and Colorado Rivers where the water table is close to the surface, and in some of the highest mountains where the precipitation is great enough coniferous trees grow. The rest of the region is virtually treeless except for the giant yucca or Joshua tree (*Yucca* or *Clistoyucca arborescens*), which grows in some localities above altitudes of 2,500 feet. (See pl. 4, *B*.)

The number of species found in the desert is not as great as in an area of the same size in more humid regions, but Coville,[77] in his report on the Death Valley expedition, lists about 200 genera and more than 300 species. A very few species, however, predominate. Over most of the region the creosote bush (*Covillea tridentata* Vail), often erroneously called greasewood or sagebrush, is the dominant shrub. It is generally larger than the other plants that are present and more or less obscures them, so that it gives a monotonous appearance to the landscape. (See pl. 4, *A*.) The species *Franseria dumosa* is almost as widely distributed as the creosote bush but not so abundant or conspicuous.

The monotonous appearance of the landscape, which is due to the widespread distribution of the creosote bush or the other few common types, is lessened somewhat in the spring. At this time of the year, after the winter rains, the desert floor in many places is literally carpeted with small annual plants that bear brilliantly colored flowers. As the dry summer progresses, however, these plants wither away, and unless one looks carefully he is unaware that the ground between

[76] Coulter, N. M., Barnes, C. R., and Cowles, H. C., A textbook of botany for colleges and universities, vol. 2, p. 486, American Book Co., 1911.

[77] Coville, F. V., op. cit., pp. 39-41.

the creosote and other shrubs ever bears any vegetation. The seeds of the annuals lie dormant during the greater part of the year but spring into life at the coming of the rainy season and send forth their flowers for a short period.

Another noticeable characteristic of the desert vegetation is the fact that in most parts of the region the larger plants generally grow several feet apart, doubtless because of the scanty supply of moisture that is available for them. Except in the areas where the water table is close to the surface, about the only water available to plants comes from the scanty rainfall, which generally moistens only the upper layers of soil. The investigations of Cannon [78] have shown that in order to obtain sufficient moisture to sustain life the plants have developed extensive root systems with many branching roots, which draw water from a relatively large volume of soil. He found that perennials develop three types of roots—one in which there is a very prominent tap root, one in which the laterals are well developed, and a generalized type having both the tap root and the laterals.

The perennials that have the generalized type of roots were found to have the widest local distribution in the region studied, doubtless because they were best able to adapt themselves to a variety of conditions. The creosote bush (*Covillea tridentata*) has this type of roots. On the alluvial slopes where the depth to water is great a prominent tap root was not found, but the roots spread out laterally over a considerable area. An example of the length of the lateral roots of the creosote bush is shown in Plate 5, *A*. These roots were exposed by the flood run-off that followed a cloudburst near Newberry Spring a few months before the photograph was taken.

Cannon found that most of the cactuses have prominent laterals, although many of them also have an anchoring root. The giant yucca apparently has a root system somewhat similar to the cactuses. A sturdy yucca in full life exhibits a broad base above ground, comparable to the base of an oak tree, and one would suppose that large roots extended downward below the surface. But where a yucca has been uprooted it is obvious that a few inches below the surface there is a sharp change, and many very slender roots lead from the larger roots, which spread out like feet. (See pl. 5, *B* and *C*.) The numerous small roots evidently can gather moisture from a much larger volume of soil than a few thick roots could. This is significant, for the yuccas are found where the depth to ground water is great. The development of the roots is such that moisture can be derived even from the slight amount of water that percolates into the ground after a single shower.

Not only have the desert plants developed methods of increasing their supply of moisture but they have also developed means of

[78] Cannon, W. A., The root habits of desert plants: Carnegie Inst. Washington Pub. 131, 1911.

conserving the supply of moisture which they absorb, for if such means were not present, under the heat and great evaporation that occurs in the desert, the entire supply of moisture would be transpired quickly, and the plant would wither and die. Many of the desert perennials have very small leaves, so that the transpiration surface is thus reduced. The leaves of some species have a resinous coating or a close covering of hairs, which reduces transpiration to the minimum. From the resinous coating on its leaves the creosote bush gets its popular name, for in burning the wood and leaves it gives off a dense smoke accompanied by a pungent odor.[79] When the plant is wet by rain the peculiar odor is also noticeable. On hot days the stomatic openings in the leaves are closed thus reducing the transpiration. In dry seasons some plants also drop their leaves.

Many of the desert plants, especially cactuses, possess special structures for storing water. The interior of many of the cactuses consists of pulp, which contains much water,[80] and in fact, the desert Indians drink the juice from some species. The water is obtained by cutting off the top of the plant and crushing the pulp. The water in some of the cactuses is bitter and unpalatable. It is found that the cactuses in which the juice is bitter are not as well protected with spines as the species which yield juice that can be drunk, as if the spines had been developed to protect the plants from animals seeking water.

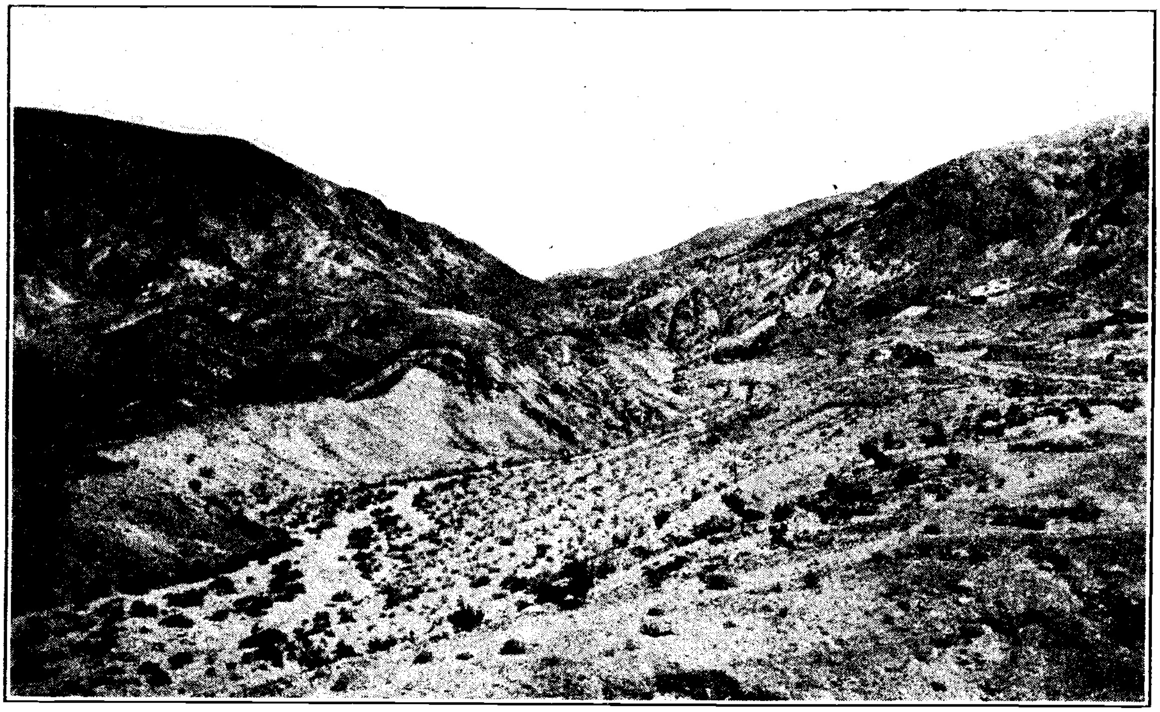
A striking feature of the landscape in many parts of the Mohave Desert region is the presence of areas of land entirely devoid of vegetation. These areas, which range in size from a few acres to many square miles, are in the lowest parts of the closed basins of the region and comprise what are known to the geologist as playas, but more commonly called "dry lakes." [81] The soil of the playas generally contains more or less alkali, and the absence of vegetation on some of them is undoubtedly due to the excessive amount of alkali. However, analysis of the soil of some playas shows that their alkali content is less than that endured by some plants, so that the absence of vegetation on such playas can not be due entirely to the alkali. The soil of these playas is generally so compact that plant roots have difficulty in penetrating it, and the water level is some distance below the surface. It is therefore probable that in addition to the chemical character of the soil, its physical character and deficient moisture supply are responsible for the absence of vegetation on the playas.

The Mohave Desert region may, with respect to vegetation, be separated into three more or less distinct zones, embracing (1) the mountains that are high enough to receive sufficient precipitation to produce coniferous trees and associated types; (2) the flood plains of

[79] Coville, F. V., op. cit., p. 51.

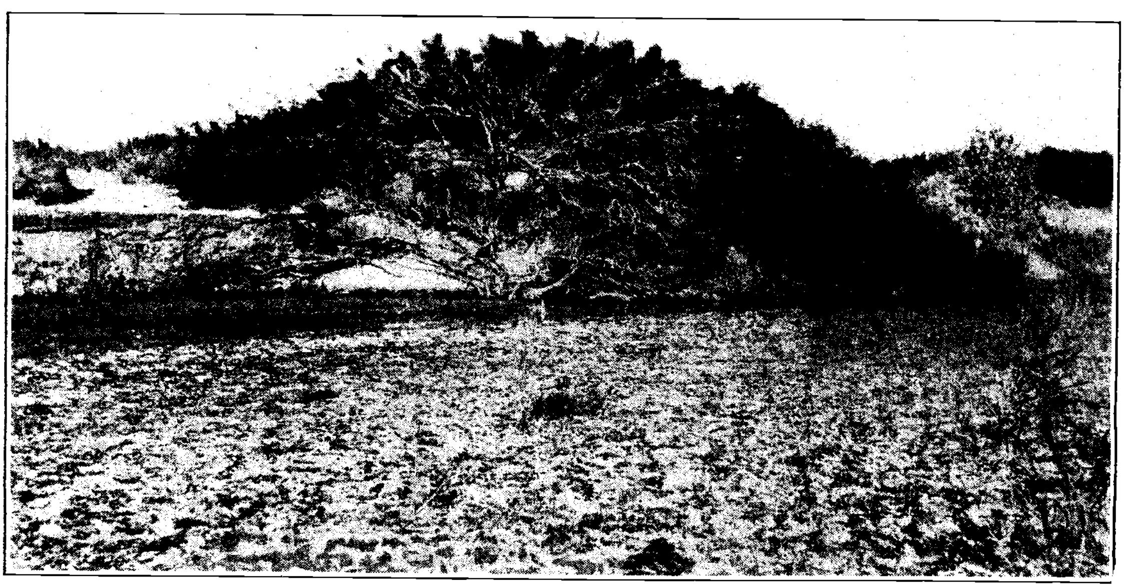
[80] Coville, F. V., Desert plants as a source of drinking water: Smithsonian Inst. Ann. Rept. for 1903, pp. 499–505, 1904.

[81] See footnote, p. 109, for definition of a playa.



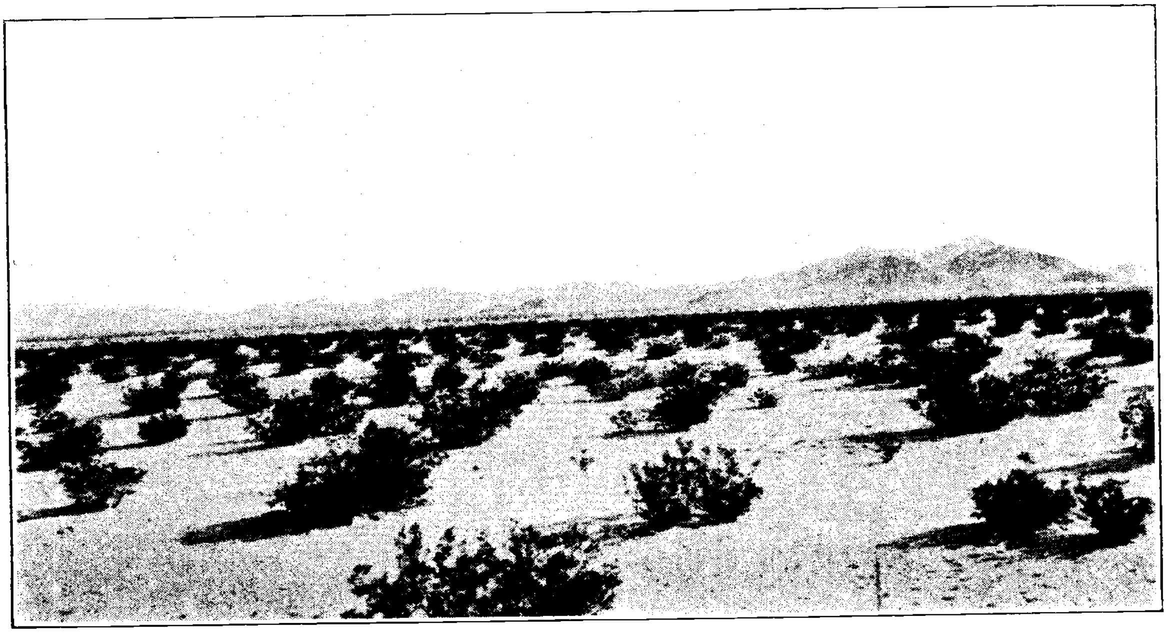
A. VIEW LOOKING NORTH UP WALL STREET CANYON IN CALICO MOUNTAINS

Shows remains of abandoned town of Calico



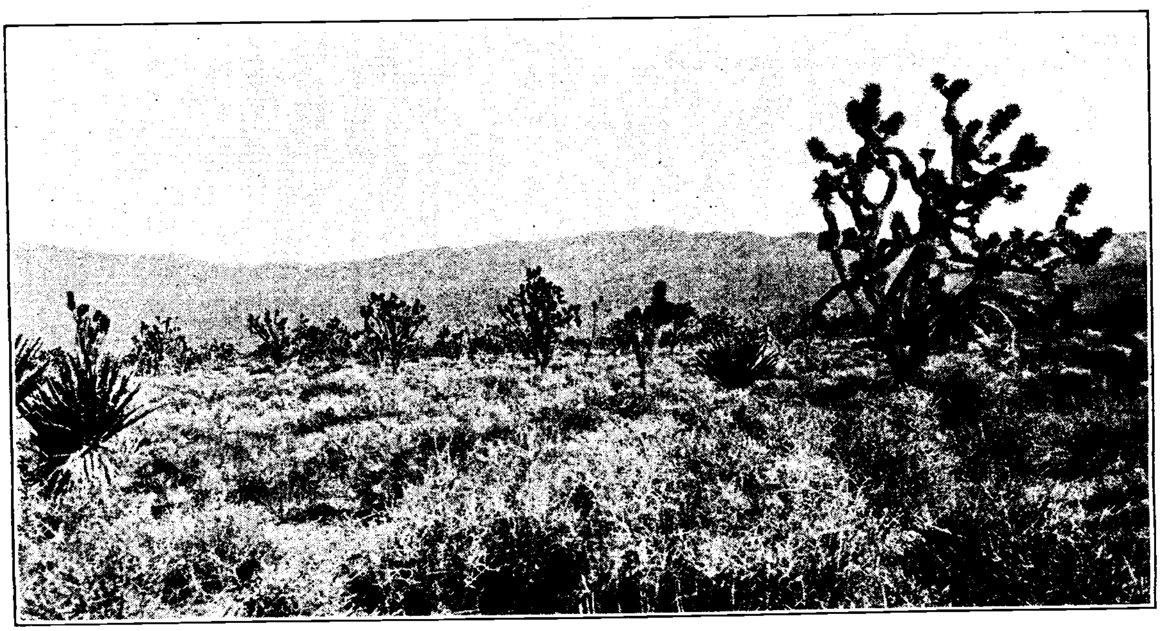
B. MESQUITE BUSH ON SAND DUNE ALONG MOHAVE RIVER

Shows how a single plant extends over a large area. Roots partly exposed



A. TYPICAL VIEW IN MOHAVE DESERT

Shows predominance of the creosote bush



B. JOSHUA TREES, OR GIANT YUCCAS, NEAR CIMA

A characteristic desert plant that grows above the altitude of 2,500 feet. Photograph by G. A. Waring

A. ROOTS OF A CREOSOTE BUSH EXPOSED BY FLOOD WASH

B. ROOTS OF A GIANT YUCCA
(*Yucca arborescens*)

C. ROOTS OF A GIANT YUCCA
(*Yucca arborescens*)

Mohave, Colorado, and Amargosa Rivers and the lowest parts of some closed basins, where the water table is close to the surface and thus supports a relatively dense vegetation; and (3) the low hills, alluvial slopes, and plains, where the rainfall is low and the water table is too far below the surface to be reached by the plant roots. In this third zone the conditions that affect plant growth are of a truly arid type. It separates more or less completely the mountains from the areas of high water table. In altitude, however, the third zone is not always intermediate between the other two. Thus salt grass, the willow, and the mesquite grow along Mohave River in the areas of shallow water table at altitudes as great as 2,500 or 3,000 feet above sea level, whereas the creosote bush, which is characteristic of the zone of true arid conditions, is found in Death Valley as low as 200 feet above sea level.

The following paragraphs contain notes on the occurrence and distribution of a few typical plants in each of the zones mentioned above, as observed during the present investigation. The observations are those of one not specially trained in botany and were made with the view of obtaining evidence of the relation between vegetation and occurrence of ground water. Specimens collected in the field work were identified by Miss Alice Eastwood, of the California Academy of Sciences, to whom the writer is indebted for much information of value in regard to the desert vegetation. On pages 54–57 is given a list of all the specimens collected by the writer and identified by Miss Eastwood.

VEGETATION OF THE HIGH MOUNTAINS

Parts of the San Bernardino and San Gabriel Mountains, the Sierra Nevada, the Providence and New York Mountains, Clark Mountain, Potosi Mountain, and the Kingston and Panamint Ranges have sufficient precipitation to bear coniferous trees or other vegetation typical of a nonarid region. The writer did not have an opportunity to visit most of these high mountains, and no special attention was paid to the vegetation of these areas.[82] Coniferous trees, some of them several feet in diameter, are abundant in the San Bernardino and San Gabriel Mountains. The California live oaks are found on the desert slopes of the Tehachapi Range, a southern extension of the Sierra Nevada. The juniper (probably *Juniperus californica*) and the piñon (*Pinus monophylla*) occur on the ranges at the southwest and west borders of the desert, and the piñon at least is found in the Providence and New York Mountains. Along the base of the San Bernardino and San Gabriel Mountains the juniper extends down

[82] The description and distribution of trees that grow in the Mohave Desert region, according to individual species, are given in Sudworth, G. B., Forest trees of the Pacific slope, U. S. Dept. Agr. Forest Service, 1908.

into a zone of giant yuccas which marks the upper parts of the arid zone. In the vicinity of Quartz Hill, in T. 66 N., R. 12 W., where the average annual precipitation is about 8 inches, the juniper grows at an altitude of about 2,500 feet, whereas in the interior of the desert, where the rainfall is much less, it is not present at elevations of 4,500 to 5,000 feet.

VEGETATION OF THE LOWER MOUNTAINS AND ALLUVIAL SLOPES

The zone in which the precipitation is low and in which the water table is so far below the surface that ground water is not available to plants is by far the largest of the three zones. It includes both the gently sloping alluvial slopes which reach almost to the bottoms of the numerous closed basins in the region and also the slopes of all the mountains except a few of the very highest. The vegetation on the mountain slopes is generally more sparsely distributed than that on the alluvial slopes, but the principal species are found in both environments, although most species are more abundant in one environment or the other.

The creosote bush, *Covillea tridentata*, is the most widespread and one of the most conspicuous plants in the region. It is most abundant on the alluvial slopes but is also common, though in fewer numbers, in the mountains. Its range in altitude is great. Coville[83] reports that it grows below sea level in Death Valley and at an altitude of more than 5,500 feet in the Panamint Range, although commonly it does not grow at so high an altitude.

Although the creosote bush is widespread, it does not grow everywhere. The conditions that govern its growth, whether of soil, temperature, and moisture supply, are not definitely known, but some observations were made in regard to its distribution. It is generally not found where the water table is close to the surface. In Indian Wells Valley, in the northern part of T. 26 S., R. 40 E. Mount Diablo meridian, the boundary of the creosote zone is sharp (see p. 145 and fig. 4), and well data indicate that the depth to the water table in this zone in this locality is at least 25 feet. The lower boundaries of the zone are generally several hundred feet from the borders of the playas or "dry lakes" in the lowest part of the numerous closed basins in the region, even though beneath some of the playas the water table is not close to the surface. Doubtless the clayey texture of the soil or the presence of alkali prevents its growth in such places. The bush is absent throughout a very large area in the lower part of Antelope Valley, not only near the playas but some distance away from them. Specific observations show that it is absent in the vicinity of Lancaster, 7 miles south of Rosamond Dry Lake, and for a

[83] Coville, F. V., Botany of the Death Valley expedition: Contr. U. S. National Herbarium, vol. 4, pp. 21, 76, 1893.

number of miles east and northwest of that place. It was not seen in sec. 19, T. 9 N., R. 13 W. San Bernardino meridian, more than 10 miles from Rosamond Dry Lake. Throughout a large part of this extensive area the water table is so close to the surface that there is discharge by evaporation and transpiration by plants, but in section 19 the depth to water is probably at least 40 feet. The bush is found on the slopes of the Rosamond Buttes, which border Rosamond Dry Lake on the north. The absence of the bush in so large an area in the valley is probably due to the texture of the soil.

One well driller stated that he believed that the creosote bush was an indication that bedrock would be encountered before water was found and that the water supply in such area was not great. There is abundant evidence, however, that this opinion is not warranted, for wells in the creosote bush zone have reached water at depths of 400 to 500 feet without striking bedrock, and some wells with large yields have been obtained where the bush is the dominant vegetation. The creosote bush seems to be of no value as an indicator of ground-water conditions except as indicating that the depth to water is more than 25 feet. In places where floods are frequent the plants grow larger than elsewhere, attaining heights of 6 or 8 feet.

Franseria dumosa is a common shrub with rigid branches that generally grows in the same localities as the creosote bush, but it is less noticeable because it is smaller, ranging from 1 foot to 2 feet in height. In the Mohave Desert region *Franseria* is the common associate of the creosote bush.

Eriogonum inflatum is a peculiar plant of the alluvial slopes. It grows about a foot high and has a straight stem, from which there are several branches. Several inches above the ground the stem has an inflated bulblike structure somewhat like a small onion, which has suggested the name "cigarette plant." A species of the same genus, which, however, does not have the inflated bulb on the stem, *Eriogonum trichopodum,* is found in many places where the land has been cleared and perhaps sowed to a crop and later abandoned. It is reddish brown when dry and gives to such abandoned tracts a characteristic red color.

Ephedra californica, commonly known as Mormon tea, is also found in many places on the alluvial slopes. It is a low, bushy plant characterized by pale-greenish jointed stems which are devoid of leaves.

A very peculiar species is *Holocantha emoryi.* It has no leaves, and its branches are like long sharp spikes. It bears reddish berries. It is of special interest because, so far as the writer is aware, it has been reported from only three places in California, all of them in the Mohave Desert. The writer was given a specimen by Mr. E. H. Martin, of Oatman, Ariz., who had found it growing in the wash of a broad valley that extends from Goffs southward to Ward station, on the Parker branch of the Atchison, Topeka & Santa Fe Railway, at a place about 20 miles south of Goffs. The specimen was sent to Miss Alice Eastwood, who stated that it was the first time the species had been recorded in California. It occurs more abundantly in Arizona. The writer was also shown a specimen that had been collected in a wash along a road that leads southward from the National Old Trails Road about 25 miles east of Ludlow, though the location was not very accurately described. It has also recently been reported from a locality near Ludlow.[84]

Several species of trees grow on the alluvial slopes, where the depth to water is great, but the only one that is abundant is the giant yucca or Joshua tree (*Yucca arborescens*). The yucca is one of the most interesting species found in the desert. (See pl. 4, *B*.) It is the largest spine-bearing form in the Mohave Desert region and is often erroneously called a cactus. The following description is quoted from Sudworth:[85]

Of the two tree yuccas indigenous in the Pacific region the Joshua tree, also called "yucca cactus," is much the larger and more treelike. From 18 to 25 feet, or occasionally 30 or 35 feet, is the usual height, with a diameter of from 1 to 2 feet. It is easily the most wild-looking denizen of desert hills and plains. The keenly pointed bayonet-like leaves, bristling at the ends of big clumsy branches, defy every intrusion and compel respect from many natural enemies. Young trees are unbranched until they have produced flowers, which is commonly at a height of from 8 to 12 feet. Usually two branches are then formed at the top of the single stem and, in succession, each of these forms two or more until a broad, low-branched crown results at maturity. When from 3 to 6 feet high the trunks are often set with bristling leaves down to the ground. No living thing intrudes upon the ground they occupy. The topmost leaves are upright in position, but as the stem increases in height the first leaves grown begin, during about their second year, to droop, finally dying and becoming closely pressed down upon the trunk in a thatchlike cover. Trunks 10 feet high may be entirely covered. Gradually these dead, but always stiff and prickly leaves are forced off at the base of the trunk by the growth of the trunk and by wind, uncovering an ashy gray, cross-checked, and ridged bark. Except on old trees the greater part of the tree is covered with dead, closely thatched leaves. This covering of formidable living and dead leaves suggests a wise protective measure through which alone the tree is able to maintain and extend itself, with little check from its enemies, in a region often lacking in other vegetation. The bluish-green leaves are from 6 to about 10 inches long and about five-eighths of an inch wide; longer leaves occur on young trees. Leaves taper gradually from just above the base (1½ inches wide) to the point. The upper half is concave, tapering to a long, keen reddish or blackish-brown point; the lower half of the leaf is flat or only slightly concave, while the two edges have minute teeth throughout. A single stiff, branched cluster (about 15 inches long) of rather fetid flowers grows from the end of the crown branches. The fruit, usually matured early in June. is borne on short stems, at first standing more or less erect but after maturity somewhat drooping or bent down. The fruit covering is dry and soft. It

[84] Ferris, R. S., A new plant record for California: Southern California Acad. Sci. Bull., vol. 18, pt. 1, p. 13, 1919. Thompson, D. G., idem, vol. 19. pt. 3, pp. 54–55. 1920.

[85] Sudworth, G. B., op. cit., pp. 201–203.

rarely opens of its own accord, but when very dry and brittle it is blown or falls from the tree and later is blown about and broken open by the wind and its seed scattered. The six chambers of the fruit are filled with flat, jet-black seeds. Wood rather soft and light (when dry) but tough on account of its strong fibers; pale yellowish white. Further investigation may establish its permanent usefulness for paper pulp, for which it is suitable.

Nothing can be said definitely of the age to which this tree attains. It is very probable that an individual lives at least 100 to 200 years, and there seems little doubt that these trees may live 200 to 300 years. The growth appears to be very slow in both height and diameter, but very persistent.

The giant yucca is found only on the higher alluvial slopes and occasionally on the slopes of some of the interior mountains. It has a rather definite range in altitude and is seldom found below 2,500 feet above sea level. It is sparsely distributed, however, as low as about 2,300 feet in Antelope Valley. It is rather widespread where the altitude is sufficient. It is most abundant on alluvial slopes extending northward from the San Gabriel Range and near Cima, in each of these places forming a veritable forest. The giant yucca is not found in Arizona except in a small area in the northwestern part of the State. On the other hand, some forms found in Arizona, notably the giant cactus or sahuaro (*Cereus giganteus*), are reported at only two or three places on the California side of Colorado River.[86]

The yucca is sometimes used for fuel, but although it makes a hot fire it burns rapidly and does not last long. It is said that despite its protective structures the fruit is eaten by cattle, which obtain it by raising on their hind legs and avoiding the sharp blades of the leaves. Paper pulp has been made from the trunks, but the manufacture of paper from this tree can hardly prove successful. The tree grows so slowly that the supply would soon be exhausted.

Several other species of yucca occur in the region, but they do not form trees. One of these, *Yucca macrocarpa*, generally grows in clumps on short trunks 4 or 5 feet high, from which the leaves extend without any branches. Another species is *Yucca whipplei*, which is especially abundant on the south slopes of the San Bernardino and San Gabriel Ranges and extends onto the desert side of these mountains. The plant consists of a number of daggerlike leaves that radiate upward from a common base at the surface of the ground, and because of its shape it is commonly known as Spanish bayonet or Spanish dagger. The flowers of this plant are especially striking. Early in the spring a shoot appears in the center of the plant and grows rapidly. In a few weeks it attains a height of 8 to 10 feet, occasionally 15 to 20 feet, and is 2 inches or more in diameter. On this stalk there develop many beautiful cream-colored flowers, which are bell-shaped and have a waxy luster. With the coming of the dry season the stalk dies and turns yellow, but it stands where it grew for many

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[86] Chase, J. S., California desert trails, pp. 51, 310, Houghton Mifflin Co., 1919.

months. The leaves of the Spanish bayonet have been used for making binder twine.[87]

Other tree forms besides the giant yucca that were seen on the dry alluvial slopes in the region are palo verde (*Cercidium torreyanum*) and ironwood (*Olneya tesota*). Palo verde was seen in a large wash in Chemehuevis Valley. (See p. 737.) Ironwood was found in a wash a mile or two north of Vidal. The depth to the water table at this place, according to well data, is probably at least 250 feet, and it is 50 feet or more where the palo verde was seen. The localities mentioned apparently are the farthest north that these species have been found in the region. They are abundant farther south and in Arizona.

The cat's-claw (*Acacia greggii*), so named because of its clawlike thorns, was seen at a number of places in gravelly washes, especially within the mountain borders. Although in some places it grows luxuriantly, it apparently does not indicate the presence of ground water but rather depends on flood water that percolates into the gravel in stream channels.

The desert palm (*Neowashingtonia filifera*) is found at Twenty-nine Palms, on the southern border of the region, which seems to be the most northerly station of this plant.

Cactuses are not as common in the Mohave Desert region as in other parts of the arid Southwest. They occur generally on the alluvial slopes at intermediate and high altitudes but not in the lower valleys. Probably the most common and most noticeable are species of *Opuntia*, generally called cholla (pronounced cho'ya). Chollas are fantastic plants, usually with a treelike habit but only 2 or 3 feet high. The branches bear numerous menacing spines, which are long or short according to the species. They have the evil reputation of shooting their spines into a person's flesh if he approaches within a few inches of them, even without touching them. This reputation arises from the fact that the spines are separated from the stem very easily and the plants are often unknowingly touched by the clothing or articles that are being carried by one walking among them. The spines penetrate the flesh at the slightest pressure and are removed with difficulty and pain.

The forms of cactus commonly known as "prickly pear" seem to be scarce, possibly because they are too small or low to be noticeable except as one sees them directly underfoot. Some of them have prominent spines. Other species seem to have no spines but bear a kind of fuzz on the surface which, if the plant is not handled carefully, proves to be as efficient as the large spines in penetrating the flesh.

Fouquieria splendens or ocotillo (pronounced ocotee'yo) consists of a number of straight stems from 5 to 10 feet or more in length and an inch or two in diameter, which radiate upward from a common

[87] Von Blon, J. L., Binder twine from the desert: Sci. Am., vol. 121, p. 82, 1919.

base. The stems have no branches. Minute leaves are attached to them, and they also bear thorns. In the spring they bear brilliant purple flowers. This plant was seen at only one locality in the Mohave Desert region, along the Needles-Parker road, on the south side of a low divide about 16 miles south of Needles. The ocotillo, however, is common farther south in the Salton Sea region.

An interesting species is *Atriplex hymenelytra*, commonly known as desert holly. It receives its name from the fact that the leaves are shaped much like the holly that is used extensively for Christmas decorations, and it has a red seed or berry, which, however, is smaller than the berry of the true holly. The leaves are of a silver-gray color. The plant presents a pleasing appearance and is used for holiday decorations in the towns and cities adjacent to the desert. The plant was seen in washes where the soil was rather hard and perhaps slightly alkaline and also on rocky hill slopes. It was especially abundant on the rocky slopes near Newberry Spring.

VEGETATION WHERE WATER TABLE IS NEAR SURFACE

The third type of vegetation found in the Mohave Desert region is that which grows where the water table is close enough to the surface for the plant roots to reach it. The areas where these conditions exist are of three general kinds. One kind comprises lands along streams, as along the flood plain of Colorado River and at places along Mohave River, although in some of the flood plain of the Mohave the water table is too deep to be reached by plant roots.

Another kind of area comprises lands that lie near the lowest parts of closed basins. The playas or clay flats, some of them covering many square miles, are generally devoid of vegetation, but a characteristic vegetation grows around their borders if the water table is close to the surface. Where the water table is not close to the surface the vegetation of the arid alluvial slopes extends to the border of the playa.

The third kind of area comprises lands where the water table is close to the surface but which lie neither along rivers nor in the lowest parts of closed basins. Such conditions are generally due to the geologic structure, which brings the ground water near the surface. The vegetation in such areas is generally similar to that in one or both of the other kinds of areas. The essential difference between the conditions along the streams and those in the low parts of the closed basins is that the soil near the playas is generally more alkaline than that along the streams. Accordingly, the vegetation in such places is of a type that can endure considerable alkali. The relation of plants to ground water in portions of the United States has been discussed recently at some length by Meinzer.[88]

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[88] Meinzer, O. E., Plants as indicators of ground water: U. S. Geol. Survey Water-Supply Paper 577, 1927.

Along the streams grow several kinds of trees, notably species of willow, cottonwood, and mesquite. The first two kinds are not as common as the mesquite. MacDougal has pointed out that mesquite requires less water than poplar.[89] A grove of poplars, in which the trees were a foot in diameter, was seen in the lower part of the wash of Big Rock Creek a mile or two southwest of the Lovejoy Buttes. Elsewhere they were observed only along Mohave River. They doubtless grow along the flood plain of Colorado River but were not seen in the parts of that region that were visited.

Two species of mesquite occur in the region, *Prosopis pubescens* or *P. odorata*, commonly called the screw bean mesquite, and *Prosopis juliflora* or common mesquite. The screw bean mesquite is most easily distinguished from the other species by the fruit, which is a leathery pod shaped somewhat like an Archimedes screw and which contains beanlike seeds. The fruit of the ordinary mesquite is much like the pod of ordinary beans. The beans of both species are eaten with relish by cattle and when crushed into a meal are used for food by the Indians. Both plants grow either as trees or as bushes and have small leaves and sharp thorns. The root wood of *Prosopis juliflora* and probably also that of the screw bean is heavier than the wood of the trunk. The roots also are very long, some of them extending 50 or 60 feet below ground.[90] Indeed, it is said that the plant usually has more wood below ground than above. In this region the trunk and branches are usually small, so that the roots are more generally used for firewood than the parts above ground. When one goes to cut mesquite for fuel, a shovel is as essential as an ax.

The screw bean and ordinary mesquite often occur together. They are abundant in stretches along Mohave River where ground water is close to the surface but are absent in other stretches where the depth to water is considerable. They are found in the lower parts of some of the closed basins and in other places where the geologic conditions hold the water table close to the surface. They are found in the lower parts of the basins near playas in Antelope Valley, in Ind an Wells Valley, and in Crucero Valley bordering Soda Lake and elsewhere. They are also found in a belt that stretches northwest from the vicinity of Newberry Spring (see p. 445 and pl. 26, *B*), where some unknown geologic condition brings the water to the surface.

In many places where the mesquite grows in open expanses of land, wind-blown sand accumulates around the plants. As the plant grows the sand accumulates more and more, and dunes, some of them 15 or 20 feet high, are formed. The mesquite spreads out, and the different branches, when covered by sand, appear to form a number of indi-

[89] MacDougal, D. T., Botanical features of the North American deserts: Carnegie Inst. Washington Pub. 99, p. 13, 1908.
[90] Sudworth, G. B., op. cit., p. 365.

vidual plants. The roots generally penetrate some distance below the original ground surface in search of water, although the plants may appear to be perched on top of the dunes. (See pl. 3, *B*.)

In the Salton Sea region and parts of southwestern Arizona mesquite grows where the depth to water may be from 50 to 100 feet or more, and it is thus not a reliable indicator of ground water.[91] In the Mohave Desert region, however, wherever mesquite was observed the depth to water was not more than 25 or 30 feet, and it is generally considered to indicate that ground water is within that distance of the surface.

Another plant that is found along streams is the arrow weed (*Pluchea sericea*, also known as *Tessaria borealis*), so called because its straight stems were used by the Indians for arrow shafts. This plant is reported by Coville [92] to occur at several springs in the desert region. It was observed by the writer in great abundance on the flood plain of Colorado River near Topock, Ariz. It is generally considered to indicate that ground water is close to the surface.

Around the borders of the playas where the water table is close to the surface the soil generally contains considerable alkali, so that the plants that grow in such environments are those that can resist alkali. Many of them actually absorb some of the salts in such quantity that they can be tasted if the leaves are chewed, and hence these plants receive the general name of "salt bushes."

The commonest alkali-resisting plant is salt grass (*Distichlis spicata*). This plant is found almost everywhere in the desert where the water table is within 8 feet of the surface. It grows along the flood plain of Mohave River, near many of the playas, and around springs, where the area of moist soil covers many acres or only a few square feet. It is especially troublesome in alfalfa fields where the water table is close to the surface, because with its long, tough roots and general endurance of adverse conditions it is very hard to eradicate once it gets a start. The plant can withstand considerable alkali, but where the ground is very saline it turns a rusty-brown color.

Rabbit bush, which includes several species of *Chrysothamnus*, also grows where the ground water is close to the surface. *Chrysothamnus mohavensis* was found where the depth to the water table was probably a little greater than in areas of salt grass and the soil was probably a little less alkaline. Thus a rather definite zone of *Chrysothamnus mohavensis* was seen at the southeast side of Harper Dry Lake, and

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[91] Brown, J. S., The Salton Sea region, a geographic, geologic, and hydrologic reconnaissance: U. S. Geol. Survey Water-Supply Paper 497, pp. 114-117, 1923. Bryan, Kirk, The Papago country, Ariz., a geographic, geologic, and hydrologic reconnaissance: U. S. Geol. Survey Water-Supply Paper 499, p. 41, 1925. Meinzer, O. E., op. cit., pp. 42-54.

[92] Coville, F. V., Botany of the Death Valley expedition: Contr. U. S. Nat. Herbarium, vol. 4, p. 128, 1893.

what is probably the same species is common in the lower part of Antelope Valley. Other species of *Chrysothamnus* are found in the Mohave Desert region, but although they all seem to grow where the water supply is abundant they do not all occur in the same kind of environment. Thus *Chrysothamnus nauseosus* was found in a canyon on the north slope of the San Gabriel Mountains south of Valyermo post office, where the soil is probably less alkaline than in the closed basins.

Investigations made during the recent war have shown that the different species of *Chrysothamnus* contain a good quality of rubber in quantities up to 6.5 per cent.[93] It is estimated that 3,000,000,000 pounds of rubber could be obtained from plants of this genus in an emergency if the Nation's supply of this necessary article from outside sources were cut off in time of war. The percentage of rubber is so small, however, and the growth of the plants so slow that it is not worth while to exploit this source of supply under ordinary conditions.

Two plants that grow in very alkaline moist soils are *Suaeda suffrutescens* and *Sesuvium portulacastrum*. *Suaeda suffrutescens*, commonly called inkweed, was noticed especially at the south end of Silver Lake after the flood of 1916, at the west side of Troy Dry Lake (T. 8 N., R. 4 E. San Bernardino meridian) and in the depressions between sand dunes northwest of Newberry Springs. *Sesuvium portulacastrum* was abundant around the border of Silver Lake after the flood of 1916. Apparently the seeds had been washed to the edge of the playa during the period of high water.

Other species that grow where the water table is close to the surface and where the soil is generally alkaline are the tule (species of *Phragmites*), sometimes called Indian sugar cane; yerba mansa (*Anemopsis californica*), a plant somewhat like plantain weed; wire grass (*Juncus balticus*); and several species of *Atriplex*, including *A. polycarpa* and *A. torreyi*.

SPECIES OF PLANTS COLLECTED IN THE MOHAVE DESERT REGION

A number of species of plants were collected from the Mohave Desert region by the writer and were identified by Miss Alice Eastwood, of the California Academy of Sciences at San Francisco. The names of these species with brief statements as to their occurrence are given below. The observations are incomplete and were made primarily for the purpose of determining the significance of certain species in respect to the presence or absence of ground water near the surface. The species are listed alphabetically.

Acacia greggii. Cat's-claw. Found in dry gravelly washes where the moisture from the surface run-off may be abundant but does not indicate that ground water is close to the surface.

[93] Hall, H. M., and Goodspeed, T. M., A rubber-plant survey of western North America: California Univ. Publications in Botany, vol. 7, Nos. 6, 7, 8, pp. 159–278, 1919.

Adenostoma fasciculatum. Chamiso. Summit of Cajon Pass.

Anemopsis californica. Yerba mansa. In moist alkaline soil near Newberry Spring, where water table is only 3 or 4 feet below the surface.

Arctostaphylos glauca. Manzanita. At the summit of Cajon Pass. Common on the south slope of the San Bernardino Mountains.

Artemisia tridentata. Sagebrush. Near Government Holes in the elevated valleys of the New York Mountains, along the foot of the San Gabriel Mountains, and about 7 miles west of Lancaster in Antelope Valley; otherwise absent in practically the entire region. Where it is present the rainfall is generally a little greater than in other parts of the desert.

Atriplex hymenelytra. Desert holly. In gravelly washes where the soil is perhaps slightly alkaline and on some rocky slopes near the foot of the mountains.

Atriplex parryi?. In the sand dunes northwest of Newberry Spring.

Atriplex polycarpa?. In the sand dunes northwest of Newberry Spring. A salt bush common in clayey valley bottoms where the soil is damp and alkaline.

Atriplex torreyi. In moist alkaline soil a short distance west of Newberry Spring.

Baccharis viminea? In the dry channels of Mohave River a few miles west of Soda Dry Lake.

Baccharis emoryi. Near springs along Mohave River in sec. 2, T. 9 N., R. 1 E. San Bernardino meridian, where it grew to a height of 7 feet. Probably indicates presence of ground water that is fresh or only slightly alkaline.[94]

Baccharis sarothoides. In wash near Colton Well, 15 miles northwest of Fenner. Possibly indicates ground water close to the surface.

Chilopsis saligna. Desert willow. Abundant in the dry sandy channels of Mohave River in the north-central part of T. 11 N., R. 7 E. San Bernardino meridian, and locally in dry washes. Although this species was found in channels along Mohave River where the depth to water is probably not more than 25 or 30 feet it is not a certain indicator that the water table is close to the surface.

Chorizanthe thurberi. On north slope of first range of mountains north of Barstow.

Chrysothamnus or *Bigelovia mohavensis.* Rabbit brush. A short distance away from southeast edge of the alkali flat of Harper Dry Lake, north of Hinkley, associated with sparse growth of *Distichlis spicata.* The species apparently grows where the ground water is abundant.

Chrysothamnus or *Bigelovia paniculatus?.* Locality not recorded.

Cleomella obtusifolia. On clay flats between sand dunes at Edwards ranch, near Newberry Spring.

Croton californicum. Locally called "dove cover." Between Crucero station and Cronise Valley.

Dicoria canescens. Dry sandy bottom of Mohave River just west of bridge at Daggett.

Distichlis spicata. Salt grass. Very common where the depth to the water table is less than 8 to 10 feet, as in places along Mohave River and around such playas as Harper Dry Lake and Rosamond Dry Lake. Can exist where the soil is very alkaline.

Elymus condensatus. On a pile of windblown sand in a sheltered spot on the western slope of the Cronise Mountains 50 or 100 feet above the alluvial slope.

Ephedra californica. Mormon tea, Brigham's tea, etc. Locality not recorded, but common in the creosote zone.

Ericameria monactis. Locality not recorded.

Eriogonum inflatum. Cigarette plant. Common on alluvial slopes with the creosote bush.

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[94] Coville, F. V., op. cit., p. 127.

Eriogonum trichopodum. Common on land that has been cleared and later abandoned for some time.

Eriodictyon californicum. On north slope of San Gabriel Mountains a few hundred yards south of Valyermo post office.

Fouqueria splendens. Along road between Needles and Parker, about 17 miles south of Needles.

Frankenia grandifolia. A salt weed. In moist alkaline soil about one-third mile west of Newberry Spring. Depth to water table 3 or 4 feet.

Franseria dumosa. Very commonly found with the creosote bush.

Hilaria rigida. Locally called galleta grass. In the vicinity of Crucero station and elsewhere.

Holocantha emoryi. Reported from only three localities in California, all of them in the Mohave Desert region. (See pp. 47–48.)

Isocoma acradenia. In sand dunes northwest of Newberry Spring, probably in damp alkaline soil.

Juncus balticus. Wire grass. Moist alkaline soil about one-third mile west of Newberry Spring and in moist soil at other places.

Juniperus californica. Juniper. Very abundant on north slopes of San Gabriel Mountains.

Lycium cooperi?. Locality not recorded. Rather common on the upper alluvial slopes.

Olneya tesota. Ironwood. Abundant in wash a short distance north of Vidal. Depth to water table about 250 feet. This is the only place it was seen in the region.

Quercus dumosa. A scrub oak. At summit of Cajon Pass, extending a short distance down on north slope.

Parosela or *Dalea spinosa.* Palo blanco. In wash along National Old Trails Road north of Atchison, Topeka & Santa Fe Railway, probably in sec. 25, T. 7 N., R. 10 E. San Bernardino meridian; called indigo bush by Sudworth.[95]

Petalonyx thurberi. Locally called honeybush. Between Crucero station and Cronise Valley.

Phoradendron longispicum?. A large mistletoe on sycamore trees on north slope of San Gabriel Mountains a few hundred yards south of Valyermo post office.

Phoradendron californicum. A mistletoe growing on mesquite, common along Mohave River east of Daggett.

Phoradendron densum. A small mistletoe on juniper on north slope of San Gabriel Mountains a few hundred yards south of Valyermo post office.

Phragmites communis. Tule or Indian sugar cane. On moist alkali soil about one-third mile west of Newberry Spring, where water is only 3 or 4 feet below surface. This or another species is found at Saratoga Springs.

Plantago scariosa?. Common in the creosote bush zone but inconspicuous because of its small size and because it dies after the spring rains.

Prosopis juliflora. Mesquite. Common along Mohave River and in other localities where the depth to the water table is not great.

Prosopis pubescens or *odorata.* Screw bean mesquite, characterized by the bean, which is shaped somewhat like an Archimedes screw. Common along Mohave River and in other localities where the depth to water is not great.

Psathyrotes annua. On hard clay flats between dunes northwest of Newberry Spring; not on the dunes.

Sesuvium portulacastrum. Abundant around the edges of Silver Lake playa after water from flood of 1916 had disappeared. (Type locality is in the West Indies.)

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[95] Sudworth, G. B., op. cit., p. 377.

Sideranthus sp. In wash near Colton Well about 15 miles northwest of Fenner. Water supply probably abundant; water table probably not far below the surface.

Sporobolus asperifolius. On edge of sand dunes northwest of Newberry Springs; probably in moist alkaline soil.

Suaeda suffrutescens. Inkweed. On moist flat areas between sand dunes northwest of Newberry Spring. Abundant at the south end of Silver Lake and on Troy Dry Lake. In saline moist soil.

FAUNA

The desert is not devoid of animals. The individuals doubtless are not as numerous as the plants, but in the aggregate a considerable number of species are found. The Death Valley expedition listed about 290 species of birds, 56 species of reptiles, more than 250 species belonging to 170 genera of insects, 47 species of mollusks, and 13 species of fish.[96] A large proportion of these species were collected from the Mohave Desert region.

Mammals are not numerous. J. C. Merriam[97] gives a list of 35 species found at present in the region, of which 21 are rodents. Mice and rats of many kinds are abundant but seldom seen. One of the commonest species is the kangaroo rat, whose holes are found everywhere. The habits of this little creature of the desert, who ventures out only at night, have been described most interestingly by the eminent naturalist Ernest Thompson Seton.[98]

Rabbits, both the cottontail and the jack rabbit, are probably seen more than any other mammals. In unsettled territory a traveler will usually see several each day. In some places they have caused considerable damage to crops, especially to fruit trees.

The coyote ranges over the whole region. His mournful howls are a customary serenade at night, and he has been known to come within a few feet of camp. Occasionally he steals a chicken from a rancher and robs a camp, but he generally keeps a safe distance from human beings.

Mountain sheep are said to have been common in the higher mountains 30 years ago, but they are not now abundant. Two were reported on the east side of the Old Woman Mountains in 1919, and individuals have been seen occasionally in recent years in some of the more rugged mountains of the region. Antelope Valley derives its name from the abundance of antelope in former years. Occasionally a few remaining individuals are seen in the western part of the valley.

The most common reptiles are lizards. They can be seen scampering across the road in front of the traveler's automobile every few

[96] Merriam, C. H., and others, The Death Valley expedition, a biological survey of parts of California, Nevada, Arizona, and Utah: North American Fauna No. 7, pt. 2, 1893.

[97] Merriam, J. C., Tertiary mammalian fauna of the Mohave Desert: California Univ. Dept. Geology Bull., vol. 11, No. 5, p. 439, 1919.

[98] Seton, E. T., Dipo, sprite of the desert: Century Mag., vol. 105, No. 1, pp. 106–115, 1922.

yards. Although it seems that many of them must be crushed under the wheels, they are so quick and lithe that they always escape. Each bush seems to be the hiding place of one or more of these interesting little creatures. Most of the lizards are from 1 inch to 8 inches in length and slender. The chuckawalla (*Sauromalus ater*), however, is 15 inches or more in length and has a heavy body with wrinkled skin. It is especially common in the Salton Sea region, where its name has been given to the Chuckawalla Mountains. The Death Valley expedition found it as far north as the Argus Range, the Panamint Mountains, and Pahrump Valley, but the writer did not see any specimens during his field work.

Snakes, especially the rattlesnake, are said to be common in some places but none were seen by the writer, perhaps because the field work was mostly done in the winter. The horned rattlesnake or "sidewinder" (*Crotalus cerastes*) is perhaps the most common. It derives the popular name of sidewinder from its peculiar mode of locomotion, which is described as "a peculiar looping movement which carries it obliquely sidewise as well as forward, an adaptation to progression over yielding sand." [99]

The land tortoise is occasionally found in the desert many miles from the nearest known source of water. Other animals—rabbits, rats, and lizards—likewise live far from known water supplies and in places where the depth to the water table is so great that it is obviously impossible for them to burrow down to water. Possibly these animals obtain some moisture from the molecular water that always exists in the soil. Experiments made with desert mice show that some of them apparently do not know what water is, for when shut up they do not drink it, but eat only dry seeds and twigs.[1] Apparently this dry food furnishes sufficient moisture.

Birds are frequently seen, although neither in species nor in number of individuals are they as common as in more humid regions. They are naturally most numerous near the springs and along the streams where water is abundant. Ducks and geese are seen at the largest springs, as Saratoga Springs, and at other places where there are bodies of water of considerable size. Quail are seen in many places. Desert owls are occasionally scared up. Mourning doves are heard around many of the springs. Wading birds of unknown species were seen along Soda Lake. The road runner (*Geococcyx californianus*) is met occasionally. This bird receives its name from the fact that when it is surprised, instead of jumping out of the road, either through stupidity or by preference it scurries along for many yards ahead of the traveler's automobile.

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[99] Vorhies, C. T., Poisonous animals of the desert: Arizona Univ. Agr. Exper. Sta. Bull. 83, p. 360, 1917.

[1] Coville, F. V., Desert plants as a source of drinking water: Smithsonian Inst. Ann. Rept. for 1903, pp. 501-503, 1903.

Insects are particularly numerous around springs and are exceedingly bothersome around evening camp fires. Mosquitoes are present throughout the year but never troublesome. Flies seem to appear from nowhere when camp is made many miles from habitation. A number of species of moths, beetles, and other creeping things were seen, but no attempt was made to distinguish any of them. The large hairy spiders commonly called tarantulas are occasionally seen. These hideous creatures have the reputation of being able to spring several feet into the air if disturbed, but the writer has never seen any of them do so. One scorpion was found in digging a post hole near Victorville. It was unearthed in February and was very sluggish. Although both tarantulas and scorpions are believed by many persons to inflict fatal bites or stings, careful investigations do not show that persons poisoned by either of these insects necessarily will die.[2] The effect of the poison, however, may be serious, and these animals should be avoided by the desert traveler.

A number of species of mollusks, both land and fresh-water forms, have been found in the region but they are not generally discovered except by close observation. A number of the species occur in some of the larger springs. The writer found a number of one species (*Physa elliptica* Lea, identified by W. H. Dall, of the United States Geological Survey) in Buckhorn Springs, at the northeast end of Antelope Valley. This species, with several other species that are listed in the report of the Death Valley expedition, including *Anodonta nuttalliana*, *Planorbis lentus*, and *Planorbis parvus*, were found as fossils in a beach ridge at the north end of Soda Lake, near Baker station. Fossil mollusks which probably include the same species were seen in cliffs along Mohave River and on the surface at the east side of East Cronise Lake.

Several species of fish are found in the Mohave Desert region. No data are at hand in regard to the fish in Colorado River, but at least two species are known from Mohave River—the common catfish (*Ameiurus nebulosus*) and a species of chub (*Siphateles mohavensis*). The catfish has been introduced into the region.

Siphateles mohavensis is indigenous to Mohave River; in fact, this species of *Siphateles* has been found only in that stream.[3] Other species of *Siphateles* are found in Owens River and the Lahontan system. The presence of *Siphateles mohavensis* in Mohave River raises the question as to how members of the genus reached that stream. The solution of the problem perhaps depends on the solution of the physiographic history of the Mohave Desert region. (See pp. 566–568.)

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[2] Vorhies, C. T., op. cit., pp. 380–385, 387–388.

[3] Snyder, J. O., The fishes of Mohave River, Calif.: U. S. Nat. Mus. Proc., vol. 54, pp. 297–299, 1918.

Fish are found in a number of the larger springs in the desert. *Cyprinodon macularius* was found in Saratoga Springs by members of the Death Valley expedition in 1891, and fish seen in those springs by the writer in 1918 were probably of the same species. The presence of fish in these springs, many miles from any other body of water, raises an interesting question as to how they reached that place.

SOILS

GENERAL CHARACTERISTICS OF DESERT SOILS

Soil surveys have been made only of the portion of the region south of latitude 34° 30′ and between longitudes 116° 30′ and 118° 30′,[4] of an area around Victorville,[5] and of part of Antelope Valley.[6] Some general statements in regard to soil conditions in the region can be made, however, based on published studies of the soils of desert regions as a whole and on observations of the writer during the field work.

Some of the principal characteristics of soils of the desert are

abundance of soluble mineral matter, low content of organic matter, gray or light color, great depth with little change in character or depth, small quantity of clay, unless formed from older clay deposits, relatively nonsiliceous nature of the sand, and marked productiveness when irrigated.[7]

These characteristics are nearly all interrelated, and they are largely dependent upon the factors that operate in the desert regions to form soils.

The principal constituents of a soil have their source in the rocks which originally existed in the region. Soils are formed by the action of two general kinds of processes—mechanical and chemical. The mechanical processes, which include the action of heat and cold, wind, and moving water, break the rocks up into small particles, which are composed of the minerals that existed in the original rocks. The chemical processes result in the decomposition of most of these minerals and frequently in the formation of new chemical compounds.

The chemical processes are most rapid in soils that have an abundant supply of moisture. In humid regions the moisture supply is sufficient to enable the chemical processes to play a notable part in the formation of the soil, but in arid regions the soil is formed for the most part by the mechanical disintegration of the rocks. In humid regions the rainfall is, however, sufficient to leach out most of the

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[4] Dunn, J. E., and others, Reconnaissance soil survey of the central southern area, California: U. S. Dept. Agr. Bur. Soils Field Operations, 1917, advance sheets, 1921.

[5] Soil Survey of the Victorville area, California: U. S. Dept. Agr. Bur. Soils Field Operations, 1921, advance sheets, 1924.

[6] Carpenter, E. J., and others, Soil survey of the Lancaster area, California: U. S. Dept. Agr. Bur. Soils Field Operations, 1922, advance sheets, 1926.

[7] Coffey, G. N., A study of the soils of the United States: U. S. Dept. Agr. Bur. Soils Bull. 85, p. 38, 1912.

soluble material, whereas in the arid regions more of the soluble material remains in the soil and is available to plants. For this reason soils in arid regions are generally highly productive when irrigated. Because chemical decomposition is relatively slight in arid regions less clay is formed than in humid regions.

Humus gives the dark color to most soils in humid regions. Because of the lack of humus in the desert soils, these soils are generally not dark but rather of a grayish or buffish color. In humid regions the humus is concentrated near the surface, and the soil below a depth of a few feet is generally of a different color and of different chemical composition, forming what is known as the subsoil. Because of the lack of humus in the desert soils there is no sharp contrast in them between the surface soil and the underlying material.

In many of the desert basins water that contains substances dissolved from soil on the uplands collects on the lowest land, and by long-continued evaporation produces a concentration of soluble salts, either in salt lakes or in the soil of the lowlands. Dissolved mineral matter is also deposited in other places where the ground water is near enough to the surface to evaporate.

ALKALI IN SOILS

Some of the substances deposited in the soil are injurious to plants.[8] These substances are commonly called alkali, although they are not all alkalies in the chemical sense. Unfortunately alkali is usually most abundant in places where ground water for irrigation is most easily obtained. Many settlers, unaware of the harmful effects of alkali, have taken up land affected by it, only to find their time and money spent in vain. For this reason it is considered advisable to give some of the principal facts concerning alkali in desert soils.

Alkali includes the chlorides, sulphates, and nitrates of sodium, potassium, and magnesium, the carbonates of sodium and potassium, and the chloride and nitrate of calcium. The sulphate and carbonate of calcium are not sufficiently soluble to be injurious to plants. The most common of these salts are sodium carbonate (sal soda), sodium chloride (common salt), and sodium sulphate (Glauber's salt). Sodium carbonate is commonly called "black alkali" because it acts on vegetable matter in such a way as to produce a black stain on the ground. Sodium carbonate itself is white, and as there may be no black stain the term may be misleading. The other salts are commonly called "white alkali."

[8] Much work has been done on the study of alkali in soil and many reports have been published, both by the United States Department of Agriculture and by State and other organizations. For some of the more comprehensive discussions see Hilgard, E. W., Soils, their formation, properties, composition, and relations to climate and plant growth in the humid and arid regions, pp. 422–484, New York, Macmillan Co., 1906. Harris, F. S., Soil alkali, its origin, nature, and treatment, New York, John Wiley & Sons (Inc.), 1920. Dorsey, C. W., Alkali soils of the United States: U. S. Dept. Agr. Bur. Soils Bull. 35, 1906.

Practically all plants can withstand small quantities of alkali, but if the alkali exceeds certain limits the plants can not live. The quantities that produce toxic or harmful effects are different for the different salts and for different plants. Furthermore, they differ according to other conditions, such as the porosity of the soil, the moisture supply as affected by the rainfall or irrigation, the position of the water table, and the distribution of the alkali in the soil. It is therefore very difficult to set any definite limits as to the quantities of the different salts that produce harmful effects.

Scofield[9] states that

> It is the consensus of opinion among investigators that the roots of ordinary crop plants can not tolerate concentrations of mixed salt in solution much above 1.5 per cent. * * *
>
> While many crop plants may obtain water from a soil solution which contains more than 1 per cent of dissolved mineral matter, it would appear to be advisable generally to keep the solution below that degree of concentration. In order to do this it follows that in applying irrigation water it should be the aim to use enough so that the proportion lost by percolation is large enough to offset the concentration due to evaporation and transpiration. Thus if the irrigation water contains 1,000 parts per million of salt, enough should be used so that 10 per cent of the quantity applied may percolate below the root zone.

The most harmful alkali is sodium carbonate. Sodium chloride is less harmful than sodium carbonate, and sodium sulphate is less harmful than sodium chloride. Kearney[10] gives a list of plants that are likely to succeed in the presence of different amounts of alkali. In this list alfalfa is shown as being likely to produce a fair to good crop only if the total alkali is not more than 0.4 per cent. Young alfalfa is easily affected until a good stand is obtained. Some of the common crops which are more resistant are rye, barley, oats, wheat, asparagus, cotton, timothy, redtop, sorghum, and sugar beets. The limits given are not hard and fast, but they may vary according to the factors mentioned above. The only sure test in soils where the alkali content may be near the limit is the actual trial of crops in the ground.

Some soils impregnated with alkali may be improved by various methods adapted to special conditions. The harmful effects of black alkali (sodium carbonate) may be counteracted by the addition of gypsum or land plaster (calcium sulphate) to the soil, provided the quantity of alkali is not too great. The gypsum reacts with the sodium carbonate and changes it to sodium sulphate, which is less harmful. No substance has been found which can be added to the soil to neutralize white alkali.

Several methods of removing the alkali in soils have been developed. In some places the greater part of the alkali that accumulates at the surface may be scraped off. If drainage conditions are favorable the

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[9] Scofield, C. S., The movement of water in irrigated soils: Jour. Agr. Research, vol. 27, No. 9, pp. 636, 681–682.

[10] Kearney, T. H., The choice of crops for alkali land: U. S. Dept. Agr. Farmers Bull. 446, p. 15, 1917.

alkali may be leached out of the soil by flooding it with water and then drawing it off, either on the surface or by subsurface drainage, after the alkali has been dissolved. Certain plants assimilate large quantities of salts, and if they are grown and removed from the land the alkali is accordingly reduced. Each of the methods of reducing the alkali requires careful consideration as to local conditions, and the farmer should be well informed on the proper procedure. Methods of eradication of alkali are described in numerous publications of the United States Department of Agriculture and other institutions.[11]

Not only is it often necessary to find some means of removing alkali from the soil in order to grow crops on it, but in many places where apparently no alkali occurs in the soil it is necessary to take precautions in irrigating to prevent the appearance of alkali. In some places the water used for irrigation is so highly mineralized that when applied to the land and evaporated it will deposit salts in such quantities that within a few years so much alkali has accumulated as to endanger the usefulness of the land. In other places the water may not be highly mineralized, but irrigation on near-by lands may cause the water table to rise so close to the surface that an increasing amount of alkali is deposited as the result of evaporation, and the alkali content may be increased to the danger point. This condition is especially common in places where the water table is not far below the surface before irrigation is begun. After heavy rains the alkali may not show at the surface, having been temporarily dissolved, but it reappears as the soil dries out. Certain native plants are adapted to alkali soils and may show the presence of harmful salts when there is no other indication. (See pp. 53–54.)

DISTRIBUTION OF SOILS

With respect to soil conditions the lands in the Mohave Desert region that are level enough to be cultivated may be divided into three types—lands of the alluvial slopes, lands in the lowest parts of the closed basins, including the playas and lands along Mohave River, Colorado River, and other large streams.

SOILS OF THE ALLUVIAL SLOPES

The lands of the alluvial slopes cover by far the greatest area and have as a whole the best soils in the region, but unfortunately no water is available for most of them. In general the soils of these lands are composed of small particles of rock of different sizes formed by mechanical disintegration. They contain sufficient soluble min-

[11] In addition to the papers already cited the following are of special interest: Dorsey, C. W., Reclamation of alkali soils: U. S. Dept. Agr. Bur. Soils Bull. 34, 1906. Brown, C. F., Drainage of irrigated lands: U. S. Dept. Agr. Farmers Bull. 371, 1909. Fortier, Samuel, and Cone, V. N., Drainage of irrigated lands in the San Joaquin Valley, Calif.: U. S. Dept. Agr. Office Exper. Sta. Bull. 217, 1909. Scofield, C. S., The alkali problem in irrigation: Smithsonian Inst. Ann. Rept. for 1921, pp. 213–223, 1923.

eral matter for plant food but generally not enough to be harmful. These soils are generally productive when irrigated but probably require fertilizer. The water table lies so far beneath most of the alluvial slopes that there is no danger of alkali appearing after the land has been irrigated, but on lands on the lower parts of some of the alluvial slopes the water table is so near the surface that alkali may appear after irrigation has been practiced for some time. Such areas include a large tract that extends several miles south and west of Rosamond, Buckhorn, and Rogers Dry Lakes in Antelope Valley; and smaller tracts around such playas as El Mirage, Harper, China, Searles, Soda, Mesquite, Bristol, Cadiz, and Danby Dry Lakes.

In some places on the alluvial slopes a layer of hard material, commonly called caliche, is found at depths of a few inches to several feet below the surface. It consists of cemented alluvium, in which the cement is principally calcium carbonate. The caliche layer is generally only a few inches thick. In some places it is as hard as limestone, but in other places it is only a little harder than ordinary soil. Where it is very hard plants may have difficulty in pushing their roots through it, but it may be broken up by blasting. Although caliche was found at several places it did not, with minor exceptions, seem to be troublesome in the parts of the region where conditions are favorable for agriculture.

SOILS OF PLAYAS AND ADJOINING LANDS

Land of the second type lies in the lowest parts of the numerous closed basins that exist in the region. The very lowest parts of these basins are generally occupied by playas or expanses of clayey soil which are barren of vegetation and which range in area from a few acres to several square miles. The playas are of three general types. Some of them are characterized by a hard, smooth surface with practically no surface indication of alkali. Playas of this type are found in Antelope Valley, Superior Valley, Ivanpah Valley, and elsewhere. Some of them have a rougher surface which is somewhat soft and is generally covered with more or less alkali. The soil of such playas is often called "self-rising ground." (See p. 148 and pl. 34.) Playas of this type include China Dry Lake, in Indian Wells Valley, and Bristol, Cadiz, and Danby Dry Lakes. Two or three of the playas, notably Searles Lake, contain thick bodies of crystalline salt in the middle and on the edges have "self-rising ground."

Playas with a hard, smooth surface have ground water at considerable depths, and the soil within a few feet of the playa is generally of good quality unless the playa deposits extend beneath it. Where the playas are of either of the other two types the water table is generally close to the surface for some distance away from the playa, and more or less alkali has accumulated in the soil as the result of long-continued discharge of ground water by evaporation. The distance from the playa at which alkali may be found differs in different places. In the vicinity of Lancaster, in Antelope Valley, where the ground water is under artesian pressure and the grade of the alluvial slope is very gentle, alkali is found as far as 10 miles from Rosamond Dry Lake. At other places where the alluvial slope rises more steeply from the playa and the depth to ground water increases greatly in a short distance the alkali extends only a few hundred feet.

In some places near the playas the alkali content is high. In samples of the crust analyzed it has been more than 50 per cent of the total air-dried material. The alkali content is generally greatest near the surface and decreases downward. A sample of the surface crust one-sixteenth to one-eighth of an inch thick, collected on the alkali-covered moist land near Newberry Spring contained 58.33 per cent of soluble mineral matter. A sample from the depth of 1 foot at the same place contained only 0.44 per cent of soluble material, and a sample from a depth of 2½ feet contained only 0.23 per cent.

Attempts have been made to cultivate crops on a number of the barren playas, but so far these attempts have been unsuccessful. The facts that the playas are so level and have no brush and that in some places ground water for irrigation is so close to the surface have proved strong incentives to attempt to cultivate these barren tracts. The most notable project has been on Rosamond Dry Lake, where since 1919 several hundred acres of the clay flat has been plowed with the purpose of sowing rice. Many of the playas contain a very large percentage of clay, which bakes so hard on drying that the roots can not penetrate it, and playas in which the soil is loose enough to be penetrated by plant roots generally contain too much alkali.

Samples of the clay from several playas were analyzed to determine their content of total alkali, and the results are given in the table on page 67. A sample (No. 1706) taken from the surface of Rogers Dry Lake contained 1.21 per cent of total alkali and more than 0.2 per cent of sodium carbonate. The surface was baked hard and was smooth, and from the appearance of the surface the alkali content at this place is not higher than that at the locality where it was proposed to grow rice on Rosamond Dry Lake. A sample (No. 1704) collected from a depth of 1 to 2 feet on the middle one of three playas in Superior Valley contained 1.52 per cent of total alkali, mostly sodium chloride and sodium nitrate. The surface of this playa is hard and smooth. A sample (No. 1702) taken at a depth of 1 to 3 inches on El Mirage Dry Lake contained 3.45 per cent of total alkali, mostly sodium sulphate and sodium chloride. The surface was much like that of Rogers Dry Lake and that of the playa in Superior Valley. A sample (No. 1703) taken at the same place 15 to 18 inches below the surface, contained only 0.79 per cent of total alkali. A sample (No. 1694) of soil from the East Cronise Dry Lake contained 0.69 per cent of total alkali, of which a little more than 0.1 per cent was sodium carbonate. This sample was taken by scraping down the side of a hole 2 feet deep and accordingly represents the average mineral content to that depth. The playa surface at this place was hard and broken into blocks by cracking. An attempt had been made to grow fruit trees here, but when visited they were dead. A sample (No. 1693) of the crust to a depth of about 4 inches at the northwest side of the same playa contained 1.76 per cent of total alkali.

All the samples just mentioned were taken at places where there was no evidence that there was alkali in the soil, but the analyses show that in each place there is sufficient alkali to kill all except the most resistant plants. Analyses from other playas, given on page 67, show much higher contents of alkali. There seems to be little hope, therefore, that any of the playas can be successfully cultivated. Probably the most significant fact in this connection is that the native plants which can resist considerable quantities of alkali and have had the best opportunity to become adapted to the conditions are almost entirely lacking on these clay flats.

Analyses of water-soluble constituents in soils from playas in the Mohave Desert region, Calif.

[Margaret D. Foster, analyst. Per cent of air-dried sample.]

Laboratory No.	Name of playa	Location [a] Section	Location [a] Township	Location [a] Range	Character of surface	Depth of sample (inches)	Calcium (Ca)	Sodium and potassium (Na+K) [b]	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Borate radicle (BO_3)	Nitrate radicle (NO_3)	Total salts determined	Remarks
1680	Harper Dry Lake	30?	11 N.	3 W	Hard, mud cracked; no alkali visible.	0–2	Tr.	0.87	0.10	0.22	0.46	0.76	--------	Tr.	2.41	
1682	-----do	30?	11 N.	3 W.	-----do	2–6	Tr.	[c] 2.82	.72	.38	1.02	2.50	--------	.02	7.46	
1681	-----do	30?	11 N.	3 W.	-----do	12	Tr.	.97	.17	.32	.20	.96	--------	.01	2.62	Slightly moist.
1683	-----do	30?	11 N.	3 W.	Soft and powdery; "self-rising ground" covered with alkali.	0–1	Tr.	[d] 3.10	.06	.18	3.16	2.26	--------	Tr.	8.76	Samples 1683 to 1685 from low mound about 25 feet east of samples 1680-1682.
1684	-----do	30?	11 N.	3 W.	-----do	2–12	.05	[d] 6.99	.81	.54	3.88	6.70	0.10	.04	19.11	Soil dry and powdery with crystals.
1685	-----do	30?	11 N.	3 W.	-----do	Below 12	.05	[d] 2.43	.78	.28	.47	2.40	--------	.02	6.43	Soil moist and plastic
1690	West Cronise Dry Lake.	11?	12 N.	6 E.	Soft and powdery; "self-rising ground" with a little alkali.	0–6	Tr.	[d] 4.7	.11	.12	2.63	5.10	.06	.01	12.73	Top crust dry.
1691	-----do	11?	12 N.	6 E.	-----do	15	Tr.	1.61	.23	.07	.46	1.82	--------	.01	4.20	Soil moist and sandy.
1692	-----do	11?	12 N.	6 E.	-----do	24	Tr.	1.85	.23	.10	.53	2.12	--------	.01	4.84	Do.
1693	East Cronise Dry Lake.	8?	12 N.	7 E.	Black, hard, and mud cracked.	4	Tr.	.63	0	.11	.41	.60	--------	.01	1.76	No moisture at a depth of 1 foot.
1694	-----do	17	12 N.	7 E.	-----do	0–24	Tr.	.23	.01	.15	.16	.13	--------	.01	.69	No moisture. Attempts made to grow crops here.
1697	Epsom Dry Lake	21	11 N.	8 E.	Alkali-covered surface near Epsom Spring.	0–1	.13	[d] 16.68	2.08	2.66	28.31	.99	.02	Tr.	50.87	Sample moist. (See analysis of Epsom Spring, p. 532.)
1698	-----do	21	11 N.	8 E.	-----do	6	Tr.	.11	.03	.01	.03	.10	--------	Tr.	.28	Sample very moist.
1699	-----do	21	11 N.	8 E.	-----do	15	Tr.	.20	0	.15	.06	.18	--------	Tr.	.59	Sample taken below water level.
1702	El Mirage Dry Lake.	7	6 N.	6 W.	Hard and smooth; no alkali.	1–3	.54	.63	0	.03	1.06	1.01	--------	.18	3.45	Depth to water is probably 15 feet.
1703	-----do	7	6 N.	6 W.	-----do	15–18	Tr.	.26	0	.09	.29	.14	--------	Tr.	.79	
1704	Crutts Dry Lake	17	31 S.	46 E.	-----do	12–24	.08	.44	0	.04	.12	.54	--------	.30	1.52	Depth to water nearly 100 feet.
1705	China Dry Lake	31	25 S.	40 E.	"Self-rising ground" with ridges an inch or two high.	0–2	Tr.	[e] 5.29	.01	.12	.55	7.71	.02	Tr.	13.75	Sample taken on low land some distance west of the playa.
1706	Rogers Dry Lake	25	9 N.	9 W.	Hard and smooth; no alkali.	0–2	Tr.	.42	.02	.28	.10	.39	--------	Tr.	1.21	

[a] All south township numbers refer to Mount Diablo base and meridian; all north township numbers refer to San Bernardino base and meridian.

[b] Calculated as sodium, except as otherwise stated in footnotes.

[c] Potassium determined, 0.01 per cent.

[d] Potassium determined less than 0.01 per cent.

[e] Potassium determined 0.04 per cent.

SOILS ALONG THE PRINCIPAL RIVERS

The soils along the principal rivers in the region are of two general types, according to the ground-water conditions. In most of its length Mohave River is a river in name only, for except at times of flood its channel is entirely dry. In most places there is a distinct channel which is sandy and generally not fit for agriculture. There is also generally a flood plain a few feet above the channel, which extends from a few feet to half a mile or more on either side of the channel. In some places this flood plain is sandy, like the river channel, and not fit for agriculture. In other places, where the depth to ground water is not great, vegetation has gained a strong enough hold to prevent the sand from blowing, and sufficient humus and clay have accumulated to make a soil of fair quality. In such places the water table is generally so close to the surface that there is some alkali in the soil, although crops can be grown. Some of these lands require very little if any irrigation. One difficulty on such lands is that salt grass usually grows abundantly and is hard to eradicate. Even when entirely cleared out it soon reappears. In a few places the soil on the river flood plain contains much clay and bakes when it is dry. Such soil would probably be unfit for cultivation.

Flood plains of greater extent occur along Colorado River, but these were observed at only one or two places. The water table beneath these flood plains is generally close to the surface, and they bear a luxuriant vegetation. Sloughs exist at a number of places. The soil of the flood plain is probably fertile, but in places some alkali is present.

Lands along Amargosa River were seen only in the vicinity of Saratoga Springs, where the soil contains much alkali. It is probable that the soil along other stretches of the river contains alkali.

CLIMATE

CLIMATIC RECORDS

Climatic records have been kept at about 20 stations in the Mohave Desert region for periods that range from a few years to 40 years. More than half of these stations are in the part of the region that lies south and west of Barstow. Only two of the others, Bagdad and Needles, have records of sufficient length to be of much value. However, the records for six stations from 1 to 35 miles beyond the border of the region covered by this report are of value in the study of the climate of this region and are therefore given in part in the tables on the following pages.

These stations outside of the Mohave Desert region are Keeler, in Owens Valley, 35 miles north of the northwest corner of the region; Greenland ranch, also called the Furnace Creek ranch, in Death

Valley, 33 miles north of the north border of the region shown on Plate 11; Las Vegas, Nev., 15 miles northeast of the northeast corner of the area shown on Plate 12; Mohave City, Ariz., formerly called Fort Mohave, on the east side of Colorado River about 12 miles north of Needles; and Parker, Ariz., on the east side of Colorado River at the southeast corner of the region. The records of precipitation at San Bernardino cover a period of more than 50 years (pp. 85–86) and are included for comparison. Most of the data given in the tables are compiled from published records of the United States Weather Bureau or from unpublished data which the Weather Bureau has kindly furnished for this report. Some data, not collected by the Weather Bureau, were furnished by the observers or were taken from previous reports on the region. Unless otherwise stated, the data in the tables are taken from the records of the Weather Bureau.

GENERAL CONDITIONS

The climate of the Mohave Desert region is characterized by slight annual precipitation, low humidity, comparatively high temperatures in both summer and winter, great daily ranges in temperature, and strong winds at certain seasons of the year.

Although the annual precipitation is generally very small, single storms may be very intense and may do great damage. Different parts of the region differ greatly in precipitation. Thus Bagdad has an average annual precipitation of only 2.28 inches, and in 3 of the 17 years for which records have been kept it had no precipitation. On the other hand, parts of the San Bernardino Mountains have an average annual precipitation of 30 to 35 inches, and in some years they have as much as 50 inches. Although the relative humidity is generally low, yet at the Greenland ranch, in Death Valley, which is supposed to be the hottest and driest place in the United States,[12] a humidity of more than 90 per cent was recorded for several days in 1912. The highest temperature officially recorded in the United States, and so far as is known in the whole world, 134° F., was reported from this station, and yet it has also had a temperature as low as 15° F.[13]

Topography and altitude cause great local differences in climate, and hence the prospective homesteader should not jump to the conclusion that a certain locality has a favorable climate because the records show that conditions at some point 15 or 25 miles away are favorable.

[12] McAdie, A. G., Relative humidity in Death Valley: Monthly Weather Review, vol. 41, No. 6, p. 931, 1913.

[13] Palmer, A. H., Death Valley, the hottest known region: Monthly Weather Review, vol. 50, No. 1, pp. 10–13, 1922.

TEMPERATURE

A summary of the records of temperature at 12 stations in and near the Mohave Desert region is given in the following table. The Mohave Desert region has high temperatures in both summer and winter. Except at high altitudes temperatures of 100° F. are common in summer and may be expected during five to eight months of the year. The temperature of 134° F. at the Greenland ranch in Death Valley is the highest natural-air temperature that has been recorded on the earth's surface by means of a tested standard thermometer exposed in a standard ventilated instrument shelter.

Temperatures at stations in or near the Mohave Desert region

Keeler, Calif.

[Altitude 3,620 feet]

	Length of record (years)	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Mean	14	41.6	46.6	53.6	62.5	71.4	78.6	85.1	84.6	76.2	65.0	52.8	44.1	63.5

Mojave, Calif.

[Altitude 2,751 feet]

	Length of record (years)	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Mean	37	46.0	49.0	52.2	59.5	68.0	77.4	85.5	83.7	76.3	65.7	54.6	47.2	63.8
Highest	18	82	90	95	100	102	112	117	118	110	99	96	78	118
Lowest	18	10	15	20	24	32	42	51	48	31	28	20	15	10

Tehachapi, Calif.

[Altitude 3,964 feet]

	Length of record (years)	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Mean	25	38.2	39.3	44.1	50.2	59.2	69.4	76.4	74.5	66.1	56.1	46.5	39.5	54.9

Monterio, Calif.

[Altitude 4,500 feet]

	Length of record (years)	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Mean	15	45.5	46.2	48.6	51.8	56.4	66.6	76.4	76.0	69.7	60.0	53.6	47.8	58.2
Highest	14	76	78	80	90	100	104	106	102	100	92	90	78	106
Lowest	14	4	14	26	28	30	34	44	34	36	32	22	18	4

Greenland Ranch, Calif.

[Altitude 178 feet]

	Length of record (years)	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Mean	9	52.9	58.2	65.5	75.3	82.6	94.5	101.2	99.0	89.7	74.8	60.9	52.1	75.6
Mean maximum	9	64.3	71.0	79.5	90.5	98.2	111.1	115.8	114.2	106.0	88.8	75.2	64.9	90.0
Mean minimum	9	39.8	45.3	51.5	60.2	67.0	77.9	86.6	83.8	73.4	60.5	48.8	40.4	61.2
Highest	9	85	90	98	109	120	124	134	126	118	106	91	82	134
Lowest	9	15	28	30	36	48	55	67	68	54	40	27	21	15

Barstow, Calif.

[Altitude 2,105 feet]

	Length of record (years)	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Mean	17	46.3	50.4	56.4	61.8	67.4	77.8	83.6	82.4	74.2	64.0	54.2	45.9	63.7
Mean maximum	13	59.4	63.5	70.8	77.2	83.6	95.8	101.2	100.0	91.8	80.7	70.2	60.2	79.5
Mean minimum	13	30.9	34.0	40.6	45.6	50.4	60.1	63.2	64.6	57.3	47.6	37.8	30.2	46.8
Highest	17	82	86	94	99	111	113	114	112	111	97	90	87	114
Lowest	17	12	16	21	30	34	40	50	48	39	27	14	12	12

Temperatures at stations in or near the Mohave Desert region—Continued

San Bernardino, Calif.

[Altitude 1,054 feet]

	Length of record (years)	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Mean	28	51. 5	53. 4	55. 9	59. 8	63. 4	70. 1	75. 6	75. 7	71. 4	64. 4	57. 5	52. 0	62. 6
Mean maximum	22	66. 2	68. 1	70. 6	75. 9	78. 5	89. 3	95. 8	96. 0	91. 9	82. 8	75. 7	68. 6	80. 0
Mean minimum	22	36. 8	39. 5	41. 5	44. 2	48. 0	51. 4	56. 0	56. 0	51. 6	46. 0	39. 9	35. 8	45. 6
Highest	23	90	90	97	103	108	116	111	111	111	105	99	89	116
Lowest	23	18	22	26	29	33	37	42	42	38	31	24	19	18

Bagdad, Calif.

[Altitude 784 feet]

	Length of record (years)	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Mean	17	52. 8	57. 1	63. 8	72. 8	79. 1	89. 1	95. 2	93. 8	84. 2	65. 9	61. 1	52. 5	72. 3
Mean maximum	14	63. 1	67. 5	75. 0	83. 0	90. 6	101. 7	106. 0	103. 8	96. 8	84. 8	72. 8	62. 7	84. 0
Mean minimum	14	42. 8	47. 4	53. 6	61. 0	67. 7	77. 4	84. 4	82. 9	71. 9	59. 0	49. 7	42. 0	61. 6
Highest	17	78	83	95	103	117	119	119	116	116	102	95	82	119
Lowest	17	10	25	33	40	40	57	60	68	56	40	30	25	10

Las Vegas, Nev.

[Altitude 2,033 feet]

	Length of record (years)	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Mean	13	42. 0	45. 5	51. 9	60. 1	66. 9	76. 0	81. 9	80. 3	72. 3	61. 1	49. 8	40. 8	60. 7
Mean maximum	13	54. 8	59. 3	66. 9	77. 2	84. 0	93. 7	98. 4	97. 2	89. 2	76. 5	64. 5	54. 6	76. 4
Mean minimum	13	29. 7	31. 8	37. 5	45. 9	50. 9	58. 3	66. 2	64. 7	55. 9	45. 9	36. 1	26. 9	45. 8
Highest	13	77	78	96	102	114	112	115	110	108	97	87	91	115
Lowest	13	8	10	16	26	28	35	40	47	38	29	14	12	8

Fort Mohave (Mohave City), Ariz.

[Altitude 604 feet]

	Length of record (years)	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Mean	36	51. 3	56. 0	63. 7	71. 4	80. 1	89. 0	95. 1	93. 6	85. 3	73. 4	60. 2	53. 1	72. 7
Highest	12	81	92	101	110	109	123	124	124	117	104	94	81	124
Lowest	12	18	25	31	35	43	53	64	54	49	38	24	18	18

Needles, Calif.

[Altitude 477 feet]

	Length of record (years)	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Mean	28	52. 0	57. 2	63. 6	71. 2	78. 6	87. 6	93. 8	91. 9	83. 0	70. 8	59. 4	51. 5	71. 7
Mean maximum	18	63. 6	69. 2	76. 6	85. 2	92. 0	102. 8	106. 0	104. 0	96. 7	83. 4	71. 0	62. 4	84. 4
Mean minimum	18	39. 3	44. 6	49. 6	56. 2	63. 6	71. 8	80. 8	77. 8	67. 5	55. 4	45. 8	38. 6	57. 6
Highest	23	83	90	96	105	118	122	118	119	112	112	90	86	122
Lowest	23	23	23	28	33	39	46	60	60	40	36	25	23	23

Parker, Ariz.

[Altitude 353 feet]

	Length of record (years)	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Mean	16	50. 0	55. 7	62. 3	69. 8	76. 0	84. 6	92. 2	90. 9	82. 0	71. 4	59. 1	50. 2	70. 4
Mean maximum	16	68. 2	74. 4	80. 4	88. 9	96. 3	105. 3	109. 2	108. 2	102. 9	92. 0	79. 8	69. 0	89. 6
Mean minimum	16	32. 8	37. 0	44. 2	50. 2	55. 7	64. 6	74. 6	73. 5	63. 1	50. 8	38. 5	31. 4	51. 4
Highest	20	85	96	100	113	117	126	127	126	120	117	98	92	127
Lowest	20	10	13	24	30	38	42	43	53	41	27	18	9	9

Other high temperatures recorded are 127° at Parker, 124° at Fort Mohave, 122° at Needles, and 119° at Bagdad. All these places are located in valleys at low altitudes. The air temperature in unshaded places is undoubtedly considerably higher than the temperatures recorded above.

Winter temperatures are generally higher than those in regions of the same latitude farther east. They frequently reach 60° in the daytime and seldom fall below 20°. The lowest temperature recorded is 4° above zero, at Monterio, which is 4,500 feet above sea level and considerably above most of the desert. Except in the mountains the minimum temperature for most of the region is probably not below 10°. Very low winter temperatures are rare, and on many nights the thermometer does not go below freezing.

As a result of the relatively high winter temperatures the length of the growing season in most parts of the region is long, as shown in the following table:

Frost record in the Mohave Desert region

Stations	Altitude above sea level (feet)	Length of record (years)	Average date of last killing frost in spring	Average date of first killing frost in autumn	Average length of growing season (days)	Latest recorded date of killing frost in spring	Earliest recorded date of killing frost in autumn
Mojave, Calif.	2,751	8	Feb. 27	Nov. 18	263	Apr. 1	Sept. 30
Tehachapi, Calif.	3,964	8	Apr. 7	Nov. 14	220	May 8	Oct. 19
Monterio, Calif.	4,500	12	Apr. 3	Nov. 18	228	May 7	Oct. 10
Barstow, Calif.	2,105	14	Mar. 6	Nov. 9	247	Apr. 3	Oct. 19
San Bernardino, Calif.	1,054	21	Mar. 8	Nov. 22	258	Apr. 18	Oct. 23
Bagdad, Calif.	784	11	Jan. 12	Dec. 24	345	Feb. 3	Dec. 6
Las Vegas, Nev.	2,033	13	Apr. 4	Nov. 5	214	May 12	Oct. 16
Jean, Nev.	2,864	8	Mar. 27	Nov. 4	221	May 16	Sept. 9
Fort Mohave, Ariz.	604	8	Feb. 16	Nov. 21	277	Mar. 8	Oct. 22
Needles, Calif.	477	14	Feb. 5	Dec. 1	298	Mar. 27	Nov. 8
Parker, Ariz.	353	14	Mar. 8	Nov. 22	258	Apr. 6	Oct. 26

The mean of the average length of the growing season at the 11 stations given in the table is 257 days. The average length of the growing season of 345 days at Bagdad is probably exceeded at few stations in the United States. It is greater than the growing season at three stations in Imperial Valley for which Weather Bureau records are available, and it is exceeded by only four other stations in southern California, all of them south of the San Gabriel Mountains. The long growing season is of importance to the irrigation farmer, for it means that his crops are less liable to damage by frost, and in such crops as alfalfa the yield per acre is greater than where the growing season is short. Although the average growing season is long, frosts occasionally occur late in the spring or early in the fall.

In all the temperature records the influence of altitude is noticeable to some extent. In general, the temperature, both summer and winter, is higher at stations situated at low altitudes than at those at high altitudes. Thus the mean annual temperature at Tehachapi and Monterio is lower than at Mohave, Las Vegas, and Barstow, and it is lower at those places than at Greenland ranch, Bagdad, Fort Mohave, Needles, and Parker, which are only a few hundred feet above sea level. There are, however, some anomalous conditions. For instance, the mean annual temperature at Parker is lower than that at Needles or Fort Mohave, although Parker is farther south and at a lower altitude than either of the other two stations. Strangely enough, so far as the records show, the highest temperature at Parker has been exceeded only at Greenland ranch, and the lowest only at two stations, both of which are at much higher altitudes. The mean annual temperature is only 0.3° lower at Keeler than that at Mohave, although Keeler is much farther north and almost 1,000 feet higher. Although the growing season is much longer at Bagdad than at Fort Mohave, Needles, and Parker, the mean annual temperature is higher at Fort Mohave and only a little lower at Needles and Parker. Doubtless some of these anomalous conditions are due to differences in the length of the records and in the periods covered by them, but they are doubtless due in part to local topographic differences. One place may be so situated that cold air can drain down from the mountains, and another place may be so sheltered that the air after being heated in the daytime is not disturbed by winds.

The daily range of temperature in most parts of the region is large. On many days it is more than 30°, and sometimes it is as high as 45°. In summer the temperature frequently falls from above 100° in the daytime to below 75° or 70° at night, and in winter it frequently rises from below the freezing point in the early morning to 65° or 70° at midday. The daily range is probably a little less in winter than in summer. Because of the great daily range one generally needs a sweater or other light garment in summer and an overcoat in winter, to be discarded as the day grows warmer and put on again in the evening.

Although the daily range is generally great in the desert, probably considerably greater extremes in a single day have been recorded at other places in the country. Such extremes, however, are of irregular occurrence and are generally due to the sudden approach of warm or cold winds, as the warm chinook wind in the Northwest and the cold "northeasters" in Texas and Oklahoma.

The difference between the highest and lowest recorded temperatures in the region are not as great as in many other parts of the country. Thus the total range is 119° at the Greenland ranch, 118° at Parker, and less than 110° at each of the other stations, whereas in the Dakotas and Montana differences of 150° have been recorded, and differences of 100° to 120° are fairly common in many other parts of the United States.

HUMIDITY

The only records of humidity in or near the Mohave Desert region are some for short periods at the Greenland ranch, also called the

Furnace Creek ranch, in Death Valley, where daily readings were made from May 1 to September 30, 1891.[14] Observations were also made in 1912 and 1913.[15] A summary of the data for 1891 is given in the following table:

Summary of record of relative humidity at Greenland ranch (Furnace Creek ranch), Calif., May 1 to September 30, 1891 [a]

	May		June		July		August		September	
	a. m.	p. m.	a. m.	p. m.	a. m.	p. m.	a. m.	p. m.	a. m.	p. m.
Per cent of saturation:										
Average	34	18	27	14	27	13	29	13	34	20
Maximum	62	48	48	26	72	23	75	29	74	46
Minimum	9	7	13	8	13	6	16	5	19	10
Number of days with relative humidity 20 per cent or more	29	8	23	3	23	3	25	5	29	13
Number of days with relative humidity 30 per cent more	19	5	9	0	10	0	12	0	20	3
Number of days with relative humidity 40 per cent or more	9	1	4	0	4	0	5	0	7	1

[a] Compiled from table given by Mark W. Harrington in Notes on the climate and meteorology of Death Valley, Calif.: U. S. Weather Bur. Bull. 1, p. 45, 1892. Observations were made at 5.13 a. m. and 5.13 p. m. local time, which corresponds to 8 a. m. and 8 p. m. seventy-fifth meridian time.

The record shows that the relative humidity is generally rather high in the morning and low in the late afternoon. The high relative humidity in the morning is due to the great daily range of temperature. As the temperature is somewhat lower at about 5 p. m. than in the middle of the day, the minimum relative humidity was doubtless a little lower than recorded.

The detailed records for 1912–13 have not been published. In summarizing the results of these observations McAdie [16] says:

> While humidities are low, as might be expected, there are periods when a high degree of saturation prevails. A notable instance of this was from the forenoon of October 2 until the forenoon of October 18, 1912, when during the night hours the relative humidity frequently exceeded 90 per cent, while during the midday and afternoon hours the humidity did not fall below 50 per cent during most of the period. Taking the year's records as a whole it appears that the humidity is not much below that of the Great Valley of California and closely resembles conditions in the San Gabriel Valley. These records would appear to uphold the belief that the dreaded terrors of heat and dryness in Death Valley have been exaggerated, and that it is quite possible, if proper care be taken in the matter of supplies and provision for physical comfort, to live and work in this section.

A comparison with other stations in the United States shows that the relative humidity in Death Valley is considerably lower than that at places in more humid parts of the country. Thus at Chicago during the period 1889–1913 the lowest average relative humidity at

[14] Harrington, M. W., Notes on the climate and meteorology of Death Valley, Calif.: U. S. Weather Bur. Bull. 1, p. 45, 1892.

[15] McAdie, A. G., Relative humidity in Death Valley, Calif.: Monthly Weather Review, vol. 41, No. 6, p. 931, 1913.

[16] Op. cit., p. 931.

8 a. m. (seventy-fifth meridian time) was 74, and the lowest at 8 p. m. was 66.[17] These figures were recorded in July.

WINDS

Data on the prevailing direction of the wind at several stations are given in the table below. These data show that at Barstow the wind is prevailingly from the west and that at San Bernardino it also generally has a westerly component. It is probable that throughout the western part of the region the wind is generally from the west. The winds at the stations in the eastern part of the region show considerable variation, but in the summer at least there is a prevailing southern component. These southerly winds are sometimes accompanied by rains. The direction of winds in some parts of the region is influenced by the local topography. Thus at certain times strong winds blow down Cajon Pass. Thus also the direction of the winds in Death Valley is doubtless affected by the deep troughlike character of the valley.

Prevailing direction of wind at stations in the Mohave Desert region

Station	Length of record (years)	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Barstow, Calif.	17	W.	W.	W.	W.	W.	W.	W.	W.	W.	W.	W.	W.	W.
San Bernardino, Calif.	28	N.	SW.	SW.	SW.	SW.	SW.	SW.	SW.	SW.	SW.	SW.	N.	SW.
Las Vegas, Nev.	14	W.	W.	W.	W.	S.	S.	N.-S.	S.	S.	W.	W.	W.	W.
Fort Mohave, Ariz.	12	N.	N.-S.	S.	S.	S.	S.	S.	S.	S.	N.	N.	N.	S.
Parker, Ariz.	12	SW.	S.	SW.	SW.	SW.	SW.	S.	S.	SW.	SW.	SW.	SW.	SW.

During the period of the observations at the Greenland (Furnace Creek) ranch, May 1, to September 30, 1891, the highest average velocity recorded for any one day was 25.9 miles an hour and the lowest was 2.3 miles an hour.[18] Calms were recorded only four times, all in the morning. In general, the velocity is less in the day than at night. Doubtless velocities of wind greater than those recorded at the Greenland ranch occur in the region, especially in the winter, but the force of the wind in the desert has probably been considerably exaggerated.

EVAPORATION

Observations on evaporation have been made from a pan floating in the Harold Reservoir, near Palmdale, during part of one year;

[17] Day, P. C., Relative humidities and vapor pressures over the United States, including a discussion of data from recording hair hygrometers: Monthly Weather Review, Suppl. 6, p. 21, 1917.

[18] Harrington, M. W., Notes on the climate and meteorology of Death Valley, Calif.: U. S. Weather Bur. Bull. 1, pp. 27-29, 36-37, 48-49, 1892.

at Pahrump, Nev.,[19] about 15 miles north of the northwest corner of the area shown on Plate 12, during parts of two years; and at Independence, in Owens Valley, Calif.,[20] about 65 miles north of the northwest corner of the area shown on Plate 10, during parts of four years. The monthly evaporation at these stations is shown in the accompanying table:

Evaporation from free water surfaces at stations in or near Mohave Desert region

Station	Year	Jan.	Feb.	Mar.	Apr.	May	June
Harold Reservoir, Calif.[a]	1898	--------	--------	--------	--------	9.45	10.70
Pahrump, Nev.[b]	1920	--------	--------	6.04	8.60	10.38	12.54
	1921	2.29	2.89	5.25	--------	--------	10.85
Independence, Calif.:[c]							
Pan in water	1908	--------	--------	--------	--------	--------	--------
Do	1909	1.60	2.40	4.70	7.30	9.60	10.10
Do	1910	1.75	2.50	5.15	7.05	8.29	9.90
Do	1911	1.65	2.35	3.70	6.25	8.01	--------
Pan in soil	1909	--------	--------	--------	--------	--------	--------
Do	1910	--------	--------	[e] 4.25	9.50	10.61	11.95
Do	1911	2.25	2.25	4.80	8.12	10.25	--------
Deep tank in soil	1909	--------	--------	--------	[f] 2.90	7.50	7.80
Do	1910	2.00	2.90	5.60	7.40	7.21	8.60
Do	1911	2.30	2.55	3.95	6.80	7.90	--------

Station	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total for season
Harold Reservoir, Calif.[a]	11.20	10.00	11.80	6.50	3.25	2.95	--------
Pahrump, Nev.[b]	12.13	11.90	8.52	5.40	2.24	1.71	--------
	12.10	9.40	8.82	5.04	2.84	2.12	--------
Independence, Calif.:[c]							
Pan in water	--------	[d] 4.90	5.30	3.50	2.50	1.50	--------
Do	10.40	8.00	6.60	3.90	2.60	(1.85)	69.05
Do	8.50	8.20	6.30	4.20	2.36	1.24	65.44
Do	--------	--------	--------	--------	--------	--------	--------
Pan in soil	--------	10.70	8.50	5.80	3.80	--------	--------
Do	12.55	11.80	8.80	5.60	2.85	1.60	--------
Do	--------	--------	--------	--------	--------	--------	--------
Deep tank in soil	7.90	8.20	7.20	5.00	3.30	(2.20)	--------
Do	8.30	8.80	7.30	5.15	3.10	2.15	69.01
Do	--------	--------	--------	--------	--------	--------	--------

[a] Record furnished by Mr. Burt Cole, engineer for the Palmdale Water Co.
[b] From records of U. S. Weather Bureau.
[c] Lee, C. H., An intensive study of the water resources of a part of Owens Valley, Calif.; U. S. Geol. Survey Water-Supply Paper 294, pp. 118–122, 1912.
[d] Aug. 10–31.
[e] Mar. 14–31.
[f] Apr. 16–30.

The records at the different places are not fully comparable because different types of pans and tanks were used in the different places, and furthermore they were made in different years. The records for Pahrump and Independence show that even in the same month in different years the evaporation differs so much that definite comparisons can not be made. The data for Independence give three complete annual records, representing two years for a pan in water and one year for a deep tank in soil. During January, February, March, and April the average of the three records at Independence is 24.3

[19] Observations and records furnished by U. S. Weather Bureau.
[20] Lee, C. H., An intensive study of the water resources of a part of Owens Valley, Calif.: U. S. Geol. Survey, Water-Supply Paper 294, pp. 48–63, 118–122, 1912.

per cent of the annual totals. If the evaporation is in the same proportion as at Independence, the total evaporation at Harold Reservoir in 1898 was about 87 inches. That year was one of the driest on record. The evaporation at Independence during January and February averaged 6.4 per cent of the total, and on this basis the total evaporation at Pahrump in 1920 would be about 85 inches. The evaporation at Independence for April and May averaged 22.8 per cent of the total annual evaporation, and on this basis the total evaporation at Pahrump in 1921 would be about 80 inches.

The evaporation at Harold Reservoir and Pahrump estimated in the above manner is somewhat higher than at Independence. It is believed, however, that the estimates are not far wrong. The evaporation at different places varies in accordance with the mean annual temperature and is greatest where the mean annual temperature is the highest, other conditions being constant. The mean annual temperature is about 57° at Independence, about 61° at Las Vegas, the nearest station to Pahrump, and about 64° at Mojave, the nearest station to Harold Reservoir. Although the altitudes of Las Vegas and Mojave are silghtly different from the altitudes of Pahrump and Harold Reservoir, respectively, the differences are not great, and the mean annual temperatures are probably not greatly different. On this basis it would be expected that the evaporation would be greater at Pahrump than at Independence and greatest at Harold Reservoir.

In most of the region that is adapted to agriculture the evaporation is probably at least 6 feet annually, and in some places it is even greater. Because of the great evaporation a large proportion of the scanty rainfall is quickly disposed of before it can form large streams or lakes, or before it can reach the water table, and therefore large amounts of water are required in irrigation.

PRECIPITATION

Records of precipitation for periods of 1 to 36 years have been kept at more than 25 localities in or near the Mohave Desert region. About half of these localities are south and west of Barstow. The annual precipitation at 11 stations where the record has been kept for 10 complete years or more is given in the table on pages 90–91. The monthly records for these stations have been published by the United States Weather Bureau or other organizations and are readily available. The yearly rainfall at nine of these stations is shown graphically in Plate 6. Some of the records for stations where the observations have been made for only a few years have not been published. For this reason the monthly records for all stations where the period of observation is less than 10 years are given in the table on pages 78–82. The yearly totals for eight stations are given on pages 85–86. Some of the records have not heretofore been published, and in order that they may be available to engineers who may have use for them all of them are given in the table. Unless otherwise specified the records are compiled from data furnished by the United States Weather Bureau.

In California most of the annual rainfall comes in the winter. The rainfall year is generally considered as extending from July 1 of one year to June 30 of the following year in order that the precipitation of the entire rainy season may be shown as a total, and this system is used in the records given in this report. In some of the records the figures for certain months have been interpolated by the United States Weather Bureau on the basis of records at near-by stations. In a few records figures have been interpolated by the writer if the records at near-by stations indicated that the precipitation was zero or only a small fraction of an inch. Blanks indicate that the record is lacking, and "Tr." (trace) means less than 0.01 inch.

Monthly and annual precipitation at stations in Mohave Desert region for which record covers period of less than 10 years

[Authority, U. S. Weather Bureau except as otherwise stated]

Fairmont, Calif.

[From July, 1914, gage located at Los Angeles Aqueduct Reservoir, about 1½ miles south of Fairmont, altitude 3,036 feet; before that time it was probably nearer the town, at an altitude of about 2,800 feet]

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1908–9								5.99	5.96	0.00	0.00	Tr.	(a)
1909–10	Tr.	0.12	0.24	0.65	1.37	5.46	4.47	Tr.	3.47	.55	.00	0.00	16.33
1910–11	0.03	.00	.03	1.37			10.50	2.25	9.50	.00	.00	.00	(a)
1911–12	Tr.	.00	.80	.45	.04	.99	.15	Tr.	5.83	1.80	1.35	.10	11.51
1912–13	.00	.00	.00	.75	Tr.	.00	3.10	8.80	.70				(a)
1913–14							11.73	6.32	.75				(a)
1914–15	[b].00	.00	Tr.	.43	1.22	4.83	7.16	6.12	1.08	1.60	1.94	Tr.	[c]24.38
1915–16	.00	Tr.	Tr.	.00	.71	2.40	11.59	1.74	1.66	.37	.07	.00	18.54
1916–17	.00	Tr.	.36	1.38	.11	4.33	3.85	2.97	.38	.40	.22	.00	14.00
1917–18	.06	Tr.	.02	Tr.	.44	Tr.	.28	6.79	6.52	Tr.	.09	.11	14.31
1918–19	.26	.18	1.82	Tr.	1.41	2.75	.17	1.42	2.32	.07	.14	.00	10.54
1919–20	Tr.	.00	.35	.13	.40	1.22	.82	4.27	4.01	.29	Tr.	.00	11.49
1920–21	.00	.00	.00	.11	1.36	.52	4.27	1.20	.43	.23	2.10	.00	10.22
9-year mean	.03	.03	.40	.35	.78	2.50	3.64	2.72	2.85	.59	.66	.02	14.59
Per cent of mean annual precipitation	0	0	2.7	2.4	5.3	17.1	24.9	18.6	19.5	4.0	4.5	0	------

Valyermo, Calif.

[Authority, L. F. Noble. Altitude 3,800 feet]

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1911–12	0.01	0.00	1.75	Tr.	Tr.	1.00	0.01	0.10	5.80	1.10	0.35	0.00	10.12
1912–13	.15	.00	.00	3.00	.12	.00	1.30	4.71	.13	.06	.00	.00	9.47
1913–14	.83	3.21	.00	.03	1.76	.12	7.32	5.57	.35	.87	.38	.00	20.44
1914–15	.06	.06	.01	.19	.21	4.26	4.98	4.95	.10	.62	.25	.02	15.71
1915–16	.00	.00	.00	.00	.28	3.06	6.68	.41	1.38	.00	.08	.00	11.89
1916–17	.00	.06	.37	1.06	.00	3.43	1.48	.50	.33	Tr.	Tr.	.00	7.23
1917–18	.83	Tr.	.00	.05	.00	.00	.75	5.67	4.53	Tr.	Tr.	.30	12.13
1918–19	.64	Tr.	1.41	.67	.80	1.11	.50	1.36	2.25	.40	1.10	.00	10.24
1919–20	.57	.00	.49	.09	1.10	1.52	1.03	3.10	2.51	.00	.00	.00	10.41
9-year mean	.34	.37	.45	.57	.47	1.61	2.67	2.93	1.93	.34	.24	.03	11.96
Per cent of mean annual precipitation	2.8	3.1	3.8	4.8	3.9	13.5	22.3	24.5	16.1	2.8	2.0	.2	------

[a] Record for 1 or more months in the year lacking.
[b] Interpolated by the author.
[c] Record for 1 or more months in the year interpolated.

Monthly and annual precipitation at stations in Mohave Desert region for which record covers period of less than 10 years—Continued

Liebre Ranch, Calif.

[Authorities: 1897–1899, U. S. Weather Bureau; 1914–1919, J. C. Knecht. Located approximately in sec. 16, T. 8 N., R. 17 W. San Bernardino meridian, unsurveyed. Altitude 3,170 feet]

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1896–97	------	------	------	------	------	------	3.67	4.01	2.30	0.10	0.00	0.00	([a])
1897–98	0.00	0.00	0.00	0.05	0.00	0.40	.53	.38	.81	.00	.45	.00	2.62
1898–99	.00	.00	.20	.00	.00	.66	1.79	.04	2.26	.09	.04	.27	5.35
1899–00	.00	.00	.05	1.47	.90	.46	------	------	------	------	------	------	([a])
1900–1914 [d]	------	------	------	------	------	------	------	------	------	------	------	------	------
1914–15	[b].00	[b].00	[b].00	.17	.28	1.88	4.74	2.95	.00	1.40	1.24	.00	[c]12.66
1915–16	.00	.00	.00	.66	.05	1.60	5.38	1.10	1.97	.12	.08	.00	10.96
1916–17	.00	.00	.00	1.25	.00	2.30	2.50	.59	.05	.30	.00	.00	6.99
1917–18	.00	.00	.00	.00	.00	.00	.55	8.59	5.40	.00	.00	.00	14.54
1918–19	.00	.00	1.65	.00	1.53	2.25	.30	1.62	1.86	.00	.00	.00	9.21
1919–20	.00	.00	.65	.00	.40	1.97	([e])	([e])	([e])	([e])	([e])	([e])	([a])
7-year mean	.00	.00	.26	.30	.26	1.30	2.26	2.18	1.76	.27	.26	.04	8.90
Per cent of mean annual precipitation	0	0	2.9	3.4	2.9	14.6	25.3	24.5	19.8	3.0	2.9	.4	------

Manzana, Calif.

[In sec. 24, T. 8 N., R. 16 W. San Bernardino meridian. Altitude 2,870 feet]

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1894–95	0.00	0.10	0.49	0.00	0.00	3.60	2.79	0.00	1.36	0.08	Tr.	0.00	8.42
1895–96	.00	.00	.00	.40	.48	.18	1.09	.00	1.70	.63	Tr.	.00	4.48
1896–97	Tr.	1.04	.00	.61	.30	1.46	2.70	3.04	1.71	.04	.01	Tr.	10.91
1897–98	Tr.	.28	.00	.21	Tr.	.14	1.70	.02	.47	.00	.25	.00	3.07
1898–99	.00	.00	Tr.	.00	Tr.	.50	1.15	Tr.	1.35	.04	.09	.04	3.17
1899–00	.00	.00	.00	1.27	.71	.29	1.11	.10	.93	.42	.38	.00	5.21
1900–01	.00	.08	.10	.09	2.55	.00	3.20	6.68	.25	.61	.12	.00	13.68
1901–02	.00	.65	Tr.	2.02	.20	Tr.	.67	1.52	1.14	------	------	Tr.	([a])
1902–03	.00	.00	[f].00	[f].03	[f]1.99	1.78	.60	.96	3.02	3.46	.00	[b].00	[c]11.84
8-year mean	.00	.19	.07	.33	.75	.99	1.79	1.35	1.35	.66	.10	.01	7.60
Per cent of mean annual precipitation	0	2.5	.9	4.3	9.9	13.0	23.6	17.8	17.8	8.7	1.3	.7	------

E. T. Earl ranch

[In sec. 36, T. 7 N., R. 13 W. Record furnished by E. T. Earl estate. Altitude about 2,450 feet]

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1913–14	0.13	0.10	0.00	0.00	0.35	1.07	4.40	3.53	0.12	0.12	0.15	0.00	9.97
1914–15	.02	.00	.00	.15	.12	3.24	4.10	3.55	.45	.46	.76	.00	12.85
1915–16	.00	.00	.00	.00	.47	1.17	4.62	1.04	.98	.15	.00	.00	8.43
1916–17	.00	.00	.12	.31	.06	2.86	1.88	.43	.15	.10	.00	.00	5.91
1917–18	.55	.00	.00	.00	.05	.00	.06	3.10	3.66	.00	.02	.31	7.75
1918–19	.04	.97	1.75	.00	.79	1.39	.22	.84	1.83	.15	.04	.00	8.02
1919–20	.00	.00	.00	.00	.17	.93	1.13	2.55	1.88	([e])	([e])	([e])	([a])
6-year mean	.12	.18	.31	.08	.31	1.62	2.55	2.08	1.20	.16	.16	.05	8.82
Per cent of mean annual precipitation	1.4	2.0	3.5	.9	3.5	18.4	28.9	23.6	13.6	1.8	1.8	.6	------

Lancaster, Calif.

[At Southern California Edison station, record furnished by Mr. J. R. Haskin. Altitude about 2,350 feet]

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1918–19	------	------	------	------	------	------	0.25	0.25	1.23	0.00	0.00	0.00	------
1919–20	0.00	0.00	0.00	0.00	0.23	0.55	1.00	1.07	1.44	.00	.00	.00	4.29
1920–21	.00	.00	.00	.00	.57	.40	1.53	.40	.48	.07	1.39	------	------

[a] Record for 1 or more months in the year lacking.
[b] Interpolated by the author.
[c] Record for 1 or more months in the year interpolated.
[d] No record.
[e] Record for 1920 not available.
[f] In Water-Supply Paper 278 an error exists in the record for 1902–3. The figures for September were omitted and those for October, November, and December were each pushed forward 1 month, according to the Report of the Chief of the Weather Bureau for 1902–3, p. 192.

Monthly and annual precipitation at stations in Mohave Desert region for which record covers period of less than 10 years—Continued

Palmdale, Calif.

[Authorities: 1895–1901, Burt Cole; 1903, U. S. Weather Bureau. Altitude 2,657 feet]

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1895–96	[b]0.00	[b]0.00	[b]0.00	------	0.05	0.18	0.60	0.05	1.43	0.08	0.12	0.00	([a])
1896–97	.00	.09	.00	1.20	.33	.86	3.00	3.72	1.26	.00	.01	.00	10.47
1897–98	.98	.38	.00	.16	.00	.00	.48	.15	.63	.00	.24	.00	3.02
1898–99	.00	.00	.00	.00	.02	1.40	.94	.16	.84	.00	.00	.00	3.36
1899–00	.00	.00	Tr.	.82	.22	.16	.50	.00	.49	.30	.43	[b] .00	[c]2.92
1900–01	[b] .00	[b] .00	[b] .00	.39	2.10	.00	.92	3.80	------	------	------	------	([a])
1901–02	------	------	------	------	------	------	------	------	------	------	------	------	([a])
1902–03	------	------	------	------	------	------	.36	.65	2.58	2.00	.00	Tr.	([a])
1903–04	.00	.00	.00	.00	.00	------	------	------	------	------	------	------	([a])
4-year mean	.25	.12	.00	.55	.14	.61	1.23	1.01	.81	.08	.17	.00	4.94
Per cent of mean annual precipitation	5.1	2.4	0	11.1	2.8	12.3	24.9	20.5	16.2	1.6	3.4	0	------

Palmdale headworks on Little Rock Creek

[Authority, U. S. Geol. Survey Water-Supply Paper 278, p. 15. Altitude 3,299 feet]

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1896–97	0.25	1.35	0.32	1.42	0.43	0.98	3.78	3.71	1.31	0.04	0.32	0.00	13.91
1897–98	.03	1.57	Tr.	.86	.00	.14	2.38	.07	.90	.00	.21	.00	6.16
1898–99	.02	.05	.00	.00	Tr.	.87	1.00	.31	.97	.00	.00	.00	3.22
1899–00	.00	.00	.00	1.28	.27	.32	.65	.00	.80	.57	.76	.00	4.65
1900–01	.00	.00	.00	.20	1.79	.00	1.34	4.50	.38	.15	Tr.	.00	8.36
1901–02	.00	.33	Tr.	.32	.04	.00	------	------	------	------	------	------	([a])
5-year mean	.06	.59	.06	.75	.50	.46	1.83	1.72	.87	.15	.26	.00	7.26
Per cent of mean annual precipitation	.8	8.2	.8	10.3	6.9	6.3	25.2	23.7	12.0	2.7	3.6	0	------

Llano, Los Angeles County, Calif.

[Altitude about 3,200 feet]

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1917–18	------	------	------	------	------	------	0.30	2.55	2.08	Tr,	Tr.	0.40	([a])
1918–19	0.10	0.30	0.85	0.16	0.75	0.80	.15	.80	1.05	0.10	1.00	.00	6.06
1919–20	.04	.00	.26	.03	1.20	1.45	1.20	1.21	.98	.00	.00	.00	6.37
1920–21	.00	.05	.00	.00	.20	.40	2.70	1.00	1.05	.10	1.44	.00	6.94
3-year mean	.05	.12	.37	.06	.72	.88	1.35	1.00	1.03	.07	.81	.00	6.46
Per cent of mean annual precipitation	.8	1.9	5.7	1.0	11.1	13.6	20.9	15.5	15.9	1.1	12.4	0	------

Gray Mountain, Calif.

[In or near sec. 10, T. 6 N., R. 7 W. San Bernardino meridian. Altitude 3,000 feet]

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1914–15	------	------	------	------	------	------	------	------	0.08	------	------	Tr.	([a])
1915–16	Tr.	Tr.	Tr.	0.00	0.25	0.80	2.32	0.50	.40	0.00	Tr.	0.00	4.27
1916–17	Tr.	0.37	0.17	.10	.00	1.25	2.00	Tr.	.15	.00	.00	.00	4.04
1917–18	0.82	.12	Tr.	.05	Tr.	.00	.25	1.02	------	------	------	------	([a])
1918–19	------	------	.00	.30	.04	.00	Tr.	.90	.17	.07	.01	.00	([a])
1919–20	.00	.00	.00	.00	.15	[g] Tr.	.90	.64	1.88	.00	.12	.00	3.69
1920–21	0	------	------	------	------	.25	1.45	.71	------	------	------	------	([a])
3-year mean	.00	.12	.06	.03	.13	.68	1.74	.38	.81	.00	.04	.00	4.00
Per cent of mean annual precipitation	0	3.0	1.5	.8	3.3	17.0	43.5	9.5	20.2	0	1.0	0	------

Camp Cady, Calif.

[Latitude 34° 58′; longitude 116° 32′. Altitude about 1,800 feet]

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1867–68	------	------	------	------	------	------	------	------	0.00	------	0.00	0.00	([a])
1868–69	0.69	1.00	0.00	------	0.20	0.30	0.55	1.00	1.00	0.50	------	------	([a])
1869–70	.00	.30	.00	0.10	.60	.00	.00	.00	.12	.00	.16	.00	1.28
1870–71	------	.58	.00	.50	.00	.18	.00	------	------	------	------	------	([a])

[a] Recori for 1 or more months in the year lacking.
[b] Interpolated by the author.
[g] As a precipitation of more than 1 inch is recorded at several near-by stations it is believed that this record is incorrect.

Monthly and annual precipitation at stations in Mohave Desert region for which record covers period of less than 10 years—Continued

Daggett, Calif.

[Authority, Southern Pacific Co. Altitude about 2,000 feet]

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1883–84		0.06	0.00	0.00	0.00	0.29	0.48	1.44	1.17	0.10	0.49	0.00	(a)
1884–85	0.00												(a)

Fenner, Calif.

[Authority, Southern Pacific Co. Altitude 2,096 feet]

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1883–84		0.00	0.06	0.00	0.00	2.40	0.15	1.30	1.25	0.15	1.09	0.05	(a)
1884–85	0.00	.00	.00										(a)

Goffs, Calif.

[Altitude 2,584 feet]

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1915–16											0.00	0.00	(a)
1916–17	1.17	0.13	0.27	0.17	0.00	0.90	1.22	0.25	0.03	0.73	.67	0	5.54
1917–18	.48	.43	.10										(a)
1918–19							.89	.87	1.08	.03	.09	.00	(a)
1919–20	.40	.80	1.50	.10									(a)

Greenland ranch, Inyo County, Calif.

[In Death Valley, also called Furnace Creek ranch. Altitude 178 feet below sea level]

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1911–12							0.00	0.00	1.10	Tr.	Tr.	0.00	(a)
1912–13	0.10	0.00	0.00	0.20	0.00	0.00	.01	1.90	.10	0.00	0.01	.00	2.32
1913–14	.60	.01	.30	.00	1.61	.00	.67	.21	.00	.12	.00	.05	3.57
1914–15	.00	.00	.00	.00	.00	.60	1.10	.02	.02	.08	.02	.00	1.84
1915–16	.07	.00	.00	.00	.00	.00	1.51	.20	.02	.00	.40	.00	2.20
1916–17	.00	.00	.00	.10	.00	.00	.04	.00	.00	.01	.30	.00	.45
1917–18	.06	.00	.01	.00	.00	.00	.00	.30	.75	.05	Tr.	.00	1.17
1918–19	.00	.01	.00	.01	.00	.00	.00	.00	.01	.00	.00	.00	.03
1919–20	.01	.00	.00	.00	.20	.30	.60	1.00	.30	.00	.10	.60	3.11
1920–21	.00	.10	.00	.20	.00	.00	.40	.00	.00	.00	.00	.00	.70
9-year mean	.09	.01	.03	.06	.20	.10	.48	.40	.13	.03	.09	.07	1.71
Per cent of mean annual precipitation	5.3	.6	1.8	3.5	11.7	5.8	28.1	23.4	7.6	1.8	5.3	4.1	(a)

Pahrump, Nev.

[Altitude 2,668 feet]

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1913–14									0.14	1.56	Tr.	0.09	(a)
1914–15		0.02	0.42	0.05	0.00	1.01	1.20	1.40					(a)
1915–16 [d]													
1916–17	0.64	.42	.00		.00	.58	1.13	.13	.10	.49		.00	(a)
1917–18							.13	1.15	1.83		0.37		(a)
1918–19						2.25							(a)
1919–20				.00			.94	1.31	.72	.07	.79	1.10	(a)
1920–21	.21	.40	.00	1.25	.12	.35	1.27	.25	.42			.00	(a)

Jean, Nev.

[Altitude 2,864]

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1907–08							1.30	0.10	0.20	0.00	Tr.	0.00	(a)
1908–09	0.10	0.06	2.71	1.00	0.00	0.00	.09		1.32	.30	0.00	.00	(a)
1909–10	.03	.12	2.03	.00	.67	1.59	.00	.00	.00	.00	.00	.00	4.44
1910–11	2.05	1.13	.40	.60	.90		.44	.75	1.00	.00	.00		(a)
1911–12	Tr.	.00	.00		.00	Tr.	.00	.00		.27	.10	Tr.	(a)
1912–13	.46	.20	.00	.30	.00	.00	.30	.40		.25	.00	Tr.	(a)
1913–14		.52	.23	Tr.	1.25	.00	1.50	.05	Tr.	1.25	.00	Tr.	(a)
1914–15	.03	.00	.65				1.25	1.00	.20	Tr.	Tr.	Tr.	(a)
1915–16	.29	Tr.											(a)

[a] Record for 1 or more months in the year lacking.

Monthly and annual precipitation at stations in Mohave Desert region for which record covers period of less than 10 years—Continued

Lanfair, Calif.

[Authority, E. L. Lanfair. Altitude about 4,040 feet]

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1911–12	------	------	------	------	------	------	------	------	3.60	0.68	0.13	0.00	(a)
1912–13	0.60	0.25	(h)	1.28	(h)	0.10	0.39	[i] 2.98	(j)	(j)	(j)	(j)	(a)
1913–14	1.29	1.43	0.63	(h)	1.56	(h)	2.32	3.39	.53	1.01	(h)	.46	(a)
1914–15	1.05	.19	2.29	3.16	(h)	(h)	.30	5.70	------	------	------	------	(a)

Searchlight, Nev.

[Altitude 3,445 feet]

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1913–14	------	------	------	------	------	------	2.00	2.57	0.25	1.79	Tr.	0.48	(a)
1914–15	1.10	0.42	0.82	0.22	0.02	0.51	2.46	2.14	.45	1.35	.13	Tr.	9.62
1915–16	.10	.99	.09	.00	.65	.31	3.73	.71	.48	.00	.16	.00	7.22
1916–17	.66	.22	.23	.13	.00	.47	1.36	.26	.04	.47	1.09	.00	4.93
1917–18	.50	2.49	.07	.00	.04	.00	.00	.55	3.71	Tr.	.07	.33	7.76
1918–19	2.03	.57	1.65	.51	.15	2.25	.50	.78	.48	.17	.09	.00	9.18
1919–20	4.01	.98	.86	.79	.41	.42	1.48	3.39	.81	.00	.70	.85	14.70
1920–21	.34	1.20	.00	.65	.05	04	2.01	.04	.47	.00	.88	.00	5.68
1921–22	.96	3.25	2.02	1.91	.00	3.68	2.36	.77	.86	.03	.22	.16	16.22
8-year mean	1.21	1.26	.72	.53	.16	.96	1.74	1.08	.91	.25	.42	.17	9.41
Per cent of mean annual precipitation	12.9	13.4	7.7	5.6	1.7	10.2	18.5	11.5	9.7	2.7	4.5	1.8	------

[a] Record for 1 or more months in the year lacking.
[h] It is not clear from Mr. Lanfair's record whether an absence of data for certain months indicates no precipitation or a suspension of observations; probably no precipitation.
[i] Does not include a 6-inch fall of snow on Feb. 22, which was not measured in inches of rain.
[j] It is not clear whether the absence of data for the months of March, April, May, and June, 1913, indicates no precipitation, but the nature of the record suggests that no observations were made during these months.

The records show that the precipitation in any one year may vary considerably from the mean, and at most of the stations observations have not been made during long enough periods to give reliable figures for the mean. The longer the record the more likely is the observed mean to be near the true mean. Lee, in studies of the precipitation in the San Diego region, found that the average departure of 5-year means from the mean annual precipitation for a period of 65 years was 15 per cent.[21] The departure for 10-year means was about 10 per cent, for 25-year means about 5 per cent, for 40-year means about 2 per cent, and for 60-year means only about 1 per cent.

The records given in the table are not all for the same years, and hence, as they stand, they are not all comparable. For instance, the mean annual rainfall for the station at the Palmdale headworks on Little Rock Creek for the 5-year period from July 1, 1896, to June 30, 1901, was 7.5 inches, and the mean annual rainfall at the E. T. Earl ranch, in sec. 36, T. 7 N., R. 13 W., for the 6-year period from July 1, 1913, to June 30, 1919, was 8.8 inches. At first glance it would seem that the mean annual precipitation is greater at the Earl ranch than at the Palmdale headworks. But a study of the records from several stations within a radius of 70 miles for which

[21] Ellis, A. J., and Lee, C. H., Geology and ground waters of the western part of San Diego County, Calif.: U. S. Geol. Survey Water-Supply Paper 446, pp. 82–83, 1919.

data are available for 20 years or more reveals the fact that three of the five years during which the record was kept at the Palmdale headworks were the driest ever recorded in that part of the region. On the other hand, three of the six years covered by the record at the Earl ranch were among the wettest years on record in this region.

Obviously to obtain an adequate idea of the precipitation in different parts of the region the relative wetness or dryness of the years of record must be taken into consideration. A method for estimating the mean annual precipitation at stations for which only short records are available [22] is based on the assumption that the yearly rainfall of neighboring stations shows more or less close relations. If the annual precipitation is greatly below normal at one point it is likely to be below normal at neighboring points. Accordingly if there is a record covering a long period at one station (which may be called a control station) and a short record at a point not too far away, an approximation of the true mean annual precipitation at the short-period station may be estimated by assuming that the ratio of the precipitation in the observed years to the mean annual rainfall is the same for both stations.

The procedure is as follows: First, the ratio of the observed precipitation for each year at the control station to the mean annual precipitation at that station is determined. This ratio may be called the precipitation index, or coefficient of wetness. Second, the observed precipitation for each year recorded at the short-period station is divided by the precipitation index of the control station for the corresponding year. Third, theoretically the results thus obtained for each of the several years at the short-record station should be equal, but as the departure from normal at any two stations in a region is never always in exactly the same ratio it is necessary to average the computed normal precipitation. If long-time records are available at several control stations the computed normal for the short-period station ordinarily will be more accurate if the average of the precipitation indices of all the control stations is used.

By this method it was determined that the mean annual precipitation at the Palmdale headworks is more nearly 9.7 inches than 7.5 inches and that at the Earl ranch is more nearly 7.8 inches than 8.8 inches. As the headworks are in the mountains, about 800 feet higher than the Earl ranch, and as the precipitation in the mountains is generally greater than in the valley it is believed that the corrected results show more nearly the true conditions.

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[22] On working up precipitation observations (translated from Meyer, Hugh, Guide to the working up of meteorological observations for the benefit of climatology); Monthly Weather Review, vol. 45, pp. 164–165, April, 1917. See also Ellis, A. J., and Lee, C. H., op. cit., pp. 77–85. The precipitation indices or coefficients of wetness, referred to below, for many stations in California, including several in the Mohave Desert region are given in Calif. Dept. Public Works, Bull. 5, Flow in California Streams, 1923.

The method just described was employed to determine the corrected average precipitation over a long term of years at several stations in Antelope Valley, in the southwestern part of the Mohave Desert region, and others just beyond the borders of the region. The stations having long records which were used as control stations in the calculations are Los Angeles, San Bernardino, Barstow, Mohave, Tehachapi, Bakersfield, Tejon ranch, and Newhall. The observed yearly precipitation records and computed precipitation indices or coefficients of wetness for the control stations are given in the table on pages 85–86, and in the table on page 87 is given the corrected long-time average of those stations and other stations for which shorter records are available.[23]

[23] In order to bring the table on pp. 85–86 up to date at the time the report is ready for press, new means and all the precipitation indices would have to be recomputed, a task for which time is not available. The following supplemental table, giving the annual precipitation, with precipitation indices based on the 1920 means, for the only four stations of those used on pp. 85–86 for which records are available, will give some idea of the trend of conditions of precipitation from July 1, 1920, to June 30, 1927:

Year	Los Angeles		San Bernardino		Bakersfield		Tejon ranch		Average index of 4 stations
	Observed precipitation	Precipitation index	Observed precipitation	Precipitation index	Observed precipitation	Precipitation index	Observed precipitation	Precipitation index	
	Inches	*Per cent*	*Inches*	*Per cent*	*Inches*	*Per cent*	*Inches*	*Per cent*	*Per cent*
1920–21	13.65	86	16.46	102	7.02	126	10.46	87	100
1921–22	19.66	126	27.75	172	8.88	159	11.48	96	138
1922–23	9.59	62	11.04	68	5.95	107	6.83	57	73
1923–24	6.68	43	11.34	70	3.68	66	10.40	87	66
1924–25	7.94	51	10.89	68	4.62	83	12.60	105	76
1925–26	17.56	113	20.40	127	5.02	90	7.90	66	100
1926–27	17.76	114	20.55	127	6.20	111	9.51	69	105

Observed annual precipitation and precipitation indices for 8 stations near Antelope Valley

Year	Los Angeles		San Bernardino		Barstow		Mojave		Tehachapi		Bakersfield		Tejon ranch [b]		Newhall		Average index of all control stations
	Observed precipitation	Precipitation index	Observed precipitation	Precipitation index	Observed precipitation	Precipitation index	Observed precipitation	Precipitation index	Observed precipitation	Precipitation index	Observed precipitation	Precipitation index	Observed precipitation	Precipitation index	Observed precipitation	Precipitation index	
	Inches	*Per cent*	*Inches*	*Per cent*	*Inches*	*Per cent*	*Inches*	*Per cent*	*Inches*	*Per cent*	*Inches*	*Per cent*	*Inches*	*Per cent*	*Inches*	*Per cent*	
1870–71	-----	-----	13.94	86	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	86
1871–72	-----	-----	8.98	56	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	56
1872–73	-----	-----	15.10	94	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	94
1873–74	-----	-----	23.81	148	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	148
1874–75	-----	-----	13.65	85	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	85
1875–76	-----	-----	19.90	123	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	123
1876–77	-----	-----	9.52	59	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	59
1877–78	21.26	137	20.33	128	-----	-----	6.42	129	16.40	155	-----	-----	-----	-----	11.44	64	123
1878–79	11.35	73	11.54	72	-----	-----	2.67	53	5.84	55	-----	-----	-----	-----	6.77	38	58
1879–80	20.34	125	20.36	128	-----	-----	6.79	136	15.53	147	-----	-----	19.22	161	19.52	109	134
1880–81	13.13	84	13.50	84	-----	-----	1.27	25	10.20	97	-----	-----	9.58	80	9.15	51	70
1881–82	10.40	67	11.54	72	-----	-----	.63	13	7.08	67	-----	-----	9.98	83	13.99	78	63
1882–83	12.11	78	9.17	57	-----	-----	Trace.	0	12.00	114	-----	-----	9.10	76	11.62	65	65
1883–84	38.18	245	37.51	233	-----	-----	11.64	233	18.09	171	-----	-----	18.27	153	42.11	235	212
1884–85	9.21	58	10.81	67	-----	-----	[a] 2.84	57	7.16	68	-----	-----	7.95	66	7.94	44	60
1885–86	22.31	144	21.93	136	-----	-----	5.97	120	20.89	198	-----	-----	13.50	113	24.57	137	141
1886–87	14.05	90	14.50	90	-----	-----	5.07	102	13.68	130	-----	-----	11.67	97	15.70	88	99
1887–88	13.87	89	17.76	110	-----	-----	8.50	170	10.43	99	-----	-----	11.09	93	18.84	105	111
1888–89	19.28	124	20.97	143	-----	-----	8.22	165	13.24	125	-----	-----	9.40	93	21.54	120	128
1889–90	34.84	224	25.45	158	5.58	130	12.47	250	12.25	116	5.67	102	14.14	118	39.09	218	165
1890–91	13.36	86	18.08	112	3.83	89	4.40	88	9.86	93	4.00	72	11.20	94	15.39	86	90
1891–92	11.85	76	14.35	89	-----	-----	4.46	89	[a] 11.75	111	5.51	99	16.22	136	12.80	72	96
1892–93	26.28	169	19.82	123	-----	-----	5.48	110	10.51	100	5.42	97	10.30	86	23.14	129	116
1893–94	6.73	43	8.13	50	2.55	59	3.65	73	[a] 12.56	119	2.77	50	12.28	103	7.19	40	67
1894–95	16.11	104	20.98	130	2.18	51	7.88	158	[a] 10.08	96	6.44	115	12.97	108	19.86	111	109
1895–96	8.51	55	8.11	50	.57	13	3.92	79	6.30	60	5.67	102	-----	-----	8.76	49	58
1896–97	16.86	108	16.74	104	5.95	138	5.66	113	8.20	78	6.23	112	17.33	145	18.42	103	113
1897–98	7.06	45	8.24	51	-----	-----	.60	12	5.21	49	3.20	57	9.18	77	[a] 5.62	31	46
1898–99	5.59	36	7.49	47	-----	-----	1.14	23	3.70	35	2.80	50	5.65	47	5.44	30	38
1899–1900	7.91	51	8.64	54	-----	-----	2.81	56	6.05	57	5.21	94	10.60	89	7.59	42	67
1900–1	16.29	105	17.36	108	-----	-----	5.85	117	7.77	74	-----	-----	11.69	98	19.08	107	101
1901–2	10.60	70	11.15	69	-----	-----	3.51	70	9.68	92	4.51	81	8.98	75	9.89	55	73
1902–3	19.32	124	17.42	108	-----	-----	2.92	59	9.29	88	4.98	89	11.68	98	19.64	110	97
1903–4	8.72	56	9.37	58	.90	21	1.96	39	[a] 6.64	63	4.33	78	10.10	84	8.22	46	56
1904–5	19.52	126	20.78	129	5.90	137	6.10	122	15.86	150	8.40	151	13.65	114	27.53	154	135
1905–6	18.65	120	19.88	159	1.80	42	6.75	135	18.61	176	8.72	157	[a] 166.46	138	18.39	103	129

[a] Record for 1 or more months in the year interpolated.
[b] Record for seasons 1879–80 to 1899–95 from U. S. Geol. Survey Bull. 140, pp. 257–258.

Observed annual precipitation and precipitation indices for 8 stations near Antelope Valley—Continued

Year	Los Angeles		San Bernardino		Barstow		Mojave		Tehachapi		Bakersfield		Tejon ranch		Newhall		Average index of all control stations
	Observed precipitation	Precipitation index	Observed precipitation	Precipitation index	Observed precipitation	Precipitation index	Observed precipitation	Precipitation index	Observed precipitation	Precipitation index	Observed precipitation	Precipitation index	Observed precipitation	Precipitation index	Observed precipitation	Precipitation index	
	Inches	*Per cent*	*Inches*	*Per cent*	*Inches*	*Per cent*	*Inches*	*Per cent*	*Inches*	*Per cent*	*Inches*	*Per cent*	*Inches*	*Per cent*	*Inches*	*Per cent*	
1906-7	19.30	124	23.17	144	------	------	9.09	184	[a] 11.29	107	4.85	136	------	------	33.06	185	147
1907-8	11.72	78	15.62	97	7.03	164	[a] 4.28	86	[a] 7.08	67	3.31	59	------	------	15.31	86	91
1908-9	19.18	123	17.36	108	4.81	112	7.13	143	[a] 10.98	104	7.39	133	------	------	22.63	127	121
1909-10	12.63	81	15.02	93	4.16	97	2.97	60	[a] 6.43	61	6.19	111	------	------	19.85	111	88
1910-11	16.18	104	16.34	101	2.90	68	9.12	183	9.21	87	------	------	------	------	22.72	127	111
1911-12	11.60	75	13.84	86	3.67	86	6.50	130	9.35	88	------	------	12.31	103	20.03	112	96
1912-13	13.42	86	11.08	69	3.28	76	1.10	22	------	------	------	------	12.13	101	17.79	99	75
1913-14	23.65	152	21.45	133	7.51	175	------	------	------	------	7.92	142	12.08	101	31.24	175	146
1914-15	17.05	110	20.34	126	5.08	118	------	------	------	------	9.30	167	15.58	130	27.50	154	134
1915-16	19.92	141	24.72	153	5.30	124	------	------	------	------	5.60	101	8.56	72	------	------	118
1916-17	15.26	98	13.79	85	3.85	90	------	------	------	------	6.27	113	------	------	------	------	96
1917-18	13.86	89	13.33	83	7.65	179	------	------	------	------	4.95	89	------	------	------	------	110
1918-19	8.58	55	13.62	84	7.03	164	------	------	------	------	4.97	89	10.31	86	------	------	95
1919-20	12.52	81	19.28	120	2.94	69	------	------	------	------	5.84	105	------	------	------	------	94
Observed means	15.55	100	16.12	100	4.29	100	4.99	100	10.55	100	5.57	100	11.97	100	17.88	100	------
Number of years of record	43	------	50	------	22	------	36	------	35	------	27	------	32	------	38	------	------

[a] Record for 1 or more months in the year interpolated.

Summary of precipitation records at stations in and near Antelope Valley, Calif., calculated to 1920

Station	Altitude above sea level (feet)	Number of years of record	Observed average annual precipitation (inches)	Correction factor	Corrected long-term average precipitation (inches)	Ratio of corrected average annual precipitation (in inches) to altitude (in feet above sea level)
Los Angeles	293	43	15.55	1.00	15.55	0.0532
San Bernardino	1,054	50	16.12	1.00	16.12	.0153
Barstow	2,105	22	4.29	.99	4.30	.0020
Mojave	2,751	36	4.99	.99	5.04	.0018
Tehachapi	3,964	35	10.55	.99	10.66	.0027
Bakersfield	404	27	5.57	.99	5.63	.0139
Tejon ranch	1,500	32	11.97	1.01	11.85	.0079
Newhall	1,200	38	17.88	1.01	17.70	.0147
Fort Tejon	3,245	5	13.70	.64	21.40	.0066
Monterio	4,500	13	17.56	.97	18.10	.0040
Liebre ranch	3,170	7	9.34	.91	10.26	.0032
Manzana	2,870	8	7.60	.79	9.62	.0034
Fairmont	3,036	8	15.14	1.01	14.99	.0049
E. T. Earl ranch	2,450	6	8.82	1.13	7.80	.0032
Palmdale	2,657	4	4.94	.66	7.48	.0028
Palmdale headworks	3,300	6	7.48	.77	9.71	.0029
Valyermo	3,750	9	11.96	1.05	11.39	.0030
Llano	3,250	2	6.22	.92	6.76	.0021
Gray Mountain	3,000	3	4.00	1.03	3.96	.0013

Similar corrected long-term averages might be obtained for the other stations in the eastern part of the region, but it is believed that the same control stations should not be used, because, as pointed out below, rainfall conditions in the eastern part of the region are somewhat different from those in the western part. Pressure of other work prevented the writer from making the many computations needed to get the corrected averages for the stations in the region not listed in the accompanying table.

A study of the data on precipitation given above and of general conditions of rainfall in southern California shows certain dominant features. There is a distinct seasonal distribution of rain, most of it coming in the winter, but in the eastern part there is a minor rainy season in the late summer; the precipitation varies in different parts of the region, but in general it is least in the low valleys and greatest in the high mountains. The mean annual precipitation in most of the region is less than 10 inches, an amount so small that irrigation is necessary for successful agriculture.

The seasonal distribution of the rainfall at 12 stations is shown graphically in Figures 1 and 2, which are drawn in part from data given in the table on pages 90–91.

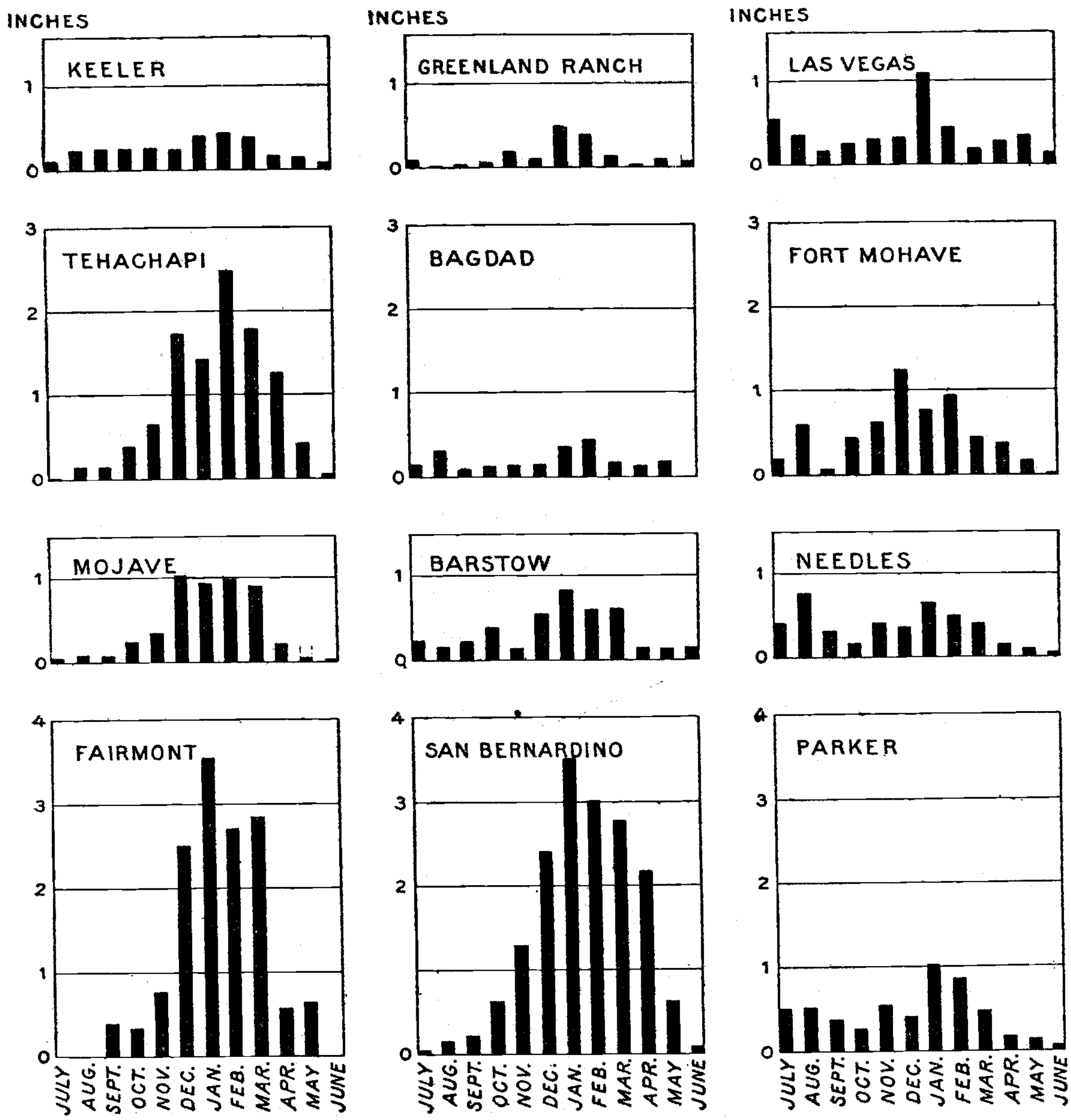


FIGURE 1.—Mean monthly precipitation at stations in or near the Mohave Desert region

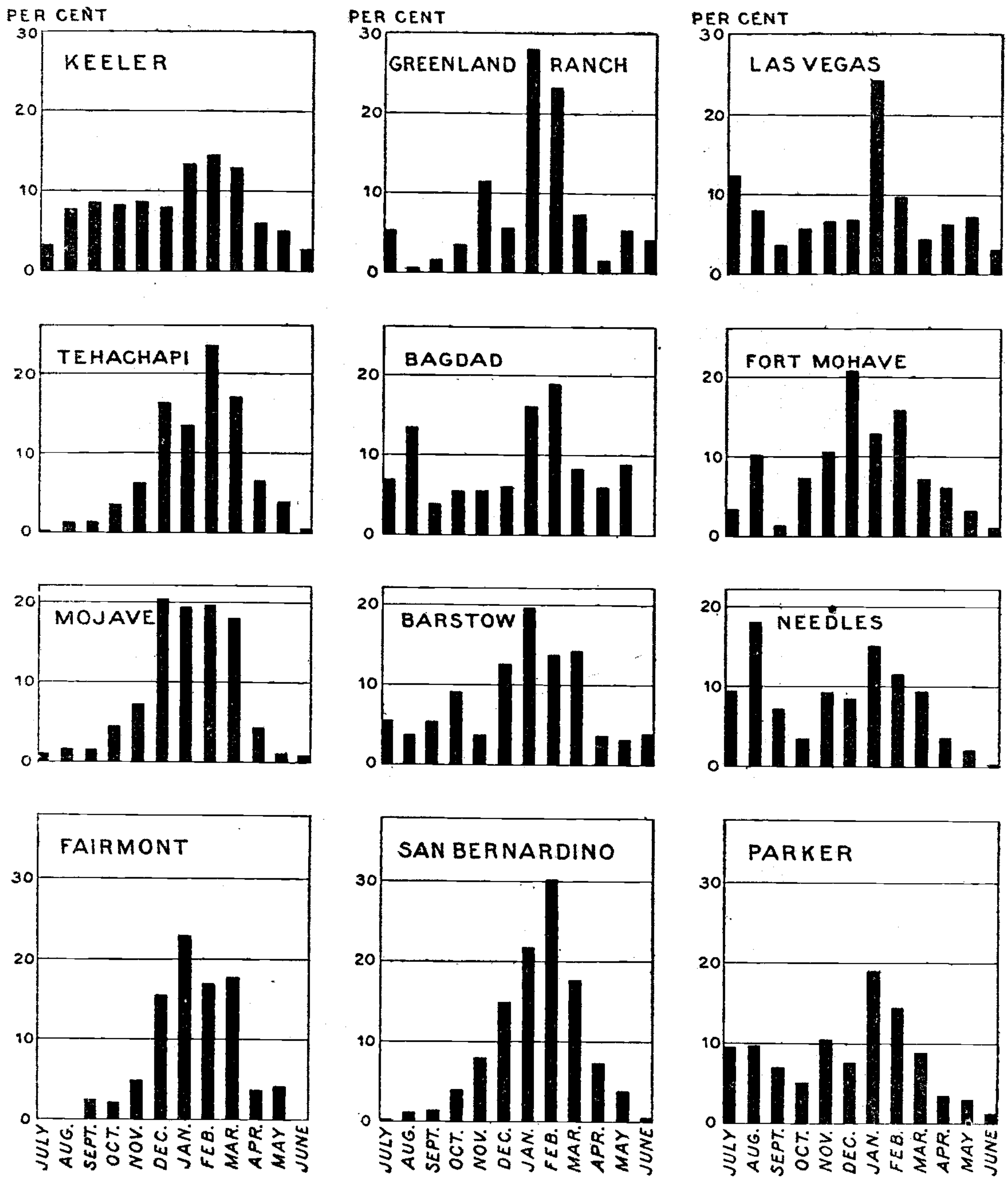


FIGURE 2.—Percentage of precipitation in each month at stations in or near the Mohave Desert region

Maximum, minimum, and mean monthly precipitation in inches and percentage of mean annual precipitation at 11 stations in and near Mohave Desert region, Calif.

[Compiled from records of U. S. Weather Bureau]

	Number of years of complete record	July	Aug.	Sept.	Oct.	Nov.	Dec.
Keeler, Calif.	24						
Maximum monthly precipitation		0.52	1.42	2.75	1.94	1.75	1.05
Minimum monthly precipitation		.00	.00	.00	.00	.00	.00
Mean monthly precipitation		.10	.24	.26	.25	.26	.24
Per cent of annual precipitation		3.3	7.9	8.7	8.3	8.7	8.0
Tehachapi, Calif.	37						
Maximum monthly precipitation		2.00	1.70	1.95	2.70	3.70	5.52
Minimum monthly precipitation		.00	.00	.00	.00	.00	.00
Mean monthly precipitation		.06	.15	.14	.40	.65	1.68
Per cent of annual precipitation		.6	1.4	1.3	3.7	6.1	15.7
Mojave, Calif.	36						
Maximum monthly precipitation		1.75	1.75	.87	2.21	2.18	7.30
Minimum monthly precipitation		.00	.00	.00	.00	.00	.00
Mean monthly precipitation		.05	.09	.08	.23	.37	1.02
Per cent of annual precipitation		1.0	1.8	1.6	4.6	7.4	20.4
Monterio, Calif. (Knecht's ranch)	13						
Maximum monthly precipitation		.65	1.91	1.00	3.60	3.94	4.02
Minimum monthly precipitation		.00	.00	.00	.00	.10	.10
Mean monthly precipitation		.07	.13	.25	.88	1.67	2.12
Per cent of annual precipitation		.4	.7	1.4	4.9	9.4	11.9
Barstow, Calif.	23						
Maximum monthly precipitation		1.35	.87	1.50	3.39	2.00	3.87
Minimum monthly precipitation		.00	.00	.00	.00	.00	.00
Mean monthly precipitation		.24	.16	.23	.39	.16	.55
Per cent of annual precipitation		5.6	3.8	5.4	9.2	3.8	12.9
San Bernardino, Calif.	51						
Maximum monthly precipitation		.34	2.16	2.37	2.75	7.50	10.85
Minimum monthly precipitation		.00	.00	.00	.00	.00	.00
Mean monthly precipitation		.04	.17	.22	.64	1.29	2.41
Per cent of annual precipitation		.2	1.1	1.4	4.0	8.0	15.0
Bagdad, Calif.	17						
Maximum monthly precipitation		1.29	2.20	1.00	1.86	1.50	1.33
Minimum monthly precipitation		.00	.00	.00	.00	.00	.00
Mean monthly precipitation		.16	.31	.09	.13	.13	.14
Per cent of annual precipitation		7.0	13.6	3.9	5.7	5.7	6.1
Las Vegas, Nev.	13						
Maximum monthly precipitation		1.88	1.78	2.00	.95	1.09	1.35
Minimum monthly precipitation		Tr.	.00	.00	.00	.00	.00
Mean monthly precipitation		.55	.36	.17	.26	.30	.31
Per cent of annual precipitation		12.4	8.1	3.8	5.9	6.8	7.0
Mohave City, Ariz.	22						
Maximum monthly precipitation		1.80	4.42	1.31	2.60	6.16	11.17
Minimum monthly precipitation		.00	.00	.00	.00	.00	.00
Mean monthly precipitation		.21	.61	.08	.44	.63	1.25
Per cent of annual precipitation		3.5	10.2	1.3	7.3	10.5	20.8
Needles, Calif.	30						
Maximum monthly precipitation		1.45	7.21	1.47	1.15	2.20	3.30
Minimum monthly precipitation		.00	.00	.00	.00	.00	.00
Mean monthly precipitation		.41	.78	.31	.15	.40	.37
Per cent of annual precipitation		9.6	18.2	7.2	3.5	9.3	8.6
Parker, Ariz.	21						
Maximum monthly precipitation		2.82	4.64	1.96	1.81	4.49	1.86
Minimum monthly precipitation		.00	.00	.00	.00	.00	.00
Mean monthly precipitation		.51	.52	.38	.27	.55	.41
Per cent of annual precipitation		9.6	9.7	7.1	5.1	10.3	7.7

Maximum, minimum, and mean monthly precipitation in inches and percentage of mean annual precipitation at 11 stations in and near Mohave Desert region, Calif.—Continued

[Compiled from records of U. S. Weather Bureau]

	Jan.	Feb.	Mar.	Apr.	May	June	Year
Keeler, Calif.							
Maximum monthly precipitation	1.55	1.21	3.30	1.25	1.10	1.00	8.60
Minimum monthly precipitation	.00	.00	.00	.00	.00	.00	.53
Mean monthly precipitation	.41	.44	.39	.18	.15	.08	3.01
Per cent of annual precipitation	13.6	14.6	13.0	6.1	5.0	2.8	100
Tehachapi, Calif.							
Maximum monthly precipitation	4.90	8.88	7.05	4.57	1.73	1.05	20.89
Minimum monthly precipitation	Tr.	.00	.00	.00	.00	.00	3.70
Mean monthly precipitation	1.55	2.54	1.84	1.20	.40	.09	10.72
Per cent of annual precipitation	14.5	23.7	17.2	11.2	3.7	.8	100
Mojave, Calif.							
Maximum monthly precipitation	3.27	5.69	5.00	1.50	.50	1.05	12.47
Minimum monthly precipitation	.00	.00	.00	.00	.00	.00	Tr.
Mean monthly precipitation	.96	.99	.91	.22	.05	.04	4.99
Per cent of annual precipitation	19.2	19.8	18.2	4.4	1.0	.8	100
Monterio, Calif. (Knecht's ranch)							
Maximum monthly precipitation	6.50	7.05	9.60	3.53	3.25	.96	25.64
Minimum monthly precipitation	.70	.34	.48	.25	.00	.00	11.68
Mean monthly precipitation	2.63	3.19	4.02	1.60	1.19	.12	17.87
Per cent of annual precipitation	14.7	17.9	22.5	8.9	6.7	.7	100
Barstow, Calif.							
Maximum monthly precipitation	3.39	2.47	3.50	1.20	.99	2.97	7.65
Minimum monthly precipitation	.00	.00	.00	.00	.00	.00	.57
Mean monthly precipitation	.84	.60	.61	.16	.14	.16	4.25
Per cent of annual precipitation	19.8	14.1	14.4	3.8	3.3	3.8	100
San Bernardino, Calif.							
Maximum monthly precipitation	15.51	12.20	9.95	5.68	3.34	1.02	37.51
Minimum monthly precipitation	.00	.00	.06	.00	.00	.00	7.49
Mean monthly precipitation	3.52	3.01	2.89	1.19	.63	.09	16.11
Per cent of annual precipitation	21.8	18.7	17.9	7.4	3.9	.6	100
Bagdad, Calif.							
Maximum monthly precipitation	2.40	3.20	2.30	1.57	1.75	.00	10.20
Minimum monthly precipitation	.00	.00	.00	.00	.00	.00	.00
Mean monthly precipitation	.37	.43	.19	.14	.20	.00	2.28
Per cent of annual precipitation	16.2	18.9	8.3	6.1	8.8	.00	100
Las Vegas, Nev.							
Maximum monthly precipitation	4.67	1.70	2.63	1.42	1.40	.67	8.46
Minimum monthly precipitation	.00	.00	.00	.00	.00	.00	.76
Mean monthly precipitation	1.09	.44	.20	.28	.33	.14	4.44
Per cent of annual precipitation	24.5	9.9	4.5	6.3	7.4	3.2	100
Mohave City, Ariz.							
Maximum monthly precipitation	4.15	5.00	3.00	4.50	1.20	1.00	19.37
Minimum monthly precipitation	.00	.00	.00	.00	.00	.00	.96
Mean monthly precipitation	.78	.96	.43	.37	.19	.05	6.00
Per cent of annual precipitation	13.0	16.0	7.2	6.2	3.2	.8	100
Needles, Calif.							
Maximum monthly precipitation	3.36	4.50	2.31	1.00	.78	.88	12.48
Minimum monthly precipitation	.00	.00	.00	.00	.00	.00	.60
Mean monthly precipitation	.65	.50	.41	.16	.10	.07	4.29
Per cent of annual precipitation	15.2	11.7	9.6	3.7	2.3	.16	100
Parker, Ariz.							
Maximum monthly precipitation	3.64	3.67	1.77	.89	2.00	.50	9.12
Minimum monthly precipitation	.00	.00	.00	.00	.00	.00	.84
Mean monthly precipitation	1.01	.78	.47	.19	.16	.07	5.34
Per cent of annual precipitation	18.9	14.6	8.8	3.6	3.0	1.3	100

From 50 to 85 per cent of the average annual precipitation falls in the five winter months November to March. The greatest precipitation usually occurs in January, February, and March. The records for Bagdad, Las Vegas, Fort Mohave, Needles, and Parker show that a secondary rainy season of less magnitude occurs in the eastern part of the area in July and August. The average monthly precipitation during these two months at the places mentioned ranges from about 19 to nearly 28 per cent, whereas at all the other stations, with the exception of Keeler, it is less than 10 per cent. At Needles the mean monthly precipitation has been greater in August than in any other month, although the total for the six summer months is much less than the total for the winter.

The winter precipitation comes from storms that cover large areas. These storms move in general from the Pacific Ocean eastward. The rainfall from such storms is more or less steady, continuing from several hours to a day or two, and an inch or more of rain may fall during a storm. The winter precipitation over most of the region usually comes in the form of rain. Occasionally snow falls, but it usually melts within a few hours. In the high San Bernardino, San Gabriel, and Tehachapi Mountains much of the winter precipitation occurs as snow, which remains on the ground for longer periods. The relative amount of snow that may be expected in different parts of the region is shown in the following table by records at five stations, the only places for which data are available.

Mean monthly snowfall at stations in the Mohave Desert region (in inches) [a]

Station	Altitude (feet)	Length of record (years)	July	August	September	October	November	December
Bear Valley Dam, Calif.	6,700	9	--------	--------	--------	0.7	5.5	20.6
Holcomb, Calif.	7,800	7	--------	--------	--------	.9	6.1	17.8
Las Vegas, Nev.	2,033	14	0.0	0.0	0.0	.0	.0	1.8
Fort Mohave, Ariz.	604	11	.0	.0	.0	.0	.0	Tr.
Parker, Ariz.	353	11	.0	.0	.0	.0	.0	.0

Station	January	February	March	April	May	June	Seasonal
Bear Valley Dam, Calif.	26.1	28.1	21.9	1.7	2.7	--------	117.2
Holcomb, Calif.	29.1	19.3	15.2	9.9	2.9	--------	101.1
Las Vegas, Nev.	.1	.2	Tr.	.0	.0	0.0	2.1
Fort Mohave, Ariz.	Tr.	.0	.0	.0	.0	.0	Tr.
Parker, Ariz.	Tr.	Tr.	.0	.0	.0	.0	Tr.

[a] Compiled from records of U. S. Weather Bureau.

The precipitation is more irregular during the summer than during the winter. It usually occurs in thunderstorms in which the fall may be only a fraction of an inch, but sometimes the fall is very great in a short time. The slightly greater precipitation in the eastern part of the region in July and August comes from thunderstorms that move up from the south. The stations in this part of the region are on the western border of an area that is affected by storms that strike Arizona and reach northward into Nevada. This area does not have any sharp boundary, but Bagdad seems to lie within it.

Although the precipitation in a single storm occasionally amounts to an inch or more, a very large percentage of it in most of the region comes in small amounts of less than half an inch. Under such conditions the moisture is quickly evaporated and is of little value to growing crops or in replenishing the ground-water reservoirs.

As shown in the diagrams on Plate 6 and by the tables on pages 78–91, the distribution of the rainfall from year to year and for the same months in different years is very irregular and uncertain. The departure from normal in successive years at a station frequently differs by 50 per cent and occasionally as much as 100 or 150 per cent. Although it is true that several wet years may be followed by several dry years, there is no evidence of any definite periodic fluctuation of wet and dry years.

It may be pointed out that in the region there are generally more seasons when the rainfall is below the average than seasons when it is above. This relation is due to the fact that an occasional unusually wet season may give an excess of precipitation equal to or greater than the whole amount of the average, but there can be no seasons with an equally great deficiency. Thus at several of the stations there have been one or more years when the precipitation has been more than 100 per cent in excess of the long-time average, but the deficiency in a dry year can never be more than 100 per cent. It would take two years without rainfall to equal a year with 100 per cent above the normal. In estimating the rainfall available for agricultural use it is therefore necessary to make some allowance for the unusually wet years of rare occurrence. The normal year is really one in which the rainfall is somewhat below the mathematical average annual rainfall.

The winter rainfall generally comes when crops in the region are dormant. The summer rainfall is generally of little value to crops because it is small in amount and quickly evaporated. These conditions, together with the irregular and uncertain distribution of precipitation from year to year, make it necessary that storage of some kind be provided if the rainfall is to be useful for irrigation. The storage may be accomplished in artificial reservoirs or in the natural underground reservoirs composed of the water-bearing sand and gravel that underlie the valleys in the region. Storage in the ground-water reservoirs is considered further on pages 124 and 315–320.

The records show that, although the mean annual precipitation differs considerably at different points, it is generally greater at stations high above sea level than at lower stations. The moisture-laden winds from the ocean in approaching mountains rise to higher levels and become cooler. Cool air can not hold as much moisture as warm air and accordingly the winds must drop some of their moisture if they become saturated. After passing over the mountains the winds descend to lower levels again. They become warmer and can absorb more moisture, so that evaporation rather than precipitation takes place, or, if the air is still oversaturated the rainfall becomes less and less at successively lower altitudes.

The winter storms move eastward from the Pacific Ocean. Before reaching the desert they encounter the high San Bernardino, San Gabriel, and Tehachapi Mountains and the Sierra Nevada, which present an almost unbroken barrier. For the reasons just mentioned the rainfall on the southwest and west sides of these ranges is relatively heavy, but on the northeast and east sides it decreases rapidly, as is shown by a comparison of the rainfall at stations between San

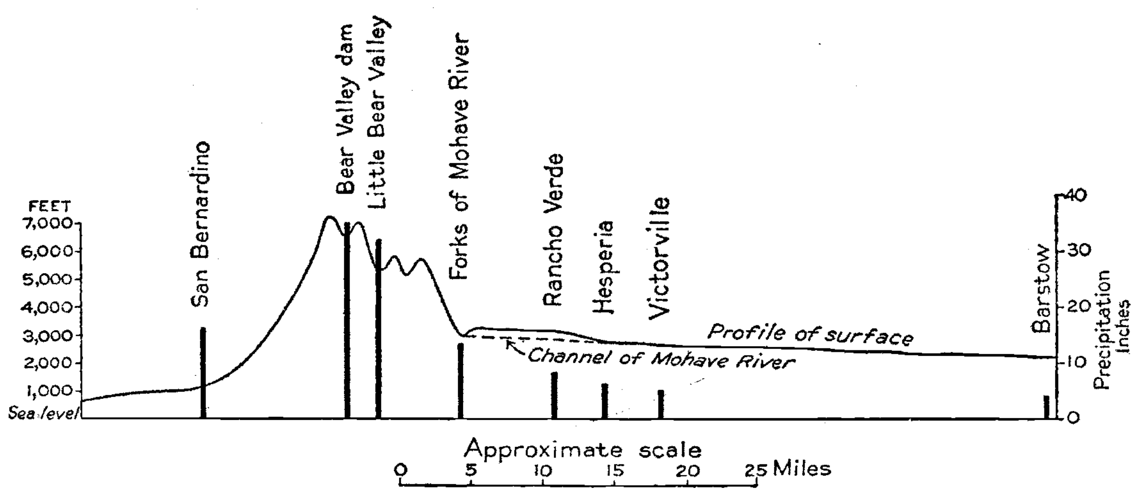


FIGURE 3.—Relation of mean annual precipitation (heavy vertical lines) to altitude between San Bernardino and Barstow

Bernardino and Barstow. The mean annual rainfall at San Bernardino, altitude 1,054 feet, is approximately 16 inches; at Bear Valley Dam, altitude 6,500 feet, near the summit of the San Bernardino Mountains, it is approximately 35 inches; at Little Bear Valley, altitude 5,200 feet, it is approximately 32 inches; at the Forks of Mohave River, altitude 3,000 feet, it is approximately 13.5 inches; at Hesperia, altitude 3,190 feet, it is approximately 7.75 inches; at Rancho Verde, altitude 2,760 feet, it is approximately 6 inches; at Victorville, altitude 2,726 feet, it is approximately 5 inches; and at Barstow, altitude 2,150 feet, it is approximately 4 inches. These relations are shown graphically in Figure 3.

Although the mean annual precipitation is generally greater at high altitudes than at low altitudes the relation between altitude and precipitation is not uniform throughout the region. Thus Tehachapi, at an altitude of nearly 4,000 feet, should have a mean annual precipitation of approximately 22 or 23 inches if the relation between precipitation and altitude were the same there as in the San Bernardino Mountains, but it is actually only about 10.5 inches. Also, the rainfall in the New York Mountains, which reach altitudes of 5,000 to 7,000 feet, should be from 30 to 35 inches. There is no evidence of such heavy rainfall in these mountains. It is nevertheless true, according to the testimony of local inhabitants, that the precipitation is somewhat greater in these mountains than at lower altitudes a few miles distant. The difference in the relation between the altitude and precipitation is due in part to topographic situation with respect to the rain-bearing winds. Thus the precipitation in in the vicinity of Cajon Pass apparently is affected by the fact that winds blowing through the pass do not rise as high as those that cross the mountains on both sides. Data on rainfall in Antelope Valley show that there is considerable difference in the rainfall at places at about the same altitude, apparently owing to local topographic features that influence the course of the winds.

The data are not sufficient to allow definite conclusions to be drawn in regard to the mean annual precipitation throughout the area. Probably, however, in most of the area, except at higher altitudes, the precipitation does not exceed 5 inches. The records at Bagdad and Greenland ranch show that in some of the valleys it is less than 3 inches. Further information in regard to precipitation in individual valleys is given in the detailed descriptions of those valleys.

INFLUENCE OF CLIMATE ON HUMAN ACTIVITIES

The climate of an arid region like the Mohave Desert has certain features which are considerably different from those in a more humid climate and which are supposed by many persons to be detrimental if not dangerous to human beings. Brief consideration may be given here to the influence of the arid climate on human activities.

The most marked feature of desert climate is the unusually high summer temperature and the low relative humidity. In humid regions high temperature frequently causes deaths from sunstroke, but in the desert sunstroke is almost unknown. The high temperature alone does not seem to cause any noticeable discomfort. Loew [24] found that after marching 20 miles over the desert on a day when the air temperature was 110° to 116° F. the body temperature at the most rose only 1° or 2° above the normal of 98.5°. The pulse was generally much increased, but the respiration showed little or no increase. The low humidity and consequent high evaporation probably produces the most harmful effects in the desert, and yet it

[24] Loew, Oscar, On the physiological effects of a very hot climate: U. S. Geog. Surveys W. 100th Mer. Ann. Rept. for 1876, Appendix H 15, pp. 328–330, 1876.

is of value in making the high temperatures bearable. Because of the dryness of the air the moisture given off by the body quickly evaporates and there is no visible perspiration, but the evaporation produces a cooling effect. Hence one is seldom affected as long as he can drink sufficient water to make up for the rapid loss through the skin. It is usually only when a person can not get water that there is any harmful effect. One should never go far from a source of water even in winter, and much less in summer, without enough water to last until another supply can be reached. From a series of observations on days when the temperature was as high as 108° to 114° F. Loew concluded that the evaporation from a human body in half a day amounted to about 2 quarts, and if the person did heavy work, as climbing mountains, it was nearly double this quantity. To provide for emergencies travelers should carry at least 2 to 4 gallons of water per 24 hours for each person. A Geological Survey party of two men used in September for all purposes, including drinking, cooking, washing, and filling the automobile radiator, from 9 to 13 gallons a day.

Advantage is taken of the great evaporation for cooling water and foodstuffs. Thus water is cooled by being kept in porous earthen jars or water bags through which the water slowly seeps to the outside, where it evaporates. The refrigerator of many a desert home consists of a vessel wrapped in gunny sacks, which are kept moist by water dropping from holes in a can. The cooling effect is greatest where there is a current of air.

The winds of the desert cause trouble because of the sand which they carry. The sand is often driven with sufficient force to cut off young plants and trees unless they are protected by windbreaks. In some places it is difficult to prevent railroad tracks from being buried by wind-blown sand. As a whole, however, there is less difficulty from wind-blown sand in the Mohave Desert region than in some other arid parts of the country.

The influence of precipitation is naturally of great importance, for if it were not for the low rainfall throughout the region 2,000,000 acres or more that will probably never be of any value could be used for agriculture. Wherever sufficient water is available for irrigation, either from streams or from underground sources, the land is productive, but because of the irregularity and uncertainty in the supply it is necessary that the water be stored, either in artificial reservoirs or in the natural underground reservoirs. The evaporation of water from the natural or artificial reservoirs and from the distributing systems constitutes a serious waste, part of which can be prevented by the installation of expensive pipe lines and other works but a large part of which can not be prevented.

Storms, especially those occurring in the summer, frequently do great damage. At several places the crops of entire ranches have been washed away or buried by débris in a single storm. Large sums of money have been expended in protecting railroads from the floods that rush down from the mountains. Large drainage channels several thousand feet long are constructed to lead the floods to specially protected culverts, and concrete walls have been built at a number of places to protect the Atchison, Topeka & Santa Fe Railway. In spite of all these protective works sections of track are washed out every few months. Considerable damage is also frequently done to highways. Strangely enough, in this land of little rain the monetary losses due to excessive rainfall probably exceed those due to all other climatic conditions.

DRAINAGE

A belt along the east side of the region drains into Colorado River, but all the rest of the region has an interior drainage. There are about 50 closed basins, each of which has one or more playas, or "dry lakes," in its low central part, toward which the surrounding mountains and uplands drain. The boundaries of these basins are shown on Plate 7. The largest is the basin of Mohave River, which rises in the relatively well-watered San Bernardino Mountains and in occasional wet years receives enough water to persist through many miles of desert country and to discharge into Silver Lake, in the lowest part of the basin. Another large and relatively well watered basin is that of Antelope Valley, in the southwest corner of the region. A huge but very dry basin is that occupied by Bristol and Cadiz Dry Lakes. A still larger basin, intensely arid in most parts, is that of Amargosa River, which drains into Death Valley, only the southern part of which is described in this report and shown in Plate 7. Except in the San Gabriel and San Bernardino Mountains, in the southwest corner of the region, there are only a very few tiny perennial streams in the entire region. The surface waters come chiefly from freshets that occur at long intervals. Some of the smaller basins shown in Plate 7 are entirely devoid of springs or streams. Each of the basins is described in detail. (See pp. 144–747.)

In the Pleistocene epoch Owens River flowed through Rose, Indian Wells, Salt Wells, Searles, and Panamint Valleys. It formed a chain of lakes in these valleys and apparently discharged for a time into Death Valley. (See pp. 110–111.) In the same humid epoch Mohave River for a time raised the level of Silver Lake until it overflowed toward the north into Death Valley. (See pp. 563–568.) Evidence of other lakes that existed in the Pleistocene epoch has been found in other parts of the region, notably in Antelope, Lower Mohave, and Cronise Valleys. (See pp. 302–303, 450, and 538.)

GEOLOGY

PREVIOUS LITERATURE

Descriptions of the geology of parts of the Mohave Desert region are scattered in a large number of reports. Most of the work has been of a reconnaissance nature, and such detailed work as has been done has been confined to small areas, as around some particular mine or mineral deposit. On account of the inadequate knowledge and scattered distribution of the localities studied little has been done in correlating the rocks in different parts of the region.

The first geologic information of any value was collected by geologists attached to the exploring parties that were seeking a railroad route between the Central States and the Pacific coast. (See p. 17.) Jules Marcou served as geologist with the party under Lieutenant Whipple, who crossed the region from the Mohave villages to San Bernardino in 1854. On the basis of his scanty notes W. P. Blake prepared a brief description, a geologic map, and a cross section of the region traversed.[25] Blake accompanied the expedition in charge of Lieutenant Williamson which traveled along the north foot of the San Gabriel Range from Tejon Pass to Mohave River and down that river to Soda Lake. He prepared a more satisfactory description of the geology of this part of the region.[26] In 1871 G. K. Gilbert[27] crossed the region from Owens Valley to Camp Mohave on Colorado River by way of Pilot Knob, Saratoga Springs, and Ivanpah. His notes are good, but the points of observation were very few. Notes on the geology of the Mohave Desert region are included in a report by Loew.[28]

A report by Spurr[29] covers that part of the region lying north of an east-west line drawn a mile or two south of Randsburg and Pilot Knob. His notes on the geology close to the route he followed are good, but his geologic map is inaccurate in parts of the region which he did not visit. The entire range of mountains on his map called the Leachs Point and Burnt Rock Mountains is shown as composed of Tertiary sedimentary and volcanic rocks, whereas at least the north side of the range between longitude 116° 30′ and 117° is composed of granitic rocks, and sedimentary and intrusive rocks of Paleozoic age or older, form a large part of Avawatz Mountain, at

[25] Whipple, A. W., Report of explorations for a railway route near the thirty-fifth parallel of latitude: U. S. Pacific R. R. Expl., vol. 3, pp. 51–56, 161–164, Washington, 1856.

[26] Blake, W. P., Geological report in Williamson, R. S., Report of explorations in California for railroad routes to connect with the routes near the 35th and 32d parallels of north latitude: U. S. Pacific R. R. Expl., vol. 5, pt. 2, pp. 52–88, 198–227, geologic map, 1856.

[27] Gilbert, G. K., Report on the geology of portions of Nevada, Utah, California, and Arizona examined in the years 1871 and 1872: U. S. Geog. and Geol. Surveys W. 100th Mer. Rept., vol. 3, Geology, pp. 25, 32, 34, 42, 124, 128, 135, 143, 170, and other scattered references, 1875.

[28] Loew, Oscar, Report on the geological and mineralogical character of southeastern California and adjacent regions: U. S. Geog. Surveys W. 100th Mer. Ann. Rept. for 1876, Appendix H2, pp. 173–188, 1876.

[29] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California: U. S. Geol. Survey Bull. 208, pp. 187–218, 1903.

the east end of the range. A paper by Hershey [30] contains a somewhat detailed geologic map of the southwestern part of the region. In two other papers he gives notes on the old crystalline rocks [31] and Tertiary rocks [32] in the same area. Baker [33] has described briefly the geology of part of the same region with special emphasis on the Cenozoic sedimentary rocks and the erosional history. Darton [34] mapped the geology of that part of the region that lies from 5 to 25 miles on each side of the Atchison, Topeka & Santa Fe Railway between Colorado River and the city of San Bernardino.

The most useful reports which describe the geology of certain other localities in the region are as follows:

Campbell, M. R., Reconnaissance of the borax deposits of Death Valley and Mohave Desert: U. S. Geol. Survey Bull. 200, 1902.

Hess, F. L., Gold mining in the Randsburg quadrangle, Calif: U. S. Geol. Survey Bull. 430, pp. 23–47, 1910.

Baker, C. L., Physiography and structure of the western El Paso Range and the southern Sierra Nevada: California Univ. Dept. Geology Bull., vol. 7, No. 6, pp. 117–142, 1912.

Hill, J. M., The Yellow Pine mining district, Clark County, Nev.: U. S. Geol. Survey Bull. 540, pp. 223–274, 1914.

Pack, R. W., Reconnaissance of the Barstow-Kramer region, Calif.: U. S. Geol. Survey Bull. 541, pp. 141–154, 1914.

Noble, L. F., Mansfield, G. R., and others, Nitrate deposits in the Amargosa region, southeastern California: U. S. Geol. Survey Bull. 724, VII, 99 pp., 35 pls., 1922.

D. F. Hewett has been engaged for several years in mapping the geology of the Ivanpah quadrangle, which covers the north half of the area shown on Plate 12, but his report is not yet ready for publication.

A great amount of information is scattered through the reports of the California State Mining Bureau,[35] and it is not possible to list all of them. Reference is made to these reports as well as to other reports of less value at appropriate places in the descriptions of the individual drainage basins.

Geologic maps covering the entire region have been poor. Marcou [36] in 1855 published a geologic map of the United States, on which

[30] Hershey, O. H., The Quaternary of southern California: California Univ. Dept. Geology Bull., vol. 3, No. 1, p. 2, 1902.

[31] Hershey, O. H., Some crystalline rocks of southern California: Am. Geologist, vol. 29, pp. 273-290, 1902.

[32] Hershey, O. H., Some Tertiary formations of southern California: Idem., pp. 349–372.

[33] Baker, C. L., Notes on the later Cenozoic history of the Mohave Desert region in southeastern California: California Univ. Dept. Geology Bull., vol. 6, No. 15, pp. 33-383, 1911.

[34] Darton, N. H., Guidebook of the western United States, Part C, The Santa Fe Route: U. S. Geol. Survey Bull. 613, pp. 143-169, 1916; Some geologic features of southeastern California: Washington Acad. Sci. Proc., vol. 6, No. 1, pp. 23-24, 1916.

[35] Boalich, E. S., Catalogue of the publications of the California State Mining Bureau: California State Min. Bur. Bull. 77, 1917. Vogdes, A. N., A bibliography relating to the geology, paleontology, and mineral resources of California: California State Min. Bur. Bull. 10, 1896; revised ed., Bull. 30, 1904.

[36] Marcou, Jules, Résumé explicatif d'une carte géologique des États-Unis et des provinces anglaises de l'Amérique du Nord: Soc. géol. France Bull., vol. 12, pp. 813-936, pl. 20 (geologic map), 1855.

he showed practically all of the Mohave Desert region and all of the Great Basin as being underlain by eruptive and metamorphic rocks, but made no attempt to show any of the alluvium-filled valleys. He showed a belt of Tertiary rocks as extending approximately from Cajon Pass northwestward to the El Paso Mountain area. In 1883 he published a geologic map of California.[37] On this map he left blank the entire area of the Mohave Desert region except two areas of volcanic rocks near Soda Lake and the southwestern and western part of the region, including the San Bernardino and San Gabriel Ranges and the Sierra Nevada. Apparently the first attempt to show the large areas of Quaternary alluvium in the desert region was on a geologic map of the United States and part of Canada, compiled by Hitchcock [38] in 1886.

On the preliminary mineralogic and geologic map of California, published in 1891 by the State Mining Bureau, the geology is shown only for the San Bernardino and San Gabriel Ranges, the Sierra Nevada, the Calico Mountains, and the Coso Mountains in the northwest corner of the area. The geologic map of North America published by the United States Geological Survey in 1911 [39] is a great improvement over previously published maps, although several large areas of Tertiary volcanic rocks are omitted. The geology of the region is shown in much more detailed and accurate manner on a lithologic map of California compiled by Waring.[40] This map is considerably in error in local details, especially in showing such large areas of granitic rocks. In 1916 the California State Mining Bureau published a geologic map of the State based on all data then available.[41] The map shows fairly accurately the general distribution of geologic formations in the desert region, but in some places it is very inaccurate. One of the principal errors is that Quaternary alluvium is shown in several areas where there are large mountains composed of rocks of Tertiary age or older. This map is not to be depended on so far as roads and watering places in the desert are concerned.

PRESENT CONTRIBUTION

The observations of the writer on geology, except in regard to the Quaternary deposits, were incidental to the study of ground-water conditions in a few of the valleys or to work connected with the placing of signposts directing to watering places and were made at many scattered localities. The occurrence of ground water in large quanti-

[37] Marcou, Jules, Note sur la géologie de la Californie: Soc. géol. France Bull., 3d ser., vol. 11, pp. 407–435 pl. 9 (geologic map), 1883.

[38] Hitchcock, C. H., The geological map of the United States: Am. Inst. Min. Eng. Trans., vol. 15, pp. 465–488, 1887.

[39] Willis, Bailey, Index to the stratigraphy of North America, accompanied by a geologic map of North America: U. S. Geol. Survey Prof. Paper 71, 1911.

[40] Waring, G. A., Springs of California: U. S. Geol. Survey Water-Supply Paper 338, pl. 2, 1915.

[41] Smith, J. P., The geologic formations of California, with reconnaissance geologic map: California State Min. Bur. Bull. 72, 1916.

ties in the region is closely related to the Quaternary deposits, and accordingly most attention was given to those formations. The geologic map (pl. 8) has been compiled from a number of sources but contains much information that has not heretofore been published. Many of the new data have been furnished by geologists to whom the writer is greatly indebted for their kindness in permitting the use of unpublished material. (See inset map in pl. 8.)

The data credited to C. A. Waring are taken from a geologic map of Inyo County, published by the California State Mining Bureau.[42] The geology of this county is described very briefly in a report by Waring in which it is stated that the map is partly a compilation with additions and alterations from personal observations.[43] The data that are credited to L. F. Noble, except those from the extreme southwestern part of the region, were collected by him in connection with his investigations for the United States Geological Survey of deposits containing nitrate of potash. The data which Noble has kindly furnished for the southwestern part of the region are based on a detailed study, principally of the region along the San Andreas rift zone, over a period of several years. The small scale of the map (pl. 8) necessitates the omission of many details shown on his maps. The geology in the vicinity of Randsburg is copied from an unpublished large-scale geologic map of the Randsburg quadrangle made by F. L. Hess, of the United States Geological Survey, between 1908 and 1910, but many details have necessarily been omitted.[44]

The geology of the region in the vicinity of Barstow and for some distance northwest of that town is copied from a map that accompanies a report by Pack.[45] The geology of the region along the Atchison, Topeka & Santa Fe Railway has been taken chiefly from the maps by Darton.[46] The geology of the region south of Goffs is taken from a map that accompanies a manuscript report by Leroy A. Palmer, field examiner of the United States General Land Office. The geology of part of the San Bernardino Mountains, credited to W. C. Mendenhall, is based on reconnaissance work by him in connection with investigations of the hydrology of San Bernardino Valley.[47] The geology in the area along the south border of the region which is

[42] Geological map of Inyo County, Calif., with notes on geology by C. A. Waring, California State Min. Bur., 1917.

[43] Waring, C. A., and Huguenin, E., Inyo County, in Mines and mineral resources of Alpine County, Inyo County, Mono County: California State Mineralogist Rept. 1915–16, California Bur. Mines, p. 25, 1917.

[44] Since Plate 8 was prepared a geologic map of the Randsburg quadrangle has been published by C. D. Hulin in Geology and ore deposits of the Randsburg quadrangle: Calif. State Mining Bur. Bull. 95, 1925.

[45] Pack, R. W., Reconnaissance of the Barstow-Kramer region, Calif.: U. S. Geol. Survey Bull. 541, pp. 141–154, pl. 7, 1913.

[46] Darton, N. H., and others, Guidebook of the western United States, Part C, The Santa Fe Route: U. S. Geol. Survey Bull. 613, map sheets 21–24, 1916.

[47] Since Plate 8 was prepared a detailed geologic map of this part of the region has been published by F. E. Vaughan in Geology of the San Bernardino Mountains north of San Gorgonio Pass: California Univ. Dept. Geology Bull., vol. 13, No. 9, pp. 319–411, 1922.

credited to J. S. Brown was mapped by him in connection with a survey of desert watering places in the region adjoining on the south. This work was of a reconnaissance nature. Where there is no indication on the inset map (pl. 8) as to the source of the data, the geology has been compiled largely from observations of the writer, with reference to other available sources, including short reports on mining districts.

The boundary of the Quaternary alluvium has been drawn largely on the basis of the contour maps by assuming that the relatively level land is underlain by unconsolidated alluvium. Where there were no topographic maps the boundaries are based on plane-table and compass sketches, and in places where the mountains were not seen or only observed at a great distance the only information available consisted in the township plats of the General Land Office. These give a fairly accurate location of the boundary between the Quaternary alluvium and the older rocks. In such places the boundaries are broken on Plate 8. In some places lands that have the appearance of being underlain by Quaternary alluvium are in reality underlain by hard rocks and form what has been called a "mountain pediment."[48] In such places it is very difficult to locate the boundary of the rock formation except by careful observation, and there also the boundaries are broken on Plate 8.

STRATIGRAPHY

GENERAL FEATURES

For most of the region the data from which the geologic map has been compiled are so meager that they do not warrant the use of more than a few very general units.

The map brings out several features that have not heretofore been shown so clearly. One of the most marked features, which is brought out by the distribution of the Quaternary deposits, is the much scattered arrangement of the older rocks. Especially noticeable is the absence, except along the northern border, of any linear arrangement of the mountains, such as is so characteristic of the Great Basin farther north. As shown in the section on structure (p. 120), however, there is, some indication of linear trend lines in a large part of the area. Another feature is the occurrence of small isolated areas of pre-Tertiary sediments where they have not been previously recorded, especially in the western two-thirds of the area. Future detailed work will doubtless show them to be more abundant. The Tertiary volcanic rocks are also shown to be somewhat more widely distributed than they are shown on previously published geologic maps. The widespread distribution of intrusive and

[48] Bryan, Kirk, Erosion and sedimentation in the Papago country: U. S. Geol. Survey Bull. 730, p. 52, 1922.

metamorphic crystalline rocks is very noticeable, but as granitic rocks of pre-Cambrian and Mesozoic age and metamorphic rocks of unknown age are shown by the same symbol this distribution may be of no special significance.

The principal features of the units shown on the map are described briefly below. Further details are given in the descriptions of the individual drainage basins.

SEDIMENTARY ROCKS

PRE-TERTIARY SEDIMENTARY ROCKS

The sedimentary rocks of pre-Tertiary age in the Mohave Desert region are nearly all Paleozoic, mostly either Cambrian or Carboniferous. The largest areas of these rocks occur in the northern and northeastern parts of the region. The exposures found elsewhere in the region are scattered and small. Some of these exposures are shown on the geologic map for the first time. Others are mentioned in the literature, but the information is not sufficient to locate them accurately. The presence of these scattered exposures in nearly all parts of the region suggests that detailed work may reveal others which may be of value in the correlation of the rocks.

Cambrian rocks.—Rocks definitely known to be of Cambrian age have been found in the Marble Mountains, near Cadiz station on the Atchison, Topeka & Santa Fe Railway.[49] Here Lower Cambrian and Upper Cambrian fossils have been found.

Rocks that contain Cambrian fossils were found by Rowe in the vicinity of Resting Springs, in the northeastern part of the region, and in the Kingston Range, east of those springs.[50] Other sediments of presumably Cambrian age are shown on Waring's geologic map of Inyo County in the part of the area considered in this paper, extending from the Argus Range (near Trona) eastward to the State line. Spurr [51] states that rocks of presumable Cambrian age occur in the Panamint Range as far south as Wingate Pass, but the correlation is based on lithologic grounds and not on fossils. Cambrian fossils are found in the Argus Range,[52] some distance north of the limits of the area covered by this report. Rocks at Saratoga Springs may be Cambrian, but no fossils have been found in them, and they may be pre-Cambrian.[53] A series of quartzite and metamorphosed limestone

[49] Darton, N. H., Discovery of Cambrian rocks in southeastern California: Jour. Geology, vol. 15, No. 5, pp. 470–474, 1907. Clark, C. W., Lower and Middle Cambrian formations of the Mohave Desert: California Univ. Dept. Geology Bull., vol. 13, No. 1, pp. 1–7, 1921. The range in which the rocks were found is called the Iron Mountains by Darton and the Bristol Mountains by Clark. On Plate 12 in this paper it is called the Marble Mountains, a name that is in common use according to residents at Amboy. The name Bristol Mountains is applied to a range that lies north of Amboy and Bristol Dry Lake.

[50] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California: U. S. Geol. Survey Bull. 208, pp. 196–197, 1903. The Kingston Range as referred to by Spurr probably includes the Nopah Range.

[51] Idem, p. 202.

[52] Idem, p. 212.

[53] Idem, p. 188. Campbell, M. R., Reconnaissance of the borax deposits of Death Valley and Mohave Desert: U. S. Geol. Survey Bull. 200, p. 14, 1902.

east of Oro Grande is considered by Hershey to be of Cambrian age. His correlation is based entirely on lithologic grounds. Hewett [54] reports Cambrian rocks in the Spring Mountain region.

Ordovician rocks.—So far as the writer is aware no rocks which have been definitely determined as Ordovician have been found in the region. About 3½ miles east of Twelvemile Spring (about 12 miles north of Resting Spring, just north of the area shown on the map) Rowe found trilobites which he believed to be "somewhere between the Trenton and the Lower Cambrian," so that Ordovician rocks may be present.

Silurian rocks.—On the geologic map of Inyo County compiled by Waring the first range east of Shoshone and Zabriskie is shown as consisting of Silurian rocks, but the basis of this correlation is not known.

Devonian rocks.—Rocks that contain fossils which are regarded as of Devonian age have not been found in the region but are known to occur about 15 miles north of Shoshone, at the north border of the region, and on the basis of lithologic resemblances to these rocks Spurr [55] believes that some of the rocks of Clark Mountain may be Devonian. Darton [56] states that Devonian rocks are found in the Providence Mountains. Hewett [57] has found Devonian rocks in the Spring Mountain range.

Carboniferous rocks.—Rocks that contain fossils of Carboniferous age are found at a number of places in the region. They are nearly all in the eastern part, but small areas have been found elsewhere.

Part of Spring Mountain is composed of rocks of both Mississippian and Pennsylvanian age,[58] and on lithologic similarities Spurr [59] believes some of the sedimentary rocks of Clark Mountain to be of the same age. Larsen [60] has found fossils in the New York Mountains which he believes to be of Carboniferous age, and Darton [61] states that Carboniferous rocks occur in the southern extension of that range known as the Providence Mountains. Darton [62] has also found rocks containing Carboniferous fossils in the Marble Mountains, near Cadiz station on the Atchison, Topeka & Santa Fe Railway. During the present field investigation the writer collected two specimens of fossiliferous limestone from an outcrop in a hill

54 Hewett, D. F., Structure of the Spring Mountain Range, southern Nevada: Geol. Soc. America Bull., vol. 34, No. 1, pp. 89–90, 1923.

55 Spurr, J. E., op. cit., pp. 197, 200.

56 Darton, N. H., Guidebook of the western United States, Part C, The Santa Fe Route: U. S. Geol. Survey Bull. 613, p. 149, 1915.

57 Hewett, D. F., op. cit., pp. 89–90.

58 Hill, J. M., The Yellow Pine mining district, Clark County, Nev.: U. S. Geol. Survey Bull. 540, pp. 230–232 and map, pl. 4, 1914. Hewett, D. F., op. cit., pp. 89–90.

59 Spurr, J. E., op. cit., p. 200.

60 Larsen, E. S., personal communication.

61 Darton, N. H., op. cit., p. 150.

62 Clark, C. W., Lower and Middle Cambrian formations of the Mohave Desert: California Univ. Dept. Geology Bull., vol. 13, No. 1, pp. 1–7, 1921.

about half a mile southwest of Baker station, on the Tonopah & Tidewater Railroad, which G. H. Girty considers are probably of Carboniferous age, possibly Mississippian. (See p. 557.) Limestone and other sedimentary rocks were observed at several places in the hills west of the two playas between the north end of Silver Lake and Soda Lake station, and it is probable that a careful search will reveal better fossils. In the El Paso Range, northwest of Randsburg, Hess [63] found specimens resembling fossils which Girty believed might be of Carboniferous age.

No fossils that could be identified with sufficient certainty to permit the determination of the age of the rocks have been found in the region west of a line extending from Cadiz northward to the vicinity of Goodsprings and south of the south end of Death Valley. Small outcrops of limestone and other sedimentary rocks have been found at a number of places. Some of these are highly metamorphosed and may be of earlier Paleozoic age or even pre-Cambrian. Others are less metamorphosed, and a careful search may reveal more fossil evidence. The finding of fossils of probable Carboniferous age at Baker station and in the El Paso Mountains suggests very strongly that these rocks may have once been much more widespread but were removed by erosion.

Mesozoic rocks.—Sedimentary rocks of Triassic and Jurassic age have been found near Goodsprings,[64] and these are the only known sedimentary rocks of Mesozoic age in the region. Their presence in this vicinity and farther north suggests that other areas may be found in the northeastern part of the region.

TERTIARY SEDIMENTARY ROCKS

Tertiary sedimentary rocks are found in a number of places in the region. On the geologic map (pl. 8) some of the areas shown as comprising Tertiary sediments also contain Tertiary volcanic rocks, but the sedimentary rocks predominate. Tertiary sedimentary rocks also occur in minor amounts in some of the areas shown as comprising Tertiary volcanic rocks.

No distinction is made on the map between marine sediments and continental sediments, as only two small areas of marine sediments are known. Dickerson [65] has described marine beds in a small area near Valyermo post office, on the north slope of the San Gabriel Mountains, which he correlates with the Martinez formation, of Eocene age. These beds are overlain by land-laid or lacustrine beds, which Dickerson believes to be of Miocene age. Marine beds of middle Tertiary age have been found near Quail Lake, 35

[63] Hess, F. L., Gold mining in the Randsburg quadrangle, Calif.: U. S. Geol. Survey Bull. 430, p. 30, 1910.

[64] Spurr, J. E., op. cit., pp. 173–174. Hill, J. M., op. cit., pp. 232–233. Hewett, D. F., Structure of the Spring Mountain Range, southern Nevada (abstract): Geol. Soc. America Bull., vol. 34, No. 1, pp. 89–90, 1923.

or 40 miles west of Lancaster, at the extreme southwest corner of the Mohave Desert region.[66] No marine Tertiary beds are found in the interior of the region.

The principal areas of nonmarine Tertiary beds which have been studied so far are five in number—the Rosamond area, near Rosamond station on the north side of Antelope Valley [67]; the Ricardo or Red Rock Canyon area, 25 to 30 miles northeast of the town of Mojave (see p. 204) [68]; the Barstow area or Barstow syncline and adjacent territory, several miles north of Barstow (see p. 442) [69]; an area that extends from the vicinity of Cajon Pass northwestward along the San Andreas fault zone on the north slope of the San Gabriel Mountains (see pp. 38 and 305); and an area in the vicinity of Tehachapi, in the Tehachapi Mountains or southern Sierra Nevada (see p. 205).[70] The rocks of the Rosamond area are principally a series of volcanic rocks, but as they have been correlated with the rocks in the Barstow and Ricardo areas they are considered with them.

Beds of nonmarine origin near Valyermo post office have been described by Dickerson,[71] who believed them to be Miocene and identical with rocks exposed in Cajon Pass. The rocks along the San Andreas fault zone have since been studied in considerable detail by L. F. Noble, of the United States Geological Survey, but his results have not yet been published.

The information in regard to the correlation of the Tertiary beds of the Rosamond, Ricardo, and Barstow areas has been summed up by Merriam.[72] The beds at Rosamond were first described by Hershey, under the name "Rosamond series." He also considered the Tertiary rocks in the Barstow area to belong to the same formation. Baker followed him in this correlation, and also correlated the Ricardo formation with the "Rosamond series." This correlation of the rocks in the three areas as all belonging to the "Rosamond series" was based on the assumption that the beds all represent a single period of accumulation. More recently mammalian

[65] Dickerson, R. E., The Martinez Eocene and associated formations at Rock Creek, on the western border of the Mohave Desert area: California Univ. Dept. Geology Bull., vol. 8, pp. 289–298, 1914.

[66] Merriam, J. C., Tertiary mammalian fauna of the Mohave Desert: California Univ. Dept. Geology Bull., vol. 11, p. 445, footnote 18*b*, 1919.

[67] Hershey, O. H., Some Tertiary formations of southern California: Am. Geologist, vol. 29, pp. 365, 369, 1902.

[68] Baker, C. L., Notes on the later Cenozoic history of the Mohave Desert region in southeastern California: California Univ. Dept. Geology Bull., vol. 6, pp. 354–357, 1911; Physiography and structure of the El Paso range and the southern Sierra Nevada: California Univ. Dept. Geology Bull., vol. 7, pp. 117–142, 1912.

[69] Baker, C. L., Notes on the later Cenozoic history of the Mohave Desert region in southeastern California: California Univ. Dept. Geology Bull., vol. 6, pp. 342–353, 1911.

[70] Lawson, A. C., The geomorphogeny of the Tehachapi Valley system: California Univ. Dept. Geology Bull., vol. 4, pp. 431–462, 1906. Buwalda, J. P., New mammalian faunas from Miocene sediments near Tehachapi Pass in the southern Sierra Nevada: California Univ. Dept. Geology Bull., vol. 10, pp. 75–85, 1916.

[71] Dickerson, R. E., op. cit., p. 296.

[72] Merriam, J. C., Tertiary mammalian fauna of the Mohave Desert: California Univ. Dept. Geology Bull., vol. 11, pp. 437a–585, 1919.

remains have been found in the Ricardo and Barstow formations, by which the relative age of these beds has been determined more accurately. On the basis of these remains Merriam[73] considers the Ricardo formation to be lower Pliocene and the Barstow formation to be upper Miocene. No fossils have been found in the "Rosamond series," and it has not been possible to trace the lithologic units from the type locality to the other areas. Merriam[74] states that "the Rosamond series of Hershey may include beds containing the older fauna of the Barstow, but it is doubtful whether it comprises sediments of the stage represented at Ricardo." On the basis of lithologic similarities the name "Rosamond series" has been applied by some geologists to the Tertiary rocks in other parts of the region.

Two distinct faunas have been found in the Tertiary beds near Techachapi. One of these faunas, the Cache Peak fauna, which is found along Cache Creek, about 12 miles northeast of Tehachapi, is considered by Buwalda[75] to be probably late middle or upper Miocene and of about the same age as the fauna of the Barstow formation. The other fauna from the Phillips ranch, about 3½ miles west of the Cache Peak locality, he believes to be somewhat older, although possibly middle Miocene.

Tertiary sedimentary rocks are found at a number of other places in the region, but there is no evidence on which to base definite correlations. The most notable of these areas lie in the southern part of the Death Valley and Amargosa Valley regions. The beds in this area have been studied in connection with the search for nitrate deposits during the World War, but no evidence was found bearing on their age.[76] On the basis of lithologic similarities and general relations of Tertiary rocks in surrounding areas it is believed that the beds a few miles west of Saratoga Springs are more probably late Miocene or Pliocene than early Tertiary.[77] Other areas of Tertiary sedimentary rocks have been reported from the south end of the Slate Range extending southwestward nearly to Johannesburg, in the vicinity of Twenty-nine Palms, along Colorado River near Beal station on the Atchison, Topeka & Santa Fe Railway, and near West Well in Chemehuevis Valley. It is probable that other areas that may yield fossil evidence will be found. The knowledge obtained by a study of the Tertiary sediments already observed in the region has been of considerable value in correlating the Tertiary rocks in other parts of the Great Basin.

[73] Merriam, J. C., op. cit., p. 454.
[74] Idem, p. 441.
[75] Buwalda, J. P., op. cit., p. 83.
[76] Noble, L. F., Mansfield, G. R., and others, Nitrate deposits in the Amargosa region, southeastern California: U. S. Geol. Survey Bull. 724, 1922.
[77] Idem, p. 35.

QUATERNARY DEPOSITS

GENERAL FEATURES

Deposits of Quaternary age are widespread throughout the region and probably cover nearly as large an area as the rocks of all other ages except in the San Bernardino, San Gabriel, and Tehachapi Mountains and the Sierra Nevada. The Quaternary is subdivided into the Pleistocene and Recent; but in most places it is not possible to make any distinction between the deposits of the two ages, as they merge into each other. Furthermore, in some parts of the region the Quaternary deposits doubtless merge at a greater or less depth into beds of Tertiary age. The Quaternary deposits are the principal water-bearing formations in the region. For this reason they are considered here in somewhat more detail than the older formations. On the geologic map (pl. 8) three units of Quaternary rocks are distinguished—dune sand, playa and lake deposits, and alluvium deposited by perennial streams and by ephemeral streams in the form of alluvial fans. In general, the Quaternary beds have been deposited in preexisting valleys cut in the more consolidated rocks, and accordingly they are frequently called "valley fill."

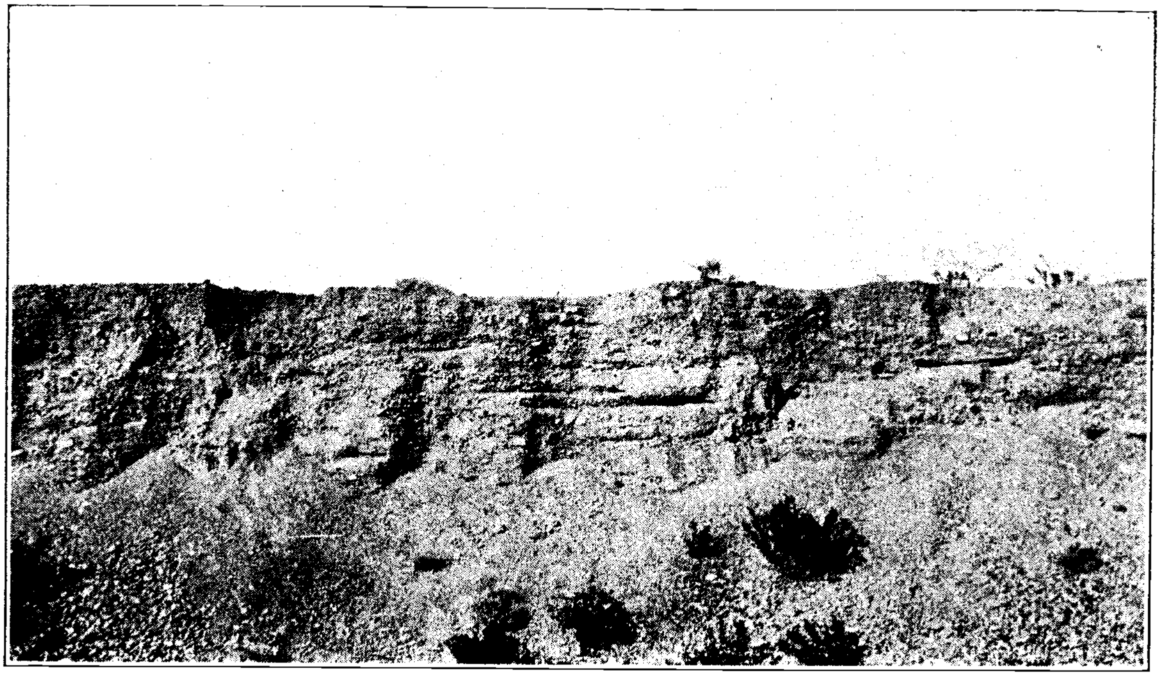
ALLUVIUM OF STREAM VALLEYS AND SLOPES

The alluvium deposited along the streams and on the slopes covers the largest area. Most of it has been washed from the mountains by ephemeral streams and spread out on alluvial fans that reach from the mountains to the lowest parts of the numerous closed basins in the area.

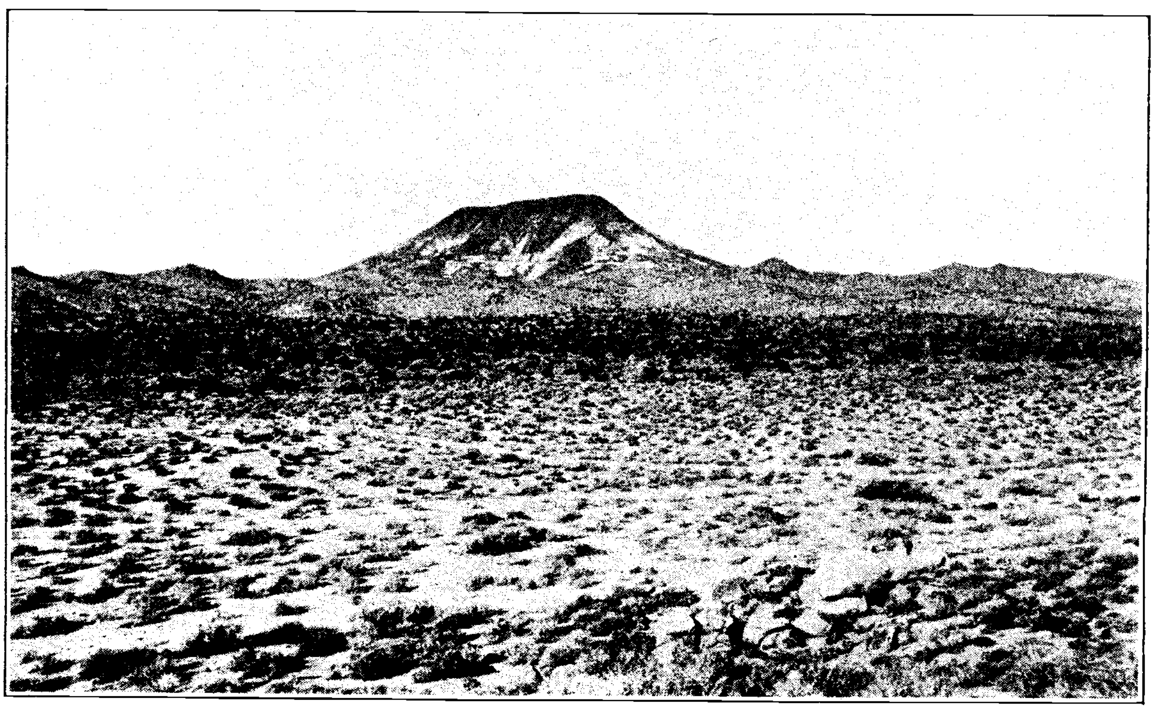
The alluvium consists of a heterogeneous mixture of boulders, gravel, and sand, with only very small quantities of clay. The deposits are generally very coarse near the mountains and grade into finer materials in the lower part of the basins. Most of the material is angular or subangular, and except in the lower parts of the basins it is generally poorly sorted and stratified. Lawson [78] has used the word "fanglomerate" to designate the coarser parts of these deposits. The deposits as a whole are poorly consolidated. A typical example of the valley fill is shown in Plate 14, *A*. The photograph was taken in a cut on the south side of the Atchison, Topeka & Santa Fe Railway, about 2½ miles east of Daggett, on the lower part of a long alluvial slope, and shows a finer phase of the valley fill than is found on the upper parts of the alluvial fans.

The thickness of the deposits differs considerably from place to place. In some places the alluvium is present only as a thin veneer and the older granites or other hard rocks may be seen in arroyos only a few feet deep. In a few places, as along Mohave River between

[78] Lawson, A. C., The petrographic designation of alluvial-fan formations: California Univ. Dept. Geology Bull., vol. 7, No. 15, pp. 325–334, 1913.

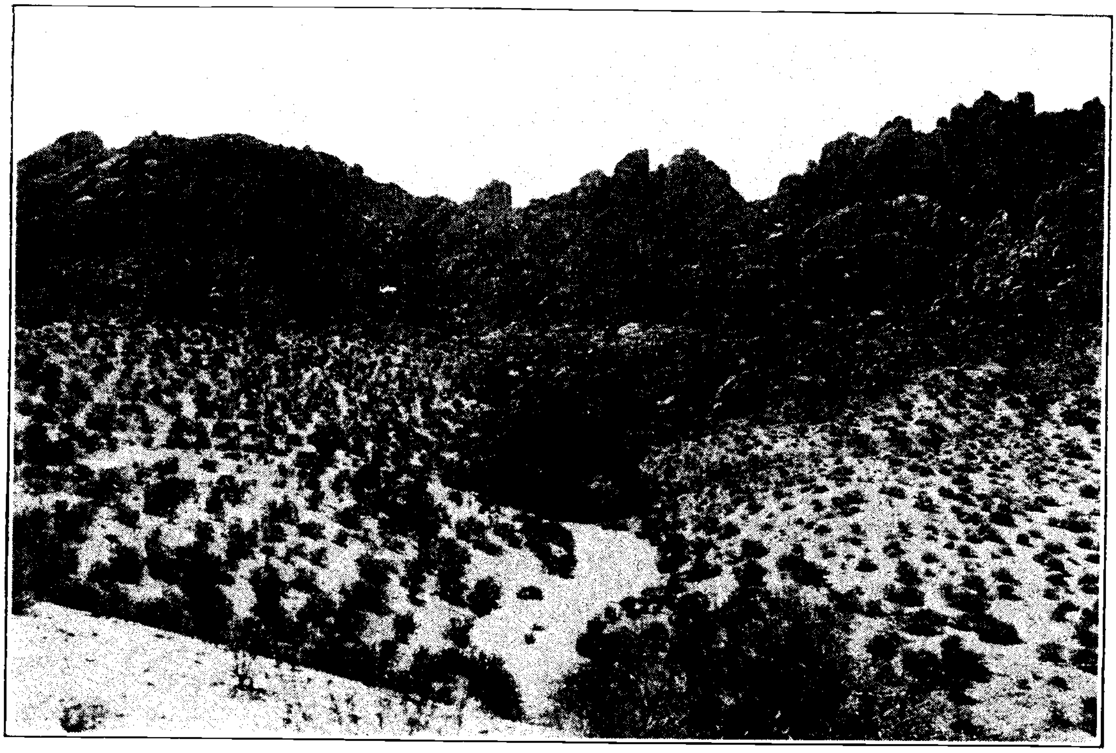


A. ALLUVIUM EXPOSED IN CUT ALONG ATCHISON, TOPEKA & SANTA FE RAILWAY 2½ MILES EAST OF DAGGETT



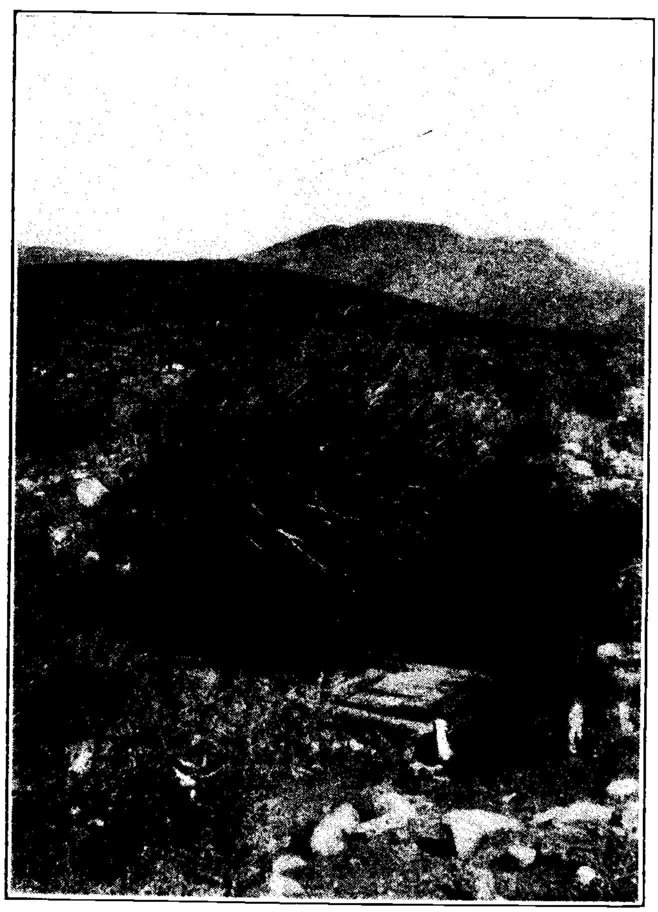
B. PILOT KNOB, IN T. 29 S., R. 44 E. MOUNT DIABLO MERIDIAN

Shows contact between Tertiary (?) volcanic rocks and older granite



A. LEACH SPRING AND PART OF GRANITE MOUNTAINS

Photograph by H. S. Gale



B. INDIAN SPRING, IN SUPERIOR VALLEY

Victorville and Helendale the alluvium is exposed to a depth of 100 feet or more. The maximum thickness is unknown. A well in the SE. ¼ sec. 15, T. 4 N., R. 6 W. San Bernardino meridian, at the north base of the San Gabriel Mountains, which was drilled to a depth of 910 feet, did not strike bedrock. A well at Amboy is said to have reached a depth of 1,500 feet without striking bedrock. A well drilled to a depth of 2,000 feet near Lancaster, in Antelope Valley apparently did not strike material different from the alluvium near the surface, except that it was more consolidated. It is possible, however, that the lower deposits in these wells may be of Tertiary age.

The alluvium also includes some deposits laid down in perennial streams, chiefly Amargosa, Mohave, and Colorado Rivers. They consist largely of sand and clay, with some gravel. Wherever observations were made along Mohave River, however, gravel was surprisingly absent or occurred only in small amounts.

Practically no fossils have been found that are of value in determining the age of any of the beds that are exposed in cuts. The writer found small molluscan shells in exposures along Mohave River 2 miles west of Daggett and in an exposure in a cut between Soda and Silver Dry Lakes, near Baker station. The following species were identified by W. H. Dall: *Anodonta nuttalliana* Lea, *Physa elliptica* Lea, *Planorbis lentus* Say, and *P. parvus* Say. The range of these species is through both the Recent and Pleistocene, and *Anodonta* extends back to Pliocene, so that they are not determinative.

Along Colorado River, where the alluvial deposits have been dissected by the river, Lee [79] has recognized two formations in addition to the Recent flood-plain deposits. The older of these he calls the Temple Bar conglomerate and correlates with the Lake Bonneville beds of Utah.[80] The younger, called the Chemehuevis gravel, is typically exposed in the Chemehuevis Valley. Both deposits are now considered to be of early Quaternary (Pleistocene) age.

PLAYA AND LAKE DEPOSITS

Beds deposited in perennial lakes or in playa lakes are found in all parts of the region.[81] They consist principally of clay with minor amounts of sand and almost no gravel. In most places they include some chemically deposited salts, and in a few places these salts are of

[79] Lee, W. T., Geologic reconnaissance of a part of western Arizona: U. S. Geol. Survey Bull. 352, pp. 17–18, 41–45, 63–66, 1908.

[80] Idem, pp. 18, 64.

[81] The word "playa" is a physiographic term of Spanish origin, used in Spanish-American countries to designate beaches along lakes, seas, or large rivers. Most English-speaking geologists, however, use the term in a sense almost entirely different from the original Spanish meaning, to designate nearly level areas of alluvium in the lowest part of closed basins in arid regions which in wet seasons may be covered with temporary lakes and which are generally devoid of vegetation. Some persons have used the word playa to designate the temporary lakes, but the writer believes that the term should be used in an areal sense. The temporary lakes may be more aptly called playa lakes, and the deposits laid down in them playa deposits. Playas are more commonly called dry lakes, a term that is paradoxical but nevertheless very expressive and always understood by the native.

economic value. These deposits have been laid down either in perennial lakes that existed during the Pleistocene epoch or in temporary lakes which have covered playas for short periods, probably both in Pleistocene and in Recent time. They merge laterally into the deposits of the alluvial slopes. With a very few exceptions the deposits now occupy the lowest parts of the numerous closed basins in the region, and additional material is slowly being deposited on the playas. In most places they are not exposed to a depth of more than 5 feet. Several of the more extensive areas may be briefly described.

Owens, Searles, and Panamint Lakes system.—The most interesting and most noteworthy area of the playa and lake deposits is that commonly known as Searles Lake.[82] Searles Lake is in reality a playa. It is covered with water to a depth of a few inches only during rainy seasons, and most of the time is dry. The central part of the deposit is composed of a body of nearly pure crystalline salts of different kinds, called the crystal body, which extends to a depth of 60 or 100 feet. The crystal body is commercially valuable because it is one of the few deposits in the United States that contain potash in workable quantities. (See pp. 175–176.) The crystal body merges outward from the center into clay and sand that contain less quantities of salts, and these in turn merge into the deposits of the alluvial slopes.

The deposits of Searles Lake, except the most recent, were laid down in a large lake that is known to have existed during the Pleistocene epoch. The evidence of the existence of this lake is the presence of beaches and wave-cut benches on the mountain slopes that surround the valley, the tufa deposits on the alluvial slope, and the thick deposit of unusually pure salts in the lower part of the valley. At its maximum extent the lake was at least 600 to 650 feet deep, and it covered an area of about 285 square miles. It filled not only most of Searles Basin but also extended westward and covered part of Salt Wells Valley and part of Indian Wells Valley.

The ancient Searles Lake formed part of a system of three large lakes that existed in Owens Valley and the northwestern part of the Mohave Desert region in Pleistocene time, when the climate was more humid than at present. The principal water supply that fed these lakes came from the high Sierra Nevada on the west side of Owens Valley by way of Owens River. The first lake of the series lay in the basin now occupied by Owens Lake but was much larger than the existing Owens Lake. This lake rose until it overflowed a divide at the south end of Owens Valley and a stream poured into Indian Wells Valley, forming a small lake. In turn this lake overflowed into Salt Wells Valley and thence to Searles Valley. Eventually Searles Lake overflowed into Panamint Valley through an outlet at

[82] Gale, H. S., Salines in the Owens, Searles, and Panamint Basins, southeastern California: U. S. Geol. Survey Bull. 580, pp. 251–323 (especially pp. 265–312). 1915.

its southeastern border, and for some time there was a third lake about 930 feet deep in Panamint Valley. It is probable that Panamint Lake overflowed through Wingate Pass into Death Valley, but this has not been definitely established. (See p. 186.) The channels that connected the lakes are readily discernible at a number of places, especially about 2 miles south of the Haiwee Dam of the Los Angeles aqueduct, in sec. 4, T. 31 S., R. 37 E. Mount Diablo meridian; south of Little Lake station, in T. 23 S., R. 38 E.; southeast of Little Lake station, in T. 24 S., R. 38 E., and the northern part of T. 25 S., R. 39 E.; and at the outlet at the southeast end of China Dry Lake (a playa), in secs. 7 and 8, T. 26 S., R. 41 E.

In addition to the deposits in Searles Lake, similar deposits were laid down in Indian Wells, Salt Wells, and Panamint Valleys. They are similar to those in Searles Lake, except that they do not contain such large quantities of salts. The salts were deposited principally as the lakes dried up, when climatic conditions assumed their present arid aspect. The details of the history of these lakes are given in the report by Gale already cited. Brief notes in regard to them are given in the sections of this report on Indian Wells Valley (pp. 149–150), Searles Valley (pp. 174–175), and Panamint Valley (pp. 185–187).

Manix lake beds.—Another lake deposit of interest is found in the northeastern part of the broad, flat valley east of Daggett, which in this report is called Lower Mohave Valley. The lake in which the beds were deposited has been called Manix Lake, from the name of a station on the Los Angeles & Salt Lake Railroad near which they are well exposed.[83] East of old Camp Cady the beds are well exposed where they have been cut through by Mohave River and dissected to a depth of about 75 feet. (See pls. 26, *A*, and 27.) They differ from the deposits in the Searles, Indian Wells, and Panamint Basins in that they contain almost no saline minerals.

The beds consist principally of green clay, with very little coarse material. The greenish color is interpreted to indicate deposition in water. Toward the top of the series in the west end of the area the beds grade into slightly coarser buff material. This material is either alluvium washed in after the lake ceased to exist or material deposited in a late stage when playa conditions prevailed. The dissection of the beds offers an excellent opportunity to study the relation between the deposits of the alluvial slopes and the playa and lake deposits, for at several places the gradation from coarse fanglomerate through finer phases to the very fine lake clays can readily be traced. (See pl. 26, *A*.) In places pebbles several inches in diameter are seen to have been carried surprisingly far out into the fine sand and clay that apparently was deposited in or close to the lake. The

[83] Buwalda, J. P., Pleistocene beds at Manix, in the eastern Mohave Desert region: California Univ. Dept. Geology Bull,, vol. 7, No. 24, pp. 443–464, 1914.

change from the grayish or buff beds to the greenish beds is almost imperceptible. (See pl. 27, *A*.)

The age of the Manix lake beds is not definitely known. Buwalda[84] found remains of mammals, including horses, camels, a mastodon or elephant, and an antelope, which J. C. Merriam considers is of Pleistocene age.

The conditions that brought Manix Lake into existence are not fully known, except that the precipitation must have been greater than now to cause a lake to form. The present course of Mohave River is of comparatively recent origin, and it is possible that the ancient Mohave River was diverted from some other course by the formation of a dam through faulting, folding, the outpouring of lava, or in other ways. Buwalda[85] suggests that the stream originally may not have passed through the region, but entered the region by lengthening its course in a direction determined by the relief. In any event it is probable that Manix Lake existed during that part of Quaternary time when the precipitation was apparently greater than to-day, as shown by the existence of large lakes, now extinct, in other parts of the Great Basin.

Eventually the lake was filled up until it overflowed the barrier at its northeast end. The stream that flowed from it at that point gradually cut down the barrier until the lake was entirely drained. After that the stream continued to cut through the lake deposits, forming the canyon of Mohave River. The downward cutting was apparently halted at least two or three times, for well-developed terraces due to side cutting of the stream exist 3 or 4 miles northeast of old Camp Cady. (See pl. 27, *B*.) The exact cause of the side cutting that caused the formation of the terraces has not been definitely established, but probably the stream encountered hard beds in some place which slowed the downward cutting, so that for a considerable time it cut laterally. A detailed study of the terraces will doubtless yield considerable information in regard to late Pleistocene and Recent conditions in the vicinity.

Other lake and playa deposits.—A third extensive occurrence of playa and lake beds is in Amargosa Valley, in an area that extends for several miles in all directions from Zabriskie.[86] The lake in which the beds were deposited probably was formed by the damming of Amargosa River, and the history of the beds has doubtless been much the same as that of the Manix lake beds. The precipitation in the region now tributary to Amargosa River is probably somewhat less than that of the area tributary to Mohave River, which includes the San Bernardino Mountains. As the same relative conditions

[84] Buwalda, J. P., op. cit., p. 451.

[85] Idem, p. 454.

[86] Noble, L. F., Mansfield, G. R., and others, Nitrate deposits in the Amargosa region, southeastern California: U. S. Geol. Survey Bull. 724, pp. 61–67, 1922.

doubtless existed in the Pleistocene epoch, during which the beds were deposited, it is probable that more of the beds are of playa origin than those in the Manix lake beds. The beds in the Amargosa Valley are now greatly dissected, and they offer an opportunity for the study of lake and playa deposits.

The Manix and Amargosa Valley areas are the principal if not the only places where the Quaternary playa and lake beds are well exposed. Similar beds underlie each playa, but in many of the basins it is not possible to state whether the beds are principally of playa or lake origin unless there is evidence that a lake has existed. There is evidence in the form of beaches and wave-cut terraces that lakes have existed, for short periods at least, in Antelope Valley, the valleys of Soda and Silver Lakes, East Cronise Valley, and probably West Cronise Valley. The presence of deposits of rather pure gypsum several feet thick in Bristol Dry Lake, near Amboy, and of salt deposits in Cadiz Dry Lake, south of Cadiz station, and in Danby Dry Lake, near Milligan station, suggests that lakes once existed in these basins. Definite evidence in the form of beach ridges or wave-cut cliffs has not been reported in these basins, but this may be due largely to lack of sufficient observation. Conditions in these localities are stated more fully under the regional descriptions.

DUNE SAND

Deposits of wind-blown sand are not widespread in the Mohave Desert region. Several areas of sand dunes occur, but with two or three exceptions none of them is of great extent. In many parts of the region wind-blown sand is mixed with alluvium washed from the mountains, but on the geologic map only those areas are shown where sand dunes are well developed. The largest area lies several miles southwest of Kelso on the Los Angeles & Salt Lake Railroad. (See pl. 8.) At this place an area of 20 to 30 square miles is covered by large dunes that have a maximum height of probably at least 500 feet. A large part of the region northwest of this area, extending as far as Crucero station, southwest of Soda Lake, is covered with wind-blown sand. The Devils Playground, east of Soda Lake, apparently is a sand-covered alluvial slope, but on account of the sand, which makes travel by automobile impossible, it was not seen closer than from a distance of 5 or 10 miles. The patches of wind-blown sand in this locality are irregularly distributed, and for this reason the area is not shown on the geologic map as covered by wind-blown deposits.

Other areas which contain dune deposits of noteworthy size include several places in the southern part of Death Valley, notably about 3 miles east of Saratoga Springs and west of Dumont station on the Tonopah & Tidewater Railroad; around Cadiz Dry Lake; on the west side of Dale Dry Lake and of a small playa several miles north of

Twenty-nine Palms; and in a belt that extends northwestward from a place near Newberry Spring to Mohave River. Low dunes are scattered between Rosamond, Buckhorn, and Rogers Dry Lakes, and east of these lakes in Antelope Valley.

Wind-blown sand occurs as a mantle on the alluvial slopes on the east side of nearly every valley, and in some of the valleys it extends some distance up the sides of the mountains. The largest areas where sand occurs in this manner are on the east side of Soda Dry Lake and farther north on the alluvial slope built by wash from the west side of the Kingston Range and the Shadow Mountains. Here a very large percentage of the alluvium is apparently of wind-blown origin.

The dune sand is probably mostly of Recent age. Where lakes have existed the sand is possibly derived partly from beach deposits formed by these lakes. The west face of the dunes on the east side of Rosamond Dry Lake has been cut by wind action or by waves in a lake that covered the playa and the cross-bedding is exposed. These dunes may be older than most of the other dunes.

IGNEOUS AND METAMORPHIC ROCKS

PRE-TERTIARY IGNEOUS AND METAMORPHIC ROCKS

All the intrusive rocks and undifferentiated gneisses and schists of pre-Tertiary age are included in one unit on the map. The intrusive rocks so mapped are of at least two different ages—pre-Cambrian and post-Pennsylvanian. The age of individual masses of granite in most places is difficult to determine, except in a few localities where they are seen in contact with other rocks. In the Marble Mountains, north of Cadiz, Darton [87] found Lower Cambrian beds resting unconformably on an erosional surface of granite. He has also mapped a number of other areas of pre-Cambrian granite in the region.[88] Hershey [89] believes that a small area of schistose and gneissic rocks near Barstow is pre-Cambrian. Vaughan [90] has described a large area of undifferentiated schists in the San Bernardino Mountains and smaller areas near Old Woman Springs. The age of these is uncertain, but they may in part be pre-Cambrian.

In some places the intrusive rocks are younger. Spurr [91] states that granitic rocks in the south part of the Panamint Range are appar-

[87] Darton, N. H., Discovery of Cambrian rocks in southeastern California: Jour. Geology, vol. 15, No. 5, pp. 470–474, 1907. Clark, C. W., Lower and Middle Cambrian formations of the Mohave Desert: California Univ. Dept. Geology Bull., vol. 13, No. 1, pp. 1–7, 1921.

[88] Darton, N. H., Guidebook of the western United States, Part C, The Santa Fe Route: U. S. Geol. Survey Bull. 613, sheet 22, 1916.

[89] Hershey, O. H., Some crystalline rocks of southern California: Am. Geologist, vol. 29, No. 5, p. 286, 1902.

[90] Vaughan, F. E., Geology of the San Bernardino Mountains north of San Gorgonio Pass: California Univ. Dept. Geology Bull., vol. 13, No. 9, pp. 345–352, map, 1922.

[91] Spurr, J. E., Descriptive geology of Nevada south of the fortieth paralell and adjacent portions of California: U. S. Geol. Survey Bull. 208, p. 203, 1903.

ently intrusive in post-Paleozoic rocks. Vaughan [92] has described numerous areas of granite, which he believes to be of Jurassic age, in the San Bernardino Mountains and smaller isolated mountains in the near-by desert region. Hershey [93] considers most of the granitic rocks in the San Gabriel Mountains and at other places in the southwestern part of the region to be of Mesozoic age. The granitic rocks of that portion of the Sierra Nevada within the area considered in this report are doubtless of the same age as those a few miles farther north in Owens Valley. These rocks are of early Cretaceous age, according to Knopf,[94] and the younger granites in the Mohave Desert region have generally been assumed to be of about the same age or at least to be Mesozoic. However, Finlay [95] has expressed the belief that the intrusive rocks of the San Gabriel, San Bernardino, and San Jacinto Ranges are of Permian age. He found Pennsylvanian fossils in Holcomb Valley in the San Bernardino Mountains, and these established the post-Pennsylvanian age of the intrusion. His postulate of Permian age of the intrusive rocks rather than Mesozoic age, however, is based not on paleontologic or stratigraphic evidence but on a consideration of climatic conditions farther east in Permian time. He believes that by intrusion a great range of mountains, which he calls the Old Mohave Range, was formed and that this range produced arid conditions such as are known to have existed from Arizona to Kansas during the Permian.

Gneiss and schist occur at a number of places, but as a whole they apparently form a smaller proportion of the area shown as granite and metamorphic rocks than the granite. The largest areas are probably those found in the San Gabriel Range and its westward extension, the Sierra Pelona. Most of the extensive areas of gneiss and schist are generally believed to be of pre-Cambrian age,[96] but some of them may be found to be younger. In some places the gneiss and schist grade into the intrusive rocks, of which they are a metamorphic phase. For this reason and because sufficient data are not available to separate them, they have been mapped as a unit with the intrusive rocks. So far as possible metamorphosed sedimentary rocks were not included in the unit.

TERTIARY IGNEOUS ROCKS

Igneous rocks of supposed Tertiary age cover considerable areas in the Mohave Desert region. They are found in all parts of the region and are probably next in abundance to the pre-Tertiary igneous

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[92] Vaughan, F. E., op. cit., pp. 363–374.

[93] Hershey, O. H., op. cit., pp. 281–287.

[94] Knopf, Adolph, A geologic reconnaissance of the Inyo Range and the eastern slope of the southern Sierra Nevada, Calif.: U. S. Geol. Survey Prof. Paper 110, pp. 61–62, 1918.

[95] Finlay, J. R., The Permian revolution in North America: Eng. and Min. Jour., vol. 112, No. 27, pp. 1058–1059, 1921.

[96] Hershey, O. H., Some crystalline rocks of southern California: Am. Geologist, vol. 29, No. 5, pp. 273–290, 1902. Darton, N. H., Some geologic features of southeastern California (abstract): Washington Acad. Sci. Jour., vol. 6, No. 1, p. 23, 1916.

and metamorphic rocks and the Quaternary alluvium. The Tertiary rocks probably once covered a much greater area, for in some parts of the region where there has been little or no faulting there is evidence that masses now isolated were once connected. The rocks between these masses have been eroded away.

The Tertiary igneous rocks are practically all extrusive, and include andesite, latite, rhyolite, basalt, tuffs, and volcanic ash. Their age generally has not been determined, except that they are similar to igneous rocks of Tertiary age in other parts of the Great Basin. Darton [97] states that the largest bodies of lava were accumulated in middle and late Tertiary time and that in general the order of rocks erupted in Tertiary time has been latite, rhyolite, diabase rhyolite, and several varieties of basalt.

On the geologic map the areas shown as containing Tertiary volcanic rocks may include some sedimentary rocks, but the sedimentary rocks are presumed to be present in only minor amounts.

QUATERNARY IGNEOUS ROCKS

Small flows of Quaternary basalt are found at several places in the region. The correlation as to age is made largely on their basaltic nature, their relatively uneroded surfaces, and their relation to alluvial deposits that are of Quaternary age.

There are at least three good examples of recently erupted lava flows in the region, all of which are within sight from the Atchison, Topeka & Santa Fe Railway. One of these, known as the Pisgah flow, is near Lavic station, about 12 miles west of Ludlow (p. 652), and another is a mile or two southwest of Amboy (p. 693). At each place a rather perfect cinder cone lies on an extensive lava flow. The third flow originated from a cone in the mountains southeast of Newberry Spring and flowed down a gravel-filled valley from the mountains to the lowland south of the railroad. The rock at the sides of the valley adjoining the lava has since been worn away by erosion, leaving the lava beds exposed in almost vertical cliffs. The other areas occupied by igneous rocks of Quaternary age in the region are all of smaller extent.

STRUCTURE

FOLDING

Deformation of the rocks in greater or less degree has probably occurred at one time or another in nearly all parts of the region, and the rocks of all ages have been affected. Faults have been recognized in many places, but folds have been reported from only a very few localities. Detailed studies will doubtless bring to light more folding than is now known. It is nevertheless true that in the deformation in this region faulting has predominated.

[97] Darton, N. H., Guidebook of the western United States, Part C, The Santa Fe Route: U. S. Geol. Survey Bull. 613, p. 150, footnote, 1916.

One area in which folds are exhibited is in the Tertiary beds of Barstow where there is a well-developed syncline that trends approximately east.[98] The beds are also faulted, and the faulting was probably later than the folding. Buwalda[99] states that the east end of the Alvord Mountains, about 20 miles northeast of Barstow, shows an anticlinal fold, the axis of which trends east. Keyes[1] states that the strike of the rock at Borate, on the east side of the Calico Mountains, is also approximately east. It is possible that these three areas are on the same line of deformation, although the rocks of the Alvord Mountains are much older than those in the other areas, and the deformation may be older. Folding is reported locally in the rocks of the Spring Mountains, near Goodsprings, in the northeastern part of the region,[2] in the Kingston Range,[3] and in the Tertiary beds of South Death Valley.[4]

FAULTS

San Andreas rift.—In contrast to the folds, some of the faults are of considerable linear extent and are easily traceable. The most notable, without doubt, is that known as the San Andreas rift, which lies at the foot of the north slope of the San Gabriel Mountains. It stands out very sharply on the relief maps (pls. 9 and 10), being shown by a series of almost continuous narrow valleys with a northwesterly trend. It is also well shown on the geologic map (pl. 8) by the distribution of the formations. The San Andreas rift may be traced southeastward beyond San Gorgonio Pass and northwestward beyond San Francisco.[5] Movement along this rift farther northwest, particularly near San Francisco, caused the earthquake of April 18, 1906, which did so much damage in that city and elsewhere. Apparently there was no movement along the San Andreas rift in the San Gabriel Mountains in 1906, but movement has occurred in that region at least as recently as 1857.[6] Several other faults, approximately parallel

[98] Baker, C. L., Notes on the later Cenozoic history of the Mohave Desert region in southeastern California: California Univ. Dept. Geology Bull., vol. 6, No. 15, pp. 346-347, 1911.

[99] Buwalda, J. P., Pleistocene beds at Manix, in the eastern Mohave Desert region: California Univ. Dept. Geology Bull., vol. 7, No. 24, p. 445, 1914.

[1] Keyes, C. R., Borax deposits of the United States: Am. Inst. Min. Eng. Trans., vol. 40, p. 694, 1910.

[2] Hill, J. M., The Yellow Pine mining district, Clark County, Nev.: U. S. Geol. Survey Bull. 540, pp. 233-236, 1914. See also Hewett, D. F., Structure of the Spring Mountain Range, southern Nevada: Geol. Soc. America Bull., vol. 34, pp. 89-90, 1923.

[3] Spurr, J. E., Origin and structure of the basin ranges: Geol. Soc. America Bull., vol. 12, p. 240, 1901.

[4] Noble, L. F., Mansfield, G. R., and others, Nitrate deposits in the Amargosa region, southeastern California: U. S. Geol. Survey Bull. 724, p. 32, 1922.

[5] Lawson, A. C., and others, The California earthquake of Apr. 18, 1906; report of the State Earthquake Investigation Commission: Carnegie Inst. Washington Pub. 87, vol. 1, pp. 43-44, pls. 24-28; atlas, maps 7-10, 1908. Noble, L. F., The San Andreas rift and some other active faults in the desert region of southeastern California: Carnegie Inst. Washington Yearbook 25, pp. 415-422, 1925.

[6] Lawson, A. C., op. cit., pp. 43, 52, 449.

to the San Andreas rift, are found in the San Gabriel Range, but they are not as continuous as the San Andreas fault.[7]

Southeast of Cajon Pass the San Andreas rift lies along the southwest foot of the San Bernardino Mountains. Both the San Bernardino and the San Gabriel Mountains are believed to have been raised by faulting, but the faulting that formed them was probably much older than the San Andreas and associated faults. The age of the initial uplift of the San Gabriel and San Bernardino ranges is believed to be later than Miocene.[8]

The Garlock fault.—Another very prominent fault line is one along the southeast face of the El Paso Range. This fault has been termed the Garlock fault because of its prominence near the town of that name in sec. 29, T. 29 S., R. 39 E. Mount Diablo meridian.[9] Near Garlock the fault cuts a large alluvial fan, and 5 or 6 miles northeast of this place, near Goler Well, occur large depressions, formed by the dropping of blocks of ground. The escarpments are so fresh that the faulting must have been comparatively recent. Northeast of the El Paso Mountains the fault line may be traced along low hills on the south border of Searles Valley that are composed probably of Tertiary rocks to a long, narrow strip of Tertiary rocks at the south end of the Slate Range.

East of the Slate Range a long, narrow valley, with the Leach Point Mountains rising steeply from it on the south and a more gentle slope to the north, suggests very strongly that the fault continues eastward. These features show clearly on the relief maps (pls. 10 and 11). The rocks on the north slope of Avawatz Mountain are also faulted, and the Garlock fault probably continues that far. It is possible, however, that the faulting in Avawatz Mountain may be, in part, related to a series of faults which has more of a northwestward trend and which affects Tertiary and other deposits in South Death Valley. (See pp. 585–586.)

Southwest of the El Paso Range the relief map shows a marked escarpment on the southeast side of the Tehachapi Range, which is in almost perfect alinement with the southeast side of the El Paso Range, as if the Garlock fault continued along the front of the range. It is not known whether this relief feature is a continuation of the Garlock fault. The San Andreas rift and the fault along the front of the Tehachapi Range and El Paso Range produce a very marked

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7 Dickerson, R. E., The Martinez Eocene and associated formations at Rock Creek, on the western border of the Mohave Desert area: California Univ. Dept. Geology Bull., vol. 8, No. 14, pp. 289–298, fig. 1, 1914. Darton, N. H., Guidebook to the western United States, Part C, The Santa Fe Route: U. S. Geol. Survey Bull. 613, footnote p. 167, map sheet 24, 1915.

8 Baker, C. L., Notes on the later Cenozoic history of the Mohave Desert region in southeastern California: California Univ. Dept. Geology Bull., vol. 6, No. 15, p. 368, 1911.

9 Hess, F. L., Gold mining in the Randsburg quadrangle, Calif.: U. S. Geol. Survey Bull. 430, pp. 25–26, 1910. Baker, C. L., Physiography and structure of the western El Paso Range and the southern Sierra Nevada: California Univ. Dept. Geology Bull., vol. 7, No. 6, pp. 129–132, 136, 1912. Noble, L. F., op. cit., pp. 423–425.

relief feature in the form of a letter V, or arrow head, the point of which is at the western edge of the desert. This feature is emphasized all the more by the fact that in the area within the V there are only low scattered hills and no large mountains.

Sierra Nevada faults.—A third prominent fault marks the east side of the Sierra Nevada.[10] The evidence of faulting is well developed in Owens Valley, just north of the Mohave Desert region.[11] Lawson[12] considered the initial uplift of the Sierra Nevada to have occurred as late as the Quaternary, but Knopf,[13] after a careful analysis of the evidence, considers that it began in the Tertiary, probably the late Miocene. Fossils found by Buwalda [14] in Tertiary deposits northeast of Tehachapi indicate that the uplift of the southern Sierra Nevada began in late Miocene or post-Miocene time, thus confirming Knopf's conclusions for the Sierra Nevada farther north. Faulting along the Sierra Nevada, in Owens Valley at least, has continued into recent years. A violent earthquake occurred in 1872, and fault scarps were produced at that time near the town of Lone Pine.

Other faults.—Hewett [15] has discovered numerous faults, of both the normal and thrust types, in the Spring Mountain Range, Clark Mountain, the Shadow Mountains and other mountains in the northeastern part of the Mohave Desert region. Vaughan [16] has mapped several faults, large and small, in the San Bernardino Mountains and in the desert lying to the north thereof.

In the northern part of the region there is a noticeable parallelism in the arrangement of the mountains and valleys. This parallelism continues northward for many miles in the Great Basin. It is generally believed to be due to a series of parallel faults, and the valleys then represent large blocks that have been lowered relatively with respect to the blocks that form the mountains, although some geologists have not held to this view.[17]

The parallelism is especially noticeable in the Slate, Panamint, and Amargosa Ranges, between which are Panamint and Death Valleys. Faulting on a large scale is known to have occurred in the mountains bordering the valleys, but further study is necessary to

[10] Baker, C. L., op. cit., pp. 137–140.

[11] Knopf, Adolph, A geologic reconnaissance of the Inyo Range and the eastern slope of the southern Sierra Nevada, Calif.: U. S. Geol. Survey Prof. Paper 110, pp. 77–78, 1918.

[12] Lawson, A. C., Geomorphogeny of the upper Kern Basin: California Univ. Dept. Geology Bull., vol. 3, p. 364, 1904.

[13] Knopf, Adolph, op. cit., pp. 87–88.

[14] Buwalda, J. P., New mammalian faunas from Miocene sediments near Tehachapi Pass, in the southern Sierra Nevada: California Univ. Dept. Geology Bull., vol. 10, No. 6, p. 85, 1916.

[15] Hewett, D. F., Structure of the Spring Mountain Range, southern Nevada (abstract): Geol. Soc. America Bull., vol. 34, No. 1, pp. 89–90, 1923, and reports in preparation (personal communication).

[16] Vaughan, F. E., Geology of San Bernardino Mountains north of San Gorgonio Pass: California Univ. Dept. Geology Bull., vol. 13, No. 9, pp. 319–411, 1922.

[17] Ransome, F. L., The Tertiary orogeny of the North American Cordillera and its problems: Problems of American geology, pp. 339–343, Yale University Press, 1915. (Gives a brief review of the discussion of the origin of the parallel ranges of the Great Basin, with the principal references.)

determine the origin of the valleys.[18] Nevertheless, the physiographic conditions at least strongly suggest a fault origin of the mountains and valleys. The conditions are especially striking in the relations between Panamint Valley and the Slate and Panamint Ranges. Panamint Valley is very narrow, and the mountains rise steeply on each side of it. It seems possible that faulting may have occurred even in relatively recent times.[19]

South of an east-west line in about latitude 35° 30′, or, more definitely, south of the Garlock fault described above, the parallel so-called "block-fault" ranges and valleys, which are characteristic of the Great Basin province, are not so marked as farther north. This fact is shown clearly by the relief map of the United States [20] and to a less degree by the maps in this report and a relief map of California published by the Seismological Society of America,[21] which shows the location of many important fault lines. There is, however, abundant evidence of faulting in a number of places. Although many of the faults extend for short distances only, it is probable that some of them are of considerable magnitude.

In addition to the parallel ranges north of the Garlock fault, some of the places where it is believed major physiographic features suggest the presence of faulting are Lane Mountain and the connected hills, about 15 miles north of Daggett; the basin that contains the playas known as Soda, Silver, and Silurian Dry Lakes, with the bordering mountains, extending from the Soda Lake Mountains northward to Avawatz Mountain; the New York-Providence Mountains; a series of short parallel ridges that have a northwestward trend north of Bagdad and Amboy, the highest of which is Old Dad Mountain; and a more or less continuous range of mountains south of the Atchison, Topeka & Santa Fe Railway, extending from the vicinity of Daggett southeastward for many miles and including the Bullion and Sheep Hole Mountains, with marked depressions both to the north and south of this range. The significant facts in regard to these different areas will be discussed in the regional descriptions.

Sufficient evidence has not been obtained to determine very closely the age of much of the faulting in the region. It is worthy of note, however, that there is evidence in a number of places of faulting as recent as the Pleistocene and probably even in Recent time. Movement has occurred along the San Andreas rift and along the Sierra Nevada within the last 100 years. The evidence of Recent faulting

[18] Keyes, C. R., op. cit., pp. 684-686. Campbell, M. R., Reconnaissance of the borax deposits of Death Valley and Mohave Desert: U. S. Geol. Survey Bull. 200, pp. 19-20, 1902. Noble, L. F., op. cit., pp. 425-428.

[19] Campbell, M. R., op. cit. Gales, H. S., Salines in the Owens, Searles, and Panamint Basins, southeastern California: U. S. Geol. Survey Bull. 580, pp. 317-318, 1915. See also Searles Lake and Ballarat topographic maps.

[20] Relief map of the United States, scale, 1 inch to 50 miles, U. S. Geol. Survey, 1920.

[21] Fault map of the State of California, 1922, published as supplement to Seismol. Soc. America Bull., vol. 13, No. 1, March, 1923.

in other places is not so definite, but there is evidence of Pleistocene movement. The Manix lake beds along Mohave River, which are believed to be at least as young as early Pleistocene, are cut by faults.[23] In several places, notably along the east foot of Avawatz Mountain and the west side of the Providence Mountains near Kelso, what appeared to be relatively fresh fault scarps cutting across alluvial fans were observed from a distance of several miles, but there was no opportunity to examine them.

GEOLOGIC HISTORY

The crystalline character of the pre-Cambrian intrusive granite and other rocks shows that these rocks must have been buried many thousands of feet deep in the earth, for such rocks are believed to form only when cooling at great depths. Some of the ancient schist and gneiss doubtless formed the cover over the great intrusive masses. After the formation of the granite the thick cover of rocks was eroded until the granite was exposed in some places. During this period of erosion all or most of the region must have been above the sea. During the early part of the Paleozoic era (in Cambrian time) at least some parts of the region were submerged beneath the sea, as is shown by the presence of beds of limestone and other sediments that were deposited in marine waters. The time of the submergence is fixed as the beginning of the Cambrian period by the fossils in the rocks that have been found in the Marble Mountains and at other places. It is not known whether the Cambrian sea covered the entire region. If so, the rocks that were deposited in it have been eroded from most of the region.

The sea in which the Cambrian rocks were laid down extended north and east of the Mohave Desert region. The presence of rocks containing marine fossils of Ordovician, Silurian, and Devonian age in the region north of that considered in this report shows that the sea covered that region during those periods. No fossils of these ages have been found in the Mohave Desert region except perhaps in the extreme northeastern part. If the sea covered this region in Ordovician to Devonian time, the rocks deposited in it have been entirely eroded or the fossil evidence has been obliterated by metamorphism.

Small patches of rock that contain remains of marine animals of Carboniferous age that have been found in different parts of the region show that during that period most if not all of the region was submerged. Either toward the end of Carboniferous time (in the Permian epoch) or during the early part of the Mesozoic era most of the area probably emerged from the sea, for, except near Good Springs,

[23] Buwalda, J. P., Pleistocene beds at Manix, in the eastern Mohave Desert region: California Univ. Dept. Geology Bull., vol. 7, No. 24, pp. 451-454, 1914.

no marine fossils of this age have been found here. Nevertheless, as in the earlier periods, it is possible that marine formations were deposited during part of Mesozoic time, but if so they have mostly been removed. Large masses of granitic rock were intruded into the older rocks, doubtless distorting them in folding and faulting. It is likely that as a result of the intrusion and distortion the region was greatly uplifted, forming a high land mass.

During and since the Mesozoic era the region has been the scene of great erosion, which has carried away an immense volume of the older rocks until only remnants of the Paleozoic sedimentary rocks remain. During this long period of erosion the drainage of the region was doubtless different from what it is to-day, and the streams from all parts of it probably reached the sea instead of being confined to closed basins. During part of this period of erosion the region was doubtless one of great relief, perhaps comparable to the present-day Rocky Mountain region. Toward the end of Mesozoic time, however, the relief was considerably lessened, and it was perhaps even less than it is to-day, for in a number of places where Tertiary rocks rest on older rocks the contact between the formations, although irregular, shows the relief to be measured in tens and hundreds of feet rather than in thousands. Such relations are found in many places but are especially well illustrated in Pilot Knob, in the eastern part of T. 29 S., R. 44 E. Mount Diablo meridian; in Table Mountain, in T. 12 N., R. 15 E. San Bernardino meridian (unsurveyed); and in a low mass in T. 15 N., R. 11 E. San Bernardino meridian, on the north side of the road between Halloran Spring and Valley Wells, extending for several miles east of the spring. At each of these places volcanic rocks, presumably of Tertiary age, rest upon granitic rocks whose surface has relatively little relief. The relations at Pilot Knob are shown in Plate 14, *B*.

Our ideas of events in the Mohave Desert region during the Mesozoic era are largely conjectural. On the other hand, we have much more definite knowledge of events during the Tertiary and Quaternary periods, when notable changes occurred. In the Tertiary period, especially in the early part, great lava flows broke out and spread over large areas, and volcanic ash and similar deposits were laid down. The volcanic eruptions continued, but with diminishing activity. During both the Tertiary and Quaternary periods closed basins were formed, doubtless partly as a result of the blocking of the drainage by lava flows and ash deposits or by alluvial deposits washed from the mountains and partly as a result of faulting. Lakes and playas were formed in which sediments, in some places interbedded with volcanic ash, were deposited. The conditions were somewhat similar to those in the region at the present time, although Merriam [24] considers that the faunas of the Barstow and Ricardo formations indicate somewhat moister conditions, similar to the semiarid climate of the Great Valley of California. All the evidence found so far indicates that the entire region was a land mass, with only inland bodies of water, except for a small area in the southwestern part of the region. Deposits that contain marine fossils on the north side of the San Gabriel Range, near Valyermo post office, show that the ocean reached that far during part of the Tertiary period.

At some time during the Tertiary, not yet fully determined, faulting caused very marked changes in the relief of some parts of the Mohave Desert region. The greatest events were the uplift of the Sierra Nevada and the San Gabriel and San Bernardino Mountains. The uplift of these ranges presumably began in the Miocene epoch, but it has continued in some places within the last hundred years. During all of the Tertiary and Quaternary periods erosion was active in the region. A large part of the Tertiary lava flows and other rocks were eroded until now there are only large remnants of once continuous areas. This erosion, together with the faulting that has been active from Tertiary to present time, has carved the present relief.

There is evidence that during the Pleistocene epoch the climate was somewhat more humid than at present. Lakes, some of them several hundred square miles in extent, were formed. The climate later became more arid until it reached its present state, and the lakes evaporated until now no permanent lakes remain except in the San Bernardino Mountains.

During the Tertiary and Quaternary periods the region was inhabited by a variety of animals, and some of the species were closely related to those now in the region, but others have not been known in the North American continent within the memory of man. The Tertiary faunas include several species of horses, camels, wild pigs or peccaries, antelope or deer, mastodon, rabbits, several catlike animals including the saber-tooth tiger, members of the dog or wolf group, and tortoises.[25] The Quaternary Manix lake beds have yielded remains of horses, camels, a proboscidean (probably an elephant), antelopes, and birds. The conditions that caused the extinction of the animals that no longer inhabit the region and the time of their extinction are not yet known.

[24] Merriam, J. C., Tertiary mammalian faunas of the Mohave Desert: California Univ. Dept. Geology Bull., vol. 11, No. 5, pp. 450, 526, 1919.

[25] Merriam, J. C., Extinct faunas of the Mohave Desert, their significance in a study of the origin and evolution of life in America: Pop. Sci. Monthly, vol. 86, No. 3, pp. 245–264, 1915; Tertiary mammalian faunas of the Mohave Desert: California Univ. Dept. Geology Bull., vól. 11, No. 5, pp. 437a–585, 1919.

GROUND WATER

Occurrence.—The rocks that form the mountains contain only meager amounts of water, although small springs may occur in rocks of all kinds.

By far the most notable water-bearing formation in the Mohave Desert regions is the alluvium that underlies the valleys and fills the rock basins to considerable depths. This alluvial fill generally yields water to wells that penetrate below the water table, and in some places it includes beds of sand and gravel that yield very freely.

The bedrocks chiefly form more or less impervious basins that hold the water-bearing alluvium and separate the ground water in one basin from that in another. To the extent that they are permeable or contain fissures or crevices they may allow the ground water in one basin to percolate into an adjacent basin.

Source.—The principal source of ground water is the run-off from the mountains, especially the perennial streams from the loftiest and best-watered ranges. When the mountain streams reach the alluvial slopes their water generally sinks rapidly into the gravelly alluvium and percolates down to the water table. The rain that falls on the broad expanses of the desert valleys probably does not make any large contributions to the supply of ground water because it generally comes in small quantities and seeps only a short distance into the dry soil so that it is soon evaporated.

The water that percolates to the water table tends to build up the zone of saturation. Thus the alluvial fill is a great reservoir of ground water. As a rule the depth to the water table decreases from the upper parts of the alluvial slopes, near the mountains, toward the lowest parts of the valley, where it may be at or near the surface. Ground water, however, also lies near the surface in some high localities, where it is held up by some structural features in the rocks that may appear at the surface or may be entirely concealed.

Discharge.—Where the water table is near the surface there are generally seeps and springs, and, moreover, ground water is discharged into the atmosphere by evaporation and by the action of certain plants, such as salt grass, rabbit brush, and mesquite. The ground water discharged by these processes is replaced by new supplies that percolate down from the streams and other surface sources. If the rock basin that contains the water-bearing alluvium is not impermeable the ground water may escape so rapidly to some adjacent basin at a lower level that the water table remains far below the surface, even in the lowest parts of the valley, and no ground water is discharged through springs and seeps or by evaporation or transpiration from plants. Thus there are two types of basins in the Mohave Desert region—those that have areas of ground-water discharge and those that do not.

The basins that have areas of ground-water discharge are generally characterized by "moist" or "discharging" playas or dry lakes. In these playas the water table is commonly within 10 feet of the surface, the soil is moist below a depth of a few inches, and there is more or less continuous discharge of ground water by upward capillary movement and evaporation. The surface generally exhibits puffy, "self-rising" ground and is covered with more or less alkali. Adjacent to the playas and on parts of the playas that are not bare the vegetation consists of plants that habitually depend for their water supply on the zone of saturation. Plants of this kind have been called phreatophytes, meaning "well plants," because, like wells, they draw water from the zone of saturation. They are also known as "ground-water plants." [26] Common ground-water plants in this region are salt grass, rabbit brush, and mesquite. (See pp. 51–54.)

The basins that do not have areas of ground-water discharge contain only "dry" playas. In these playas the water table lies more than 10 feet below the surface and may be at a great depth. Except during and after rains these playas are dry, hard, and smooth. Little or no alkali is visible at the surface. In basins of this type the ordinary desert vegetation generally extends to the borders of the playas, and the distinctive ground-water plants are absent. As mesquite and some other ground-water plants go to considerable depths for water, these plants sometimes grow in localities where the ground water is too far below the surface to be discharged by capillary rise and evaporation.

On Plate 7 are shown the two types of playas that have been described—those that discharge ground water into the atmosphere and those that do not. Basins of the latter type presumably lose water by underground leakage. These properties of the basins are discussed in the detailed descriptions.

Considerable evaporation takes place from the ground surface if the soil is moist, especially if the ground water is close enough to the surface to move upward by capillary action. In addition, moisture is evaporated from plants. Some observations in regard to evaporation from soil were made by Lee [27] near Independence, in Owens Valley. The reader is referred to his report for a discussion of the conditions affecting evaporation from soil, but the results are summarized in the table below.

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[26] Meinzer, O. E., Plants as indicators of ground water: U. S. Geol. Survey Water-Supply Paper 577, 1928.

[27] Lee, C. H., An intensive study of the water resources of a part of Owens Valley, Calif.: U. S. Geol. Survey Water-Supply Paper 294, pp. 119–122, 1912.

Rate of ground-water discharged from soil and vegetation in tank experiments made near Independence, Calif.

[By C. H. Lee]

Average depth to ground-water surface in soil tank	Total depth of water evaporated in 1 year (1910-11)	Condition of surface
Feet	*Inches*	
1.28	39.95	Sand without vegetation.
1.34	43.10	Sod with good growth of salt grass.
1.94	42.67	Do.
2.92	30.46	Do.
3.92	23.31	Sod with medium growth of salt grass.
4.49	22.51	Sod with vigorous growth of salt grass.
4.94	7.91	Sod with scattered growth of salt grass.

Lee concluded that near Independence, where the soil is practically saturated with water up to the surface, the evaporation from the soil was about 52 inches, and as the depth to the zone in which the soil is saturated increases the evaporation decreases, until at a depth of about 7.5 feet it is practically zero. The significance of these observations is that not only is there considerable evaporation from streams and other bodies of water at the surface, but also that much water is evaporated from the ground.

Artesian conditions.—Numerous wells sunk into the valley fill show that the fill nearly everywhere includes a variety of materials—beds of permeable gravelly and sandy deposits separated by less permeable clayey deposits. As a rule the materials become finer grained toward the center of a valley, and in the low central part there may be lake or playa deposits of clay that are effectively impermeable. Some beds of water-bearing sand or gravel, however, commonly extend under the lowest parts of a valley. If water-bearing beds pass beneath extensive clay beds in the lowest parts of the valley, and if the recharge is sufficient to bring the water table to the surface in the lowest parts and to maintain a large and active area of ground-water discharge, artesian conditions exist, and flowing wells can probably be obtained. (See under Antelope Valley, p. 317 and fig. 11.)

Quantity.—The supply of ground water annually available in a basin can be estimated from the size and character of the areas of ground-water discharge, the seepage losses from the streams, and the fluctuation of the water table. Active discharge and hence a relatively abundant supply of ground water is indicated if the area of ground-water discharge contains wet playas with the water table near the surface and with puffy, "self-rising ground" and alkali crusts at the surface and if the ground-water plants are luxuriant. If a basin has no area of discharge, its available supply is obviously small. An abundant supply is also indicated by a notable rise in the water table during the rainy season.

A good example of a basin with relatively large annual recharge and discharge of ground water is that of Antelope Valley, which is described in detail on pages 289–371.

Utilization.—Watering places consisting of either springs or wells are found at widely separated points throughout the region. Most of them are either in the mountains or in the low parts of the valleys, where the water table is near the surface. They are of inestimable value to those who wish to enter or pass through the desert. Because of their public character many of the watering places on the public domain have been withdrawn from entry, and the legal subdivisions in which the water occurs have been made Federal water reserves. In parts of the region where there is enough edible vegetation to support cattle or other range stock the watering places are essential for keeping the stock in the region. In many places they are utilized by prospectors, and in some places supplies for mines and mining camps have been developed at great cost. The railroads that cross the region require considerable quantities of water of rather good quality at regular intervals. In some areas it has been difficult or impossible to develop the required supplies, and water is hauled in tank cars to stations in these areas for use in locomotives and for the domestic use of the railroad employees and others who may reside at or near these stations. Irrigation supplies are everywhere in demand, and in a few valleys, such as Mohave, Antelope, and Indian Wells Valleys, considerable supplies are obtained from wells, chiefly by pumping. In most of the valleys, however, little or no water has been recovered for irrigation, and the prospects for future irrigation developments are in general not encouraging. This subject is discussed in detail in the descriptions of the different valleys given in this report. Some of the methods of constructing wells are briefly described in the section on Antelope Valley (p. 344).

Quality.—Numerous samples of water were collected from springs and wells and were analyzed chiefly in the water-resources laboratory of the Geological Survey, in Washington. These analyses are given in connection with the discussion of the quality of the water in the respective valleys. As might be expected in so large a region, the samples vary greatly in the quantity and relative proportions of their mineral constituents. A few of the waters are too highly mineralized for any use. Others are too highly mineralized to be satisfactory but are nevertheless used for some purposes and can be used for drinking when necessary. The outstanding fact, however, is that most of the ground water is not at all the bad water so commonly considered as occurring in the desert regions but is water of only moderate mineralization, of satisfactory quality for drinking, cooking, and irrigation, and usable for washing and in steam boilers. Indeed, these desert waters have a much lower average mineralization than the water in the Paleozoic and Cretaceous formations that underlie the Mississippi Valley region and the Great Plains. Generally speaking they are more nearly like the water in the glacial drift of the north-central part of the United States and the water in the Tertiary deposits of the Great Plains. It should be remembered, however, that notwithstanding this favorable generalization there are some areas in which the ground water is very highly mineralized and not adapted for irrigation or other uses. For definite information concerning the quality of water in any part of the region the reader should turn to the detailed descriptions.

Temperature.—In the following table are assembled the available data on the temperature of water from springs and wells in the region. Ground water at moderate depths below the surface normally has approximately the mean annual atmospheric temperature of the region in which it occurs, and the temperature increases gradually with depth. Most of the waters listed in the table are considerably warmer than the water from ordinary springs and wells in the northern part of the country, where the climate is colder. If, however, these temperatures are compared with the atmospheric temperatures in the Mohave Desert region (pp. 70–71), it becomes evident that, with a few exceptions, such as that of Paradise Springs, they are essentially normal for the region. The high temperature of the water from the deep well in Harper Valley is evidently due to the depth from which the water comes.

Temperature of water in wells and springs in the Mohave Desert region, Calif.

Leach Valley

Name of owner or of watering place	Description: Page	Description: No.	Location: Sec.	Location: T.	Location: R.	Location: Meridian	Source	Geologic formation	Temperature: Date	Temperature: Water (° F.)	Temperature: Air (° F.)
Leach Spring	196	------	14	17 N.	1 E.	San Bernardino	Spring	Alluvium near granite		55½	53
Two Springs	197	------	23?	17 N.	3 E.	do	do	do	Oct. 19, 1917 Jan. 17, 1918	62 55½	53

Fremont Valley

Name of owner or of watering place	Page	No.	Sec.	T.	R.	Meridian	Source	Geologic formation	Date	Water (° F.)	Air (° F.)
Randsburg Water Co	221	2	27	29 S.	41 E.	Mount Diablo	380-foot shaft	Tertiary lava		[a] 81	------
Yellow Aster Mining & Milling Co	221	4	12	29 S.	39 E.	do	520-foot drilled well	Alluvium		[a] 80	------
A. J. Crookshank	221	21	19	30 S.	38 E.	do	880 (?)-foot drilled well—flowing.	do		[b] 79½	------
Do	221	20	19	30 S.	38 E.	do	828-foot well—not flowing	do		70	------

Langford Valley

Name of owner or of watering place	Page	No.	Sec.	T.	R.	Meridian	Source	Geologic formation	Date	Water (° F.)	Air (° F.)
Langford well	262	------	14?	13 N.	3 E.	San Bernardino	55-foot dug well	Alluvium		66	------
Garlic Springs	262	------	10	13 N.	3 E.	do	Spring	Alluvium and rock		[c] 72	------

Harper Valley

Name of owner or of watering place	Page	No.	Sec.	T.	R.	Meridian	Source	Geologic formation	Date	Water (° F.)	Air (° F.)
Kramer Consolidated Oil Co	271	17	17	11 N.	10 E.	San Bernardino	800-foot well	Alluvium?		72	------
Do	271	18	18	11 N.	10 E.	do	2,940-foot well	Rock?		106	------

[a] Reported to the writer.
[b] Tested at point 175 feet from well; may have been warmed somewhat in passing through pipe.
[c] Determined by G. A. Waring, U. S. Geological Survey.

Temperature of water in wells and springs in the Mohave Desert region, Calif.—Continued

Coyote Valley

Name of owner or of watering place	Description: Page	Description: No.	Location: Sec.	Location: T.	Location: R.	Location: Meridian	Source	Geologic formation	Temperature: Date	Temperature: Water (° F.)	Temperature: Air (° F.)
Paradise Springs (hot springs)	285	------	7	12 N.	2 E.	San Bernardino	Spring	Granite	Oct. 11, 1917	[d] 106½	------
Paradise Springs (warm spring)	285	------	7	12 N.	2 E.	do	Spring	Alluvium	Feb. 12, 1918	[e] 102	------
L. S. Jones	282	------	28	12 N.	2 E.	do	100-foot drilled well	do		82	------
Coyote Well	283	------	22	11 N.	2 E.	do	18-foot dug well	do		(f)	------
										71	------

Lower Mohave Valley

Name of owner or of watering place	Description: Page	Description: No.	Location: Sec.	Location: T.	Location: R.	Location: Meridian	Source	Geologic formation	Temperature: Date	Temperature: Water (° F.)	Temperature: Air (° F.)
J. A. Fults	464	4	35	10 N.	1 E.	San Bernardino	407-foot drilled well	Alluvium		72½	------
Town of Daggett	466	45	16	9 N.	1 E.	do	100-foot dug well	do		70	------
E. D. Barry	467	60	20	9 N.	2 E.	do	500-foot drilled well	do		[g] 71½	------
F. H. Webber	467	69	27	9 N.	2 E.	do	42-foot drilled well	do		[c] 71	------
M. J. Edwards	468	83	19	9 N.	3 E.	do	200-foot drilled well	do		70½	------
Mr. Fry	468	85	19	9 N.	3 E.	do	151-foot drilled well	do		70½	------
Mr. Cutler	468	87	30	9 N.	3 E.	do	134-foot drilled well	do		71¼	------
L. W. Page	468	88	32	9 N.	3 E.	do	14-foot dug well	do		78	------
Do	504	------	32	9 N.	2 E.	do	10-foot dug well	Rock		80	------
Burden & Lippincott	469	97	10	9 N.	3 E.	do	170-foot drilled well	Alluvium		71½	------
H. L. Mellon	470	125	8	9 N.	4 E.	do	50-foot well	do		69½	64
C. L. Loman	471	140	18	8 N.	4 E.	do	204-foot drilled well	do		[a] 74	------
Newberry Spring	498	------	33	9 N.	3 E.	do	Spring	Alluvium ?	Nov. 28, 1917; Nov. 18, 1919	77	------

Crucero Valley

Name of owner or of watering place	Description: Page	Description: No.	Location: Sec.	Location: T.	Location: R.	Location: Meridian	Source	Geologic formation	Temperature: Date	Temperature: Water (° F.)	Temperature: Air (° F.)
Large spring at Soda Station	529	------	11	12 N.	8 E.	San Bernardino	Spring	Limestone?		75	------
Small spring at Soda Station	529	------	11	12 N.	8 E.	do	do	do		74	------
Soda Station well 1	524	10	14?	12 N.	8 E.	do	103-foot drilled well	Limestone		78½	------
Soda Station well 2	524	11	14?	12 N.	8 E.	do	39-foot drilled well	do		73½	------
L. B. Joralmon	525	23	7	11 N.	8 E.	do	150-foot drilled well	Alluvium		65	------
A. J. Ingalls	525	31	18?	11 N.	8 E.	do	91-foot drilled well	do		72¾	------
Mohave United Mining & Milling Co., Louisiana well.	525	33	29?	11 N.	8 E.	do	13-foot dug well	do		63½	------

Mesquite Spring	528	------	25	11 N.	8 E.	do	Spring	Granite?		[h] 56	------
Spring ⅓ mile east of Mesquite Spring.	529	------	25	11 N.	8 E.	do	do	do		50½	------
Epsom Springs	529	------	21?	11 N.	8 E.	do	do	Alluvium		62	------
Silver Lake Valley											
Halloran Springs	571	------	14?	15 N.	10 E.	San Bernardino	Spring	Granite		[e] 71	------
Lower Amargosa Valley											
Saratoga Springs	586	------	2	18 N.	5 E.	San Bernardino	Spring	Alluvium near base of rock hills.	Jan. 19, 1918 May, 1918	81 [i] 82½	------ ------
Crystal Hills Valley											
Hidden Spring	593	------	------	26 S.	47 E.	Mount Diablo	Spring	Tertiary lava		60	------
Lucerne Valley											
Rabbit Springs	621	------	11	4 N.	1 W.	San Bernardino	Spring	Alluvium		[j] 69	------
J. E. Goulding (Box S ranch)	619	27	11	4 N.	1 W.	do	300-foot drilled well	do		72	------
Cushenbury Spring	620	------	10	3 N.	1 E.	do	Springs	do		66½	------
Box S Springs	621	------	4	3 N.	1 E.	do	do	Alluvium or decayed granite, probably on fault plane.		55	------
Johnson Valley											
Cottonwood Spring	629	------	25	4 N.	2 E.	San Bernardino	Spring	Clay		61	------
Old Woman Spring	629	------	31	4 N.	3 E.	do	do	Lava		73	------
Fenner Valley											
Colton Well	685	------	28 or 29?	10 N.	15 E.	San Bernardino	22-foot dug well	Granite overlain by alluvium.		65	------

[d] This observation may be inaccurate. See p. 286.
[e] The same temperature was also observed by G. A. Waring in 1908 and again on Aug. 22, 1916. See p. 286.
[f] No thermometer available. Water is warm, temperature estimated at 75 or 80° Fahrenheit.
[g] Water pumped by air lift.
[h] No flow.
[i] H. S. Gale reports temperature of 4 springs to be 82½° F.
[j] Determined by G. A. Waring; 69° in morning, 71° in afternoon, Aug. 14, 1916.

SUGGESTIONS FOR DESERT TRAVEL

GENERAL COUNSEL

Until recent years the traveler in the desert used burros or horses and wagons as his means of transportation. Since the advent of the automobile the use of horses has nearly ceased. With this change travel in the desert has become less difficult and has therefore increased very much. When horses were used and travel was slow, the distance between watering places was important, and it was necessary that a watering place be reached at night or that large supplies of water be carried. If a watering place was not found as expected, or if it was in bad condition, the travelers might suffer considerable hardship or even perish before reaching another place. To-day, with automobiles for transportation, the distance is of much less importance, and if water is not found at one watering place, a few hours' trip will usually bring the traveler to another.

It must not be supposed, however, that travel in the desert with an automobile means travel without danger. In some respects the danger has increased. It is much easier to get a long distance from known watering places with an automobile than with a team, and a breakdown at a remote point may be very serious. Since automobiles have come into use there is much more travel by persons who are not familiar with the region through which they are going and therefore may not appreciate the necessity of adequate preparation to meet emergencies. Moreover, with automobiles numerous difficulties may arise that were not encountered by those traveling with horses and wagons. Foremost of these is mechanical trouble with the engine and other parts of the automobile. A useless spark plug may be the cause of a machine becoming stalled on a sandy road many miles from any place where help may be obtained. Some weak part of the engine may break when least expected. The automobilist also encounters road difficulties which, although hindrances to the teamster were not so likely to prove disastrous to him. A wagon, if not too heavily loaded, can be drawn by horses through heavy sand, but an automobile may become stalled, the wheels being unable to obtain traction and sinking deeper into the sand as they spin.

Although the desert is as a whole less dangerous than in past years, the traveler must still bear in mind that emergencies may suddenly arise that may easily prove disastrous. It is not always the newcomer who unexpectedly encounters dangerous situations, but sometimes the old prospector who has been cautious for many years and who may relax his carefulness.

For the benefit of those who have occasion to travel in the desert without previous experience a number of suggestions are given below. They are based on the writer's experience in traveling roads of all types and on the experiences of others who have spent many years in he arid region.

Much that is said below will not apply to the transcontinental tourist who follows well-marked roads that are used daily. The National Old Trails Road that leads from east to west across the Mohave Desert region from Needles to San Bernardino is so well marked that the traveler on it can not lose his way. It is traveled by a number of machines each day—in certain seasons more than 100 daily. It lies within a mile of the Atchison, Topeka & Santa Fe Railway for almost the entire distance and at no point is more than 4 miles from the railway. Water can be obtained at stations or from section crews at least every 10 miles and usually every 5 miles. Train stops on the railway are located about every 5 miles, so that if the traveler meets with serious difficulty he will have to go only a comparatively short distance in order to obtain help if other travelers do not pass. Although the railway section crews usually give water freely to travelers, they should not be asked for it unless necessary, as the water for most of the crews is hauled in by the railway company at considerable cost. At several places the water is hauled more than 50 miles.

The traveler along the National Old Trails Road therefore need only be prepared to meet such emergencies as arise in ordinary touring—for example, changing tires and making minor adjustments to the engine. However, at least one good-sized canteen of water should be carried. It is also advisable on long trips, even on the transcontinental road, to carry a shovel. On practically all the other routes in the Mohave Desert region help can not be obtained so easily, and the routes are traveled much less frequently, some of them not for days at a time. The traveler who follows these roads should therefore be prepared for greater emergencies. No one should go in an automobile far from town who is not sufficiently familiar with the mechanism to make necessary adjustment of the carburetor and spark plugs and other minor repairs or who can not make repairs to tires. This seemingly needless statement is made because there are many persons who know only how to manipulate the throttle and brakes of their cars. The traveler should be sure that his car is in good condition before he starts into the desert and not merely trust to luck that nothing will happen, for on the desert roads an unusual strain is put on all parts of the machine.

EQUIPMENT

The following equipment should be carried by travelers who expect to go very far from towns or other places where help can be obtained.

Water and gasoline containers.—Water should be carried both for drinking and for the engine radiator. Water bags are efficient in keeping the water cool, but at least one canteen should be carried in case it is necessary to walk any distance for help. A person will often consume as much as 2 gallons of water in a day if he is undergoing much physical exertion, and one should not start to walk any distance unless he carries at least a gallon canteen. Additional water may be carried in the automobile in kegs or other closed containers. Care should be taken that bags or other containers do not leak. A rope and bucket are often needed to obtain water from wells. On the poor roads of the remote regions all automobiles will consume abnormally large amounts of water, gasoline, and oil. The traveler should carry more than the amount of gasoline and oil calculated to cover the required distance. The machine may unexpectedly be stalled in sand or on a grade and thus use up a large amount of gasoline. Gasoline can be obtained in 5-gallon cans. These should be kept tightly corked.

Spare parts and tools.—Enough tools should be carried to make temporary repairs, and minor spare parts that are frequently needed should be carried, such as spark plugs, fan belt, tire-repair outfit, headlight bulbs, and ball bearings. A few feet of baling wire is very useful. Good extra casings and inner tubes should be carried. If necessary the car can be operated on flat tires, or the tires can be removed. A jack is absolutely essential.

A shovel is frequently valuable when the car becomes stalled in sand. A long-handled shovel is easier on the user's back. A good rope and tackle or one of the patented outfits for pulling out stalled cars may help to get the car safely out of an awkward position in an arroyo or across a bad gully.

ROAD DIFFICULTIES

The uninformed traveler usually thinks of desert roads as sandy, rough, and almost impassable, but as a rule they are not. In fact, the Mohave Desert region contains hundreds of miles of desert roads that are far better than the unimproved roads of the Eastern and Central States. The desert roads seldom become so muddy as to be impassable, and except for a few short stretches they never become so dusty as to make a journey unpleasant. There are, however, certain difficulties that these roads present, and the following suggestions are given for surmounting them.

The most common trouble is with sandy stretches of road. These stretches may be divided into two types—(*a*) where not only the road itself but the whole surrounding country is sandy, and (*b*) where the surrounding country may not be very sandy but deep sand collects in the road tracks as a result of windstorms.

Stretches of the first type are found very commonly on the eastern sides of the valleys, the sand having been blown in by the prevailing westerly winds, and in dry washes. Where this condition is encountered it is essential to keep the machine in the road tracks. If the machine stalls it may possibly be backed up and a new start made. If this expedient fails after being repeated several times the sand may be dug out for a few feet in front of the machine. One of the most successful methods of getting out of sand is to cover the tracks with brush of any sort, rocks, or even grass. If necessary, the wheels should be jacked up and the brush packed under them to give traction and prevent them from spinning. As soon as the wheels begin to spin no further attempt should be made to start until brush is put under them, for otherwise they will sink deeper into the sand. A method that has been found effective is to stretch two strips of canvas, about 10 yards long and 18 inches wide, under the wheels and in front of the car. This will often give the car a sufficient start to enable it to pass the worst stretch. It is necessary to lay the canvas under both the front and rear wheels. If not under the rear wheels it does not afford any traction, and if not held down by the front wheels it is pulled out and thrown behind the rear wheels.

In several places stretches of road were found where the tracks were filled with heavy sand, but the ground a few feet away from the road offered a fairly hard surface. In such places, if the car can be got out of the main track to the more solid ground less difficulty is experienced. The driver should be sure that a firmer surface is afforded away from the tracks, for if not he will simply get into worse difficulty by turning out. Wherever it is necessary to turn out to allow another car to pass it is advisable to keep the wheels on one side in one of the road tracks. If this is not possible it is often easier to back into the road again, following the same tracks, than to go ahead.

Many persons in crossing long sandy stretches partly deflate the tires. This gives a wider tire and a reduced wheel diameter and a correspondingly greater traction. If not too much air is let out, probably no damage is done to the tires in soft sand, but when hard ground is reached they should immediately be reinflated to the proper pressure.

Many desert roads that are otherwise good are cut by shallow cross washes from a few inches to a few feet deep. These must be crossed slowly to avoid putting a hard strain on the car. Where roads cross large washes and arroyos they may descend or ascend abruptly, and these changes of slope should also be taken slowly. If the descent into a wash is too rapid, a spring or the steering gear may be broken, or the car may plunge into deep sand.

In traveling roads that are used but little the driver must be on the watch for "high centers." Large rocks in the middle of the road may strike the underframe of the car, particularly the transmission housing or the differential housing. If these are broken the oil may drain out, causing serious trouble. "High centers" fortunately are not common. In a few places, particularly on roads composed of silty soil, the tracks may wear deep and the middle of the road will remain so high that the car can not pass. Such ruts may sometimes be "straddled."

In many places desert roads cross playas, or "dry lakes," as they are usually called. Many of these playas in dry weather have hard, smooth surfaces forming veritable boulevards that are a delight to the traveler. In the rainy season these same playas may be lakes of mud that must be avoided. Even a light shower may make them very slippery. Other playas have a rough, soft surface, but after a track has been broken across them they usually present no difficulties to the automobile. A very few playas are wet and soft throughout the year, and vehicles can not be driven across them.

ROADS TO WATERING PLACES

The field work on which this report is based was undertaken with the object of making it as easy as possible for desert travelers in this region to find water. Numerous signs were erected directing to watering places, but the funds available were insufficient to pay for signs at all road junctions. The places listed on the signs, with only three or four exceptions, are all known to be reliable watering places. The traveler must often use his own judgment in keeping to the proper road and in finding the watering places. In many places the maps will prove useful in indicating the proper road to be followed. Even if a branch road is not indicated the general direction of the main road will be shown on the map. A study of the topography may suggest the course or destination of a road that is not indicated on the map. The traveler should obtain the best maps available. The maps accompanying this report are believed to be the most accurate at the time they were compiled, although it is known that they contain inaccuracies, and, moreover, changes in roads have been made since they were prepared.

It should be remembered that desert routes change unexpectedly. A road used for many years may be washed out by a heavy rain and fall into disuse. Prospectors frequently camp at one place for several weeks, and the road to their camp will become well marked, possibly more so than the main road to more distant points. Once established, these unimportant roads may under desert conditions persist for years. Because of these varying conditions the traveler before starting into a region that is new to him should make careful inquiry from prospectors and others in regard to the condition of roads and watering places, checking the information carefully with the maps at hand. Garage men are usually well informed in regard to road conditions.

It is well not to depend on the memory for information about routes, but to request the informant to draw a sketch map, with distances and directions as nearly correct as possible. Particular inquiry should be made to be sure that water is still available at watering places that are to be visited.

TYPES OF WATERING PLACES

On the large maps (pls. 9, 10, 11, 12, and 13) all features printed in blue indicate water. Reliable watering places are shown in red. One who is using the maps for information in regard to watering places should refer to the explanation of symbols on the map to be sure that water is available. A few words of additional explanation may be desirable.

Three types of wells are indicated on the maps—flowing wells, nonflowing wells without pumping plants, and nonflowing wells with pumping plants. Nonflowing wells may be either dug or drilled; flowing wells are drilled. The usefulness of a nonflowing well as a watering place depends upon a means of getting the water to the surface, such as a pump or a rope and bucket.

In certain parts of the region there are a great many wells that are not shown on these maps. This is particularly true of Antelope Valley, Indian Wells Valley, Superior Valley, and the Mohave River valley—that is, districts where many homesteaders have taken up claims. Many of the wells in these and other valleys are shown on maps that accompany the descriptions of the different valleys. Some of these wells have no pumping equipment, or if equipped with power pumps they are useless unless some one is at hand to operate the machinery. For various reasons many of the homesteads are unoccupied for periods of several months. The relief maps show only those wells where it is probable that water can be obtained at all times.

Several abandoned or "dry" wells have been shown on some maps as watering places and are still frequently referred to as landmarks in giving directions to travelers. Furthermore, some persons do not know that these wells are no longer reliable sources of supply. It is thus deemed advisable to show these wells on the accompanying maps, but to indicate that they are dry or abandoned.

The water in some of the wells is poor, being either highly mineralized or insanitary. These wells have been shown on the maps, however, usually with a note that the water is poor or bad. The water from such wells may generally be used for automobile radiators or for horses and cattle, even though it may not be fit for human consumption.

Springs are likely to be in bad condition, being more easily polluted than wells, but they can usually be cleaned out in a few minutes, and if the spring has a stream flowing from it the water will soon become clear. If the spring has no visible outlet care must be exercised in cleaning away leaves and other débris, lest mud and sand be stirred up which may be a long time in settling.

What are commonly known as "tanks" are shown at a few places on the maps. These are natural reservoirs or basins formed in various ways in rocks and filled by rain water. Water may remain in the tank from a few days to several months, the time depending upon the size of the basin and other conditions. Some of the tanks may be filled with sand, which, however, holds a considerable quantity of water that may be obtained by a little digging. Tanks of this type are known as "sand tanks." In some places tanks are valuable as a source of supply to prospectors, but as they are usually situated in the more mountainous country and are not easily found, they are not of much importance to the average desert traveler.

Water is hauled to many railroad stations in cars and stored in cisterns or other reservoirs which are shown on the map. Nearly all these reservoirs are at section houses or small towns where help can be obtained.

Permanent streams and lakes are so rare in the desert region that they are practically of no importance as sources of water supply for travelers. Even where they occur better sources of water are usually available. Intermittent streams—that is, those which flow for only a part of the year—are likewise of little importance to travelers. They usually flow only after heavy rains, and then the water is likely to be too muddy to be used. They are never to be counted upon as sources of supply.

Playas, or "dry lakes," are never sources of water supply. They contain water only after heavy rains, and the water then is too muddy to be of any use. They are to be considered by the traveler only with reference to the condition of the roads that cross them.

FINDING WATERING PLACES

Watering places are not always readily seen from the road, and a search must be made for them. (See pl. 15, *B*.) Foot trails and paths made by cattle may lead to a spring or a well. Camp débris, such as tin cans and camp-fire remains, is often evidence that water is to be found near by. In mountainous country springs or wells are usually found in gravelly washes or in rocky canyons, particularly where the wash or canyon is somewhat constricted by rock ledges. In the large open valleys wells and springs are usually found in the lower parts of the valleys. The presence of water is in many places indicated by certain forms of vegetation, particularly salt grass, crawling mesquite, and arrow weed. (See pp. 51–54.) Certain types of willows and the screw-bean mesquite do not necessarily indicate the presence of water.

QUALITY OF DESERT WATERS

The newcomer on the desert often has the notion that all desert waters are bad and that he must simply endure them, his thirst never being quenched. Actually, in most places, the water is not brackish or bitter, and in some places it is as good as that used for public supplies in the less arid States, if not better. It is true that some of the waters are very brackish or bitter, and the analyses made in the Geological Survey laboratory indicate that one or two samples are more highly concentrated than sea water. The waters of poor quality are generally found in wells or springs situated in the lowest parts of closed basins. The waters from springs or wells in the mountains are usually comparatively good.

Most of the waters that are not positively distasteful can be used for drinking in small quantities without deleterious effects. If highly mineralized waters are consumed in large quantities they may cause serious physiologic disturbances, which, although they are usually only of a temporary nature, may be so weakening that the result may be fatal. The most dangerous waters are usually so distasteful that the traveler will not swallow them unless his sense of taste has been deadened by intense suffering from thirst.

Any ill effects produced by waters are usually due to the presence of large quantities of sodium sulphate (Glauber salt), magnesium sulphate (Epsom salt), sodium carbonate, or sodium chloride (common salt). Waters containing large amounts of the sulphates of sodium or magnesium have a bitter taste. Waters that contain sufficient quantities of these two substances to impart a perceptible taste, if used even in moderation, have a laxative effect, but they may serve to quench the thirst and will not cause serious discomfort. If they are used in large quantities the laxative effect may be so great as to prove serious. Waters containing large amounts of sodium carbonate have a characteristic soapy taste and cause a burning sensation in the mouth. They produce a nauseating effect. Waters of this character that are sufficiently concentrated to prove harmful are rare in the region described in this report. Waters high in sodium chloride (common salt) have a salty taste. If very much salty water is drunk it will have a nauseating effect. Waters that taste slightly salty may be drunk, but they are not effective in slaking thirst.

The waters from a number of springs or wells in the area described in this paper have been reported to contain arsenic or similar poisons. Careful tests of samples of these waters have failed to reveal the presence of any of these poisonous substances.

The notes in the report in regard to the quality of water at different places refer principally to the quality so far as mineral content is concerned. Bacteriologic or other sanitary analyses were not made.

Desert wells and springs are not usually dangerously polluted, but if there is any question as to the sanitary quality of any water it should be boiled before being drunk.

EMERGENCIES

The traveler should as far as possible be prepared to meet any emergency that may arise. Occasionally, however, something happens that no preparation or foresight can prevent. Serious breakdowns may occur that can not be repaired, or an automobile may become hopelessly stalled, and there is nothing to do but walk. In such circumstances it is a common tendency for the traveler, especially if he is not very familiar with the desert, to become panic-stricken. He should, however, consider the conditions carefully and without excitement. On a hot summer day he should rest in the shade of the car or a bush until the heat of the day is passed, walking mostly in the cool night hours. He should carry a canteen of water and if the distance is great some food, taking care to avoid thirst-producing foods, such as dried beef or other salty meats. He should consider the various possible sources of help and should consult the map to determine the nearest places, with intermediate watering places, conditions of travel, etc. The traveler should at all times know approximately how far he is from the places where help can be obtained.

Unless he can tell directions accurately from the sun and stars the traveler should always carry a compass. As he passes through new country he should make it a habit to locate prominent features that will serve as landmarks, and as far as possible he should become acquainted with their appearance from different directions. Ordinarily it is dangerous to leave a road and cut across country to save distance, unless the saving is great and the traveler is certain of the conditions to be met. This is particularly true if it is likely that it will be necessary to cross mountains.

The traveler should remember that for various reasons it is very difficult to estimate distances in the desert. A mountain that seems only a mile or two away may be 10 miles away. He should not go far from camp at any time without a canteen of water.

In conclusion it may again be emphasized that much depends on the traveler himself. If his machine is in good condition, and if he understands it, keeps it in good condition, and drives it carefully, he will have little difficulty. It is then only the occasional, unavoidable accident that may prove dangerous. Even in such an event the person who remains calm and free from panic is in comparatively little danger.

MAIN ROUTES OF THE DESERT

That part of southern California known as "the desert" is shut off from the somewhat better watered country along the Pacific coast by high mountains. These mountains, known at various places from northwest to southeast as the San Gabriel Mountains, the San Bernardino Mountains, the San Jacinto Mountains, and the Santa Rosa Mountains, extend almost due east from the Pacific Ocean between latitudes 34° and 34° 30′ beyond the cities of San Bernardino and Redlands, whence they trend somewhat east of south to the Mexican border. They act as a barrier to travel, which is concentrated through a very few passes. Access from the west to the region considered in this report may be had at only three places, but farther south, near the Mexican border, several roads lead through the mountains. Roads from the large cities converge toward these passes and, after crossing the mountains, diverge again in various directions. The principal routes of the Mohave Desert region are shown on Plate 2.

MIDLAND TRAIL

The westernmost route into the desert leads northwestward from Los Angeles, by way of San Fernando, to Saugus, a distance of 34 miles. From Saugus the traveler has a choice of two routes, known as the Bouquet Canyon route and the Mint Canyon route, both of which lead northeastward to the Mohave Desert. Either of these roads may be followed to Mojave. The Mint Canyon road, leading first to Palmdale, is paved and is therefore the one generally used. From Mojave the road leads northward to Big Pine and thence northeastward through Goldfield and Tonopah to Ely, Nev., where it joins the Lincoln Highway, the main road to Salt Lake City, and the East. This route is known as the Midland Trail.

From Saugus a third road, known as the Ridge route, branches northwestward through Tejon Pass to San Joaquin Valley and thence to Bakersfield and San Francisco, but this route does not touch the desert. The Bouquet Canyon and Mint Canyon routes are also used by travelers bound for Bakersfield. On the north side of the mountains the traveler who follows either of these roads may turn west and reach the Ridge Road a few miles south of Tejon Pass, or he may go to Mojave and thence turn west through Tehachapi Pass to Bakersfield and San Francisco.

The Midland Trail is used extensively for travel from southern California to Salt Lake City and eastern points. It is also used a great deal by travelers going only to Antelope Valley, just north of the mountains, now a comparatively well settled farming country, and to the mining districts near Randsburg and Searles Lake. These roads are much traveled, and along them water and supplies can be obtained at short intervals. They have been well signposted by the

Automobile Club of Southern California, and maps on which they are shown in detail may be obtained at the headquarters of this club in Los Angeles. Roads east of the Southern Pacific Railroad on the desert side of the mountains are described in later pages.

NATIONAL OLD TRAILS ROAD

The greater number of travelers bound for the desert follow the routes that lead eastward along the south side of the San Gabriel Mountains from Los Angeles to San Bernardino and Colton. From these two places two routes diverge to different parts of the desert, one leading northward to the Mohave Desert region and the other leading eastward to the desert areas of Riverside, Imperial, and San Diego counties, often called the Colorado Desert. (See pl. 1.) From San Bernardino the National Old Trails Road goes northward, crossing the mountains through Cajon Pass, to Barstow. Thence it continues in an easterly direction to Needles, about 305 miles from Los Angeles, and crosses Colorado River into Arizona 15 miles farther southeast. This is the main transcontinental route between southern California and the Eastern States. Important roads branch from this main road at several places. At Barstow roads go northward and northeastward to Death Valley and mining regions in eastern California and southeastern Nevada. From Daggett a road known as the Arrowhead Trail leads northeastward to Goodsprings and Las Vegas, Nev., and to Salt Lake City, Utah. (See below.) At Cadiz and Needles branches lead southeastward to Parker, Ariz., and thence to Phoenix.

Cajon Pass is the natural gateway to nearly the whole of the desert region described in this report and shown on the large maps. An area in the southern part of the region shown on Plates 10 and 11, which may be called Dale Basin, is most easily entered from the north end of Coachella Valley, which adjoins it on the south (see pp. 638–651), because the roads leading into this basin from the National Old Trails Road are rendered practically impassable by sand.

OCEAN TO OCEAN HIGHWAY

Southeast of San Bernardino there is another break in the mountains, San Gorgonio Pass, which allows access to the desert part of Riverside County and the northern part of Imperial County. Many eastbound travelers go through this pass to Mecca and Blythe, cross Colorado River by a ferry at Ehrenberg, and thence proceed to Phoenix. Roads also lead southeastward through the Salton Basin to Imperial Valley and Yuma, but these places are also reached by a road from San Diego which follows closely the Mexican border. Travelers from San Diego to Phoenix use the latter route. The southern routes are variously known as the Ocean to Ocean Highway, the Trail to Sunset, or by other names. The roads in the desert part of Riverside, Imperial, and San Diego Counties are described in a preliminary guide by John S. Brown,[28] and the geography, geology, and hydrology of the region in a more complete report by the same author.[29]

ARROWHEAD TRAIL

The Arrowhead Trail is an important route of travel to Salt Lake City, especially in winter, when the Lincoln Highway and other northern routes between California and Salt Lake City are closed by deep snow in the mountains. The Arrowhead Trail formerly branched from the National Old Trails Road near Bannock, about 16 miles west of Needles, and led northward by way of Searchlight and Las Vegas. (See p. 717.) In recent years San Bernardino County has opened a new road that shortens the distance by many miles. The road turns northeastward from the National Old Trails Road at Daggett and parallels the Los Angeles & Salt Lake Railroad (Union Pacific System) to a point beyond Manix station. Thence it continues northeastward across East Cronise Valley to Baker station and by way of Halloran Spring and Valley Wells across the Clark Mountains into Ivanpah Valley. There it turns northward and reaches the Los Angeles & Salt Lake Railroad near Roach and lies not far from the railroad for many miles to Las Vegas and Moapa, Nev. This new road is not shown on the relief maps but is shown on Plates 7 and 8.

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[28] Brown, J. S., Routes to desert watering places in the Salton Sea region, Calif.: U. S. Geol. Survey Water-Supply Paper 490-A, 1920.

[29] Brown, J. S., The Salton Sea region, Calif., a geographic, geologic, and hydrologic reconnaissance: U. S. Geol. Survey Water-Supply Paper 497, 1923.

PART II. DESCRIPTIONS OF VALLEYS

INDIAN WELLS, COSO, AND ROSE VALLEYS

GENERAL FEATURES

Indian Wells Valley occupies the northeastern part of Kern County, the southwestern part of Inyo County, and a very small area in the northwest corner of San Bernardino County. (See pl. 7.) It is bounded on the west by the high Sierra Nevada, which serves as a barrier to the rain-producing winds that blow from the Pacific Ocean in winter and causes the precipitation to be so low that crops can not be grown without irrigation. The valley has also been called Inyokern Valley, Brown Valley, and Salt Wells Valley, but the name Indian Wells Valley was approved in 1920 by the United States Geographic Board. The name Salt Wells Valley is at present applied to a smaller valley lying between Indian Wells Valley and the valley occupied by Searles Lake.

Adjoining Indian Wells Valley on the north are two smaller valleys, Rose Valley and a hitherto unnamed valley for which the name Coso Basin is suggested. These valleys are separated from Indian Wells Valley only by low divides, and they probably contribute some ground water to it. For this reason they are considered briefly with Indian Wells Valley.

Indian Wells Valley is traversed from north to south by a branch line of the Southern Pacific Railroad that runs from Mojave to Owenyo, with connections to the main line between San Francisco and Ogden, Utah. This road was built primarily for hauling materials for the construction of the Los Angeles Aqueduct, which runs through the valley along the foot of the Sierra Nevada.

The principal town is Inyokern, on the railroad in the southwestern part of the valley. In 1920 it contained two general stores, a post office, a small hotel, and several houses. Brown, about 10 miles north of Inyokern, contained a small store, a post office, and a small hotel and railroad eating house. Leliter, midway between the two towns, contained only a post office.

The valley is connected with adjoining regions by fairly good desert roads, which lead to Los Angeles and Salt Lake City and to the desert towns of Barstow, Randsburg, Trona, Borosolvay, and Westend. A road leads from Freeman up Freeman Canyon across the Sierra Nevada into the upper part of the Kern River valley. This road is used considerably by ranchers along Kern River, especially to bring cattle to Inyokern for shipment. In 1919 about 75 carloads of cattle were shipped from Inyokern, and most of them came from the west side of the Sierra Nevada.

Agriculture, including horticulture and cattle raising, is practically the only activity of the valley. One or two mines or prospects are located in the mountains east and northeast of Brown, but production from them has been more or less sporadic.

SOILS

Throughout the greater part of Indian Wells Valley the soil consists of the decomposition products of the granite of the Sierra Nevada. It is a mixture of coarse sand grains and some clay and is lacking in humus. Although the soil contains more or less sand, it is nowhere so sandy as to require unusually large quantities of water for irrigation except on the east side of the lowest part of the valley, where sand blown from the west side of the valley accumulates.

The soil of the playas and for some distance around them is essentially composed of clay. The soil of China Dry Lake and bordering it for some distance contains more or less alkali, which generally shows on the surface.

In two localities in the region, at the lower ends of two large washes, the soil is very silty. These localities are along the line between secs. 2 and 3, T. 26 S., R. 39 E., and along the road between secs. 9 and 10, T. 26 S., R. 40 E. This soil apparently tends to cake or form a crust after being wet, but it pulverizes readily, and the caking tendency probably would not be harmful to crops. It apparently has been deposited by the flood waters from the washes as they spread out over the bottom of the valley.

Caliche was reported at several places at a depth of a few feet, notably in the SW.¼ sec. 6, T. 26 S., R. 40 E., where it lies at a depth of 18 inches to 4 feet; near the southwest corner of sec. 23, T. 26 S., R. 40 E., at a depth of 3 to 3½ feet; and near the southwest corner of sec. 35, T. 26 S., R. 40 E., at a depth of 2 to 3 feet. It apparently occurs only in the lower part of the valley and probably is not continuous over any very large area, nor does it lie at a uniform depth.

VEGETATION

The creosote bush (*Larrea tridentata* or *Covillea tridentata*), often erroneously called greasewood, is the characteristic plant throughout the greater part of the alluvial slope of Indian Wells Valley. It occurs only where the soil is well drained and hence is not found in the lowest part of the valley, where the water table is close to the surface and the soil contains more or less alkali. The vegetation in the areas of alkali soil is characterized by the alkali-resistant plants, such as salt grass (*Distichlis spicata*) and the so-called saltbushes. Usually a rather distinct boundary can be drawn between the zone in which creosote is dominant and the zone where salt grass or the saltbushes predominate. It is believed that this boundary is also the boundary which separates land that will bear crops and that which is unfit for agriculture. This boundary was determined approximately in part of the valley and is shown on Figure 4.

No plants larger than the creosote bush grow in the valley, except perhaps a few mesquite in isolated localities. Some pine trees grow on the higher flanks of the Sierra Nevada, but they are difficult of access and not easily obtained for fuel.

CLIMATE

No official climatic records have been kept in Indian Wells Valley. The region has a typical desert climate, characterized by high summer temperature, relatively warm winters, and slight annual precipitation. The climate is apparently much like that in the vicinity of Mojave, Calif., for which records are available (pp. 70–91 and figs. 1 and 2).

Mr. Harry Joos, who has kept partial records at his ranch in sec. 26, T. 26 S., R. 39 E., since 1910, states that the maximum summer temperature has been 118° and the minimum winter temperature 8°. A temperature of 2° below zero was recorded at Indian Wells (old stage station) in 1908, but Mr. Joos estimates the average minimum at not lower than about 14°.

On the basis of studies on Owens Valley, of records at Mojave, and of conditions in Indian Wells Valley, Lee,[1] has estimated that the average annual rainfall is about 4 inches at Brown, 6 inches at the base of the mountains, and about 22.5 inches at altitudes of 7,000 feet in the Sierra Nevada. Mr. Joos states that the average annual rainfall at his ranch since 1910 has been about 3.8 inches.

Most of the rain comes during the winter from storms that cover a wide area and move from west to east. Lee states that probably the precipitation at a given altitude in the mountains on the north and northeast side of the valley is not quite as great as at the same altitude in the Sierra Nevada. He believes the maximum in the Argus Range to be about 15 inches.

PHYSICAL FEATURES AND GEOLOGY

GENERAL CHARACTER

Indian Wells Valley occupies a closed basin—that is, there is no outlet for its surface streams. It is almost entirely surrounded by mountains of impervious rocks that practically prevent any of the ground water from seeping out of the basin.

The area that contributes water to the ground-water supply of this valley is composed of three units, which are more or less separated by low surface divides, but these divides are of such a nature that they do not act as barriers to movements of ground-water. The largest of the units is Indian Wells Valley itself. The next largest

[1] Lee, C. H., Ground-water resources of Indian Wells Valley, Calif.: California State Conservation Comm. Rept., pp. 401–429, 1913.

unit lies northeast of the valley, and it may be called the Coso Basin or Valley, as a large part of the drainage of this area comes from the Coso Mountains and is carried down a narrow valley in which are located the Coso Hot Springs. The third and smallest unit adjoins Indian Wells Valley on the northwest and is called Rose Valley. The boundaries of these units are shown on Plate 7. The topographic and geologic features of these three units may be considered separately.

INDIAN WELLS VALLEY

The drainage basin of Indian Wells Valley is composed of topographic features of three principal kinds—mountains, alluvial slopes, and playas. All the land of value for agriculture lies on the alluvial slopes. Practically all the water for irrigation has its source in the mountains. The playas occupy the lowest part of the valley and are nearly flat expanses of clay or silt, with which is mixed more or less alkali. The alluvial slopes, which are underlain by gravel, sand, and clay, rise gradually from the playas toward the mountains but become steeper near the mountains. From the upper limit of the alluvial slopes the mountains rise steeply.

The highest of the mountain ranges that surround the valley is the Sierra Nevada on the west. From an altitude of about 3,000 feet above sea level near its base the range rises steeply, within a horizontal distance of 6 miles, to peaks that reach 6,000 to 9,000 feet. The Sierra Nevada is drained by a number of short, steep-sided canyons, some of which contain small perennial streams. The rocks of the range are all granitic.

The mountains that border the valley on the south, east, and north are not as steep or as high as the Sierra Nevada, only two or three peaks rising above 6,000 feet. Next to the Sierra Nevada in height are the mountains on the northeast side of the valley that form a part of the Argus Range, which attain altitudes of 4,000 to 6,000 feet above sea level. The rocks of this range are mostly lavas of Tertiary age.

The boundary of the drainage basin on the southeast, from the south end of China Dry Lake to Rademacher siding, on the Southern Pacific Railroad, is composed of granite hills that rise only 1,000 to 1,500 feet above the bottom of the valley. In the northwestern part of T. 27 S., R. 41 E., and the southwestern part of T. 26 S., R. 40 E., the granite is badly weathered and the features of relief seem to be formed by alluvial deposits, but bedrock doubtless lies only a short distance below the surface.

The El Paso Mountains, west and southwest of Rademacher siding, consist of a series of interbedded lava flows and sedimentary rocks of Tertiary age. In Redrock Canyon, at the southwest end of the range, these rocks are tilted to the northwest, and in the northern part of T. 29 S., R. 37 E., they underlie a mantle of Pleistocene or recent alluvial deposits washed down from the mountains on the west. For a few miles in this township the divide is composed of unconsolidated materials.

The alluvial slopes of Indian Wells Valley are composed of débris washed into the valley from the mountains. As the Sierra Nevada is higher and steeper than the other ranges, and the precipitation on it is somewhat greater than elsewhere, more débris has been carried into the valley from the west than from any other direction. In fact, Indian Wells Valley is essentially a plain formed by the alluvium from the Sierra Nevada. The alluvial slope extends from that range nearly across the whole valley, for the alluvial slopes from the mountains on the east are very narrow. On the topographic map some of the region north of Brown and east of the Southern Pacific Railroad, covering parts of Tps. 23 and 24 S., Rs. 38 and 39 E., has the appearance of an alluvial slope, but it is the surface of a large lava flow. (See fig. 4.)

The playas or "dry lakes" occupy the lowest part of the valley, where temporary shallow ponds or small lakes form after heavy rains. The lakes dry up in a few days or months, leaving a barren flat. In some places, after the water has disappeared the surface of the playa may be smooth and become hard as it dries out, but in other places the surface is soft, slightly rough, and covered with incrustations of alkali deposits. Where the alkali is present, water is reaching the surface by capillary action and is being discharged by evaporation. The alkali crust is deposited as the result of the continual discharge in this manner. Where the surface is rough and soft, exhibiting the "self-rising ground," the soil is usually moist, and ground water is usually found at depths of less than 10 feet. The roughness of the surface is believed to be due to the formation of crystals of the alkali salts, which, as they develop, push the surrounding clay or sand upward. Immediately after rains some of the alkali may be redissolved and not be noticeable, but it reappears as the surface dries out again. Where the soil is moist, wind-blown sand that falls on the playa may remain in place and form low sand dunes.

Five separate playas in Indian Wells Valley are shown on Plates 7 and 10, although Lee shows China Lake as including two of the playas. The largest playa is known as China Dry Lake. When seen by the writer most of it was covered by a moist alkali crust. The alkali also extended for some distance away from the playa. The other playas were not seen, but as they are situated at slightly higher altitudes, according to the topographic map, they probably are not so moist and do not have so much alkali on the surface. The alkali areas of China Dry Lake are shown in some detail in Figure 4, which is modified from a map by Lee.[2]

[2] Lee, C. H., op. cit., pl. 2.

At the south end of China Dry Lake occur exposures of clay that is blue when wet but bluish green when dry. The bluish color of such beds is generally considered to indicate that they were deposited under water, as in a lake, the water preventing oxidation, which

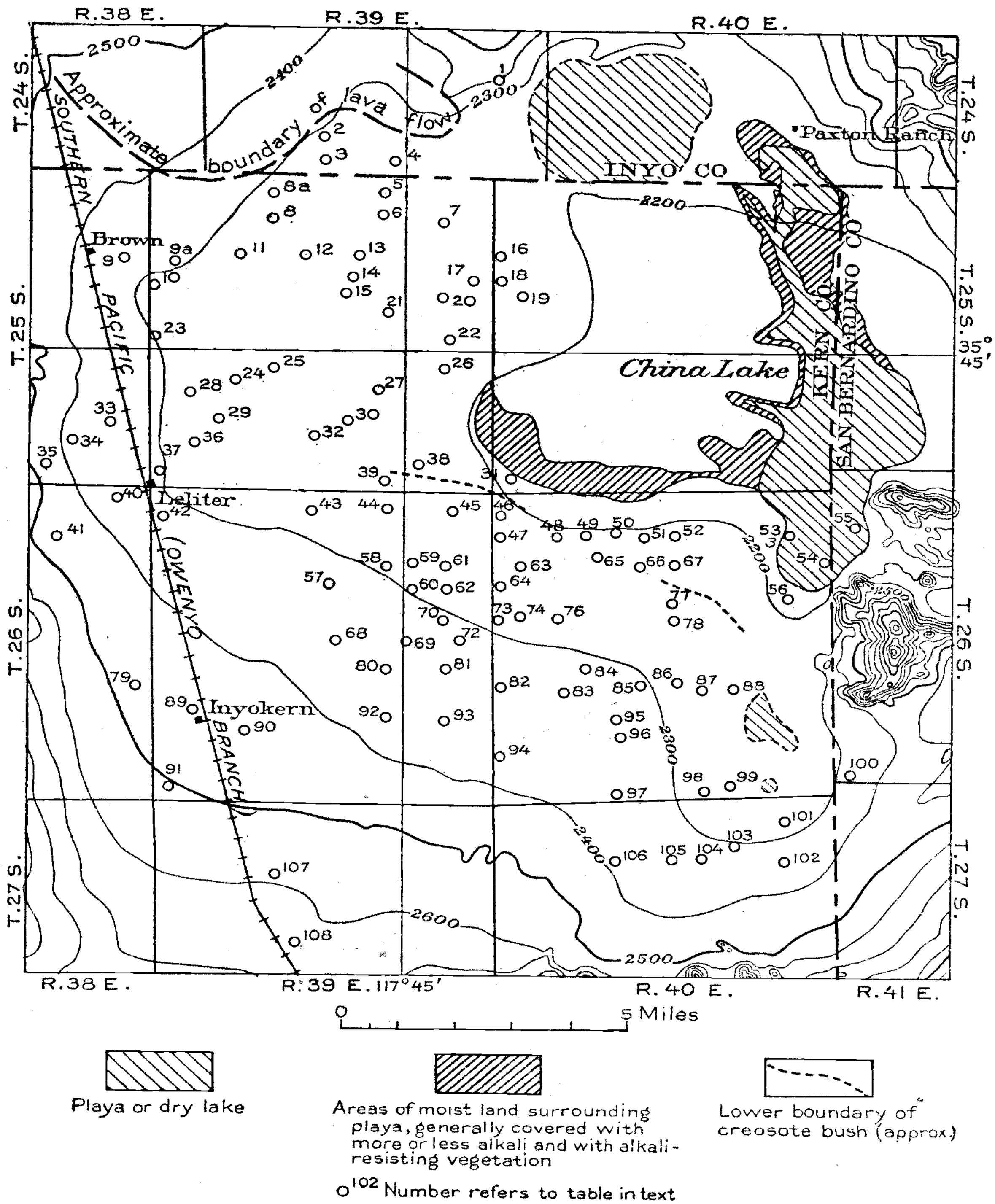

FIGURE 4.—Map of a part of Indian Wells Valley, Calif., showing physical features and location of wells

changes the color of the beds. Gale [3] has shown that a lake existed in Indian Wells Valley during the Pleistocene epoch. It was formed mainly by an overflow of Owens Lake during a period when the

[3] Gale, H. S., Salines in the Ownes, Searles, and Panamint Basins, southeastern California: U. S. Geol. Survey Bull. 580, pp. 269-270, 1914.

precipitation was greater than at present, and in turn it overflowed to the east, forming a large lake where the playa of Searles Lake now is. (See pp. 110–111.)

Well logs obtained by the writer show the beds deposited in this Pleistocene lake were spread over a much larger area than the present playa of China Lake. Since they were deposited alluvial waste has been washed out over them from the west. Blue clay was found in a number of wells south and west of the playa. In well 98, in the SE. ¼ sec. 34, T. 26 S., R. 40 E. (fig. 4), it was reached at 73 feet and in well 99, in sec. 35, a quarter of a mile to the east, it was found at 40 feet. It was said to have been reached at a depth of about 260 feet in well 82, in the SW. ¼ sec. 19, T. 26 S., R. 40 E.; at a depth of about 220 feet in well 58, in the NW. ¼ sec. 11, T. 26 S., R. 39 E.; at a depth of 151 feet in well 26, in the SW. ¼ sec. 24, T. 25 S., R. 39 E.; and at 152 feet in well 19, near the center of the N. ½ sec. 18, T. 25 S., R. 40 E. Blue clay was also found in several other wells between China Dry Lake and the wells mentioned. In some wells beds of brown or gray clay were found. These beds may be continuous with the blue-clay beds. The blue-clay beds seem to play a notable part in the occurrence of ground water in the lower part of the valley, for they are relatively impervious, and in most wells where they were encountered no water-bearing beds were found beneath them. (See pp. 154–155, 163.)

COSO BASIN

The Coso drainage basin adjoins Indian Wells Valley on the northeast. It is separated from Indian Wells Valley by a low divide which, on the surface at least, is composed of alluvium. Although the surface drainage does not reach Indian Wells Valley, the ground water undoubtedly can move freely toward the south to the larger valley.

The drainage basin consists almost entirely of mountain slopes that culminate in peaks 6,000 to 8,000 feet above sea level. With the exception of a small area of granite in T. 22 S., R. 41 E., these mountains are all composed of volcanic rocks, probably mostly of Tertiary age but some of them apparently Pleistocene. Especially prominent is a large flow or series of flows which extends from Louisiana Butte, in the northeastern part of T. 22 S., R. 40 E., westward to the valley in which Coso Hot Springs are located. This valley drains southward to a playa in the southeast corner of T. 23 S., R. 39 E. According to descriptions by persons living in Indian Wells Valley, the playa is hard and smooth, without any alkali deposits like those on China Dry Lake, and the water table lies at a considerable depth below the surface.

The features of Coso Basin are significant in the consideration of conditions in Indian Wells Valley only in so far as the basin contributes ground water to the supply of the main valley. (See p. 153.) So far as is known no farming is done in the basin.

ROSE VALLEY

Rose Valley adjoins the extreme northwest corner of Indian Wells Valley. It is connected with Indian Wells Valley by a canyon south of Little Lake station, through which, during the Pleistocene epoch, a river flowed from Owens Lake. At present the surface drainage of Rose Valley apparently is shut off from Indian Wells Valley by low divides formed by alluvial cones built out from the Sierra Nevada. One of these cones is about 5 miles south of Little Lake. A small "dry lake" lies about 5 miles north of Little Lake and is apparently due to the deposition of alluvial material from the mountains which has blocked the drainage from the north. The ground water underlying Rose Valley, like that of the Coso Basin, probably has access to Indian Wells Valley. At Little Lake lava and granite lie close to the surface, and some of the water is brought to the surface in springs. In January, 1920, a small lake existed a short distance north of the station and a much larger area was covered with salt grass and other vegetation that indicates shallow ground water.

Several wells have been drilled in the valley, but the depth to ground water is great, except perhaps near Little Lake station, and in 1919 no crops were raised.

DRAINAGE AREA

The drainage areas of the basins that may contribute to the ground-water supply of Indian Wells Valley are summarized in the following table. The areas are classified into mountains, which make the greatest contribution to the ground-water supply; valley lands that are available for agriculture; and areas that are not fit for agriculture because the ground is too rough, or the soil contains alkali, or for other reasons. The areas are obtained from planimeter measurements, but the boundaries between the lands of the different classes are only approximate; in some places they are determined from field data but in most places are determined from the maps.

Areas of drainage basins contributing to ground-water supply of Indian Wells Valley, in square miles

Drainage basin	Mountains	Valley lands		Total
		Suitable for agriculture	Not suitable for agriculture	
Indian Wells Valley	365	170	220	755
Coso Basin	235	10	30	275
Rose Valley	150	25		175
	750	205	250	1,205

RUN-OFF

There are no streams in Indian Wells Valley that maintain a perennial flow of sufficient size to be useful for irrigation. It is said that water runs throughout the year in the upper part of some of the canyons of the Sierra Nevada, but only after heavy rains does any water run out onto the alluvial slope, where it may percolate into the ground and become a part of the ground water.

Lee [4] estimated the run-off from the mountains in Indian Wells Valley alone as about 27,000 acre-feet a year. He did not give estimates for the run-off from the mountains around Rose Valley or in the Coso Basin. He estimated the annual run-off from the Sierra Nevada to be about 100 acre-feet per square mile, and he apparently allowed about half as much for the mountains on the east side of the valley. The Rose Valley basin contains about 50 square miles in the Sierra Nevada which, on the average, rises higher than the Sierra west of Indian Wells Valley and from which the run-off would be fully as great. The mountains on the east side of Rose Valley, about 100 square miles in area, are so situated that they doubtless yield as much as those on the east side of Indian Wells Valley. The total run-off into Rose Valley is therefore estimated to be about 10,000 acre-feet. The mountains bordering the Coso Basin cover about 235 square miles, and the run-off is probably fully as great as in the same range farther south, so that the total run-off in this area is estimated at about 12,000 acre-feet. The total run-off from the drainage basin tributary to Rose Valley and the Coso Basin is thus nearly equal to that of the drainage basin of Indian Wells Valley. These estimates are based on inadequate data, but it is probable that the total run-off from the mountain areas of all three basins does not exceed 50,000 acre-feet a year.

GROUND WATER

SOURCE

The ground-water supply of Indian Wells Valley comes principally from the precipitation in the mountains that are tributary to the valley itself, but some of it comes from the mountains tributary to Rose Valley and the Coso Basin. The storm run-off from the mountains is concentrated into streams in the mountain canyons, but when the streams emerge on the alluvial slopes they spread out, and much of the water is absorbed by the porous gravel. In the heaviest floods some of the water may run out on the playas and evaporate, but usually most of it is absorbed before it reaches the playas. Some of the water that percolates below the surface evaporates before it reaches the water table. The precipitation in the valleys is so much less than

[4] Lee, C. H., op. cit., p. 409.

in the mountains and it is distributed over so great an area that the quantity added to the ground-water reservoir from this source is small. The greatest contribution to the ground-water reservoir in Indian Wells Valley comes from the Sierra Nevada.

Some ground water reaches Indian Wells Valley from Rose Valley and more from the Coso Basin. As shown by Lee, most of the water that reaches the water table in Rose Valley emerges in a large spring near Little Lake or evaporates from a ciénaga or marshy area in that locality. The writer did not visit the playa in the Coso Basin, in the southeastern part of T. 23 S., R. 39 E., but information obtained by inquiry from ranchers and others indicates that the water table is not near enough to the surface there to discharge water by upward capillary movement and evaporation. A well dug by a cattleman near this playa is said to have reached a depth of nearly 100 feet without striking water, although the bottom was moist. It is reported that lava rock was encountered at the bottom. J. E. Blackburn, of the United States Geological Survey, who made the topographic map of this region and several other persons informed the writer that the surface of the playa is smooth and hard, except perhaps after heavy rains, and that there is no alkali crust on or around it. According to their statements the playa forms a distinct contrast to China Dry Lake, which is characterized by extensive accumulations of alkali formed by evaporation where the water table is close to the surface. Generally in the Mohave Desert region, where the smooth, hard type of playa is found, the water table is so far below the surface that there is no discharge by upward capillary movement and evaporation. The rocks of the mountains in the Coso Basin are nearly all of volcanic origin. The large mountain east of Coso Hot Springs, which culminates in Louisiana Butte, when viewed from the springs appears to be an immense lava flow or series of flows of comparatively recent age. Studies of ground-water conditions in the lava-covered regions of the Northwest indicate that lava rocks are capable of absorbing much of the precipitation through large joints and crevices. The water thus absorbed moves readily through the rocks. Probably a larger proportion of the precipitation therefore percolates directly into the rocks of the mountains in the Coso Basin than in Indian Wells Valley. On the other hand, a relatively larger proportion of the run-off from the mountains is doubtless lost by evaporation in the Coso Basin than in Indian Wells Valley, for the absorption area of alluvial materials is much smaller, and the flood waters may readily reach the playa in the southeastern part of T. 23 S., R. 39 E., where they evaporate.

According to data given by Lee the water table stands higher in the northern part of Indian Wells Valley than in the southern part. The playa in the southwestern part of T. 24 S., R. 40 E., is reported to have alkali crust on it, apparently because the water table is close to the surface. Data given by Lee [5] indicate that the water table lies closer to the surface at the north end of China Dry Lake than at the south end. This is especially true in an arm of the playa near the Paxton ranch, in sec. 35, T. 24 S., R. 40 E., which is shown on the Searles Lake topographic map as separated from the main playa. All these facts suggest that there is a contribution from the Coso Basin to the ground-water reservoir of the main valley.

The materials from which wells obtain water in Indian Wells Valley are principally sand and gravel. These are interbedded with clay, which yields practically no water. The yield of the wells to a certain extent is proportional to the thickness of sand and gravel that is penetrated below the water level. The gravel beds range in thickness from a few inches to many feet, and they are rather irregularly distributed. As a result it is impossible to predict the depth at which gravel beds will be encountered, or their thickness over any large area. The wells are nearly all of the California stovepipe type, which are put down with solid casing. After the drilling is completed the casing is perforated in places where water-bearing sand and gravel were penetrated. Because of the variable character of the water-bearing materials it is important that a careful log be kept of the materials penetrated, so that the casing may be perforated in such a way as to recover all the water possible.

Although the water-bearing materials are irregularly distributed in most of the valley they are relatively abundant, and most wells yield fairly large quantities of water. However, as mentioned elsewhere, in the lowest part of the valley there are extensive deposits of blue clay which begin near the surface and extend to a considerable depth and which yield little or no water. (See pp. 150, 163.)

The following logs of typical wells show the character of the materials penetrated:

Records of wells in Indian Wells Valley

Mr. Cline (No. 19, fig. 4), N. ½ sec. 18, T. 25 S., R. 40 E. Mount Diablo meridian

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Not reported	22	22	Gravel	7	152
Gravel, with water	20	42	Blue clay	8	160
Gray clay	103	145			

W. S. Main (No. 34, fig. 4), NE. ¼ sec. 35, T. 25 S., R. 38 E. Mount Diablo meridian

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Hard clay, with layers of loose white sand	202	202	Good water-bearing gravel	14	250
Clay with layers of water sand	30	232	Good water-bearing gravel with thin layers of soft clay	51	301
Hard red clay	4	236			

Casing perforated from 200 to 298 feet. Depth to water level in well, 185 feet.

[5] Lee, C. H., op. cit., pp. 423-426, pl. 5.

Records of wells in Indian Wells Valley—Continued

C. H. Guerin (No. 64, fig. 4), SW. ¼ sec. 7, T. 26 S., R. 40 E. Mount Diablo meridian

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay	10	10	"Hole"	3	81
Sand	8	18	Sand	4	85
Clay	6	24	Clay and cemented gravel	10	85
Fine sand	6	30	Clay, fine streaks of gravel	6	101
Coarse sand	2	32	Blue sand and muck	8	109
Fine sand	4	36	Muck	4	113
Sand with streaks of clay	6	42	Blue clay and cemented gravel	2	115
Sand	20	62	Good gravel	9	124
Sand and clay	2	64	Slush and blue clay	26	150
Fine sand, pocket near old well	10	74	Blue clay	10	160
Clay	4	78			

This well was drilled only 2½ feet from an older one which was abandoned when a part of a pump became stuck in it so that it could not be used.

G. W. Roe (No. 78, fig. 4), NW. ¼ sec. 15, T. 26 S., R. 40 E. Mount Diablo meridian

Like surface soil	60	60	Blue clay with streaks of coarse sand	9	115
Sand	24	84	Very coarse sand and fine gravel	5	120
Yellowish white substance like chalk	7	91	Clay, mostly blue, except for a bed of black clay between 125 and 170 feet	230	350
Yellowish blue clay	9	100			
Coarse gravel	6	106			

Depth to water level in well, 60.6 feet. Much sand was pumped from this well, and a large hole, 20 feet in diameter and 16 feet deep, was formed by caving. As caving continued with further pumping the well was abandoned. In a well 600 feet south of this one the pump lost its suction in a few minutes when it was operated at a rate of 540 gallons a minute.

J. L. Talbot (No. 98, fig. 4), SE. ¼ sec. 34, T. 26 S., R. 40 E. Mount Diablo meridian

Surface soil	3	3	Blue clay	4	77
Clay, except for a little sand and gravel at 35 feet	57	60	Sand, with streaks of hard sandstone	53	130
Water-bearing gravel	13	73	Clay, with pockets of sand	50	180

Depth to water, 60 feet.

The sand from 77 to 130 feet in well 98 contained numerous mollusk shells, which were identified by W. H. Dall as including *Valvata utahensis* Call, *Amnicola porata* Say, *A. dalli* Call, and a broken valve of a *Sphaerium* resembling *S. striatinum* Lamarck. Dall states that the fossils are of upper Bonneville age and identical with those of that stage in Great Salt Lake Valley. *Valvata utahensis* and *Amnicola dalli* were found by Gale along the shore line of the ancient lake that once existed in Panamint Valley, the history of which was related to that of the lake in Indian Wells Valley, in which the shells described above were deposited.[6]

DEPTH TO WATER

A number of wells were measured by the writer, and information was obtained from drillers and others in regard to wells in parts of the valley which were not visited. The location of these wells is shown in Figure 4, and data in regard to the depth to the water level in them is given in the accompanying table.

[6] Gale, H. S., op. cit., p. 317.

Records of wells in Indian Wells Valley, Calif.[a]

No. on Fig. 4	Location				Owner or name	Depth of well (feet)	Diameter of well (inches)	Water level			Method of lift	Yield when pumped (gallons per minute)	Remarks
	Quarter	Sec.	T. S.	R. E.				Depth below surface or reference point (feet)	Reference point for measurement	Date of measurement			
1	NW.?	25?	24	39	H. F. W. Schuette	32		21			Jack pump	20	Used for stock only.
2	NW	33	24	39	do	78	6	68			Jack pump and windmill.	20	Used for domestic purposes and stock only.
3	SW.?	33?	24	39		*170	10	*60.5	Top of casing, 1 foot above surface.	Feb. 3, 1920	Hand pump		
4	SW.?	34?	24	39		(b)		(b)			Vertical centrifugal.		Pump pit 35 feet deep; dry. Water level must be less than 60 feet.
5	NW	2	25	39		*220.4	12	*39.0	Top of casing 2.5 feet above surface.	Feb. 3, 1920	None		Probably the same as No. 6 in Lee's report.
6	SW	2	25	39	—— Boynton	(b)		*35.6	Bottom of 6 by 10 inch cross timber level with surface.	do	Vertical centrifugal.		
7	SW	1	25	39	—— Boynton	*39.0	6½	*24.5	Top of casing 1.7 feet above surface.	do	None		Salt grass growing around the well. A larger well near by could not be measured.
8a	NW.?	4?	25	39	William Cahill?	*137.5	12	*68.0	Top of 4 by 4 inch timber over well, 4 inches above surface.	do	do		
8	SW	4	25	39	William Cahill	*145	12	*79.0	Top of casing 1 foot above surface.	do	do		Lava boulders struck in this well.
•9	SE	12	25	38	Roy Jones	337	24	132			Deep-well lift	450?	Well 1 in Lee's report, originally owned by S. R. Smith. Drawdown reported to be 8 to 10 feet.
9a	SW.?	7	25	39		(b)		99			do		Information furnished by H. F. W. Schuette.
•10	NW	18	25	39	S. R. Smith	312	24	97					Well 2 in Lee's report.
11	NE	8	25	39	H. F. W. Schuette	*92.7	(d)	*73.8	Top of curb level with surface.	Feb. 3, 1920	Jack pump	24	Well 4 in Lee's report. Struck boulders at bottom.
•12	NE	9	25	39			7	61.1			Hand pump		Well 5 in Lee's report.
13	NE	10	25	39	—— Hubbard	180±	14				Vertical centrifugal.	810	Well contained much gravel.

14	S.½	10	25	39	—— Johnson	175						900	Reported to have pumped 900 gallons a minute.
15	NW	15	25	39	Mrs. M. J. Rodecker.	150	12	44			Deep-well turbine	810	Pump set at 60 feet with 30 feet of suction pipe below it.
[c] 16	NW	7	25	40			3	24					Well 8 in Lee's report.
[c] 17	SE	12	25	39	—— Wachob			16					Well 21 in Lee's report.
18	SW	7	25	40	—— Lawrence	148	12	16			None	[e] 540	Gray clay, 16 to 115 feet, gravel 115 to 140 feet; gray and blue clay, 140–148 feet.
19	N.½	18	25	40	——Cline	160	12	22			do	[e] 540	See p. 154 for log of well.
[c] 20	N.½	13	25	39	A. L. Pitzer		12	20					Well 22 in Lee's report.
[c] 21	W. ½	14	25	39	W. M. Randall	200		33.4					Well 24 in Lee's report.
[c] 22	N. ½	24	25	39	E. S. Pitzer	260	12	21.7					Well 23 in Lee's report.
[c] 23	NW	19	25	39	S. R. Smith		24	75					Well 3 in Lee's report.
[c] 24	SW	20	25	39	Mrs. J. E. Edwards	50	60	37.6					Well 12 in Lee's report.
25	SW	21	25	39	O. G. Siebenthal	175	12	32			Vertical centrifugal.	315	
26	SW	24	25	39	J. C. Coleman	151	12	24					Well penetrated 59 feet of good gravel. Blue clay struck at 151 feet.
[c] 27	NE	27	25	39	O. E. Weisel	25	6	23.1					Well 25 in Lee's report.
[c] 28	NE	30	25	39	Mrs. V. Lovenguth	40	54 x 42	31.2					Well 10 in Lee's report.
[c] 29	SW	29	25	39	R. B. Clapp	206	12	30					Well 11 in Lee's report.
30	SW	27	25	39	V. L. Carr	100	10	28				135	Well mostly in quicksand and only 10 feet of casing is perforated. Originally yielded 270 gallons a minute with only 5-foot drawdown. Now equipped with smaller pump.
31	SW	31	25	40	Chester Smith			5					Salt grass reported to grow near the well.
32	SE	28	25	39	Horace Bellows	196		30.6					Well 27 in Lee's report.
33	SW	25	25	38	R. C. Schellhouse	258		168?			Hand pump		Good water-bearing gravel between 212 and 232 feet and casing perforated only there.
34	NE	35	25	38	W. S. Main	301	16	185			None		See p. 154 for log of well.
35	SW	35	25	38	F. H. Heaton	300	12	248			Hand pump		
[c] 36	NE	31	25	39	C. B. Walker		36	57.1					Well 18 in Lee's report.
[c] 37	S. ½	31	25	39	C. C. Paxton		7	72					Well 19 in Lee's report.
38	NE	35	25	39	J. W. Calloway	*34.6	48	([b])	Cover, level with surface.	Jan. 27, 1920			Same as well 16 in Lee's report, which gives depth to water as 34.4 feet.
39	SW	35	25	39	J. D. Calloway	127	12	56			Deep-well lift	180	Cylinder set at 60 feet. Used to irrigate 8 acres of alfalfa.

[a] An asterisk (*) indicates measurements by the writer. All other data, unless otherwise stated, were reported by the owner, driller, or other person. Measurements of the depth of the well and depth to water by the writer were made from a definite reference point, such as the top of the well casing. The position of this reference point with respect to the surface is given in the table, and the measurement given should be corrected accordingly to obtain the true measurement with respect to the surface of the ground.
[b] Well could not be measured.
[c] Data taken from Lee, C. H., Ground-water resources of Indian Wells Valley, Calif.: California State Conservation Com. Rept., 1913.
[d] 60 by 60 to 74 feet; 24 from 74 feet to bottom.
[e] Well not equipped with pump. Yield estimated from test at completion of drilling.

Records of wells in Indian Wells Valley, Calif.—Continued

No. on Fig. 4	Location				Owner or name	Depth of well (feet)	Diameter of well (inches)	Water level			Method of lift	Yield when pumped (gallons per minute)	Remarks
	Quarter	Sec.	T. S.	R. E.				Depth below surface or reference point (feet)	Reference point for measurement	Date of measurement			
40	NW	1	26	38	E. C. Siebenthal	120	12	95					
41	S. ½	2	26	38	Jesse J. Walker	310	12	215			Jack pump	20	
• 42	SW	6	26	39	E. C. Siebenthal	107	6	110					Well 20 in Lee's report.
43	NE	4	26	39	—— Thompson		12	70			Vertical centrifugal.	630	Well 14 in Lee's report, formerly owned by D. N. Shanks.
44	NW	2	26	39	W. H. Calloway	*115	14	*64.1	Top of 2 by 4 inch timber on top of casing 1.2 feet above surface.	Jan. 27, 1920	Windmill		
45	NW	1	26	39	—— Galbreath	250		65				450	Drawdown about 20 feet. Blue clay struck at about 110 feet.
46	NW	6	26	40	—— Schofield?	*46.3	60	*39.6	Top of cement curb, 5 feet above surface.	Jan. 27, 1920	Hand pump and windmill.		
47	SW	6	26	40	—— E. R. Youndt	102	24	52				135	Penetrated 48 feet of gravel. Used to irrigate 11 acres of alfalfa and 25 to 30 acres of apple trees. Reservoir used.
48	SW	5	26	40		*29.2		(b)		Jan. 29, 1920			
49	SE	5	26	40	Mrs. T. H. Toombs	86	12	*31.7	Ground surface	do			
50	SW	4	26	40	—— Parks	116		18				250	Drawdown 10 to 12 feet. Well penetrated gravel between 44 and 54 feet.
51	SW	4	26	40		16 dry.							
52	SW	3	26	40	—— Smales								
53	SW. ?	1?	26	40			4	*5.1	Top of casing, 2.2 feet above surface.	Jan. 30, 1920			Probably a test hole for potash.
54	NE	12?	26	40				*5.7	Top of casing, 2.5 feet above surface.	do			Do.
55	NW	7?	26	41				*13.3	Ground surface	Jan. 30, 1920			Near east edge of playa, water salty.
56	NW. ?	13	26	40		[b] 10		(d)		do			Probably a test hole for potash.
• 57	S. ½	10	26	39	E. B. Morse	300		126					Well 17 in Lee's report.

58	NW	11	26	39	H. N. Androus	220	24, 12	*97.7	Hole in top of pump base, 3 feet below surface.	Jan. 27, 1920	Deep-well lift	495	Cylinder set at 113 feet with 17 feet of suction pipe below it. Well penetrated 56 feet of gravel. Used to irrigate 36 acres of fruit trees and 4 acres of alfalfa.
59	NE	11	26	39	F. H. Hill	225							Struck blue clay at 95 feet. Not enough water for drilling.
60	SE	11	26	39	W. B. Adams								Reported to have pumped 40 miner's inches (360 gallons a minute).
61	NW	12	26	39	Charles Biggen	200						90	Blue clay struck at about 110 feet. Well penetrated only about 10 feet of gravel.
62	SW	12	26	39									Could not measure. No data obtained.
63	N. ½	7	26	40	C. E. Smith							180	Hole sanded up and yield is small.
64	SW	7	26	40	C. W. Guerin	500 160	12 14	80			Deep-well lift	180	See p. 155 for log of well. Well used with 225,000 gallon reservoir to irrigate 47 acres of fruit trees.
65	NE	68	26	40	M. J. Moore	208		*31.0	Top of curb, level with surface.	Jan. 29, 1920	None	180	Three wells pumped together give 540 gallons a minute.
66	NE	9	26	40	J. B. Barber	167	12	32					Blue clay at 100 feet with quicksand below. Pump set at 30 feet with 35 feet of suction pipe. Suction broke when pumping 360 gallons a minute.
67	NW	10	26	40	J. B. Brink	*143	12	*26	Top of curb, 2 feet below surface.	Jan. 29, 1920	Horizontal centrifugal.	150	Water is of poor quality. See analysis 3, p. 165.
68	SW.?	15	26	39		*278		*160.0	Top of cover, level with surface.	Jan. 27, 1920	None		Dug 160 feet, with a drilled hole below that.
69	SW	14	26	39									Abandoned well; could not measure.
70	NW	13	26	39		*115	12	*110	Top of casing, 1 foot above surface.	Jan. 27, 1920			Hole is crooked.
72	SW.?	13	26	39		*188.5	10	*131.5	Top of casing 2 feet above surface.	Jan. 27, 1920	None		Hole is crooked.
73	NW	18	26	40		244	12	102			Deep-well turbine	450	Small water-bearing layer at 102 feet; good water-bearing gravel 160-200 feet; blue clay 200-244 feet.
74	NW	18	26	40	V. Hetzel	750	12						Struck blue clay at 92 feet, which extended to the bottom. Very little water.

[b] Well could not be measured.
[c] Data taken from Lee, C. H., Ground-water resources of Indian Wells Valley, Calif.: California State Conservation Com. Rept., 1913.
[d] 60 by 60 to 74 feet; 24 from 74 feet to bottom.

Records of wells in Indian Wells Valley, Calif.

No. on Fig. 4	Location				Owner or name	Depth of well (feet)	Diameter of well (inches)	Water level			Method of lift	Yield when pumped (gallons per minute)	Remarks
	Quarter	Sec.	T. S.	R. E.				Depth below surface or reference point (feet)	Reference point for measurement	Date of measurement			
76	NW	17	26	40	G. F. Guy	210		82?					All white or blue clay below 136 feet.
77	NW	15	26	40	G. W. Roe	350	12	50					Yield small, water of poor quality.
78	NW	15	26	40	do	*230	12	*60.6	Top of casing 1.6 feet above surface.		None		See p. 155 for log of well.
[c] 79	S. ½	24	26	38	L. G. Fairbanks			280					Well 32 in Lee's report.
80	NW	23	26	39	R. F. Berry		12	*165	Top of casing 2 feet above surface.	Jan. 27, 1920	None		More than 307 feet deep, the length of string used to measure the well.
[c] 81	W. ½	24	26	39	Doctor Johnson	310	14	148					Well 29 in Lee's report.
82	SW	19	26	40	S. A. Arbuthnot et al.	320	14	128			Deep-well turbine	*630	Well 34 in Lee's report. Well owned jointly by 4 persons. In 1919 used to irrigate two tracts, 85 acres of fruit trees and 11 acres of alfalfa.
83	SW	20	26	40							do		Could not measure; about 20 acres of fruit trees.
84	NE	20	26	40	—— Fritz	{ 112 / 120	}						Two wells drilled to blue clay. Practically no water in either.
85	E. ½	21	26	40	—— Wire	?	12				Deep-well lift	45-100	Quickly pumped dry with Layne & Bowler pump. With deep-well lift pumped only 5 to 10 miner's inches.
[c] 86	W. ½	22	26	40	Frank Wire		12	64					Well 36 in Lee's report.
87	SE. ?	22	26	40		*75	36	*56.4	Top of platform level with surface.	Jan. 31, 1920	Windmill		Dug to water, with 6-inch hole drilled below that.
88	SW	23	26	40	M. C. Weimer			*47.0	do	do	Jack pump	10	Dug well about 50 feet deep. Easily pumped dry.
[c] 89	NE	30	26	40	Inyokern Co.	750		225			Deep-well lift		Well 31 in Lee's report.
90	NE	29	26	40	G. E. Walhizer	427	13	231			do	225	In 1919 used to irrigate 30 acres of fruit trees and 3 acres of alfalfa.
91	SW	31	26	39	Mrs. C. J. Walhizer	*293		(f)	Top of casing, 1.5 feet above surface.	Feb. 2, 1920	None		Said to originally have been 339 feet deep.

92	NW	26	26	39	H. E. Joos	393	16	186			Deep-well lift		Perforated from 208 feet to bottom. Drawdown reported to be only 4 feet. In 1919 used to irrigate 85 acres of fruit trees and 5 acres of alfalfa and garden truck.
93	NW	25	26	39	J. F. Ulery	310	24, 12	160			do	400	Pump bowls probably set at 190 feet; 20 feet of suction. In 1919 used to irrigate 30 acres of fruit trees, 9 acres of alfalfa, 7 acres of cotton, and 12 acres of milo maize.
[c] 94	N. ½	31	26	40	Lindsey Bros.		24	164					Well 35 in Lee's report.
95	NW	28	26	40	—— Wright							180	Shells found in this well. Blue clay at bottom.
[c] 96	SW	28	26	40	C. D. Williamson	225	12	93					Well 37 in Lee's report.
97	SW	33	26	40	—— Robertson		12	105			Deep-well turbine	550?	Struck blue clay but got gravel below it. Reported to pump 60 miner's inches.
98	SE	34	26	40	J. L. Talbot	180	12	*59.6	Top of frame level with surface.	Jan. 31, 1920	None		See log, p. 155.
99	SW	35	26	40	J. R. Nichols	*63		55	Top of platform	do	Hand pump		Dug well. Blue clay from 40 to 64 feet; gravel at 64 feet in bore holes in bottom of well.
100	SW. ?	31?	26	41	—— Englesman	170		([f])					Dug well.
101	NW	1?	27	40	F. Lapp			75					Do.
102	SW	1	27	40	W. M. Bullock		14	95			None		
103	SW	2	27	40	—— Early	150?	10	80			Plunger	135	
104	NE	10	27	40	G. W. Bowman	190	24	87			Deep-well turbine	1,125	Pump bowls set at 120 feet with 35 feet of suction pipe. Water-bearing gravel and sand reported from 80 feet to bottom of well and casing all perforated below 87 feet. Original yield 1,350 gallons a minute, but it decreased. Used to irrigate 47 acres of alfalfa and 10 acres of melons.
105	NW	10	27	40	Mrs. G. W. Bowman.			95					
106	NW	9	27	40	—— Ripley			96					
107	NW. ?	9	27	39		*356	12	*341	Top of casing 1 foot above surface.	Jan. 26, 1920	None		
108	SW. ?	16?	27	39	Oil well	([g])		([g])					Reported to have been drilled to a depth of nearly 2,100 feet. Depth to water said to be 408 feet.

[c] Data taken from Lee, C. H., Ground-water resources of Indian Wells Valley, Calif.: California State Conservation Comm. Rept., 1913.
[f] Dry.
[g] See remarks.

In a drill hole in China Dry Lake, located, as nearly as could be determined, in the NE. ¼ sec. 12, T. 26 S., R. 40 E., the depth to water below the surface was 3 feet in January, 1920. The depth to water in well 78 (fig. 4), near the southwest corner of the NW. ¼ sec. 15, T. 26 S., R. 40 E., was 59 feet below the surface. At well 92, in the southwest corner of the NW. ¼ sec. 26, T. 26 S., R. 39 E., the depth to water is about 186 feet, and at Inyokern, according to Lee's report, it is 225 feet. Well 91, in the SW. ¼ sec. 31, T. 26 S., R. 39 E., measured 290 feet to the bottom and was dry. This well is said originally to have been 339 feet deep, and the depth to water in it is said to have been 290 feet. The greatest depth to water measured by the writer was 341 feet, which was found in well 107, located approximately in the NW. ¼ sec. 9, T. 27 S., R. 39 E. It is reported that the depth to water was 408 feet in a well (No. 108) drilled for oil to a depth of 2,100 feet at Terese siding.

Although the water table is nearly level, it rises slightly toward the mountains south, southwest, west, and northwest of the valley. As the surface slope is much greater than the slope of the water table, the depth to water in different parts of the valley differs largely according to the surface altitude. In general, the depth to water is less than 25 feet wherever the surface altitude is less than 2,200 feet above sea level. At higher altitudes it gradually increases until the depth to water is about 100 feet where the altitude is 2,300 feet above sea level, a little less than 200 feet where the altitude is 2,400 feet, and less than 300 feet where the altitude is 2,500 feet. There are exceptions to this general rule. Thus, in the northern part of T. 27 S., R. 40 E., the water table seems to rise somewhat more rapidly than in most of the valley, and the depth to water is only about 80 feet at an altitude of 2,300 feet, and only about 100 feet or a little more at an altitude of 2,400 feet. (See wells 101 to 106, p. 161, and fig. 4.) On the other hand, well 100, not far away, in sec. 31, T. 26 S., R. 41 E., at an altitude between 2,300 and 2,400 feet above sea level, is said not to have reached water at a depth of 170 feet. The reasons for these departures from the normal conditions in this part of the valley are not known. In the northern part of T. 25 S. and the eastern part of T. 24 S., R. 39 E., the depth to water is less than in most places in the valley at similar altitudes, and the water table appears to rise more rapidly. This may be in part due to conditions related to the lava flow, which lies a little farther north and which may produce a "perched" water table—that is, a water table held above the main water table by an intervening impervious bed. However, it also suggests that ground water is entering the region from Rose Valley and building up the water table in this locality. A large area of relatively low land extends for nearly 10 miles west from China Dry Lake to a point near Muerto (Leliter) and Brown, and in this area the depth to water is less than 100 feet. The land rises rapidly from the southwest end of the valley, and the zone in which the depth to water is less than 100 feet is much narrower.

YIELD OF WELLS

As shown in the table on pages 156–161, the yield of wells in the valley, as reported by the owners, ranges from 20 to 1,125 gallons a minute. Of 23 wells for which data were obtained in regard to yield, only 7 yielded less than 100 gallons a minute; 11 between 100 and 249 gallons, 7 between 250 and 499 gallons, 5 between 500 and 749 gallons, 3 between 750 and 999 gallons, and only 1 more than 1,000 gallons. It is evident that considerable differences in yield may be expected in different parts of the valley. However, although large yields are not common, the reported yield of more than half of the wells was sufficient to be used for irrigation.

Three of the wells that yield less than 100 gallons a minute are situated in the northwestern part of the valley, near the lava flow shown on Figure 4, and the beds penetrated seem to be relatively poor water-bearing material. Several other wells with low yields are situated in the lowest part of the valley, where there is much clay and little sand and gravel, as described below.

The silt and clay beds that underlie the playas and extend westward for some distance beneath the coarser alluvium are nearly impervious and do not yield much water. Near the playas, where they are reached above or only a few feet below the water table, very little water is obtained. In fact, if a good supply of water has not been obtained when the characteristic blue clay is reached the drillers generally consider it is not worth while to drill deeper. Farther away from the playas the wells either do not encounter the blue clay or sufficient water is obtained before it is reached.

Low yields because of the presence of the blue clay near the surface with little sand or gravel above it have been reported especially on the southwest side of China Dry Lake, in the north half of T. 26 S., R. 40 E. Among wells reported to have supplies insufficient for irrigation or near the minimum limit for that purpose are Nos. 52, 65, 66, 67, 77, 78 in the table on pages 158–159 and Figure 4. Data are lacking in regard to other wells near those mentioned, but the fact that none of the wells were in use suggests that the supply was too small to use. However, the soil near some of these wells is not very good, and that fact may in part explain the absence of irrigation. In a few wells thin layers of blue clay were encountered and good water-bearing beds were found below the clay. Such wells are apparently located near the edge of the lake deposits, where these deposits interfinger with the alluvium from the mountains. Possibly in some wells near the outer edge of the area in which the yield has been insufficient for irrigation a greater supply might be obtained by drilling deeper in the expectation of completely penetrating the lake beds. No wells have been drilled deep enough to determine whether the lake beds extend downward to the bedrock floor of the valley. A well in the NW. ¼ sec. 15, T. 26 S., R. 40 E., penetrated clay, mostly blue, from a depth of 120 to 350 feet and did not encounter any water below 120 feet.

QUANTITY OF WATER AVAILABLE

It is estimated (p. 152) that the total run-off of the three drainage basins that contribute to the ground-water supply of the valley is not more than 50,000 acre-feet. Not all the run-off is added to the ground-water reservoir, and not all that is added to it can be recovered through wells. The principal loss from the ground-water supply occurs in the lower part of the valley, where the ground water rises nearly to the surface and evaporates or is transpired by plants. Some loss may occur by seepage through the low divide at the former outlet of the lake which at one time existed in the valley. The principal feature that suggests this possibility is an alkali-covered playa in Salt Wells Valley, which lies a few miles east of the south end of China Dry Lake. Lee[7] estimated that the total discharge from the water table in Indian Wells Valley by evaporation and transpiration is about 32,000 acre-feet annually. He believed, however, that of this quantity only about 11,000 acre-feet could be recovered from wells.

No evidence was obtained that the water table was appreciably lower in 1919 than it was when Lee made his investigation in 1912, although some exceptionally dry years occurred in the intervening period. A number of wells that are listed in Lee's report were measured by the writer, and the depth to water was found to be practically the same. The wells were measured by Lee in September and October and by the writer in the later part of January. Most of the wells in the valley were measured in the period between April 15 and May 28, 1921, by G. V. Rhodes, of the California Division of Water Rights, and the data were kindly furnished to the writer. In most of the wells for which comparative data are available, the difference in the water level at that time and when the writer made his measurements was less than a foot. This difference is not significant, because where wells are pumped for irrigation the seasonal fluctuation of the water table is usually several feet.

If the water table is lowered by further pumping, the loss by evaporation will be decreased, and the quantity now wasted in that way can be used for irrigation. If the ground-water supply of the

[7] Lee, C. H., op. cit., p. 44.

valley is to be used to the greatest advantage some lowering of the water table is not only to be expected but is desirable. So much water may be pumped, however, that the draft will exceed the supply and the lowering will be too great.

QUALITY OF WATER

Samples of water were collected from four wells and analyzed in the water resources laboratory of the Geological Survey. The results are given in the accompanying table.

The water in most of the valley is doubtless of fair or good quality for all purposes. Samples 2 and 4 came from typical wells. The mineral content of the water is moderate. They may be classed as good for domestic use, except that sample 4 is high in iron. They are fair for boilers and good for irrigation.

In the lower part of the valley, especially near the playas, the water is more highly mineralized. In some wells it has a distinct brackish taste and is unsuitable for domestic use. If used for irrigation, it would deposit considerable alkali on the land unless the under drainage was very good. Sample 3 is from a well that is more than 1½ miles from China Dry Lake. It is high in sodium chloride, or common salt, and is bad for domestic purposes, poor for irrigation, and very bad for boilers. Most of the water nearer China Dry Lake is probably even more highly mineralized.

Sample 1, from well 2, shows a mineral content that is somewhat higher than may generally be expected so far from China Dry Lake. This is probably due to some condition not yet known but perhaps in some way results from the presence near by of a lava flow. The water is fairly good for domestic use, fair for irrigation, and very bad for boilers.

Analyses of ground water from Indian Wells Valley, Calif.

[Analyst, Margaret D. Foster. Parts per million]

	1	2	3	4
Silica (SiO_2)	42	35	31	42
Iron (Fe)	.13	.08	.09	3.7
Calcium (Ca)	33	30	4.4	37
Magnesium (Mg)	19	5.3	1.7	6.3
Sodium and potassium (NaK)[a]	178	40	768	38
Carbonate radicle (CO_3)	.0	.0	168	.0
Bicarbonate radicle (HCO_3)	281	121	333	128
Sulphate radicle (SO_4)	184	37	5.2	46
Chloride radicle (Cl)	88	32	799	32
Nitrate radicle (NO_3)	1.8	.66	Trace.	4.8
Total dissolved solids at 180° C	704	242	2,007	285
Date of collection	(b)	(c)	(d)	(e)

[a] Calculated. [b] Feb 3, 1920. [c] Jan. 28, 1920. [d] Jan. 29, 1920. [e] Jan. 26, 1920.

1. Well 2, fig. 4, and table on p. 156; H. F. W. Schuette, owner.
2. Well 64, fig. 4, and table on p. 159; C. W. Guerin, owner.
3. Well 67, fig. 4, and table on p. 159; J. B. Brink, owner.
4. Well 92, fig. 4, and table on p. 161; Harry E. Joos, owner.

IRRIGATION

In 1912, when Lee made his report, many wells had been drilled and many thousands of acres had been filed on under the homestead and desert-land laws, but in 1920 the valley was still in the pioneer stage of development. In 1916 12,520 acres had been patented in Indian Wells Valley, and entries had been made for 49,800 acres additional. Nevertheless, in 1919 only about 800 acres was under cultivation.

The writer visited nearly every ranch that was operated in 1919. Up to that time most of them had made no production on a large scale, because the principal products were apples and pears, and most of the trees were not old enough to bear fruit. Some data in regard to the production for 1920 were obtained by correspondence.

The acreage devoted to different crops on the ranches for which data were obtained was as follows: Fruit, 360 acres; alfalfa, 100 acres; milo maize, 12 acres; melons, 10 acres; broom corn, 8 acres; cotton, 7 acres; barley, 2 acres. Probably more than half of the orchard land was in apples, with pears second in rank and peaches third. In 1919 one man sold 8 tons of apples and 500 pounds of pears from 30 acres of 6-year-old trees. Another man sold 1,100 pounds of fruit from 44 acres of 8-year-old trees. In 1920 a third rancher sold 3 tons of fruit from 50 acres of 7-year-old trees. One or two men raised a little cotton, but as it had to be sent to Bakersfield for ginning, the marketing cost was high. Although some of the ranches had been established for 5 to 10 years or more only a small quantity of produce had been marketed. Most of the orchards that were irrigated ranged from 5 to 8 years old, but only small quantities of fruit were sold locally and at Randsburg and Trona. One man sold 11 carloads of alfalfa in 1919, and others sold much smaller amounts. According to information furnished by J. T. Saunders, general freight agent of the Southern Pacific Co., Los Angeles, 3 carloads of deciduous fruit was shipped from Inyokern in 1920, 5 in 1921, and 1 in 1922; 18 carloads of hay was shipped in 1919, 11 in 1921, and 21 in 1922; and 110 carloads of livestock was shipped in 1920, 98 in 1921, and 91 in 1922. However, much of the livestock shipped from Inyokern, and possibly some of the other products, are raised in the upper part of Kern Valley and are brought through Walker Pass.

Unfortunately, in the lower part of the valley, where the pumping lift is least, wells do not yield very much water, and conditions are not favorable for irrigation. Where water can be obtained in sufficient quantity for irrigation the depth to the water table is generally at least 30 feet, and it increases greatly upward on the alluvial slope. The area where the pumping lift is low enough to permit the profitable use of the water for alfalfa is only a narrow belt, and most of the irrigable land should be devoted to crops that yield higher returns. However, on one ranch where alfalfa was the principal crop the lift was 56 feet, and on another water was being pumped from a depth greater than 87 feet and probably nearly 100 feet. For small patches of alfalfa water was being lifted from as great a depth as 230 feet. The pumping lift for fruit was found to range from about 60 to more than 235 feet, but no place had been successful where the lift was over 200 feet.

The use of water as estimated by the writer for several ranches ranged from about half an acre-foot per acre for young fruit trees to 2.7 feet for 6-year-old trees and was mostly not more than 1.5 feet. As the trees grow older more water will be needed. The use of water for alfalfa ranged from 5 to 7 acre-feet per acre.

The wells in use in Indian Wells Valley are of the California double stovepipe type. They are drilled with sand-bucket rigs, and most of them are lined with two thicknesses of the so-called "stovepipe" casing in alternating 2-foot lengths, which is perforated after the drilling is finished. They are nearly all 12 inches or more in diameter, and several are 24 inches in diameter.

Of the pumping plants investigated 3 were equipped with deep-well turbine centrifugal pumps, 6 with deep-well reciprocating pumps, and 2 with small centrifugal pumps of ordinary types. The 3 deep-well turbine pumps furnished the largest yields. Three of the wells now equipped with deep-well lift pumps originally had deep-well turbine pumps, which were removed for different reasons, including inferior construction of the pump or insufficient water supply for the capacity of the pump. As the yield of most of the wells is relatively small, it is believed that the deep-well reciprocating pump will eventually be the type in common use.

Five of the pumping plants for which detailed data were obtained were operated by electricity and five by oil engines. In the valley as a whole, however, the oil-engine plants are in the majority. The high-voltage transmission line of the Southern Sierras Power Co. from its power plants in Owens Valley to San Bernardino passes through the west side of the valley. A substation is located half a mile east of Inyokern, and from it a branch line runs east along the section line 2 miles north of the south boundary of T. 26 S. to the potash plants on Searles Lake. In 1919 only those plants were operated by electricity that were within 2 or 3 miles of the branch line to Searles Lake.

Nearly all the orchards visited were equipped with concrete pipe lines of greater or less length for distribution of water to the rows. The distance that water was run down the rows from the pipe line ranged from 1,100 to 1,320 feet, but one man was putting in an additional line to cut the distance down to 660 feet. Owing to the length of the runs the trees at the ends of many of the rows showed evidence of a lack of water.

The yield of several wells was so small that it was necessary to use reservoirs in which to collect enough water to furnish streams of sufficient size to reach distant parts of the fields without undue loss from seepage and evaporation.

A number of pumping plants were not properly installed to obtain efficient results. In most wells for which data were obtained the pumps were set with the cylinders or bowls only a few feet below the static water level, and some suction pipe was added below the pumps. As a result the possible drawdown was small, and in some cases the yield was consequently not as great as was required by the capacity of the pumps. When the pumps were started they quickly broke suction, and the owners obtained the impression that the yield of the wells was very small. Some of these wells were abandoned and in others smaller pumps were installed.

A few wells were reported in which the original pumps broke down and pumps of a different make were substituted, generally of smaller capacity. The troubles may not have been due entirely to weakness in the old pumps, but partly to the fact that they had lost their suction and had run without load. A few wells were so crooked that pumps could not be installed in them.

PROSPECTS FOR FUTURE DEVELOPMENT

According to the estimates of Lee[8] the ground-water supply of Indian Wells Valley is sufficient to irrigate about 1,500 to 2,500 acres. With careful use of the water it may be possible to irrigate somewhat more. However, as about 100,000 acres of land would be suitable for agriculture if water were available it is obvious that only a small part of the arable land can be utilized unless some other water supply can be obtained. Any large supply would have to be obtained from some locality outside of the valley.

Prominent landowners have given serious attention to finding some suitable outside source of water and have enlisted the interest of both the United States Bureau of Reclamation and the division of water rights of the California Department of Public Works. In their investigation they have been joined by landowners in Fremont Valley, which adjoins Indian Wells Valley on the southwest.

One of the first plans considered was to bring water from Kern River through a tunnel in the Sierra Nevada, but this scheme was abandoned.[9] Subsequently projects were outlined to bring water from the valleys that lie on the east side of the Sierra Nevada north of Indian Wells Valley. Finding that nearer sources of water were not available because of prior rights attention was turned to the Mono Lake basin, which lies 200 miles north of Indian Wells Valley and is

[8] Lee, C. H., op. cit., p. 414.

[9] California Div. Water Rights Bienn. Rept., Sept. 1, 1922, to Sept. 1, 1924, p. 80, 1925.

separated from it by the long Owens Lake basin, from which a large part of the water supply for the city of Los Angeles is obtained.

The Mono Lake basin lies at altitudes of about 6,500 to 12,000 feet above sea level and has considerable precipitation. Its irrigable area is not great, and because of its great altitude the growing season is short. A large part of the run-off reaches Mono Lake, which is salty, and is wasted. It would be good economic policy to utilize this water if it could be carried to productive land at a reasonable cost.

A rather optimistic report by A. M. Strong [10] raised considerable enthusiasm. About the same time the United States Reclamation Service made studies of the proposed scheme.[11] In the report of its investigations the quantity of water available from Mono Basin is estimated to be about 142,000 acre-feet, or very much less than that estimated by Strong. As there is more land available for irrigation in Owens Valley than there is water for it, the report of the Reclamation Service does not give serious consideration to the project to carry water past this land to Indian Wells and Fremont Valleys. In 1922–23 an investigation of the Mono Basin project was made by the California Division of Water Rights, in cooperation with the Kern County board of supervisors and farm bureau.[12] The report on this investigation, by John T. Whistler, has not been published, but through the courtesy of Edward Hyatt, jr., chief of the division of water rights, the writer has been permitted to examine it in manuscript form. The estimate of quantity of water available from Mono Basin is not greatly different from that of Conklin. After fully analyzing both agricultural and power possibilities the report concludes that on account of the cost of bringing the water such a great distance, the project would not be economically feasible at that time, but that the margin of difference between estimated cost and estimated value was small and that conditions might easily arise within the next 5 or 10 years which would justify its more serious consideration.

As it appears that there is no likelihood of water being brought into Indian Wells Valley from any outside source in the near future, consideration may be given to the prospects of the valley if dependent solely on its ground-water resources. In 1919 the irrigated area was estimated not to exceed 800 acres. If the available supply is sufficient to irrigate only between 1,500 and 2,500 acres, as estimated by Lee (see p. 168), the acreage under cultivation may only be doubled or

[10] Hearings before the Committee on the Public Lands, House of Representatives, 66th Cong., 1st sess., on H. R. 406, a bill granting rights of way over certain lands for the water supply of Los Angeles, Calif., Oct. 31–Nov. 4, 1919, pp. 129–133.

[11] Brief mention of these studies is made in annual reports of the Reclamation Service as follows: Nineteenth, 1919–20, p. 414; Twentieth, 1920–21, pp. 400–401; Twenty-first, 1921–22, p. 120. Two reports on this investigation, prepared by Harold Conklin, have not been published, but the manuscripts have been consulted by the writer.

[12] California Div. Water Rights, op. cit., p. 80.

tripled. If it is sufficient for 3,500 to 4,000 acres the acreage may be increased somewhat more. It is evident, however, that only a small part of the total area of available land can be brought under cultivation. If pumpage is increased beyond the ultimate yield of the valley the effects of overdraft will be felt in increasing proportions. If so much land should be developed as to result in overdraft of the ground-water supply the final result will necessarily be the abandonment of enough acreage to bring the draft back within the limits of the safe yield of the water-bearing beds. In considering the problem of overdraft it may be pointed out that the approach of the danger point may not be obvious. The quantity of water stored in the alluvium is so great and it lies beneath so large an area that two or three times the annual safe yield of the ground-water reservoir might be pumped with a proportionately large area under irrigation, and the water level would be lowered only a few feet in several years. This would hardly be sufficient to cause great alarm, and yet the danger point would nevertheless be slowly approaching.

SEARLES AND SALT WELLS VALLEYS

GENERAL FEATURES

Searles Valley lies mostly in the northwest corner of San Bernardino County, but its north end is in Inyo County. The following description includes Salt Wells Valley, an area that is almost completely separated from Searles Valley.

The valley is traversed for almost its entire length by the Trona Railway, a short line that runs from Searles station, on the Owenyo branch of the Southern Pacific Railroad, to Trona. The towns on the borders of Searles Lake are reached from Randsburg and points to the southwest by two routes, which, however, are identical as far as the old Searles stage station, about a mile northeast of the railroad station of the same name. From this place one road, known as the valley route, goes in a more easterly direction closely following the Trona Railway. The other road, known as the canyon route, crosses the railroad and goes northeastward across a low range to Salt Wells Valley and thence down Salt Wells Canyon. It joins the valley road a short distance north of the lower end of the canyon. The canyon road is about 2 miles shorter than the valley route and for this reason is most generally used. A branch road leads westward from the canyon road. Near the old Salt Wells a road leads westward from the canyon road to Inyokern and the Midland Trail, in Indian Wells Valley.

From Trona a road leads northward to Ballarat, in Panamint Valley, and thence by way of Emigrant Canyon and Death Valley to Rhyolite and points to the northeast. This route is used especially in winter by travelers who are going to places in central and northern

Nevada and Utah, when the Lincoln Highway is closed by snow in the high mountain passes. On this route places where supplies or assistance can be obtained are far apart, and there is an element of danger in crossing Death Valley, especially in the warmer months. Persons unfamiliar with this route should make careful inquiry at Trona before attempting it.

Minor roads lead to other parts of Searles Valley. However, except a road that leads around Searles Lake, most of them are seldom used and may not be passable for automobiles. Three towns of fair size have existed on the western border of Searles Lake. These towns have been maintained almost wholly if not wholly by the operations of potash-producing companies. The largest town is Trona, at the plant of the American Trona Co. About 2 miles southwest of it is Borosolvay, at the plant of the Solvay Process Co. The third town, called Westend, is about 4½ miles south of Trona, where there is another potash plant. The size of the towns has fluctuated with changes in the production of potash and other salines. During the World War, when the supply of cheap potash from Germany was cut off, the towns were at their maximum development. Shortly after the end of the war, when German potash again came on the market, the production of potash at Searles Lake practically ceased. The Borosolvay plant was closed and in the winter of 1921–22 was deserted. Operations at the other plants were curtailed, but the production of other salts was continued at Trona and Westend. Ordinary supplies and accommodations can generally be obtained from the American Trona Co. at Trona.

Water and probably some supplies can be obtained at Westend as long as the plant there is in operation, but good water can not be obtained elsewhere between Searles station and Trona, a distance of more than 25 miles. No water is available at Spangler, a siding on the Trona Railway, or at Searles, an abandoned stage house about a mile northeast of Searles station, on the Southern Pacific Railroad. In the northern part of the valley water can be obtained from two or three wells or former springs in the Argus Mountains.

The precipitation at Trona for the year 1920–21 was 4.99 inches. On the basis of long-time records at other stations it has been estimated that the mean annual precipitation is about 4.35 inches.[13] The lower part of the valley, around Searles Lake has rather high temperatures in summer, doubtless owing to the basin-like character of the valley, with the great flat expanse of Searles Lake.

The soil of the alluvial slopes is typical of the desert—an arkosic sand formed largely by mechanical disintegration of the rocks. Around Searles Lake the soil is more clayey. As shown below, the

[13] Irrigation requirements of California lands: California Dept. Public Works, Div. Eng. and Irrigation Bull. 6, p. 83, 1923.

central part of the playa is a body of practically pure salts. The percentage of salt becomes less toward the border of the playa. However, even at the extreme southern edge, where alkali is not especially noticeable at the surface, there is apparently considerable alkali in the soil, for vegetation is very sparse.

The characteristic vegetation of the upper slopes consists of the creosote bush and the species commonly associated with it. In the lower part of the basin, around Searles Lake, species of saltbush occur. It is noticeable that for some distance from the border of the bare playa the vegetation is very sparse. This condition is believed to be due to alkali in the soil, even though it is not visible at the surface. Although the water table is near the surface around the border of the playa, mesquite and salt grass were not observed at any of the places where the playa was approached closely. The lack of these species is doubtless to be explained by the saline character of the ground water.

There has been no agricultural development in the valley. The principal resources of the valley are the saline deposits in Searles Lake, particularly potash and borax. (See pp. 175–176.) Some metal mining has been done in the mountains surrounding the valley, particularly in the Slate Range.

PHYSICAL FEATURES AND GEOLOGY

GENERAL CHARACTER

Searles Valley is a rather narrow, elongated valley almost completely shut in by mountains. The northern half of the eastern border of the valley is formed by the Slate Range, which rises about 3,000 to 4,000 feet above Searles Lake and reaches a maximum altitude above sea level of 5,565 feet. The range is narrow and steep. According to Spurr [14] and Waring,[15] the northern part of the range is composed of sedimentary rocks of Cambrian age. Farther south the range is made up largely of volcanic rocks that have been sheared.

South of the Slate Range the border of the valley bends to the southwest and is composed of high hills which extend as far as Klinker Mountain. These hills are directly in the line of the great fault line which extends from the vicinity of Garlock in Fremont Valley northeastward past the south end of the Slate Range and into Leach Valley (see p. 118), and they undoubtedly owe their origin to faulting. Where these hills are crossed by a secondary road that leads eastward from Spangler siding there are exposures of clay beds and conglomerates that dip toward the south. These beds are prob-

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[14] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California: U. S. Geol. Survey Bull. 208, pp. 213-214, pl. 1, 1903.

[15] Waring, G. A., Geological map of Inyo County, Calif., California State Min. Bur., 1917.

ably of Tertiary age and similar to other beds of that age farther southwest in the hills, which have been mapped by Hess. The northern part of Klinker Mountain that borders the valley is probably composed of Tertiary lavas. The extreme southwest end of the hills, including the Summit Range, is composed largely of granitic rocks.[16]

The western border of the valley, as far south as Salt Wells Canyon, is formed by the Argus Range. This range, which joins the north end of the Slate Range, is a massive range of mountains that reaches an altitude of more than 6,500 feet above sea level. According to Waring,[17] the eastern half of the range is composed of Cambrian sediments, and the western half of Tertiary volcanic rocks.

South of the Argus Range the western border of the valley is formed by a much lower range of unnamed mountans, composed of granitic rocks. In some places the mountain slopes are rather steep, but at the southwest end and also on the northwest side the slopes are so gentle that they simulate alluvial slopes. However, numerous low rock hills rise from the slopes, and large weathered boulders occur on them, and it is evident that the slopes are erosional and not due to deposition. These features are particularly noticeable on the road to Salt Wells Canyon between 2 and 6 miles northeast of the old Searles stage station. Along this stretch there may be seen excellent examples of the weathering of rocks into rounded boulders by exfoliation, or the peeling off of the rock in layers as a result of the rapid changes in temperature. Some of the boulders are 20 feet high. Where the road crosses the summit of the range the granite has been weathered into many sharp pinnacles a few feet high.

The mountains that lie south of Salt Wells Canyon apparently at one time formed a part of a greater Argus Range that continued southward to the Trona Railway. They are now separated, however, by Salt Wells Valley, a small valley about 6 miles across, which has been eroded out of the mountain mass. It consists almost entirely of erosional slopes which descend gently to a small alkali flat or playa that extends almost due east. It is not certain whether the surface drainage tributary to this playa reaches Searles Valley, but undoubtedly the ground water passes out through Salt Wells Canyon. If there is a divide between the two valleys, it is only a few feet high.

Salt Wells Valley and canyon are of interest in connection with the ancient Searles Lake. (See p. 174.) In the early and closing stages of the lake water from Owens Lake and Indian Wells Valley reached Searles Lake through Salt Wells Valley. When the lake was at its highest stage an arm of it extended through Salt Wells Valley into Indian Wells Valley.

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[16] See Hulin, C. D., Geology and ore deposits of the Randsburg quadrangle: California State Min. Bur. Bull. 95, pl. 1, 1925, for detailed geologic map of this part of Searles Valley.

[17] Op. cit.

The upper part of Salt Wells Canyon is only about 200 feet wide and is cut from 50 to 100 feet deep in a dark granitic rock. For a considerable distance the floor is bare rock. Farther downstream the canyon broadens out and is filled with alluvium. The valley above the canyon appears to be filled with alluvium below the rock floor of the canyon, and these features seem to be out of harmony. However, a short distance north of the canyon there appears to be another channel partly filled with alluvium that was deposited in the ancient Searles Lake, and doubtless a deeper channel existed there. If this is true, the question arises whether Salt Wells Canyon also existed prior to the existence of the ancient Searles Lake or whether it has been cut since the lake level receded below the canyon level. Small patches of lake beds in the lower part of the canyon show that this part at least existed prior to the lake and was filled as the lake rose and later reexcavated as it retreated. The observations of the writer on a hurried trip down the canyon were not sufficient to determine the significance of these features, but it is evident that a study of this locality will yield valuable information on some phases of the history of the ancient Searles Lake.

ANCIENT SEARLES LAKE

The most interesting and unusual geologic features in Searles Valley are those related to a large lake that covered part of the valley in Pleistocene time. As described on page 110, this lake was one of three lakes connected by streams which existed when the average annual rainfall was presumably greater than at present. The principal source of water was the high Sierra Nevada bordering Owens Valley. The surface run-off was so great that it formed a lake much larger than the present Owens Lake. This lake evidently overflowed into Indian Wells Valley, where another lake was formed, which in turn overflowed into Searles Valley through Salt Wells Valley. Searles Lake overflowed into Panamint Valley, and the lake formed in that valley probably overflowed into Death Valley. (See p. 186.) The principal features of Owens, Searles, and Panamint Lakes have been well described by Gale.[18] The following brief summary is based largely on his report.

The evidence of the existence of Searles Lake is found in several features, the most striking and readily observed of which are wave-cut benches on the side of the mountains several hundred feet above the bottom of the valley. These benches are best shown on the side of the Slate Range. The altitude of the highest bench cut by the waves is 2,262 feet, which shows that the lake stood at least 640 feet

[18] Gale, H. S., Salines in the Owens, Searles, and Panamint Basins, southeastern California: U. S. Geol. Survey Bull. 580, pp. 251-323, 1915.

above the present valley bottom. At this height the lake not only covered most of the valley lands in Searles Valley but an arm of it reached westward through Salt Wells Valley and covered a large area in Indian Wells Valley.

At the extreme southwest end of the Slate Range there is a low place in the divide at practically the same altitude as the highest bench. (See point marked "B. M. 2262," pl. 10.) It is quite evident that when the lake stood at its highest level it overflowed southeastward into Pilot Knob Valley and thence to Panamint Valley.

Another form of evidence, which is lacking in near-by basins where there have been no lakes, consists of deposits of calcareous tufa, which were precipitated from the lake waters. In some places the tufa is spread over the rocks as a coating. At other places a considerable thickness of the deposits has been built up. The tufa is especially well developed in The Pinnacles, which are steep-sided knobs that rise to a height of 100 feet 15 miles due south of Trona, near the point where the railroad turns southwestward. Similar crags are found about 1½ miles southwest of the Salt Wells, a short distance east of the canyon road to Randsburg.

The most unusual feature observed in connection with the evidence of the ancient Searles Lake consists of the saline deposits that underlie part of the present deposits. These deposits are believed to be unique both as to the purity of the salt beds and the variety of minerals found in them and as to the large percentage of potash present. The playa is one of the largest in the Mohave Desert region and covers about 60 square miles. Most of it is similar to playas of the moist type in other basins.

Over large areas the surface is characterized by "self-rising ground," which is covered in places with alkali crusts. The alkali increases in general toward the center of the playa. In contrast to other playas, however, in the central part there is a body of practically pure salt, locally called the crystal body, which extends to depths ranging from 60 feet to more than 100 feet. The area of the crystal body is estimated to be about 10 or 12 square miles. On its border it merges into saliferous clay.

The surface of the crystal body is generally white and smooth and solid enough to support automobiles and other heavy vehicles Although blocks of salt are broken out and pushed up in the process of crystallization re-solution smooths out the surface. The water table is usually within an inch or two of the surface. The ground water is really a saturated brine which fills the interstices between the crystals. The volume of this brine is estimated to be more than 25 per cent of the total mass of the crystal body. It is composed chiefly of the chlorides, sulphates, carbonates, and borates of sodium and potassium[19] and contains about 2.1 per cent of potassium. The crystallized salt body contains a considerable number of mineral species, several of which have been found only in these deposits.

An interesting feature is a so-called trona reef that occurs along the east border of the playa. This reef is a zone of crusted salts, chiefly trona (hydrous sodium carbonate), which have been brought to the surface by rising ground water and deposited by evaporation. Borax is also found in the marginal parts of the playa.

The saline deposits of Searles Dry Lake have been worked commercially at irregular intervals since 1873, 10 years after their discovery by J. W. Searles. For many years the principal product was borax.[20] Beginning in 1917, the production of potash has been even larger, particularly during the war, when the supply of German potash was shut off. In the 5-year period 1917–1921 the production of potash in San Bernardino County was valued at $8,441,586, and presumably all of it came from Searles Lake.[21] In 1918 the production amounted to nearly $3,500,000. However, with the end of the war and the reappearance of cheap German potash on the market the production dropped greatly.

The principal producer of potash has been the American Trona Corporation. The brine is recovered by means of wells sunk in the crystal body and is pumped by electrically operated pumps through a 4-mile pipe line to the plant on the edge of the playa. The salts are precipitated from the brine by fractional evaporation—a process which is dependent upon the fact that at different stages in the evaporation of the brine salts of different composition are precipitated, but those precipitated at any one stage are relatively uniform in composition.

The construction of the pipe line offered unusual problems, which arise from the fact that it is subjected to a range in annual temperature of fully 100° F. and daily changes of at least one-third of that. In order to provide for the expansion and shrinkage of the pipe line it was laid in sections 900 feet long, each section being anchored in the middle and provided with expansion joints at each end. The temperature was observed when each expansion joint was placed, and the proper allowance was made for expansion. The pipe, which is 10 inches in diameter, is heavily insulated to maintain the brine at a constant temperature, for if this were not done it would thicken, and crystals would form.

[19] Gale, H. S., op. cit., p. 277. Hicks, W. B., Evaporation of brine from Searles Lake, Calif.: U. S. Geol. Survey Prof. Paper 98, pp. 1-8, 1917.

[20] Bailey, G. E., The saline deposits of California: California State Min. Bur. Bull. 24, pp. 37-40, 63-65, 1902.

[21] Mining in California: California State Min. Bur., State Mineralogist Eighteenth Rept., table opp p. 688, November, 1922.

GROUND WATER

WELLS

Few wells have been put down in Searles Valley, and so far as information is available all of them are in the northern part of the valley, except one, which is in Salt Wells Valley.

Several wells or test holes have been drilled on the playa or close to its border. In these wells the water either flows or stands practically at the surface. The water in them is so salty as to be unusable for any purpose. One of these wells on the edge of the playa at Trona, which is 12 inches in diameter and 100 feet deep, flows about 40 gallons a minute. When first analyzed the water contained about 6 per cent of sodium chloride, but after being pumped for a time the salt content increased. The water from these and other near-by wells was for a time used in "sluicing" in the manufacturing process at the Trona plant.

The American Trona Corporation has put down several wells on the alluvial slope between 1 and 2 miles north of the playa. Beginning in the SE. ¼ SE. ¼ sec. 21, T. 24 S., R. 43 E., and continuing eastward for 1¼ miles, six test wells, numbered from 1 to 6, were put down at intervals of a quarter of a mile. Wells 1 and 6 were dug to the water level and then drilled to a total depth of 300 feet. The other four were dug only to the water level. In addition the company has a dug well, known as the "farm well," in the NW. ¼ sec. 28, T. 24 S., R. 43 E. The Pacific Coast Borax Co. had a dug well, now abandoned, in the SE. ¼ SE. ¼ sec. 20. Another well, known as the Ott well, is about a quarter of a mile north of the center of sec. 15 of the same township. The altitude of the water table in these wells was determined by a wye-level line run by the American Trona Corporation from a United States Geological Survey bench mark at Trona. These data, for which the writer is under obligations to Mr. A. J. Klamt, formerly general superintendent of the American Trona Corporation, are given in the table on page 182, with other information in regard to the wells. The table also contains data in regard to a well drilled by the Solvay Process Co. near its plant.

The data show that the depth to water along an east-west line near the south side of secs. 20, 21, 22, and 23, T. 24 S., R. 43 E., ranges from about 70 to 115 feet. These differences in depth to water are due to differences in the altitude of the surface, for the range in the altitude of the water table in the wells is only about 10 feet. In these wells the water table is from 43 to 52 feet above the water table beneath Searles Lake, and thus the gradient toward the playa is about 30 feet to the mile. However, according to the data obtainable, the water table in the Ott well is only 52 feet above the water table beneath the playa; that is, between it and the row of test wells (Nos. 1 to 6), a distance of nearly 1½ miles, the gradient is at most 10 feet and between the Ott well and well 4 the water table is apparently flat. No explanation is known for this condition. If the depths to water in the different wells were measured at different times in the year, the condition might be only apparent and not real, because of fluctuation of the water table between measurements.

Only one well, No. 1, has been sufficiently tested to give any idea as to the yield of properly constructed wells. This well is 12 inches in diameter from the water level to a depth of 300 feet and the casing is perforated between the depths of 86 and 176 feet. It is equipped with an 8-stage Byron-Jackson deep-well turbine, with the suction 186 feet from the surface. When first started the pump yields about 480 gallons a minute, but it decreases until the maximum drawdown is reached, when the yield is about 350 gallons a minute. The drawdown is estimated to be about 40 feet. The Farm well has been tested with a plunger pump to yield 60 gallons a minute with a drawdown of only 2 feet. If equipped with a larger pump, it would doubtless yield considerably more. This well is dug only about 7 feet below the water table. None of the other wells are known to have been tested. It seems probable, however, that properly constructed wells would yield from 100 to 500 gallons a minute.

Only two of the wells were in use in 1917. Water from well 1 was piped to the plant of the American Trona Corporation, where it was used for sluicing. Water from the farm well was pumped into a near-by reservoir and used for a swimming pool. It was intended eventually to use this well for irrigating a small area.

Samples of water from different depths in well 1 and from a depth near the bottom of well 6 were analyzed by J. E. Evans, of the American Trona Corporation, and the results are given below. These analyses show that the water from different depths is slightly different, but it is all highly mineralized, the total dissolved solids ranging from 1,516 to 2,095 parts per million. The waters are similar in general character, and sodium chloride is the predominant constituent.

Analyses of waters from wells in Searles Valley, Calif.

[J. E. Evans, American Trona Corp., analyst. Parts per million, recalculated from hypothetical combinations]

	1	2	3	4
Sodium (Na)	653	604	820	703
Carbonate radicle (CO_3)	179	175	192	150
Sulphate radicle (SO_4)	166	146	218	156
Chloride radicle (Cl)	119	603	851	783
Biborate radicle (B_4O_7)	31	31	55	17
Total dissolved solids	1,636	1,516	2,096	1,780
Date of collection	([a])	([a])	([b])	([c])

[a] May 13, 1917. [b] May 20, 1917. [c] Apr. 11, 1917.

1. Well 1 of American Trona Corp., from a depth of 150 feet.
2. Same well, from a depth of 190 feet.
3. Same well, from a depth of 240 feet.
4. Well 6 of American Trona Corp., from a depth of 290 feet.

No calcium or magnesium were reported in the analyses given herewith, and it is uncertain whether they are present in appreciable quantities. Analyses of the brine from Searles Lake show that these elements are practically absent in it,[22] probably because there has been sufficient carbonate present to precipitate them. It is not certain whether this is also true in the less mineralized waters from the wells for which the analyses are given.

Although the waters analyzed are highly mineralized, they could doubtless be used for drinking in case of emergency. The water from the wells is used by stock.

It is worthy of note that although the samples analyzed were all taken at depths below the level of the water table beneath Searles Lake, the concentration is low as compared to the brines, which contain more than 300,000 parts per million of dissolved solids.[23] This is significant, for it shows that the brine does not extend far beneath the alluvial slope, and possibly if wells are drilled at places farther from the playa than the wells sampled water of better quality may be obtained. The conditions can not be foretold with certainty, however, for as the ancient Searles Lake evaporated some salts may have been left in the alluvium which have not yet been completely leached out.

So far as the writer is aware there are no wells south of Searles Lake. Doubtless water could be obtained at almost any place in the alluvium-filled part of the valley. However, within at least a mile or two of the playa the water would probably be of poor quality. The quality of the water may be expected to improve somewhat at points farther and farther from the playa. However, the depth to water also doubtless increases, and it would not be surprising if a depth to water of 200 feet were found within 3 miles of the playa. Farther southwest the depth to water is probably much greater. The conditions as a whole are unfavorable for irrigation, but water suitable for stock could probably be obtained in deep drilled wells.

WATER SUPPLIES FOR INDUSTRIAL PLANTS

In all wells that have been drilled or dug in the alluvium the water obtained has been rather highly mineralized. The water is suitable for general use around the potash plants but is unfit for domestic use. It has therefore been necessary to obtain water for domestic use from more distant sources.

Water for domestic use at the plant of the American Trona Corporation is piped from several springs in the Argus Mountains. The main pipe line is more than 10 miles long. About 100,000 gallons a day is obtained from the springs. (See p. 180)

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[22] Gale, H. S., Salines in the Owens, Searles, and Panamint Basins, southeastern California: U. S. Geol. Survey Bull. 580, pp. 276–277, 1915. Hicks, W. B., Evaporation of brine from Searles Lake, Calif.: U. S. Geol. Survey Prof. Paper 98, p. 2, 1917.

[23] Gale, H. S., op. cit., p. 276.

Water for domestic use at the potash plants at Borosolvay and Westend, when they are in operation, is hauled in tank cars from the pumping plant of the Southern Pacific Railroad at Cantil, a distance of about 50 miles. In the fall of 1917 about 80,000 gallons a month was being used to supply water for 175 persons at Borosolvay.

SPRINGS

Springs in Argus Mountains.—A number of springs exist in the Argus Mountains. Most of these springs have been developed by the American Trona Corporation to furnish water for domestic use at its plant. The following notes on the yield of the several springs were furnished by A. J. Klamt.

The northernmost group, four in number, are located in Bruce Canyon about 11 miles north of Trona. (See pl. 10.) Cabin Spring yields about 5 gallons a minute, Middle Spring about 7 gallons, Peach Spring 21 gallons, and Dripping Springs about 3 gallons. In Graham & Jones Canyon, the next large canyon to the south, Graham Spring yields 10 gallons a minute. In Great Falls Canyon there are several springs. One of these, Argus Springs, yields about 10 gallons a minute. The water from it is piped to a tank at an old stage station near the Ballarat road. Indian Joe Spring, in a short canyon about 5 miles north of Trona, yields about 7 gallons a minute. Searles Springs, which comes from tunnels in Indian Joe Canyon, yields about 7 gallons a minute.

Layton Spring.—Layton Spring is in Layton Canyon, on the west side of the Slate Range, along an old road leading from Searles Lake to the South end of Panamint Valley. The road is impassable for automobiles, but it is said to be passable for wagons. The spring is used principally by prospectors.

Bedrock Spring.—Bedrock Spring is at the north end of the Lava Mountains, in sec. 31, T. 28 S., R. 42 E. It is nearly a mile south of an old road leading to the southeast end of Searles Lake. This road is seldom used and is almost impassable for automobiles. In August, 1919, it was reported that water could be obtained at the spring.

SALT WELLS VALLEY

Water is known to be available at only two places in Salt Wells Valley, and at each place it is of very bad quality. At the abandoned Salt Wells stage station, in the SW. ¼ sec. 32, T. 26 S., R. 42 E., there is a dug well which on September 25, 1917, measured 48 feet deep and 45 feet to water. The only means of obtaining water was a bottle to which were attached enough pieces of baling wire to reach the water. As shown by analysis 1 on page 181, the water is very highly mineralized. It might be usable in very small amounts in an emergency, but if very much of it were drunk it would probably cause sickness. The water is unfit for boiler use and very bad for irrigation.

Except perhaps in the driest months, a small stream of water flows along the rock floor at the head of Salt Wells Canyon. This stream is clear and cool and very inviting to the traveler. However, it is extremely salty. As shown by analysis 2 below, this water contains 38,980 parts per million of total solids. It is the most highly mineralized water collected during the investigation of watering places in the Mohave Desert region, and it is absolutely unfit for any use. The water is so salty that a person in normal condition would not swallow it. However, if one's mental and physical condition were so weakened by thirst that he was unable to resist the desire for water, enough of it could be drunk in a few moments to cause sickness. If very much of it was used it would probably so weaken a person that death would ensue unless proper treatment was quickly available. At least one person is known to have died from the effects of drinking this water.

Analyses of ground water in Salt Wells Valley, Calif.

[Collected Sept. 22, 1927. C. H. Kidwell, analyst. Parts per million]

	1	2
Silica (SiO_2)	104	112
Iron (Fe)	.36	1.4
Calcium (Ca)	843	48
Magnesium (Mg)	46	74
Sodium (Na)	1,681	14,420
Potassium (K)	83	449
Carbonate radicle (CO_3)	0	326
Bicarbonate radicle (HCO_3)	213	588
Sulphate radicle (SO_4)	326	3,435
Chloride radicle (Cl)	3,896	19,470
Nitrate radicle (NO_3)	46	3.9
Total dissolved solids at 180° C	7,262	38,980
Total hardness as $CaCO_3$ (calculated)	2,300	423

1. Dug well at old Salt Wells stage station in sec. 29, T. 26 S., R. 42 E., Mount Diablo meridian. See p. 180.
2. Small stream near head of Salt Wells Canyon, in sec. 28, T. 26 S., R. 42 E. See above.

The highly mineralized water in Salt Wells Canyon, as well as that in the well at the Salt Wells station, probably has its origin in saline deposits left when Searles Lake receded after covering part of the valley. The small playa in the bottom of Salt Wells Valley contains more or less alkali on its surface, and below the surface there is doubtless considerable salt. It is possible that some water seeps into the valley from Indian Wells Valley, to the west. If so, this water would doubtless be mineralized, for the playa in Indian Wells Valley known as China Dry Lake is very saline.

Conditions are not favorable for the development of good water supplies in Salt Wells Valley. Water that is better than that in the well at the Salt Wells station may possibly be obtained in wells farther south on the alluvial slope. It is probable, however, that the water table is nearly flat, for the contributory area is not great, and accessions to the water table are small. Accordingly, if water of good quality can be obtained in wells on the upper part of the slope the depth to water is likely to be great. The conditions as a whole are unfavorable to obtaining water for irrigation.

Records of wells in Searles Valley, Calif.

[T. 24 S., R. 43 E. Mount Diablo meridian, except Solvay well]

Location		Name	Depth of well (feet)	Depth to water (feet)	Altitude of surface above sea level [a] (feet)	Altitude of water table above sea level (feet)	Altitude of water table above Searles Lake [b] (feet)	Remarks
Sec.	Subdivision							
21	SE. ¼ SE. ¼	American Trona Corporation No. 1.	300	85.2	1,749.6	1,664.4	46.0	See p. 177 for additional information. For analyses see p. 178.
22	SW. ¼ SW. ¼	American Trona Corporation No. 2.	([c])	96.5	1,761.4	1,664.9	46.5	
22	SE. ¼ SW. ¼	American Trona Corporation No. 3.	([c])	115.0	1,776.0	1,661.0	42.6	
22	SW. ¼ SE. ¼	American Trona Corporation No. 4.	([c])	107.0	1,776.8	1,669.8	51.4	
22	SE. ¼ SE. ¼	American Trona Corporation No. 5.	([c])	96.8	1,761.4	1,664.6	46.2	
23	SW. ¼ SW. ¼	American Trona Corporation No. 6.	300	105.0	1,772.0	1,667.0	48.6	For analysis see p. 177.
28	NW. ¼ NE. ¼	American Trona Corporation Farm well.	65	56.7	1,718.1	1,661.4	43.0	See p. 178 for additional information.
20	SE. ¼ SE. ¼	Pacific Borax Co.	([c])	69.6	1,733.9	1,664.3	45.9	
15	N. ½	Ott well	248	232	1,902.5	1,670.5	52.1	
[d]30	SW. ¼ SW. ¼	Solvay Process Co.	200	52				Pumps 150 gallons a minute. The water is very salty.

[a] Altitude at surface is altitude of collar of well.
[b] Altitude of water table in Searles Lake near Trona at time of observation was about 1,618.4 feet.
[c] Dug only to water level.
[d] T. 25 S., R. 43 E.

PANAMINT BASIN, INCLUDING PILOT KNOB VALLEY

GENERAL FEATURES

The Panamint drainage basin lies east of Searles Valley, in the northwestern part of San Bernardino County and the south-central part of Inyo County. Fully half of the drainage basin lies north of the area considered in this report and is shown on the Ballarat topographic map. Conditions in that part of the basin are considered only in so far as they affect the occurrence of ground water in the basin. The drainage basin includes not only Panamint Valley, but also an area of several hundred square miles lying south of the valley, which in this report is called the Pilot Knob Basin. This is almost a separate basin, but the drainage from it apparently reaches Panamint Valley at times of heavy rains.

No permanent habitations are known in that part of the valley that lies within the area considered in this report. The old mining camp of Ballarat is 3 miles north of the area shown on Plate 10, and it is understood that a few prospectors are at the camp nearly all the time. Some prospecting and mining has been done, but in recent years there has been little active work. So far as is known no very valuable mineral deposits have been developed within the portion of the area considered in this report.[24] There is no agricultural development in the basin.

The region is reached most easily from Johannesburg, by way of Granite Wells. Thence a road leads northward through the Pilot Knob Basin. This road branches 14 miles north of the wells. One branch, which goes northward through Panamint Valley to Ballarat and Death Valleys, is seldom used except by prospectors. From it a branch road leads eastward through Wingate Pass to Death Valley. It is understood that this road is practically impassable for automobiles except for a few miles at its west end. The other branch of the main road leads eastward through Leach Valley to Silver Lake and South Death Valley. In the eastern part of the basin it is joined by a road from Johannesburg and Barstow by way of Indian Spring. The road through Leach Valley is used considerably for travel between the eastern and western parts of the desert, as it saves a long detour to the north or south. Watering places on the roads are described on pages 190–191.

PHYSICAL FEATURES AND GEOLOGY

The drainage area that is tributary to Panamint Valley is roughly dumb-bell shaped—that is, it has two wide parts at the north and south ends, connected by a long, narrow part. The southern part is nearly cut off from the rest of the basin at the constricted section by a ridge. For the sake of convenience the name "Pilot Knob Basin" is given to the southern enlarged portion of the drainage area. The remainder of the basin, including the constricted part, is called Panamint Valley. The physiographic and geologic conditions in the Pilot Knob Basin are different from those farther north, and therefore the features of the two parts of the basin are considered separately.

PANAMINT VALLEY

The portion of Panamint Valley shown on the relief map (pl. 10) is essentially only the constricted part or the grip of the dumb-bell, if the comparison may be continued. However, in order to understand certain features that affect the occurrence of ground water it is necessary to consider the portion farther north.

The name "Panamint Valley" is applied to a long, narrow alluvium-filled valley of structural origin that extends in a north-northwest

[24] Notes on the geology and ore deposits of the Ballarat or Panamint region, as it is called, are given in the following reports: Spurr, J. E., Geology of Nevada south of the fortieth parallel: U. S. Geol. Survey Bull. 208, pp. 200–205, 1903; U. S. Geol. Survey Mineral Resources, 1883–84, p. 642, 1885; 1907, pt. 1, p. 207, 1908; 1908, pt. 1, p. 334, 1909; 1909, pt. 1, p. 275, 1911. Fairbanks, H. W., Mineral deposits of eastern California: Am. Geologist, vol. 17, pp. 144, 151, 1896.

direction for about 60 miles. About one-fourth of the distance from the north end alluvial fans built out from opposite sides of the valley have divided the valley into two distinct basins, so far as the surface drainage is concerned. The ground water of the northern basin, however, probably drains to the southern basin.

The southern basin is very narrow at its south end, but it gradually widens toward the north. At one place, near the San Bernardino County line, the alluvium-filled valley is less than a mile wide, and for a considerable distance it is not more than 2 miles wide. The alluvium in this part of the basin rises very steeply to the mountains. Farther north, near Ballarat, the alluvium-filled area is fully 10 miles wide. The mountain area on each side of the valley is correspondingly much narrower at the south end than at the north.

The physical features of the valley, notably its narrowness and the steep slopes, suggest that it is a graben, or block downfaulted between the mountains on each side.[25] There is reason to believe that some of the faulting has taken place in comparatively recent times.

At the south the west border of the valley is the Slate Range, a long, narrow range. Near Early's Spring the rocks are quartzite, and boulders in the wash indicate the presence of other metamorphic rocks and intrusive rocks. Farther north, according to the geologic map of Inyo County, there are also some Tertiary volcanic rocks.[26] Approximately in latitude 36° the Slate Range merges with the Argus Range, and the drainage area expands westward. Part of this range is composed of volcanic rocks, but most of it is shown by Waring to consist of sedimentary rocks of Cambrian age. Throughout most of their length the Slate and Argus Ranges are more than 5,000 feet above sea level, and the highest point, Maturango Peak, reaches 8,850 feet.

At the south end of the valley the eastern border is formed by Brown Mountain, which is composed of Tertiary volcanic rocks. About 8 miles north of the south end this mountain gives way to Wingate Pass, a low, nearly level valley, about 2 miles wide, which slopes gently eastward for several miles and then drops rather steeply into Death Valley. (See pp. 591–592.) The summit of the pass is less than 300 feet above Panamint Valley, and the mountains north and south of it rise several thousand feet higher.

North of Wingate Pass the eastern border of the valley is formed by the Panamint Range, which rises steeply. For most of its length the range rises higher than 5,000 feet above sea level, and the highest point, Telescope Peak, reaches 11,045 feet. This is the highest peak that drains to any of the basins in the Mohave Desert region except

[25] Campbell, M. R., Reconnaissance of the borax deposits of Death Valley and Mohave Desert: U. S. Geol. Survey Bull. 200, p. 20, 1902. Gale, H. S., Salines in the Owens, Searles, and Panamint Basins, southeastern California: U. S. Geol. Survey Bull. 580, p. 317, 1915.

[26] Waring, G. A., Geologic map of Inyo County, Calif., California State Min. Bur., 1917.

San Gorgonio Peak, in the San Bernardino Mountains. As a whole the mountains that drain to Panamint Valley are higher than any of the mountains in the region considered in this report except the San Bernardino and San Gabriel Ranges and the Sierra Nevada. The part of the Panamint Range in the area covered by this report is mapped by Waring as metamorphic rocks of Cambrian age.

The lowest part of the narrow alluvium-filled valley is occupied by a playa. This playa is 17 miles long and less than 3 miles wide at its widest point and for much of its length is only about a mile wide. The playa is nearly a thousand feet lower than the lowest part of the valley at its south end and about 600 feet below the alluvial divide that separates it from the northern Panamint Valley.

The playa was not seen by the writer, but according to a brief description by Free [27] it is of the wet type, with a saline surface. This condition is to be expected, as the basin is completely surrounded by bedrock, and it is lower than any of the adjacent basins except Death Valley, from which it is separated by a great range of mountains.

The total area of the southern part of Panamint Valley is 690 square miles, of which about 470 square miles is occupied by mountains, 200 square miles by alluvial slopes, and 20 square miles by the playa.

PANAMINT LAKE

There is evidence that a large lake existed in Panamint Valley in comparatively recent geologic time. The traces of this ancient lake, which has been called Panamint Lake, consist of wave-cut terraces and deposits of tufa several hundred feet above the bottom of the valley. The details of these features are described by Gale.[28] The lake is believed to have existed during the Pleistocene epoch, when the climate was moister than at present—at the same time that a large lake existed in Searles Basin and other large lakes farther north in the Great Basin. (See pp. 110–111.) Apparently Searles Lake at one time overflowed into Panamint Lake, and the great size of the lake was partly due to this overflow. It is noteworthy, however, that the area now tributary to the Panamint Valley, including the northern part of the valley and the Pilot Knob Basin, is about 1,800 square miles and that a large part of the mountainous area reaches high altitudes. As a result of the great altitude of so much of the basin a notable increase in the precipitation would doubtless cause the formation of a small lake without any accessions of drainage from other basins.

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[27] Free, E. E., The topographic features of the desert basins of the United States with reference to the possible occurrence of potash: U. S. Dept. Agr. Bull. 54, p. 41, 1914.

[28] Gale, H. S., Salines in the Owens, Searles, and Panamint Basins, southeastern California: U. S. Geol. Survey Bull. 580, pp. 312–319, 1915.

The upper benches cut by the waves are indistinct, and it has been difficult to determine just how high the lake stood. Tufa has been found at altitudes as high as 1,970 to 1,980 feet,[29] which is practically the same as the summit of Wingate Pass, and it has been suggested that the lake overflowed through the pass to Death Valley. Observations by the writer tend to confirm this view. In approaching Wingate Pass from the Panamint Valley road there is a steep rise of nearly 300 feet, but no wave-cut features are visible. A few hundred feet south of the road into the pass a steep canyon enters from the east. At the summit of the pass stands a low hill, which rises 25 feet or more above the lowest point in the divide. On the top of this hill the writer found fragments of tufa cementing small pebbles and in some places adhering to the larger lava boulders that cover the hill. The cementing material is calcium carbonate but is more like the typical desert caliche than like the type that is abundant around extinct lakes. In the canyon south of the hill conglomerate cemented with this material is exposed to a depth of about 30 feet, and in several places the tufaceous cement appears as veins. The surface at this place is covered with a thin layer of boulders of a vesicular lava. Below the surface lies a conglomerate that contains boulders as large as 18 inches in diameter, but none of them are composed of basaltic lava like those on the surface. Sandy gravel lies below the boulders. Four miles east of the summit of the pass well-rounded boulders as large as 10 inches in diameter were observed. The character of the boulders and gravel suggests that they may have been deposited in a stream that discharged from Panamint Lake, but the character of the valley that constitutes Wingate Pass is such that they may have acquired their waterworn characteristics by wash from the north and south sides of the pass. Where the bottom of the valley was seen at several places as far east as 5 miles from the summit of the fans, it was without any marked channel, perhaps because signs of any old outlet may have been obliterated by more recent wash.

If the maximum depth of Panamint Lake was governed by an outlet to Death Valley, as there is reason to believe, the area of the lake at the time of its maximum expansion was about 272 square miles, and the water stood 930 feet above the present playa surface opposite Ballarat.[30] Originally the lake was probably somewhat deeper, the bottom having been raised later by the deposition of alluvium. The lake filled not only the southern part of Panamint Valley but also the northern part and was about 300 feet higher than the present divide that now separates the structural valley into two parts.

The history of Panamint Lake apparently was similar to that of Searles Lake—that is, a large, deep lake existed for a considerable time

[29] Idem, p. 317.

[30] Gale, H. S., op. cit., p. 313.

and was maintained, in part at least, by the overflow from another lake. The presence of the great salt deposits in Searles Lake is believed to be due in part to the fact that the upper lake in the chain acted as a settling basin, so that on evaporating the salts were not mixed with mud. If this were a controlling factor, Panamint Lake, being still farther down the chain of lakes, ought to have rich saline deposits like those of Searles Lake, but so far such deposits have not been found.

The absence of rich saline deposits in the basin may be accounted for in several ways. Panamint Lake was the lowest lake of which we have any evidence in the Owens-Panamint Lake system, and an unknown but probably large part of the water supply for Panamint Lake came from the upper lakes. During a considerable part of the time when the concentration of salts was taking place in the Searles Lake basin there must have been no overflow into Panamint Lake, and the quantity of water to be evaporated doubtless was less than in Searles Lake. Perhaps of even more significance are the topographic conditions in the Panamint Basin. On account of the narrowness of the valley and the great altitude of the mountains, rapid alluvial filling of the valley would be expected, and any saline deposits that resulted from evaporation would be mixed with much alluvium. In Panamint Valley the alluvial slopes have a considerably greater development than in Searles Basin.

NORTHERN PART OF PANAMINT VALLEY

The northern part of Panamint Valley which is shown on the Ballarat topographic map, is a part of the same structural depression that is occupied by the southern part. It is separated from the southern part by an alluvial divide formed by the fans that have been built out from both sides. This divide is almost 600 feet above the playa in the southern part of the valley but very little higher than the playa in the northern part. Apparently the northern part of the structural valley was originally higher than the part near Ballarat, and it has only comparatively recently been cut off.

It is probable that ground water moves from the northern basin to the southern basin. The total area tributary to the northern playa is 615 square miles, of which about 480 square miles is occupied by mountains, 125 square miles by alluvial slopes, and 6.5 square miles by playa. A large part of the mountain area lies west of the valley. The mountainous area as a whole is not as high as that of the southern part of the valley, a large part of it being less than 5,000 feet above sea level.

PILOT KNOB BASIN

The Pilot Knob Basin is elongated in an east-west direction, approximately at right angles to the southern section of Panamint Valley. It is characterized by two principal drainage lines, which drain from the east and the southwest and each of which lies in a broad valley. The eastern of these two valleys is a part of the structural basin that farther east forms Leach Valley. (See p. 193.) The principal drainage ways of these two valleys lie close to their north sides, apparently because the great Garlock fault line runs close to the north side, and the land adjacent to the fault line has been lowered with respect to the southern part of the basin.

The two principal drainage ways of the Pilot Knob Basin unite near the south end of Panamint Valley. The drainage from the southern basin at one time was probably prevented from reaching Panamint Valley by a narrow ridge uplifted along the Garlock fault, but by cutting and filling the drainage has topped this barrier and now continues northward into Panamint Valley.

The eastern part of the basin is bordered on the north by the south end of Brown Mountain, which merges eastward into the Quail Mountains. These mountains have a rather steep alluvial slope on the south side. They are composed in part of old intrusive and volcanic rocks of Tertiary age, and on the flanks in washes is exposed alluvium older than the recent deposits, probably either Pleistocene or Tertiary. (See p. 194.) The eastern divide of the valley is formed by alluvial fill and farther south by the west end of the Granite or Leach Mountains.

The south side of the valley is characterized by many knobs and buttes that in some places rise from a gently sloping surface which resembles an alluvial slope but which is probably an erosional surface or mountain pediment. The knobs are formed to a large extent by Tertiary volcanic rocks, which in places are seen to rest on granitic rocks. The most conspicuous of these knobs is Pilot Knob, which is described on page 242. The western valley is bordered on the south by a continuation of the knobs and buttes, which consist largely of volcanic rocks, but in several places sediments occur that are probably interbedded with the volcanic rocks. Sandstone, gently folded, is exposed in a ridge about 2½ miles north of Granite Wells. The northeastern border of the western valley is formed by the south end of the Slate Range. The extreme south end of this range is composed of clay beds of probable Tertiary age which have been faulted up by movement along the Garlock fault line. They form a ridge with an east-northeast trend, about at right angles to the range, which is composed of older rocks. These beds contain some saline deposits, especially nitrates, but not in sufficient quantity to be of value.[31]

Southwest of the Slate Range the valley is separated from Searles Valley by low hills. Along a road leading from the valley to Spangler siding, on the Trona Railway, clay and conglomerate beds are exposed.

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[31] Noble, L. F., Mansfield, G. R., and others, Nitrate deposits in the Amargosa region, southeastern California: U. S. Geol. Survey Bull. 724, p. 21, 1922.

These beds are tilted to the south. They probably are Tertiary beds and have been exposed by faulting along the Garlock fault. On the southwest Tertiary lavas form the boundary of the basin.

PRECIPITATION

No data in regard to rainfall are available for any part of the Panamint drainage basin. The mountains in the southern part of Panamint Valley, especially the Panamint Range, rise to altitudes of 5,000 to 10,000 feet and more, and they stretch almost directly across the path of the rain-bearing winds. It is probable therefore that the average annual precipitation in these high mountains is somewhat greater than in most of the Mohave Desert region. It is doubtless at least 10 inches and may be considerably greater. The Pilot Knob Basin does not reach very high altitudes, and it is broken into many small knobs and hills that probably have little effect on the precipitation. The average annual precipitation in the basin is accordingly probably not great, perhaps about 5 inches.

WATER RESOURCES

No permanent streams are known in that part of the Panamint drainage basin that is shown on the relief maps in this report. In the high Panamint Mountains and the Argus Range running water may be found at several places after rainy spells, and perhaps in a few places there may be a perennial flow for short distances. A number of springs exist in these mountains, but they are off the regular routes of travel and are known only to prospectors. In the Pilot Knob Basin springs are very rare.

No data are available in regard to ground water in either the southern part of Panamint Valley or the Pilot Knob Basin. On the topographic map a well is shown in Panamint Valley near the Ballarat road, about 10 miles north of the junction with the Wingate Pass road, but nothing is known in regard to it. This well is about three-quarters of a mile from the playa, which is reported to be saline, and it is probable that the water is of poor quality. No data were obtained in regard to the depth to water. Near the playa in Panamint Valley the water probably lies near the surface, but farther away the depth may increase. It is probable that water can be obtained from wells almost anywhere along the wash in the southern part of Panamint Valley but the depth to water may be great except near the playa. However, in view of the past history of the valley, including the evaporation of Panamint Lake and the consequent deposition of greater or less quantities of salts, the water is likely to be of poor quality. Saline efflorescences appear on the surface of lake beds south of the Wingate Pass road, and they are doubtless even more abundant north of that place, nearer the playa. The topographic features of the valley are such that water will not be wanted for irrigation, and the only need will likely be for mining or for travelers.

Ground-water conditions in the Pilot Knob Basin are problematic. A large part of the gently sloping lands that appear to be alluvial slopes is probably underlain by solid rocks at a depth of only a few feet, and very little ground water can be expected in such places. Water possibly may be obtained at reasonable depths along the principal drainage ways in the lowest part of the basin. However, the precipitation in the basin is small, and no great quantities of water can be expected. The conditions in the Pilot Knob Basin are not favorable to any extensive agricultural development.

WATERING PLACES

Available springs.—Water for travelers is available at Lone Willow Spring and Early's Spring, in the southern part of Panamint Valley and at Granite Wells and probably also with a little development work at Myrick's Spring in the Pilot Knob Basin.

Lone Willow Spring and Early's Spring.—Lone Willow Spring and Early's Spring are within a mile or two of each other on the east slope of the Slate Range not far from its south end. They are reached from a road that branches northwest from the Granite Well-Ballarat road about 2 miles north of the narrow pass at the south end of Panamint Valley. The turn off is marked by signposts. The road to the springs ascends a steep alluvial slope, and 1.6 miles from the main road, near the ruins of a stone building, a poorly defined branch on the left leads to Lone Willow Spring. The spring, marked by a willow tree, is high on the hillside. From the stone ruins the road continues westward up the slope to Early's Spring, 3.1 miles from the main road. A cut-off road also leads northward from the stone ruins to the main Ballarat road. It is said that a spring exists in a canyon between Lone Willow Spring and Early's Spring, but the writer did not find it.

Lone Willow Spring is on the east face of a hill about 300 yards above a wash. The water comes from a trench cut into the hillside. The trench is cut in unconsolidated material, but it is not clear whether this is alluvial fill or residual soil. Bedrock probably lies near the surface. When dipped out the spring fills slowly, and although at times there is probably a slight flow it is not always sufficient to exceed the evaporation from the small outlet channel.

When first visited by the writer the water was badly contaminated by the decayed body of a coyote. The spring was cleaned out, and about three months later a sample of the water was taken for analysis. At that time the water contained "wigglers" or larvae, and it had a bad odor. So far as the mineral analysis is concerned the water is a calcium carbonate water and is of fair quality. It contains 962 parts of total solids per million parts of water (see analysis 1 in the accompanying table), but this analysis does not give any indication as to possible pollution from decayed animal matter.

A station on an old stage line to Ballarat was located at the stone ruins mentioned above, and the water from the spring was piped to the station, but this pipe has been torn up. On account of the pollution of the spring, Early's Spring was a more desirable source of supply.

Early's Spring is in a canyon that drains from the south. It is about 150 feet up the canyon from some old prospect holes and is easily found. The spring is in the bottom of the wash just above a narrow place in the canyon and surrounded by bushes. It is dug about 3 feet deep, walled with rock, and covered with a wooden hood. When the writer visited it a sign on the door stated that iron bars in the spring were placed there for the purpose of neutralizing arsenic and should be left in the water. A careful analysis in the laboratory of the United States Geological Survey of a sample from the spring failed to show any arsenic in the water. In fact, the analysis shows a relatively good water, containing only 652 parts of total solids per million. (See analysis 2, p. 192.)

About a quarter of a mile north of Early's Spring, on the steep hillside, stands a group of four willows, and a small seep of water was found beneath them. This spring had not been developed, and apparently the seepage was immediately evaporated. A number of wild burros, said to have been liberated by miners at Ballarat, roam around this vicinity, and their trails lead to this seepage.

Granite Wells.—The watering place known as Granite Wells, as the name suggests, lies at the north base of a low granite hill a mile west of Pilot Knob. The well is reached by branch roads that turn off from the main road to Panamint Valley. The southernmost branch to the spring is one-tenth of a mile northeast of the junction of the road from Johannesburg and one from Barstow. The well is three-tenths of a mile from the main road. It is really a cave at the end of an open cut 100 feet long in disintegrated granite. The water seeps in slowly. In January, 1920, the cave was barricaded by a network of iron pipe to prevent cattle from entering, but a person could reach the water without difficulty. A pipe line carries the water to a near-by water trough, the flow being about a pint a minute. An analysis of a sample collected in October, 1918, showed the water to be of good quality. (See analysis 3, p. 192.) It is a calcium carbonate water and has 404 parts of total solids per million. During the winter and spring a number of cattle are grazed in this locality.

Myrick's Spring.—A small undeveloped watering place, known as Myrick's Spring, is a short distance east of the road from Indian Spring to Leach Spring, 5 miles by road northeast of Indian Spring.

The road to it turns off about a tenth of a mile northeast of a large wash and leads southeast behind a low hill. The place is marked by a small hole in which salt grass was growing, but there was no water. A small quantity of water could probably be obtained by digging out this hole.

Analyses of ground waters from Panamint and Pilot Knob Valleys, Calif.

[Collected January 11, 1918. Parts per million]

	1	2	3
Silica (SiO_2)	62	64	65
Iron (Fe)	.12	.13	.47
Calcium (Ca)	125	109	64
Magnesium (Mg)	27	18	13
Sodium and potassium (Na+K)	184	[a]76	53
Carbonate radicle (CO_3)	0	0	0
Bicarbonate radicle (HCO_3)	429	332	232
Sulphate radicle (SO_4)	176	128	48
Chloride radicle (Cl)	180	75	30
Nitrate radicle (NO_3)	.54	Trace.	19
Total dissolved solids at 180° C	962	652	404
Total hardness as $CaCO_3$ (calculated)	423	346	213

[a] Calculated. Analysts: 1 and 3, Margaret D. Foster and C. H. Kidwell, U. S. Geological Survey; 2, Margaret D. Foster.

1. Lone Willow Spring, probably in sec. 25, T. 26 S., R. 45 E. Mount Diablo meridian. (See p. 190.)
2. Early's Spring, probably in sec. 26, T. 26 S., R. 45 E. (See p. 190.)
3. Granite Wells, near Pilot Knob, in sec. 22, T. 29 S., R. 44 E. (See p. 191.)

LEACH VALLEY

GENERAL FEATURES

Leach Valley is in the north-central part of San Bernardino County, about 15 miles south of the county line. The name is derived from Leach Spring, a well-known watering place, and the Leach Point Mountains, on the south side of the valley. A playa in the bottom of the basin is sometimes called Leach Dry Lake.

The valley is traversed from west to east by a road that is used for travel from Randsburg and other points in the western part of the desert to South Death Valley, Silver Lake, and points in the eastern part of the State. It is the only passable east-west route in the northern part of San Bernardino County. In the eastern part of the valley there are two alternative routes—one on the north by way of Owl Holes and South Death Valley and one on the south by way of Two Springs and Avawatz Valley to Silver Lake. Water is available in the valley at Leach Spring, Desert King Spring, Two Springs, and Drinkwater Spring, and on the northern route at Owl Holes, just beyond the divide.

The valley is uninhabited. Some prospects have been developed in a small way, but so far as is known it contains no valuable mineral deposits.

PHYSICAL FEATURES AND GEOLOGY

The Leach Valley drainage basin presents some very interesting physiographic and geologic features, but as observations in the valley were confined to what could be seen from the road in two rapid trips through it, only the most obvious features can be pointed out.

The boundary of the drainage basin and the border of the mountains are shown roughly on Plate 7. A large part of Leach Valley is a long, narrow valley between two mountain ranges that trend nearly due east. It is only a mile or two wide at its west end, but farther east it broadens out to a width of 6 or 8 miles. The alluvium-filled depression between the two parallel mountain ranges continues westward for 10 miles or more, but coalescing alluvial fans built out from the mountains on each side form a divide about a mile northwest of Leach Spring. The drainage on the west side of this divide goes west and north into Panamint Valley. (See p. 188.)

From the main part of the valley a secondary valley extends southeastward, and because of this extension the drainage basin as a whole is elongated from southeast to northwest.

At the west end of the drainage basin, about a mile west of Leach Spring, the mountains are less than 2 miles apart. Those on the south side of the valley are the Granite Mountains, the west end of which is sometimes called the Leach Mountains or Leach Point Mountains. From the vicinity of the San Bernardino meridian this range extends nearly due east for about 10 miles to the eastern part of T. 17 N., R. 2 E., and thence it bends southeastward. North of the valley at its west end are the Quail Mountains, which trend nearly due east. The highest part of the Quail Mountains is a high rounded mountain in the southeast corner of T. 18 N., R. 1 E. San Bernardino meridian, from which the range gradually becomes lower eastward and ends in low hills in the eastern part of T. 18 N., R. 2 E. At this place the valley broadens northward for 2 or 3 miles, and the divide is formed in part by an alluvial slope and farther east by low hills, the west end of the Owls Head Mountains. The northeast border of the valley is formed by a ridge several hundred feet high that trends approximately east. This ridge is an arm that extends northwestward from the Avawatz Mountains. South of this arm, in the southern part of T. 17 N., R. 4 E., another arm of the Avawatz Mountains extends westward into the basin. This arm nearly joins the Granite Mountains, in the north-central part of T. 17 N., R. 3 E. San Bernardino meridian, but apparently a canyon has been cut back through the granite ridge a mile or two south of the Silver Lake road. This canyon drains the west end of an alluvium-filled valley that lies south of the arm of the Avawatz Mountains. The drainage of the east end of the valley, however, is cut off by an alluvial divide, east of which is the Avawatz Basin. (See p. 199.)

The lowest part of the basin is occupied by a small playa. The border of this playa is not very sharp, and bushes grow some distance out on it. The playa does not show any alkali, and it is believed to be of the dry type.

Several large washes drain toward the playa. A long one runs almost due east, along the axis of the valley from its extreme west end.

It receives drainage from two large embayments in the mountains, one in which Leach Spring is located and the other on the opposite side of the valley. Another wash leads almost due north from a place near the Desert King Spring. In the 4-mile stretch along the Silver Lake road between this wash and a branch road to Two Springs several deep washes are crossed. The easternmost of these washes, about a quarter of a mile west of the branch to Two Springs, is about 20 feet deep and 800 to 1,000 feet wide. It apparently carries the drainage from the small branch valley on the southeast that is nearly cut off by an arm of the Avawatz Mountains. As compared to near-by basins several of these washes seem to be wider and deeper than the size of the drainage basin would indicate.

The Granite Mountains, as the name implies, are composed of granitic rocks. At Leach Spring the rock is a coarse-grained biotite granite with large feldspars, cut by narrow pegmatite dikes, which are mostly less than 5 inches in width. The rock at Desert King Spring is of the same general character. On the Silver Lake road, where it crosses the west tip of the Avawatz Range, coarse and fine grained granites are cut by large dioritic dikes. Farther east from a distance the dioritic rocks seem to form the main mass of the range. The Granite Mountains and the southern arm of the Avawatz Mountains are rough and irregular, owing to the weathering of the granite in large joint blocks. (See pl. 15, *A*.)

The south front of the Quail Mountains shows varicolored rocks, and to judge from float on the alluvial slopes the rocks are largely rhyolite, porphyry, and other volcanic rocks of probable Tertiary age. At several places, particularly on the north side of the mountains, near the Golden Fleece camp, granitic rocks occur.

On the road to the Golden Fleece mine, in a large wash that enters Leach Valley at its extreme west end, unconsolidated alluvial beds are exposed to a depth of at least 25 feet. The beds are tilted to the southwest at a high angle. Similar beds were observed about 4 miles farther west, in a wash traversed by a road from the Leach Spring road to Hidden Spring. (See pl. 11.) These sediments are probably either Pleistocene or Tertiary. On the road to Hidden Spring it was observed that although pebbles of purple and red porphyritic rocks (probably Tertiary) were abundant in the recent wash they were absent in the exposures of older alluvium. The pebbles in the older alluvium were mostly granite and a dark-greenish crystalline rock.

The south face of the Quail Mountains is as a whole smoother in contour than the Granite Mountains, but in several places it shows badland topography. The general appearance of the range suggests that the unconsolidated sediments may be extensive and that they have easily been eroded to give the rounded outlines.

The southwestern part of the Owlhead Mountains, bordering Leach Valley, is composed of gravel and gypsum-bearing clay beds. Near the Owl Holes, about a mile east of the border of the basin, these beds strike N. 85° E. and dip 27° SE. The northwest arm of the Avawatz Mountains, which lies south of the road between Leach Spring and Death Valley, also appears from the road to be composed of relatively unconsolidated sediments. It shows topography that approaches the badland type. The geology of this range of hills within the Leach Valley basin, however, may be complex, for farther east, along Cave Springs Wash, a great variety of rocks are exposed, including ancient metamorphosed sedimentary rocks, possibly as old as the Cambrian, intrusive rocks, and unconsolidated sand, gravel, and clay of Tertiary or Pleistocene age.

The physiographic and geologic evidence indicates strongly that the main part of Leach Valley is due to faulting. The Valley is narrow, and the mountains on each side, especially the Granite Mountains, rise steeply. At the only place where bedding was observed, on the south slope of the Quail Mountains opposite Leach Spring, the beds were tilted to the southwest at an angle of about 45°. The deep arroyos observed at several places suggest that uplift has caused active erosion. On the Searles Lake topographic map and on the relief maps that accompany this report (pls. 10 and 11) a distinct fault, known as the Garlock fault, can be traced from the vicinity of Garlock station, in T. 29 S., R. 39 E. Mount Diablo meridian, northeastward to the south end of the Slate Range. (See p. 118.) The alinement of Leach Valley with this fault is so marked that there is no doubt that the fault passes through the valley. In the short time spent in the region it was not possible to determine the exact position and nature of the fault—whether the valley is a block dropped down between the Granite and Quail Mountains or whether the valley is formed by the steep tilting of the Quail Mountain block toward the Granite Mountains. The fault doubtless continues eastward beyond the border of the valley, but in the absence of detailed field work its position is problematic. The ridge southeast of the Owl Holes, which forms the northwest end of the Avawatz Mountains, has the appearance of being formed of uplifted sedimentary rocks, but these were not examined. As suggested in the description of Avawatz Valley (see p. 199) the arm of the Avawatz Mountains that ends near Two Springs and the valley south of it may be fault blocks. According to observation on a hasty trip down Cave Springs Wash, there are in that locality several fault zones (see p. 582), and the eastward extension of the Garlock fault can be determined only by detailed field work. The structure on the north slope of the Avawatz Mountains is apparently considerably complicated, as the scattered observations made so far indicate that a fault system that has a northwesterly trend, approximately parallel to the Death Valley trough, intersects with a fault system that has an easterly trend. (See p. 585.)

WATER RESOURCES

There are no permanent streams in the region. So far as known, no wells have been dug in the alluvium of the valley. Water is obtainable at four springs or wells in or close to the mountains, which are described below.

The conditions appear to be unfavorable for obtaining any large quantity of ground water from the alluvium. The contributory drainage area is not great nor is the precipitation. Furthermore, the small playa is apparently of the dry type. Underground leakage seems possible at two places—at the west end of the basin, where the divide is composed of alluvium, and on the northeast, where the border of the basin is apparently composed of unconsolidated beds of sand, gravel, and clay. There are no data to show whether water can be obtained from the alluvium. The general conditions, however, are so disadvantageous that there is little incentive to attempt to develop a supply, unless it were for mining. The area of land that is favorably situated for irrigation is small, as most of the valley is steeply sloping or cut by washes.

WATERING PLACES

Water for travelers is available at four places in the valley—Leach Spring, Desert King Spring, Two Springs, and Drinkwater Spring. Each of these places is three-quarters of a mile or more from the main traveled roads, but all are easily reached by automobile.

Leach Spring.—Leach Spring is one of the best-known springs in the Mohave Desert region and has been used as a watering place since the earliest days of white men in the country. Many fragments of flint are found around the spring, and probably the place was an old Indian camp.

The spring is high on the north slope of the Granite Mountains. Travelers from the west turn off from the main road 3 miles west of the spring and follow a branch road at a point marked by a United States Geological Survey signpost. This road for 2 miles runs about S. 75° E., gradually approaching closer to the foot of the mountains, and then turns abruptly southeastward up a steep alluvial slope that reaches back into an embayment in the mountains. Travelers from the east turn off from the main road nearly opposite the highest part of Quail Mountain. This branch road may easily be missed, for it starts up an inconspicuous wash. The spring is in a ravine about 25 feet deep, which is apparently eroded in unconsolidated alluvium that consists of decayed granite, but solid rock may lie at a depth of only a few inches. A large willow stands beside the spring. (See pl. 15, *A*.) The spring basin is about 4 feet square and 1½ feet deep. When visited it was inclosed with boards but had no top and was full of leaves. The decaying leaves formed a dirty muck on the bottom, which gave the water a bad taste. No solid rock is visible in the spring, but granite rises a few feet above it. The spring, however, apparently has its source in the granite, for water was seen in small holes in the bottom of the gulch 250 feet above the spring and grass and weeds grew in abundance at that place. When visited there was no surface flow, but when bailed out the basin filled at the rate of a gallon a minute. The temperature of the spring in January was 55½°, when the air temperature was 53½°. As there is no flow the temperature is probably influenced by the daily and seasonal temperatures. An analysis shows it to be a calcium carbonate water of good quality that contains only 334 parts of dissolved solids per million. (See analysis 1, p. 198.)

Desert King Spring.—Desert King Spring is in a gulch about 8 miles southeast of Leach Spring. In January, 1917, it could be reached from a road that branches from the Leach Valley-Death Valley road and leads in a general southeasterly direction to Silver Lake, but in 1921 it was reported that the road was impassable for automobiles. This road turns southeast from the Leach Valley road about 5 miles northeast of Leach Spring and leads to a wash, up which it goes nearly due south. About half a mile before it reaches the Granite Mountains it turns abruptly eastward out of the wash at a point marked by a Geological Survey signpost. To reach Desert King Spring, at this point the traveler continues southward up the wash for about four-tenths of a mile and turns into the right-hand one of two canyons. About three-quarters of a mile from the road junction, just beyond a southward bend in the road, stands an old cabin and stamp mill. The spring or well is east of the wash, about 300 yards south of the cabin and 50 feet above it. There is a small pool of water and near by it a well dug in granite. The well is 15 feet deep, and when visited water was 1 foot from the top. There was no overflow from either the well or the pool. An analysis (2 in table, p. 198) of a sample from the well showed the water to be of fair quality. It is a calcium carbonate water and has 583 parts of total solids per million parts of water.

Two Springs.—Two Springs is about 5 miles northeast of Desert King Spring, at the northwest end of the southern arm of the Avawatz Mountains. The place is easily reached from the Leach Valley-Silver Lake road. The springs are readily found, as they are surrounded by a patch of salt grass and other water-loving plants. The water comes from two shallow trenches dug in alluvium or residual soil, but the ultimate source is probably the granite, which is only a few yards away.

The water seeps slowly into the trenches and runs down the slope about 50 feet. It is apparently of good quality. When visited on October 19, 1917, the temperature of the water was 62°, but on

January 17, 1918, the temperature of the water was 55½°, the air temperature then being 53°. Apparently the water comes from some relatively shallow source and is affected by changes in the temperature of the air.

Drinkwater Spring.—Drinkwater Spring is on the north slope of the Granite Mountains near the southeast corner of Leach Basin. It is reached by a good road which branches southwestward from the Leach Valley-Silver Lake road a few hundred yards west of Avawatz Dry Lake. The distance to the spring by this road is about 3 miles. A poorly defined road also leads to the spring from the main road several miles west of the dry lake. The road from Avawatz Dry Lake leads to a cabin in a slight small embayment in the mountains. About 250 feet east of the cabin is a well dug in granite about 8 feet deep. The water was 3 feet deep when visited. This well was mistaken for the spring, which is said to be several hundred feet farther southeast, on the southeast side of the granite ridge. A trail running eastward along the foot of the ridge probably leads to the spring. Although a sample was not taken the water in the well is apparently of good quality.

Other springs.—In Water-Supply Paper 224 are described three springs in Leach Basin which are not now known by the names given there. A spring described as Brook Spring [32] is believed to be the same as Two Springs. Whitney Spring [33] is believed to be the same as Drinkwater Spring. Wheeler Spring is described as situated in a pass between Leach Mountain (Granite Mountains) and the Avawatz Mountains, about 3 miles south of Brook Spring.[34] From the description it may be in the canyon about 3½ miles south of Two Springs, through which the drainage of the southeastern arm of Leach Basin reaches the main valley.

Analyses of water from springs in Leach Valley, Calif.

[Parts per million]

	1	2
Silica (SiO_2)	78	63
Iron (Fe)	.22	.08
Calcium (Ca)	41	93
Magnesium (Mg)	5.8	17
Sodium and potassium (Na+K)	52	[a] 53
Carbonate radicle (CO_3)	16	7.2
Bicarbonate radicle (HCO_3)	132	179
Sulphate radicle (SO_4)	39	97
Chloride radicle (Cl)	37	91
Nitrate radicle (NO_3)	Trace.	37
Total dissolved solids at 180° C	334	583
Total hardness as $CaCO_3$ (calculated)	126	302
Date of collection	([b])	([c])

[a] Calculated. [b] Oct. 14, 1917. [c] Oct. 18, 1917.

Analysts: 1, Addie T. Geiger, U. S. Geological Survey; 2, Margaret D. Foster and C. H. Kidwell, U. S Geological Survey.

1. Leach Spring, probably in sec. 14, T. 17 N., R. 1 E. San Bernardino meridian. (See p. 196.)
2. Desert King Well, probably in sec. 31, T. 17 N., R. 3 E. (See p. 197.)

[32] Mendenhall, W. C., Some desert watering places in southeastern California and southwestern Nevada: U. S. Geol. Survey Water-Supply Paper 224, p. 46, 1909.

[33] Idem, p. 54.

[34] Idem, p. 54.

AVAWATZ VALLEY

GENERAL FEATURES

A small playa in the northeastern part of T. 16 N., R. 4 E. San Bernardino meridian, on some maps is named Avawatz Dry Lake, and in this report the small basin that is tributary to it is called Avawatz Valley. The northern boundary of the basin is formed by the western part of the Avawatz Mountains, and the southern boundary by an arm of the Granite Mountains. On the west the divide is formed by alluvial slopes that extend out from these two ranges. On the east it is formed partly by low rock hills and partly by an alluvial slope near the junction of the roads to Barstow, Silver Lake, and Cave Springs, in sec. 8, T. 16 N., R. 5 E.

The playa is probably not more than 3,500 feet above sea level, and the surrounding mountains are probably not 1,000 feet higher. There is no reason to believe that the average annual precipitation is greater than in most of the desert—that is, about 5 inches.

In 1918 no one was living in the valley. A few old buildings, the remains of an old mining camp known as Crackerjack, are visible west of the Barstow-Death Valley road in the northeast corner of the basin, about 2 miles southwest of Cave Springs. Apparently this camp was never of any importance as a producer, for no reference has been found in the literature except the mere fact that it was a gold camp. No other mines or prospects are known in the region. Conditions are not favorable for cattle grazing or irrigation.

The basin is traversed from east to west by a road from Silver Lake to Leach Spring and Johannesburg. This road is an alternative route, for a second one passes farther north through the south end of Death Valley. The principal route from Barstow to Silver Lake and Death Valley passes through the east end of the basin. No watering places exist on either of these roads within the basin, but water is available at Cave Springs and at Drinkwater Spring, within a mile or two of the northeast and southwest corners respectively of the basin.

Physiographically most of the Avawatz Valley forms the eastern part of a long, narrow valley that has been separated into two basins by alluvial wash from the mountains on the north and south. The divide thus formed is not very high, and it was probably completed comparatively recently. The narrowness of the valley and the straightness of its borders, especially at the north, suggest that it may be a down-faulted block. In the western part of this supposed structural valley, the drainage goes northwestward to Leach Dry Lake. (See p. 193.) Southeast of Avawatz Dry Lake the drainage divide is very low and apparently composed of alluvium, so that at one time there may have been a drainage outlet in this direction

Physiographically the northeastern fourth of the basin belongs to a larger basin that slopes southeastward from Avawatz Mountain, but apparently it has been cut off from that basin and the drainage has been diverted to Avawatz Dry Lake by the building of the alluvial slope southward from the Avawatz Mountains against a low rock hill. The drainage thus diverted reaches Avawatz Dry Lake through a narrow pass between low hills.

The Granite Mountains and probably most of the Avawatz Range that borders the basin are composed of granitic and dioritic rocks. An elongated hill that rises immediately southeast of the junction of the Barstow-Death Valley and Silver Lake-Randsburg roads is formed of granite surmounted by a small patch of volcanic rock at the top. In the northeastern part of the basin occur volcanic rocks, of probable Tertiary age. Talcose schist was observed in a wash along the Silver Lake road about 1½ miles east of Avawatz Dry Lake.

WATER RESOURCES

So far as is known there are no springs or wells in Avawatz Valley. A dry hole about 10 feet deep was found at the east end of the playa. There are no indications that ground water is close to the surface. There is at least one place, at the west end of the valley, where ground water may drain from the valley, and it is probable that the water table lies at a considerable depth. The contributory drainage area is small, and the precipitation is not great, so that although water can doubtless be obtained here it is unlikely that wells will yield very much.

GRANITE VALLEY

The United States General Land Office plats for several townships south of Leach Valley show an unnamed valley in Tps. 15, 16, and 17 N., Rs. 1, 2, and 3 E. San Bernardino meridian, that apparently is completely surrounded by mountains. (See pls. 7 and 11.) The name Granite Valley is suggested, as the Granite Mountains form a large part of the valley border. This valley was not visited, and no definite information is available in regard to it. So far as known, no regularly traveled roads pass through the valley, although it is understood that a road or trail enters it from the wash in which the Desert King Spring is situated. The valley apparently does not contain any valuable resources, either agricultural or mineral, that would attract the homesteader or the prospector.

Spurr,[35] in his geologic reconnaissance map, shows the mountains on the north side of this valley as composed of Tertiary volcanic or sedimentary rocks. This mapping is in error, in part of the area, at least, for the Leach Point and Granite Mountains, where observed

[35] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California: U. S. Geol. Survey Bull. 208, pl. 1, 1903.

at Leach Spring, Desert King Spring, and Drinkwater Spring, are composed of granite, and that rock apparently forms the entire north side of these ranges. Red, brown, pink, and green tints are shown by a series of volcanic rocks and probably some sedimentary rocks, which are doubtless of Tertiary age, that occur east of the road from Indian Springs to Leach Spring, in T. 28 S., R. 47 E. Mount Diablo meridian, and these rocks may extend eastward into the unnamed valley. As seen from a distance of several miles the mountains on the south side of the valley seem to be composed of granite. At the west and east ends of the valley the divide is low and is apparently formed of alluvium but may consist of older rock which has been eroded to smooth slopes that resemble the alluvial slopes.

The General Land Office plat of T. 16 N., R. 2 E. San Bernardino meridian, shows two "dry lakes" or playas in the basin. One of these playas (not shown on pl. 11 but shown on pl. 7) is close to the mountains and covers about 1 square mile in secs. 3, 4, 9, and 10. The other is about half as large and covers part of secs. 33 and 34.

No springs or wells exist in the valley, so far as is known. In the absence of information in regard to the character of the playas it is not possible to predict the chances of obtaining water. The township plats and observations from points several miles distant indicate that the divide in one or more places may be composed of alluvium. If that is true, there may be leakage of ground water from the basin. In any case the total quantity of ground water is probably not large, for the region is not surrounded by high mountains, and the contributory area is not great.

FREMONT VALLEY

GENERAL FEATURES

Fremont Valley is a little north of the west-central part of the Mohave Desert region. (See pls. 7 and 11.) It lies almost entirely in the extreme eastern part of Kern County, but a very small part of it is in San Bernardino County.

The Valley Line of the Southern Pacific Railroad crosses the southwest corner of the basin from Mojave to Tehachapi Pass and thence to San Joaquin Valley. The Atchison, Topeka & Santa Fe Railway uses the tracks of the Southern Pacific Co. from Mojave to Bakersfield. A branch line of the Southern Pacific which leads to points in Owens Valley crosses the valley in a northeasterly direction from Mojave.

The Midland Trail, a road that leads from Los Angeles to the Lincoln Highway parallels the Owens Valley branch of the Southern Pacific from Mojave to Cantil, where it turns northward away from the railroad. This road is used considerably not only by persons going to and from the northwestern part of the Mohave Desert region but also by many transcontinental tourists and by persons going to Yosemite National Park. From Cantil a less traveled road continues northeastward along the railroad and leads by way of Garlock to Randsburg and Johannesburg and other points. Randsburg and Johannesburg are also reached by a road that leads northeastward from Mojave to Atolia and thence northward. The distance from Mojave to Randsburg is almost the same by the two routes. The route by way of Cantil has the advantage of being close to the railroad for most of the distance, whereas the other passes through unsettled territory for many miles. However, the route by way of Atolia is most generally used, partly because important mines are situated near it between Atolia and Randsburg. A road leads from Mojave westward along the Southern Pacific Railroad through Tehachapi Pass to San Joaquin Valley. Two alternative routes lead southward from Mojave to Los Angeles, and a road leads eastward from Mojave along the Atchison, Topeka & Santa Fe Railway to Barstow. Numerous less traveled roads lead to ranches and mines in different parts of the valley.

Mojave and Randsburg, at the southwest and northeast ends of the valley, respectively, are the principal towns. Mojave is especially important as a railroad junction. Randsburg is not on a railroad but is only a mile from Johannesburg, on the Atchison, Topeka & Santa Fe Railway. Both towns have good stores, several good but small hotels, and good garages. Gasoline and oil and some food supplies may be obtained at Cantil and sometimes at Ricardo, in Redrock Canyon, several miles farther northwest. A salt mill is located at Saltdale, and a section crew live at Garlock. The other stations on the Owens Valley branch of the Southern Pacific Railroad are only sidings.

A number of ranches are scattered in different parts of the valley, but as late as the winter of 1919–20 the only successful development had been in the lowest part of the valley, near Cantil. Mining has been active in several parts of the valley. The most extensive developments have been in Randsburg, where more than $10,000,000 in gold has been produced. The greater part of this gold has come from the Yellow Aster mine. A considerable quantity of gold has been obtained from "dry placers" in the valley west of Randsburg and several miles farther north, at Summit Diggings. Several million dollars' worth of tungsten has been produced from the mountains south of Randsburg, but the greater part if not all of the output of this mineral has come from land just east of the border of Fremont Valley. (See p. 227.) Salt is produced from Kane Dry Lake at Saltdale. Some borax has been produced from these salt beds.[36] It is said that they also contain potash in workable quantities.

[36] Brown, G. C., Mines and mineral resources of Kern County: State Mineralogist Rept. for 1913–14, Min. Bur., p. 51, 1915.

PRECIPITATION

The average annual precipitation at Tehachapi, about 2 miles west of the southwest border of the basin, for a period of 38 years, from 1877 to 1914, was about 10.5 inches. At Mojave for a period of 37 years, from 1877 to 1913, it was about 5 inches. (See pp. 90–91 and pl. 6.) The altitude of Tehachapi is 3,964 feet above sea level and of Mojave 2,751 feet.

The difference in the average annual precipitation is due in part to the difference in altitude, but also in a large degree to the fact that the Tehachapi Mountains and southern Sierra Nevada form a continuous barrier to the moisture-bearing winds that move from the west. In rising over the mountains the air is cooled and the moisture condenses. As it descends again on the desert side it becomes warmer again and the farther it moves from the mountains the less rain falls. Accordingly, in the parts of Fremont Valley that lie at about the same elevation as Mojave but farther east the average annual precipitation is probably less than 5 inches. At lower altitudes, as near Kane Dry Lake, it may also be less. Toward the Tehachapi Mountains and Sierra Nevada it increases. At some places in these mountains the altitude is considerably greater than at Tehachapi, exceeding 5,000 feet above sea level, and the average annual precipitation is doubtless somewhat greater. Although the El Paso and Rand Mountains rise to a greater altitude than Tehachapi they do not form as continuous a barrier as the Sierra Nevada, but the winds may pass around them. For this reason it is probable that the average annual precipitation in these mountains is not as great as at equal altitudes in the Sierra Nevada.

VEGETATION

As a result of the great altitude of the southern Sierra Nevada and consequent great rainfall, conifers and other trees grow in these mountains. No trees were observed in the El Paso and Rand Mountains or other mountainous parts of the basin. The vegetation of the alluvial slopes is characterized principally by the creosote bush and its associates, but some giant yuccas occur on the higher slopes. In the lowest part of the basin scattered mesquite grow, and near Kane Dry Lake, particularly near Koehn Springs, salt grass is abundant.

PHYSICAL FEATURES AND GEOLOGY

The boundary of the drainage basin of Fremont Valley is shown on Plate 7. The basin is slightly elongated from northeast to southwest. A playa, commonly known as Kane or Cane Dry Lake, lies in the lowest part of the basin a little to the northeast of the center of the basin.

The northern boundary of the basin is formed in part by the El Paso Mountains, including the Black Mountains, which trend northeast. These mountains form a triangular mass, with the base at the northeast and the apex at the mouth of Redrock Canyon near Cantil. The southeast face of the range is very straight and steep [37] and marks the line of the Garlock fault, which continues northeastward for many miles.[38] (See p. 118.)

The faulting probably occurred not longer ago than the Pliocene epoch, as it affected rocks at the south end of the Slate Range which, according to Gregory and Noble, are probably Pliocene. There are some indications of rather recent movement in the truncated alluvial fans near Garlock station and small troughlike depressions near the Goler well.

The northeast end of the El Paso Mountains is composed of granitic rocks. Between these rocks and Goler Gulch lie sedimentary rocks including quartzite, siliceous shale, and limestones.[39] Farther southwest these rocks are overlain by beds of Tertiary sedimentary and volcanic rocks which were originally referred to the "Rosamond series" [40] but which have more recently been considered to be a distinct and younger formation, called by Merriam [41] the Ricardo formation. These beds he believes to be late Miocene or early Pliocene. The upper part of the series consists principally of sand and clay, which are considered to be waste slope and playa deposits. The lower part of the section includes a number of beds of tuff and basalt. A 14-inch bed of coal is reported near the base of the series.[42] The Ricardo beds generally dip toward the northwest. They, as well as the older rocks farther north, are overlain in part of the area by basalt, which probably had its origin in Black Mountain.

The El Paso Mountains may be considered as ending at Redrock Canyon, near Cantil. Southwest of this locality for 4 or 5 miles, as far as Jawbone Canyon, the mountains give way to high hills, and an area of badlands cut in the Ricardo series extends westward from 5 to 10 miles to the foot of the Sierra Nevada. The scenery in this section, particularly in Redrock Canyon, is very picturesque. In

37 On Plate 16 the contour interval is 100 feet in the valley but only 500 feet in the mountains, so that the relief does not stand out strongly.

38 Hess, F. L., Gold mining in the Randsburg quadrangle, Calif.: U. S. Geol. Survey Bull. 430, pp. 25–26, 1910. Gregory, H. E., and Noble, L. F., Notes on a geological traverse from Mohave, Calif., to the mouth of the San Juan River, Utah: Am. Jour. Sci., 5th ser., vol. 5, p. 230, 1923. Baker, C. L., Physiography and structure of the western El Paso Range and the southern Sierra Nevada: California Univ. Dept. Geology Bull., vol. 7, pp. 129–132, 136, 1912.

39 Hess, F. L., op. cit., p. 29.

40 Baker, C. L., cit., pp. 123–126; Notes on the later Cenozoic history of the Mohave Desert region in southeastern California: California Univ. Dept. Geology Bull., vol. 6, pp. 333–383, 1911.

41 Merriam, J. C., Tertiary mammalian faunas of the Mohave Desert: California Univ. Dept. Geology, Bull., vol. 11, No. 5, pp. 440–441, 447–448, 528–529, 1919.

42 Idem, p. 445.

this area the divide of the drainage basin lies a short distance north of Redrock Canyon and is underlain by alluvium. North of the divide a large alluvial slope descends from an altitude about 100 feet above Redrock Canyon gradually for may miles northeastward to Indian Wells Valley.

In the El Paso Mountains the divide is not along the highest part of the range, except at Black Mountain, but at least three large canyons have been cut completely through the main crest and drain a large part of the northwest slope of the range. (See p. 206.)

Southwest of Jawbone Canyon high mountains rise with a steep, rather straight border that is similar to the front of the El Paso Range and doubtless marks a continuation of the Garlock fault. These mountains stretch many miles westward and form the south end of the Sierra Nevada. In this area the drainage divide lies from 5 to 20 miles back from the front of the range.

The southern Sierra Nevada consists of a basement complex of pre-Cretaceous intrusive rocks and deformed metamorphosed stratified rocks. The metamorphic rocks include crystalline limestone, quartzite, and mica schist. This complex is overlain unconformably by a series of little-deformed igneous and sedimentary rocks, which are separated from the basement complex by a marked unconformity.[43] In the vicinity of Tehachapi the upper series consists of alluvial débris, andesitic lava flows and tuffs, and fresh-water lake or playa beds.[44] At two localities in the series Miocene mammalian fossils have been found.[45]

The southern boundary of the drainage basin is somewhat indefinite. In T. 11 N., Rs. 9, 10, and 11 W. San Bernardino meridian, it is formed by low rock hills. Between these hills and the mountains on the west the divide lies on an alluvial fan, and its location in some places can not be determined except by instrumental leveling. In the southeastern part of the basin the divide is formed in part by low hills and in part by rather smooth, gentle slopes, where it is also difficult to determine the exact divide. In this part of the region the divide as shown on Plates 7 and 16 may be considerably in error. The low hills that rise above the alluvial slopes in the southern and southeastern part of the basin are composed in part of granitic rocks. Some of the knobs, as Desert Butte, in T. 12 N., R. 10 W. San Bernardino meridian, and Castle Butte, in T. 32 S., R. 38 E. Mount Diablo meridian, show volcanic and sedimentary rocks of probable Tertiary age, and these rocks may be more widespread than is shown

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[43] Buwalda, J. P., Structure of the southern Sierra Nevada (abstract): Geol. Soc. America Bull., vol. 26, p. 403, 1915. Lawson, A. C., The geomorphogeny of the Tehachapi Valley system: California Univ. Dept. Geology Bull., vol. 4, p. 437, 1906.

[44] Lawson, A. C., op. cit., pp. 439–445.

[45] Buwalda, J. P., New mammalian faunas from Miocene sediments near Tehachapi Pass, in the southern Sierra Nevada: California Univ. Dept. Geology Bull., vol. 10, No. 6, pp. 75–85, 1916.

on Plate 8. Over many square miles in the southeastern part of the basin the surface has a gentle slope that gives the impression of an alluvial slope. However, in a number of places rock crops out in erosion channels and prospect shafts, and it is apparent that the slope is in part an eroded rock surface or pediment.

In the northeastern part of the basin the divide lies in the Summit Range, Klinker Mountain, Red Mountain, and the extreme northeast end of the Rand Mountains. The geology of this part of the basin has been described by Hess [46] and Hulin.[47] Klinker and Red Mountains are composed largely of Tertiary volcanic rocks. The Rand Mountains and the Summit Range consist largely of granitic rocks and schist. Minor areas of sedimentary rocks of supposed Tertiary age occur at several places in the Summit Range and Klinker and Red Mountains. The Rand Mountains lie almost wholly within the drainage basin. They have a northeasterly trend, approximately parallel to the El Paso Mountains. They are much steeper on the northwest side than on the southeast, and it is possible that they are an unlifted fault block.

The drainage system of Fremont Basin presents some unusual features. In the El Paso Mountains, the southern Sierra Nevada, and the Rand Mountains the divide does not everywhere lie along the principal ridges, as it commonly does in mountainous areas. On the contrary, in a number of places the drainage channels have cut entirely through the principal ridges and drain large areas on the side of the mountains farthest from the main part of the valley. Thus Goler Gulch, Last Chance Gulch, and Redrock Canyon head on the northwest side of the main range of the El Paso Mountains and cut through it in a southeasterly direction. The course of Last Chance Gulch is especially peculiar in that it extends for several miles in a southwesterly direction on the far side of the range and approximately parallel to it and then turns at right angles across it. Redrock Canyon, on the other hand, rises more than 10 miles northwest of the El Paso Range, and its course for its entire length is in general at right angles to the range.

Similarly the drainage channels of the southeastern or far slope of the Rand Mountains, which start in a southeasterly direction, gradually trend westward and reach a large wash that carries the drainage around to the northwest side of the range.

In the southern Sierra Nevada from Jawbone Canyon to Tehachapi Pass a large mountain mass rises steeply from the valley. This mass has almost been isolated into a low ridge by Jawbone Canyon and

[46] Hess, F. L., Gold mining in the Randsburg quadrangle, Calif.: U. S. Geol. Survey Bull. 430, pp. 23–47, 1910.

[47] Hulin, C. D., Geology and ore deposits of the Randsburg quadrangle: California State Mining Bur. Bull. 95, 1925.

Cache Creek. Cache Creek rises on the northwest side of the ridge and has a course analogous to that of Last Chance Gulch in the El Paso Mountains. The peculiarities of drainage of the basin, particularly those in the El Paso Mountains and southern Sierra Nevada, are to a large extent related to orogenic movements in the region The unusual drainage features of the El Paso Mountains have been discussed by Baker [48] and those of the southern Sierra Nevada near Tehachapi Pass by Lawson.[49]

A notable feature of the drainage is the extent to which the run-off from large mountainous areas is concentrated into a few principal channels. The drainage of a very large part of the El Paso Mountains is carried into three canyons—Goler Gulch, Last Chance Gulch, and Redrock Canyon. In the southern Sierra Nevada the drainage from an area of about 350 square miles is concentrated into four streams—Cache Creek, Lone Tree Canyon, Jawbone Canyon, and to a lesser extent Redrock Canyon. Most of this area lies at an altitude greater than 4,000 feet, and a considerable part is higher than 5,000 feet. The drainage from the Summit Range, Klinker Mountain, and Red Mountain is concentrated into a single channel near Rand station, on the Southern Pacific Railroad. The drainage from most of the southeast side of the Rand Mountains is concentrated into a single channel that extends northward through the west side of Tps. 31 and 32 S., R. 38 E. Mount Diablo meridian.

The significance of this concentration of drainage is that at times of heavy rains a much larger quantity of water is poured into the valley to be absorbed by the alluvium than if a great many smaller channels discharged water on to the alluvium. Under the latter condition a considerable proportion of the run-off would be required to moisten the surface soil and would be evaporated in a short time. Where the drainage is concentrated into fewer channels a relatively smaller proportion of the water is lost in this manner, and more is available for recharge of the water table. However, so far as the drainage of the southeast side of the Rand Mountains is concerned, the slope of the land is so gentle that most of the run-off is probably dissipated before it reaches the main channel.

According to planimeter measurements the total area of Fremont Basin is about 1,050 square miles, of which about 525 square miles, or 50 per cent, is mountains and about 15 square miles, or a little more than 1 per cent, is playa. The remaining area, about 510 square miles consists mostly of alluvial slopes but includes some low hills.

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[48] Baker, C. L., Physiography and structure of the western El Paso Range and the southern Sierra Nevada: California Univ. Dept. Geology Bull., vol. 7, No. 6, pp. 134–136, 1912.

[49] Lawson, A. C., The geomorphogeny of the Tehachapi Valley system: California Univ. Dept. Geology Bull., vol. 4, No. 19, pp. 431–454, 1906.

The lowest part of Fremont Valley is occupied by a playa called Kane or Cane Dry Lake, which is a playa of the moist type. Ground water is close to the surface beneath it, and there is a discharge of ground water by capillary rise and evaporation from it. It is surrounded by vegetation that discharges ground water by transpiration. The playa deposits are more saline than those of many of the other playas in the Mohave Desert region. Salt is produced from the surface deposits.

The relative purity of the salt deposits raises a question as to their origin. No data are available as to whether they extend to a great depth, as in Searles Lake. It is therefore not clear whether the salt is the result of evaporation of a large lake that may have existed formerly, as in the Searles Lake basin, or whether the salt is formed by the evaporation of the storm water that collects from time to time, together with some resulting from the evaporation of salt water. No unmistakable evidences of a lake, such as the wave-cut cliffs or deposits of tufa which are found in the Searles Basin, have yet been discovered around Kane Dry Lake. Beds of blue sand and clay have been found at different depths down to at least 735 feet from the surface. (See log, p. 209.) Blue clay is said to have been struck in a well drilled about 8 miles southwest of Randsburg by the Valmedath Mining Co. The clay was reached at a depth of about 250 feet and apparently extended to a depth of about 500 feet. These blue beds may indicate deposition in a perennial body of water. It is not unlikely that a lake existed in the basin during the Pleistocene epoch, when lakes are known to have existed in other parts of the Mohave Desert region. The mountainous area tributary to the valley is large. The high Sierra Nevada, which now receives a rather abundant rainfall, constitutes about a third of the entire basin, and in a moister period it undoubtedly produced a considerable run-off. Furthermore, there is some reason to believe that a lake existed in Antelope Valley, south of Fremont Valley, and that it overflowed into Fremont Valley near the north end of the present playa known as Rogers Dry Lake. (See p. 303.) It seems that the water supplied from the two sources mentioned would have been sufficient to form a perennial lake. Further investigation may bring to light evidence of such a lake.

The alluvium in the lower part of Fremont Valley, east and southeast of Cantil, appears to be unusually clayey, and according to logs of wells fine alluvium continues to a considerable depth, as is shown by the following log of a well on the ranch of Fred Hartsook:

Log of well of Fred Hartsook, in SE. ¼ NE. ¼ sec. 36, T. 30 S., R. 37 E.

[Furnished by S. F. Caty, driller]

	Thickness (feet)	Depth (feet)
Soil	7	7
Clay	22	29
Dark clay	11	40
Sand and fine gravel (casing perforated)	12	52
Soft dark clay	54	106
Sand (casing perforated)	4	110
Dark clay	28	138
Sand (casing perforated)	6	144
Dark clay	27	171
Good gravel (casing perforated)	9	180
Dark clay	30	210
Yellow clay	10	220
Dark clay	10	230
Yellow clay	8	238
Sand and fine gravel (casing perforated)	12	250
Soft yellow clay	43	293
Sand and fine gravel (casing perforated)	16	309
Black clay	63	372
Yellow clay	46	418
Sand (casing perforated)	6	424
Yellow clay	12	436
Sand (casing perforated)	4	440
Clay	6	446
Sand (casing perforated)	4	450
Clay	7	457
Gravel (casing perforated)	6	463
Yellow clay	121	584
Blue clay	20	604
Red clay	80	684
Dark clay	24	708
Yellow clay	10	718
Light-colored clay	8	726
Blue clay	9	735
Yellow clay	32	767
Good gravel (casing perforated)	20	787
Yellow clay	29	816
Sand and fine gravel (casing perforated)	8	824
Sandy clay	8	832
Gravel (casing perforated)	6	838
Sandy clay	64	902
Sand and fine gravel (casing perforated)	5	907
Sandy clay	9	916
Sand (casing perforated)	3	919
Sandy clay	9	928
Sand and fine gravel	8	936
Tough clay	2	938

In this well only 94 feet of gravel, or sand and gravel, was struck, or about 10 per cent of the total depth of the well. For more than 86 per cent of the total depth this well passed through clay beds. This proportion of clay to gravel is unusual as compared to that in wells in other parts of the Mohave Desert region for which data are available. (Compare wells in Lower Mohave Valley, p. 487.) The clay beds, particularly the blue clays, were probably laid down in playa lakes or perennial lakes. Apparently this locality has been the low part of a closed basin for a long period. Near the borders of the valley the alluvium is undoubtedly coarser. The wells of the Yellow Aster Mining & Milling Co. at Goler penetrate coarse gravel that contains many large boulders.

WATER RESOURCES

SURFACE WATER

At several places in the southern Sierra Nevada there are short stretches of perennial streams. For longer stretches streams probably flow for several months of the year but are dry during the hot summer. Running water is said to persist for several months at short stretches in Red Rock Canyon and Last Chance Gulch, in the El Paso Mountains. So far as is known there are no other streams in the valley.

GROUND WATER

GENERAL FEATURES

Data in regard to 57 wells, including most of the wells in the valley, are given in the table on pages 221–222, and the location of these wells is shown on Plate 16. In the short time that the writer could spend in

Fremont Valley it was possible to visit only a very few of these wells, and the data for many of them were reported to him by persons other than the owners of the wells. As frequently happens when data are obtained in this manner there are some evident discrepancies. However, sufficient data were obtained to show the conditions in most of the valley.

Nearly all the wells are situated in the large alluvium-filled tracts, but the public supplies of the two principal towns in the valley, Mojave and Randsburg, come from wells in the mountains. The ground-water conditions may therefore be considered in two parts—ground water in the mountains and ground water in the valley.

GROUND WATER IN THE MOUNTAINS

Ground-water supplies in the mountains that border Fremont Valley are of relatively little consequence. The only notable developments, as mentioned above, are the wells that supply Mojave and Randsburg and adjacent towns. These places are so situated that water can not easily be obtained from wells in the main valley, and the sources in the mountains have been developed.

Wells of Randsburg Water Co.—For some years the public supply of Randsburg and Johannesburg has been furnished by the Randsburg Water Co. In 1917 the service was extended to Atolia, where previously water for all purposes had been hauled by train from Hinkley. It is understood that during the silver boom that began in 1919, the increase in the quantity of water required for milling and other purposes was so great that it became necessary to develop additional supplies. No data are available in regard to these recent developments.

The Randsburg Water Co. in 1917 obtained water from three wells, known as the Mountain Well, the Skilling Well, and the Squaw Spring Well. These wells are about 5 miles east and northeast of Randsburg, in T. 29 S., R. 41 E.—the Mountain Well in the NE. ¼ sec. 27, the Skilling Well in the SE. ¼ sec. 22, and the Squaw Spring Well in the SE. ¼ sec. 34. The Squaw Spring Well is in the drainage basin of Golden Valley and is described on page 231. One of the other two wells may also be just over the divide in that basin, but the two wells are so near to each other that they are here described together.

The principal source of supply is the Mountain Well (No. 2 in table on p. 221 and on pl. 16.) The well is really a shaft about 7 by 9 feet in area and 380 feet deep. There is a 30-foot drift at the bottom. The depth to water in 1917 was about 375 feet. The shaft is sunk through the lava that forms Klinker Mountain. The water comes from crevices in the rock at the bottom of the shaft. The well is pumped with an electrically operated Fulton triplex pump set at the bottom of the well. The yield of the well in 1917 was about 40,000 gallons in 24 hours. At this rate of pumping the well practically went dry each day. Prior to the summer of 1916 the well was less than 372 feet deep, and the water stood several feet above the level in 1917. In 1916 the well was deepened to 372 feet, and it yielded about 60,000 gallons a day. In the spring of 1917 the yield dropped to about 7,500 gallons a day. It was increased again by further deepening and shooting to open up the crevices. It is said that in 1919 there again was a marked decrease in the yield.

An analysis of a sample from the Mountain Well shows that it is moderately mineralized and contains 387 parts per million of total solids. (See analysis 1, p. 223.) It is good for domestic use, but only fair for boilers because it contains fairly large quantities of scale-forming and foaming constituents.

The Skilling Well (No. 1, pl. 16) is a double-compartment shaft, about 8 by 12 feet in cross section. It is 400 feet deep and at the bottom a drift 400 feet long leads toward the Mountain Well, ending about 450 feet from it. It is estimated that the bottom of the Skilling Well is about 70 feet below the bottom of the Mountain Well. This well is also in lava rock, and the water comes from crevices in the face of the drift. The depth to water when not pumping is 390 feet. About 5,000 gallons collects in the sump in 24 hours, and this is pumped out in about 1½ hours. The well is pumped by a 2-cylinder mine pump with the electrically operated power head at the surface of the ground.

Three other wells have been put down near the wells described, but in 1917 they had been abandoned. One, drilled by the Yellow Aster Mining & Milling Co., is said to have been about 1,700 feet deep, and the depth to water about 600 feet. The yield was about 45,000 gallons in 24 hours. The water in this well apparently came from a different horizon than that in the wells now pumped, for it was poorer in quality. The location of this well with respect to the others just described is not known.

An unusual condition at the wells being pumped is that the water level is generally higher in summer than in winter and the yield accordingly is a little greater. This condition is in contrast to that in many parts of the desert, where the water table is highest in the early spring and lowest in the fall, at the end of the pumping season. The reason for this difference is not known. It may be that it takes the water a longer time to percolate downward to the water table at the wells.

Although the wells in use are of considerable cross section and the drifts offer a large percolating area, the yield of the wells is relatively small. The Mountain Well yields less than 30 gallons a minute. Even with this low rate of pumping in recent years the water table has dropped several feet. It is evident that the ground-water supply in this locality is not great, and the wells now seem to be depleting the supply.

Water has been struck in several shafts in the Randsburg district, but in none of these has the supply been very great. The large consumers of water, principally the ore mills, have been obliged to seek water elsewhere. The Yellow Aster Mining & Milling Co. has for a number of years pumped water from wells about 7 miles northwest of its mill, lifting it 440 feet to the surface and then boosting it more than 1,000 feet to the mill. (See p. 213.) There seems to be little hope that water sufficient for all purposes can be obtained from wells in the mountains near Randsburg.

In 1917 the Randsburg public supply was carried to the town in 6 miles of 5⅝-inch pipe. The water is pumped first to a pressure reservoir at the old Yellow Aster mill, which is high above the town, and pressure ranged from 250 pounds to the square inch in the lowest part of the town to 100 pounds in higher parts. The water was furnished to most domestic users at a flat rate, which for families was $3.50 a month. Water delivered to large consumers was metered, and the rate for less than 1,000 gallons was 1 cent a gallon; between 1,000 and 5,000 gallons, ¾ cent; between 5,000 and 20,000 gallons, ½ cent; between 20,000 and 30,000 gallons, ¼ cent; between 30,000 and 150,000 gallons, ⅕ cent a gallon, or $2 per 1,000 gallons; over 150,000 gallons, $1.50 per 1,000 gallons.

Water supply for Mojave.—Although Mojave is situated in the alluvium-filled valley, its water supply is brought by pipe line from Cameron, about 8 miles northwest (12 miles by the railroad). Water could perhaps be obtained in drilled wells at Mojave, but the depth to water probably would be at least 500 feet. It is possible, however, that bedrock might be struck before water was reached. If this happened it is unlikely that much water would be found in the rock.

At Cameron the Southern Pacific Co. has several wells. One well, about 150 feet deep, is reported to yield about 900 gallons a minute. Other wells yield only about 300 gallons a minute. The wells were not visited, and very little definite information was obtained in regard to them. It is believed, however, that they are in alluvium that fills the narrow valley of Cache Creek. Some water is obtained from a spring. The water is carried to Mohave in a 12-inch pipe line under a head of several hundred feet.

Other wells in the mountains.—At Ricardo, in Redrock Canyon, is a well 60 feet deep. In 1917 it yielded about 23,000 gallons a day (about 16 gallons a minute). No data were collected in regard to any other wells in the mountains. However, there are doubtless other wells in canyons, especially in the southern Sierra Nevada.

GROUND WATER IN THE ALLUVIUM

The area in which wells are obtained from the alluvium may be divided into two parts—that lying northeast of Kane Dry Lake and that lying south and southeast of it. Most of the wells lie south and southeast of the playa.

NORTHEASTERN PART OF THE VALLEY

Goler Wells.—The most productive wells northeast of the playa are those of the Yellow Aster Mining & Milling Co., probably in sec. 12, T. 29 S., R. 39 E. Mount Diablo meridian, and known as the Goler Wells. The wells are within a few hundred yards of the base of the El Paso Mountains, on an alluvial fan built in front of Goler Gulch. The wells are very near to the Garlock fault line, which lies along the base of the El Paso Mountains. (See p. 204.) One well (the company's No. 5 but No. 3 in the table on p. 221 and on pl. 16) is near the wash, and another (company No. 3 but No. 4 on pl. 16) is on an elevated tongue of alluvium, about 40 feet higher than No. 5.

The company's well 5 is 12 inches in diameter and 1,400 feet deep. The depth to water in 1917, when not pumping, was reported to be 440 feet. The well is cased with screw casing, 12 inches in diameter, to a depth of 700 feet, 10 inches from 700 to 900 feet, and 8 inches from 900 to 1,400 feet. It is perforated from 516 to 563 feet and from 1,300 to 1,400 feet. Most of the water comes from beds between 516 and 563 feet. The well apparently penetrated sand, gravel, and boulders nearly to the bottom. It is generally pumped at the rate of only 65 gallons a minute, but this is not its capacity. The drawdown at this rate is 40 feet.

The company's well 3 is 9⅝ inches in diameter and 520 feet deep. The depth to water in 1917 was 460 feet. The well is cased to the bottom with screw casing. It is generally pumped at the rate of 65 gallons a minute. The temperature of the water from this well is reported to be 80° F.

The two wells are operated by electrically driven plunger pumps, with the motors at the surface and the plungers actuated by cables. Near the wells is an old shaft 450 feet deep, which penetrated only alluvium. This was the original source of supply, and the water was raised in 500-gallon buckets. When the deeper new wells were put into use the shaft became dry. In 1917 the water from the wells was raised to a tank in a drift at the bottom of the shaft, from which another pump boosted it to the surface. A third pump raised the water from the station to Randsburg against a head of about 1,000 feet.

The water from the Goler Wells is used principally for mining and milling. As shown by analysis 2 on page 223, it is highly mineralized, containing 1,008 parts per million of total dissolved solids. It is only fair for domestic use, being rather hard. It is bad for boilers because it contains a large quantity of both scale-forming and foaming constituents. The water would be of good quality for irrigation, but the great lift prevents its use for this purpose. Calcium sulphate is abundant in the water, and in this respect it is different from most other waters in the region. The immediate source of this constituent is not known.

Other wells.—About 3 miles southwest of the Goler Wells, west of the road to Mojave, probably in the SW. ¼ sec. 14, T. 29 S., R. 39 E., there are three holes within 250 yards of one another. One of these, a dug well 4 feet in diameter, is 65 feet deep, and on October 1, 1917, the depth to water was 55.7 feet. Another well, 250 yards southwest of the first well, is more than 70 feet deep, but it could not be measured. The third, about 200 yards south of the first, was 42 feet deep and was dry when visited.

There are several wells at the settlement of Garlock, which is about 2 miles northeast of the siding of that name. In these wells the depth to water ranged from 28 to 42 feet (see Nos. 6 to 9 in table, p. 221), but the difference is due, in part at least, to difference in the altitude of the surface. Southeast of these wells a number of others have been put down in the axial part of the valley. Near the northeast end of Kane Dry Lake water stands within a few feet of the surface, but the depth increases away from the playa until in sec. 27, T. 29 S., R. 39 E., it is said to be 200 feet to water. (See Nos. 10, 11, and 12, p. 221.) A well drilled for the Valmedath Mining Co. at a place indefinitely described as 8 miles southwest of Randsburg is 502 feet deep, and the depth to water is 170 feet. This well is reported to have yielded about 180 gallons a minute with a deep-well plunger pump. It is said that there was very little drawdown when pumping at this rate, so that doubtless more water could be pumped. The water level in wells 5, 7, 8, and 9, near Garlock, is about 150 feet higher than in well 10, in the central part of the valley, and about 100 feet above the level in the Goler Wells (Nos. 3 and 4), although the Goler wells are farther up the valley. The causes of these great differences are not clear, but perhaps the water level in the wells near Garlock is affected in some way by the Garlock fault. A mile or two southwest of these wells the Mesquite Springs issue from the base of a scarp, which may be due to faulting, and this fact supports the belief that the conditions in the wells may be affected by the faults.

No data were obtained in regard to the yield of any of the wells except that of the Valmedath Mining Co. It is probable, however, that yields of at least 450 gallons a minute could be obtained from properly constructed wells in the area northeast of the playa. However, the wells already drilled show that within 3 or 4 miles of the playa the depth to water becomes so great that pumping for irrigation would not be profitable. At best the belt in which irrigation may be successful appears to be only a mile or two wide from northwest to southeast and possibly 2 or 3 miles across the valley. No analyses have been made of the water.

SOUTHWESTERN PART OF THE VALLEY

Depth to water.—In the area south and southeast of Kane Dry Lake at least 40 or 50 wells have been drilled. Near Kane Dry Lake the water table is within a few feet of the surface and several deep wells flow at the surface. (See Nos. 15, 19, 21, and 22 in table, p. 221, and on pl. 16.) Salt grass and other plants that transpire ground water cover a considerable area, which extends as far as 2 miles from the edge of the playa. The water table rises more or less uniformly toward the south and southeast. The rise of the surface of the land in the same direction, however, is so much greater that the depth to water is greater at points progressively farther from the playa. As shown by well 25, the depth to water of 100 feet is reached at points about 10 miles from the playa. The maximum depth to water reported is 425 feet in well 47, in the SW. ¼ sec. 28, T. 32 S., R. 36 E. Mount Diablo meridian. In well 53, belonging to George A. Arper, in the NW. ¼ sec. 12, T. 11 N., R. 12 W. San Bernardino meridian, the depth to water is said to be 400 feet.

According to the data given in the table on page 221, there are some marked changes in the depth to water that do not seem to be accounted for by difference in the altitude of the surface at the wells. Thus in wells 33 and 34 the depth to water is a little more than 300 feet, whereas in wells 44, 45, and 46, which according to the topographic map are at a higher altitude, it is less than 275 feet to water. Also in well 55 the depth to water is about 200 feet, whereas in well 48, about 3½ miles north of west of well 55 and certainly at no greater altitude, it is reported to be 245 feet to water.

These discrepancies may be due in part to errors in the reports received from different persons and to lack of actual measurements made at approximately the same time. However, it seems possible that they may result from the geologic conditions.

The gradient of the water table is evidently greater in the higher southwestern part of the valley than in the lower part of the valley. Thus between Kane Dry Lake and well 33 it is between 10 and 15 feet to the mile, whereas between wells 33 and 47 it is between 40 and 50 feet to the mile. Between the playa and well 44 it is between 15 and 20 feet to the mile, and between wells 44 and 47 it is at least between 30 and 40 feet to the mile. The explanation of this condition is believed to be as follows:

Of the wells reported the water table is highest in No. 47. This well is not far from the apex of a large alluvial cone that has been built out by Cache Creek where it emerges from the mountains. This stream drains a large area of the southern Sierra Nevada and undoubtedly contributes most of the water that is absorbed by the alluvium in the southwestern part of the valley. Near the apex of the cone a relatively large quantity of water is poured onto a small area. It can not percolate rapidly and piles up, as it were. As the water moves farther and farther from the mountains it spreads over a larger and larger area, and the lower part of the cone is more readily drained, so that the gradient becomes gentler. On the other hand, in the lower part of the basin the cross section through which percolation occurs is smaller than farther south, and the water table is also held near the surface because the basin is nearly or wholly impervious. As a result the water piles up again in the lower part of the basin and the gradient is lessened.

An unusual condition is found in the southern part of the valley, where in wells near the boundary of the basin the depth to water is less than in wells at lower altitudes. Thus in well 57, which is near the divide but is probably in Antelope Valley, the depth to water is 106 feet. In well 56 it is 170 feet; in well 55 it is 199 feet, in well 48 it is 245 feet, in well 46 it is 258 feet, and in well 44 it is 242 feet. The profile of the water table between these wells is shown in Figure 5. These wells are on the sides or near the axial line of a marked surface drainage line that extends southward from Kane Dry Lake to the border of the drainage basin in the northwestern part of T. 11 N., R. 9 W. San Bernardino meridian. As suggested on pages 208 and 303 it is probable that a lake once existed in Antelope Valley and overflowed into Fremont Valley at the low place in the divide in secs. 17 and 18, T. 11 N., R. 9 W. The divide appears to be composed of alluvium, but it is not known to what depth the alluvium may reach. The water table in Antelope Valley several miles south of the divide is at least 150 feet higher than it is in well 55. The conditions are thus favorable for movement of the ground water from Antelope Valley to Fremont Valley. The increase in the depth to water northward from the divide as shown in the wells mentioned above suggests very strongly that there is movement from Antelope Valley at this point. (See fig. 5 and p. 324.)

No information was obtained as to any wells on the long slope on the south side of the Rand Mountains and east of the large wash that stretches about due south from Kane Dry Lake. It is believed that only a few if any wells have been drilled in this part of the valley. In this area bedrock probably lies at no great depth, and it may be struck before water is reached. However, if the alluvium is thick it is nevertheless likely that the depth to water is very great in most of this area, probably at least 300 or 400 feet. This depth would be expected because of the great altitude of the surface above parts of the valley where the water table is at a depth of 200 feet or more, as in well 44.

Artesian conditions.—Throughout a large part of the valley south of Kane Dry Lake the ground water is under more or less artesian pressure. Within 3½ miles of the playa there are several flowing wells. The farthest well which is known to flow is No. 19, in the NE. ¼ sec. 36, T. 30 S., R. 37 E. Mount Diablo meridian, owned by Fred Hartsook. This well, which is 900 feet deep, is reported to flow about 45 gallons a minute. Another well owned by Mr. Hartsook, No. 31, in the NW. ¼ sec. 20, T. 30 S., R. 38 E., is reported to spout about 10 inches above the top of a 2-inch pipe that is 1 foot above the surface. A well of A. J. Crookshank, No. 21, near the center of sec. 19, T. 30 S., R. 38 E., which is 900 feet deep, originally flowed about 90 gallons a minute. Another well, No. 20, which belongs to Mr. Crookshank, about half a mile to the south, does not flow, although it is at least a mile nearer to the playa than well 19, which flows. Possibly the difference is due to the fact that No. 20 may not penetrate to as great a depth as No. 19, but the depth of No. 20 could not be learned accurately.

No data were obtained in regard to the depth at which the artesian beds were struck. In wells 20 and 21 the first water-bearing stratum was struck at 45 and 35 feet, respectively, but it is not clear whether the water at this depth rose to the surface or was merely "surface" water.

South of the area of flowing wells the water is reported to be under pressure in a number of wells. In well 17, which is near the border of the area of flowing wells, water that was struck at 140 feet rose to 65 feet below the surface. In this well the first water was struck at 76 feet. In the Conklin well, No. 44, in the SW. ¼ sec. 24, T. 32 S., R. 37 E., the water was struck at about 270 feet and rose about

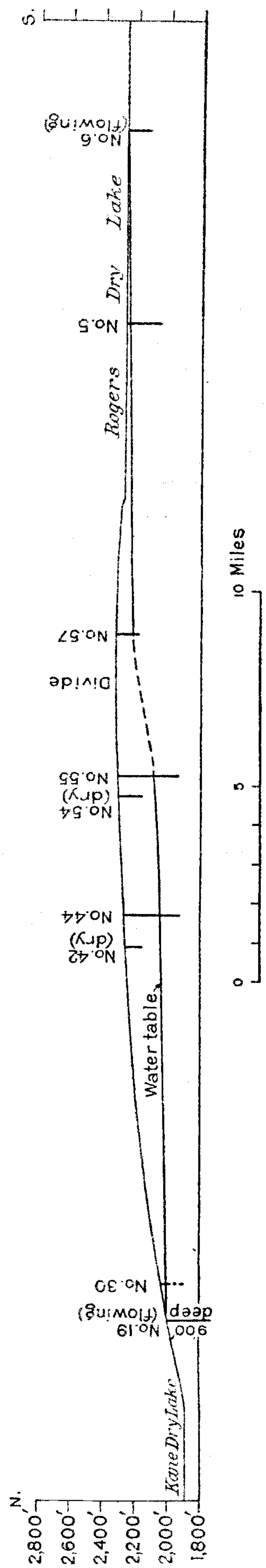

FIGURE 5.—Profiles of the surface and of the water table between Rogers Dry Lake and Kane Dry Lake. Nos. 5 and 6 refer to Plate 19 and table on page 395; other numbers refer to Plate 16 and table on page 221

30 feet. In well 48 the water is reported to have risen about 25 feet after being struck at 270 feet.

Yield of wells.—Most of the wells for which data were obtained furnish enough water for irrigation. Some of them in the lowest part of the valley yield very large quantities. Thus well 19, which belongs to Fred Hartsook, is reported to yield fully 1,200 gallons a minute (about 132 "inches" [50]) with a drawdown of 60 feet. Well 21, which belongs to A. J. Crookshank, is reported to yield 1,125 gallons a minute (125 inches). Both these wells are 900 feet deep. Few wells in the Mohave Desert region yield as much as these. Several other wells near Cantil yield from 800 to 1,000 gallons a minute.

Apparently most of the wells that have been adequately tested yield at least 270 gallons a minute (30 inches). A few wells yield less than this quantity, but in some of them it is evident that the yield is low either because the pump is not large enough to pump the well to its capacity or because the well is poorly constructed. Several wells on the upper parts of the alluvial slopes are reported to make good yields, notably well 49, which is said to yield 450 gallons a minute. The standing depth to water in this well is 205 feet. No complaints that wells did not yield enough water were heard by the writer.

Springs.—Springs occur at several places around the borders of Kane Dry Lake. One of the best-known localities is Kane or Koehn Springs, the last name being that of the present owner. These springs are near the center of sec. 8, T. 30 S., R. 38 E. At this place water is near the surface over a large area, as is shown by the presence of salt grass. Water flows at the surface from a dug well that is 19 feet deep.

Most of the springs are not far from the playa and are probably due to the cutting of the water-bearing stratum by surface erosion. However, one spring, known as Desert Spring, is about 2 miles from the playa, probably in the southeast corner of sec. 24, T. 30 S., R. 37 E. The flow from this spring is considerable but could not be measured. The opening has been dug out and curbed with boards. The spring is doubtless fed by water that comes up along a channel from a stratum in which it is confined under pressure and may be termed an artesian spring. The quality of the water from this spring is discussed briefly on page 219.

Quality of water.—Analyses were made of samples of water collected by the writer from wells 20 and 21 in the southern part of Fremont Valley and from Desert Spring, and an analysis of water from the railroad pumping plant at Cantil was furnished by the Southern Pacific Co. These analyses are given on page 223. The mineral

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[50] The miner's inch as established by law in California is one-fortieth of a cubic foot a second, or 11.2 gallons a minute. In southern California, however, the unit miner's inch, sometimes called the agricultural inch, is one-fiftieth of a cubic foot a second, or 8.97 gallons a minute (approximately 9 gallons a minute). The latter unit is used in this report.

content in each of the samples is moderate, and the greatest is in well 20, which contains 531 parts per million of total solids. The least mineralized, No. 21, contains 366 parts per million of total solids. This sample came from a 900-foot well that is within a mile of Kane Dry Lake, nearer to it than any of the other sources from which samples were taken. It shows that good water can be obtained at least within a mile of the saline playa. The first perforations in this well are at a depth of about 100 feet.

All the samples analyzed are good for domestic use, although those from well 21 and Desert Spring are rather hard. The water from well 20 (sample 4, p. 223) is fair for boiler use, but that from the spring (sample 6) is poor because it contains considerable quantities of both scale-forming and foaming constituents. The water from all the wells sampled is good for irrigation.

The waters are of the same general character, with bicarbonate the predominating acid constituent. The sodium is about equal to the magnesium and calcium, but on account of slight variation the samples from well 21 and Desert Spring are calcium carbonate waters and that from well 20 is a sodium carbonate water. The relatively slight variations in the quality are doubtless due to the wells drawing their supplies from different beds.

All the samples analyzed come from sources that are within 2 or 3 miles of Kane Dry Lake. Although none were collected from wells farther south and southwest, there is little doubt that in that part of the region the water will be of as good quality as the samples analyzed.

IRRIGATION

There has been very little if any irrigation with ground water in the part of Fremont Valley northeast of Kane Dry Lake. Near the playa, where the water table is close to the surface, there is more or less alkali in the soil. Farther away from the playa the depth to water increases so greatly that within 2½ miles it is more than 100 feet, and 4 miles from the playa it is 200 feet. Where the depth to water is so great the pumping lift is doubtless prohibitive under present economic conditions. Where the depth is not more than 100 or 150 feet the irrigation of high-priced crops might prove feasible. The irrigable area is limited by soil conditions and pumping lift to an area about 3 miles wide that extends 2 or 2½ miles northeastward from the playa.

In the area south and southeast of Kane Dry Lake there has been considerable use of ground water for irrigation. The successful developments, however, have been confined almost entirely to an area that extends not more than 4 or 5 miles from the playa. At places farther than that the depth to water is more than 100 feet, and the pumping cost is so great that irrigation of ordinary crops is unprofitable. Several ranchers have set out fruit orchards, but at the time of the writer's visit none had been planted long enough to determine whether fruit could be produced at a profit. Some of the orchards were situated where the depth to water is known to be at least 240 feet, and the pumping lift is undoubtedly somewhat more.

In the region where irrigation has been successful the principal crops have been alfalfa and melons. A considerable acreage has been set in fruit trees, but most of them were not bearing in 1919. About 200 tons of alfalfa was shipped from Cantil in 1919, and nearly all of it came from one ranch. In addition, considerable alfalfa was fed to cattle. Alfalfa is said to yield as much as 1¼ to 1½ tons to the acre for each cutting, with seven cuttings a year. Melons have proved a good crop. One man reported selling locally about $400 worth of casabas and watermelons from about 10 acres. Another man obtained about 3 tons an acre from 20 acres of casaba melons. In the midst of the season these sold for $30 to $40 a ton f. o. b., and the highest price was $80 a ton. Melons were being shipped as late as the first week in February, 1920.

The conditions appear to be favorable for additional development in an area about 4 miles wide that extends about 5 miles southwestward from Kane Dry Lake. The southwest limit of this area will be determined by the depth from which pumping will be profitable. There seems to be no danger that draft on the ground-water supply in this area will be so great as to lower the water table, as is true in other desert valleys, notably Antelope Valley, directly south of Fremont Valley. This statement is believed to be true because the ground-water reservoir is recharged by the run-off from a large area of mountains where the precipitation is relatively abundant; and on the other hand the area to which irrigation is limited by the economic pumping lift is comparatively small.

In view of the fact that there is so large an area of land which would be suitable for agriculture if water were available but in which the depth to water is excessive, landowners in Fremont Valley have sought additional sources. They have joined with landowners in Indian Wells Valley, on the north, in a proposed plan to bring water from the Mono Lake Basin, about 200 miles north of Fremont Valley. The project would compare in magnitude with the construction of the Los Angeles aqueduct and would be very expensive. The principal features of the project and the results of preliminary investigations are described on pages 168–169.

Records of wells in Fremont Valley, Calif.

No. on Pl. 16	Location (Mount Diablo meridian)				Name of owner or entryman	Type of well	Depth of well (feet)	Diameter of well (inches)	Water level below surface (feet)	Method of lift	Reported yield (gallons per minute)	Remarks
	Quarter	Sec.	T. S.	R. E.								
1	SE	22	29	41	Yellow Aster Mining & Milling Co. (Skilling well).	Dug	400	96 by 144	390	Cylinder	55	Furnishes part of Randsburg public supply. See p. 211.
2	NE	27	29	41	Randsburg Water Co. (Mountain well).	do	380	84 by 108	375	Triplex plunger	28	Furnishes part of public supply for Randsburg. See p. 210 and analysis, p. 223.
3		12	39	39	Yellow Aster Mining & Milling Co. No. 5.	Drilled	1,400	12	440		65	See p. 213.
4		12	29	39	Yellow Aster Mining & Milling Co. No. 3.	do	520	9⅝	460		65	See p. 213 and for analysis p. 223.
5	SW. ?	14?	29	39	Jack Watson	Dug	[a] 65.2	48	[a] 55.7			Two other wells within 250 yards.
6	NW. ?	23?	29	39		do	30		Dry.			
7	?	22?	29	39	Mrs. Sarah Slocum	do	[a] 48		[a] 42.1			Water originally stood about 35 feet from surface.
8		22?	29	39	do	do	46					Water originally stood 20 feet from surface.
9		22?	29	39	Lee Reams	Drilled	[a] 102		[a] 28			Another well 10 feet distant is 150 feet deep.
10		27	29	39			?		200			
11	NE	33	29	39			300		130			
12	SE	32	29	39			295		90			
13	Center	8	30	38	C. A. Koehn	Dug	19	60 by 60	Flows.	Steam cylinder	70	Drawdown 18 feet in 6 hours.
14	?	34?	29	37	R. Hardin		60		?		16	At Ricardo in Red Rock Canyon.
15	NE	30	30	38	H. E. Bean		?		Flows.		450	Flows about 90 gallons a minute.
16	SW	24	30	37	Southern Pacific R. R.	Drilled	431		[b] 60.4		56	Not pumped to capacity. See p. 223 for analysis.
17	NW	26	30	37	Blaylock & Dean	do	350	12	65	Rotary	810	Drawdown 13 feet. First water struck at 76 feet. Water struck at 140 feet rose to 65 feet.
18	SW	26	30	37	L. E. Van Winkle	do	640	12	60	Air lift	900	
19	NE	36	30	37	Fred Hartsook	do	938	12	Flows.	Rotary	1,200	Drawdown 60 feet. See p. 209 for log.
20	SW	19	30	38	A. J. Crookshank	do	880?	12	12	3-stage centrifugal	936	Drawdown about 68 feet. See p. 223 for analysis.
21	Near center.	19	30	38	do	do	828	12	Flows.	do	1,125	Flows 90 gallons a minute at height of 4 feet above surface. See p. 223 for analysis.
22	NW	30	30	38	E. H. Price	do	?		Flows.			Flows about 40 gallons per minute.
23	S. ½	20	30	38		?	130		6			
24	SW	32	30	38	L. E. Van Winkle	Drilled	615		13	Horizontal centrifugal	585	Drawdown about 20 feet. Surface water struck at about 40 feet.
24-A	SW	32	30	38	do	do	300		27			Near No. 24.
25	SE	2	31	37			300		100			
26	NE	10	31	37		Drilled	174	6	124			
27	SE. ?	10	31	37		Dug	177		?			

[a] Measured by D. G. Thompson Oct. 2, 1917.
[b] Depth to water in summer of 1919.
[c] Measured by D. G. Thompson Oct. 3, 1917.

Records of wells in Fremont Valley, Calif.—Continued

No. on Pl. 16	Location (Mount Diablo meridian) Quarter	Sec.	T. S.	R. E.	Name of owner or entryman	Type of well	Depth of well (feet)	Diameter of well (inches)	Water level below surface (feet)	Method of lift	Reported yield (gallons per minute)	Remarks
28	Near center.	12	31	37					96			
29	NE	13	31	37					130			
30	NW	6	31	38	—— Jarves				35		720	
31	NW	20	30	38	Fred Hartsook	Drilled	600	7	Flows.			
31-A	SE	6	30	38	W. M. Munsey				Flows.			
32	SW	18	31	38					140			
33	NE. ?	30	31	37	—— Giddings (?)	Drilled		16	[c] 304			
34	NE	31	31	37	W. E. Gantt	do	349	10 and 6	[c] 307	Windmill	18	
35	NE	32	31	37	F. H. Soders	do	320		275		180	
36	NE. ?	26	31	37		do	374	16	[d] 233	Windmill		
37	S. ½	30	31	38					230		450	
38	NW	2	32	37	G. S. Turrill	Drilled	446		244		315	Last 125 feet reported to be all clay.
39	NW	8	32	37	H. V. Reeves	do	410		370			
40	SW	19	32	37		do	98	8	Dry.			
41	SE. ?	14?	32	37								Not completed when visited.
42	SE	17	32	38	Desert well (abandoned)	Dug	90		Dry.			
43	SE	22	32	37		Drilled	513	12	[d] 312			Reference point for measurement, top of casing 3 feet above surface.
44	SW	24	32	37	Chester C. Conklin	do	337	12	242	Deep-well lift	315	Water struck at about 270 feet, raised 30 feet.
45	N. ½	26	32	37	J. Coykendall	do			268?			
46	S. ½	26	32	37	C. W. Townsend	do	335		258			Water struck at about 285 feet.
47	SW	28	32	36		do	515		425			
48	SE. ?	36?	32	37	Schoolhouse	do	287	8	245			Water struck at 270 feet.
			San Bernardino meridian T. N.	R. W.								
49	NW	8	11	11					205		450	
50	SE	26	11	12	Frank H. Forbes	Drilled	250	14	155		270	Water struck at 180 feet.
51	SW	2	11	11					92?			
52	S. ½	31	12	10			380		156			
53	NW	12	11	12	George A. Arper				400?			
54	?	34	12	10			150		Dry.			
55	SW. ?	35	12	10			[d] 378		[d] 199			Reference point for measurement, top of support for pump 1 foot above surface.
56	E. ½	6	11	9			235		170			
57	?	18	11	9			140		106			

[c] Measured by D. G. Thompson Oct. 3, 1917.

[d] Measured by D. G. Thompson Feb. 5 or 6, 1918.

Analyses of ground water from Fremont Valley, Calif.

[Parts per million]

	1	2	3	4	5	6
Silica (SiO_2)	74	55	[a] 32	31	66	30
Iron (Fe)	.09	.15	----------	.22	.57	.50
Calcium (Ca)	32	99	65	38	60	66
Magnesium (Mg)	9.7	52	14	9.6	15	18
Sodium and potassium (Na+K)	[b] 67	154	90	83	90	[b] 78
Carbonate radicle (CO_3)	10	0	----------	0	0	0
Bicarbonate radicle (HCO_3)	176	285	294	214	302	294
Sulphate radicle (SO_4)	59	468	116	33	127	124
Chloride radicle (Cl)	27	21	37	66	25	26
Nitrate radicle (NO_3)	6.4	.83	----------	2.0	.94	2.2
Total dissolved solids at 180° C	387	1,008	[b] 499	366	531	487
Total hardness as $CaCO_3$ (calculated)	120	461	220	134	212	239
Date of collection	([c])	([d])	([e])	([f])	([f])	([g])

Analysts: 1, A. A. Chambers, U. S. Geological Survey; 2, 4, 5, and 6, Margaret D. Foster, U. S. Geological Survey; 3, Southern Pacific System.

[a] Includes silica (SiO_2) and iron and aluminum oxides ($Fe_2O_3+Al_2O_3$).

[b] Calculated.

[c] Oct. 5, 1917.

[d] Oct. 2, 1917.

[e] June 7, 1909.

[f] Oct. 3, 1917.

[g] Feb. 5, 1920.

1. Well 2, pl. 16 and table on p. 221; Randsburg Water Co., owner.
2. Well 4, pl. 16 and table on p. 221; Yellow Aster Mining & Milling Co., owner.
3. Well 16, pl. 16 and table on p. 221; Southern Pacific Railroad, owner. Analysis furnished by the owner; recalculated from hypothetical combinations in grains per United States gallon.
4. Well 20, pl. 16 and table on p. 221; A. J. Crookshank, owner.
5. Well 21, pl. 16 and table on p. 221; A. J. Crookshank, owner.
6. Desert Spring, in SE.¼ sec. 24, T. 30 S., R. 37 E. Mount Diablo meridian.

GOLDEN VALLEY

GENERAL FEATURES

Golden Valley lies in the northwestern part of San Bernardino County, a few miles southeast of Randsburg. The valley has sometimes been called Cuddeback Valley or Willard Valley, these names being given at different times to a playa that lies in the lowest part.

A number of homesteads have been taken up in the valley, and about 10 wells have been drilled. In these wells the depth to water is from 50 to 160 feet, which is too great to pump water for alfalfa but yet probably within the limit of economic pumping for fruit. The quality of water in a number of the wells is reported to have been poor, and some of the homestead entries have been relinquished on this account. Conditions in the valley are not favorable for any great agricultural development. The western part of the valley has valuable mineral deposits, which are described briefly below in the section on geology (p. 227).

The drainage basin of Golden Valley is shown in Figure 6. The Kramer-Johannesburg branch of the Atchison, Topeka & Santa Fe Railway crosses the west side of the basin. On this railway is Atolia. The towns of Johannesburg and Randsburg are about a mile beyond the northwest boundary of the basin.

Atolia is in the center of a district that contains valuable deposits of tungsten, and for a number of years the population of the town numbered several hundred. After the war tungsten was imported from Asiatic countries so cheaply that American producers could not compete, and consequently the mines were closed down. An opportune and unexpected discovery of rich silver ores about 3 miles north of Atolia, however, has kept the town alive. General supplies and good hotel and garage accommodations could be obtained in

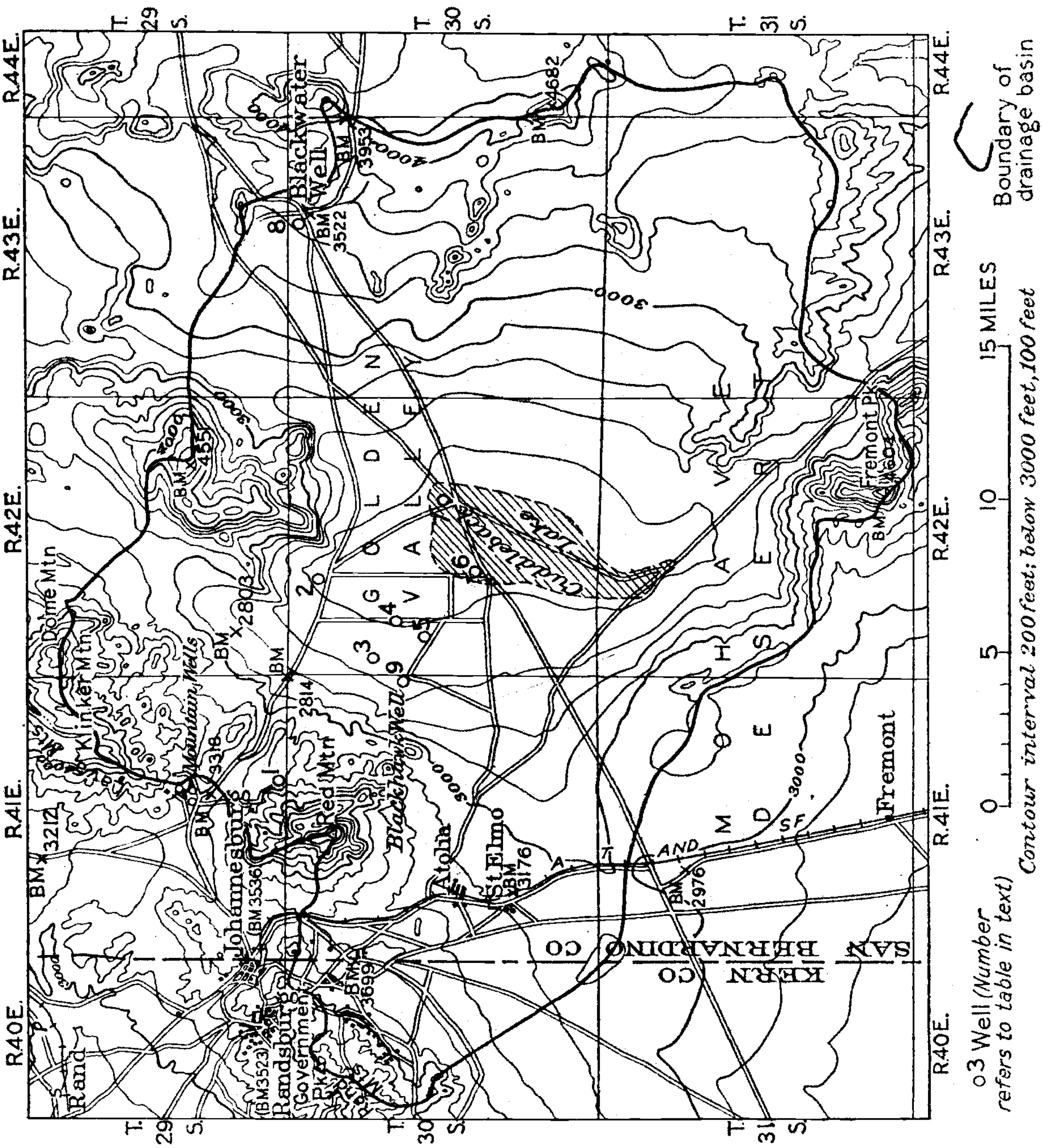

FIGURE 6.—Map of Golden Valley, showing boundary of drainage basin and location of wells

Atolia, Randsburg, or Johannesburg in 1920, and as long as mining activity continues in the vicinity one or more of these places may be regarded as reliable supply points.

Roads lead across the valley from Randsburg and Johannesburg, either by way of Atolia or Mountain Wells, to Blackwater Well and Granite Wells, and thence to Barstow or to Silver Lake and points in Death Valley and Panamint Valley. A road also leads southeastward from Atolia to Barstow by way of Harper Valley. Most of the travel to Barstow, however, goes south from Atolia to Kramer, and thence east along the Atchison, Topeka & Santa Fe Railway. A road leads southwest from Atolia to Mojave.

No data are available in regard to climatic conditions in the valley. Conditions in regard to precipitation and temperature are probably about the same as in the Superior Valley. (See p. 245.) At only one or two places do the mountains that border the basin rise to an altitude of 5,000 feet, and most of the drainage basin is less than 4,000 feet above sea level. The annual rainfall is probably not more than 5 inches. In the winter the temperature doubtless falls several degrees below freezing.

PHYSICAL FEATURES AND GEOLOGY

The part of the basin west of latitude 117° 30′ has been described by Hess [51] and Hulin.[52] The part of the geologic map (pl. 8) covered by Hess's report is compiled from an unpublished map by him, but the units are necessarily more generalized than on his map.

On the south side of the basin the divide is formed by Fremont Peak, which is high and steep on the side that faces Golden Valley but which has a more gentle slope to the southwest. Northwest of Fremont Peak the divide is formed by a low ridge.

The drainage basin is elongated from east to west, but the playa in its lowest part, called Cuddeback or Willard Dry Lake, is elongated from north to south. Hence there is not much valley land at the north and south ends of the playa, for the mountains reach within 2 or 3 miles of the playa. Toward the east and west, however, the land rises gradually, in some places practically to the border of the drainage basin, 8 or 10 miles from the playa. These long slopes have the appearance of alluvial slopes, but in several places it is evident that they are eroded rock surfaces or mountain pediments, beveled across hard rocks and covered with alluvium only to a comparatively slight depth. (See p. 102.) Around Atolia bedrock has been reached in placer diggings for tungsten and gold at depths ranging from a few inches to 215 feet.[53] Probably the entire slope west of Atolia is composed of rock with only a thin covering of soil. The eastern border of this rock slope is not known. Hess states that a shaft about 2 miles east of St. Elmo did not reach rock at a depth of 250 feet but that granite crops out about halfway between St. Elmo and the shaft.[54] A well in the SW. ¼ sec. 7, T. 30 S., R. 42 E. Mount Diablo meridian, dug to a depth of 162 feet, did not reach bedrock. On the east side

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[51] Hess, F. L., Gold mining in the Randsburg quadrangle, Calif.: U. S. Geol. Survey Bull. 430, pp. 23–47, 1910.

[52] Hulin, C. D., Geology and ore deposits of the Randsburg quadrangle: California State Mining Bur. Bull. 95, 1925.

[53] Cloudman, H. C., and others, Mines and mineral resources of San Bernardino County, Calif., pp. 59, 65, pl. 20, California State Min. Bur., 1917.

[54] Hess, F. L., op. cit., p. 31.

of the valley many small outcrops of rock, especially near the borders of the basin, show that a large part of the seeming alluvial slope is an erosional slope on bedrock, as on the west side.

The rocks of the basin include intrusive rocks of probably at least two ages, a series of ancient metamorphic rocks, volcanic rocks of presumably Tertiary age, Tertiary sedimentary rocks, and Quaternary alluvium.

According to Hess the Rand Mountains consist of a series of schists, in which occur small areas of quartzite and metamorphosed limestone, intruded by granite. The age of the schists is not known, but as the granite is presumably Mesozoic they are probably at least as old as Paleozoic and may be pre-Cambrian.

In addition to the granite in the Rand Mountains, intrusive rocks are also found south of Atolia, and Fremont Peak is probably composed of these rocks. Granite crops out in washes in the northeastern part of the basin along the road from Mountain Wells to Granite Wells. Low hills east of Blackwater Well are composed of granite, and the soil all along the road from the well westward to Cuddeback Lake apparently is derived largely from granite. Several of the hills on the east side of the valley, however, are composed of volcanic rocks. Probably the conditions there are similar to those a little farther east, near Pilot Knob, where Tertiary volcanic rocks rest on an erosion surface of granite. (See p. 242.) Hess believes that the granite in the vicinity of Randsburg may represent two different periods of intrusion. The younger rock is probably coincident with diorite and granite of presumable Mesozoic age which form the great mass of the Sierra Nevada. The other granite seems to be older than the schists. Observations in other parts of the basin were not sufficiently detailed to determine the age relations of the granite.

Red Mountain, Klinker Mountain, and the mountain east of Klinker Mountain are composed principally of lavas, including, according to Hess, andesite, basalt, rhyolite, and probably latite and dacite. Some of the low hills in the northeastern and eastern part of the basin are also probably composed of volcanic rocks. These mountains also probably contain small patches of sedimentary rocks. On a lithologic basis the volcanic rocks are believed to be of Tertiary age.

Low hills in the southeast corner of the basin are formed of a series of clay, shale, sand, and limestone, interbedded with ash and lava that are considered to be of Tertiary age.[55] Small areas of Tertiary sedimentary rocks are also found in the northwestern part of the drainage basin.

The Quaternary alluvium consists of clay, sand, and gravel. The clay seems to be confined largely to the playa deposit in the lowest

[55] Pack, R. W., Reconnaissance of the Barstow-Kramer region, Calif.: U. S. Geol. Survey Bull. 541, pp. 148–149, 1913.

part of the valley. Along the road from Atolia to Blackwater Well a narrow belt of sand was observed a short distance east of the playa, as if it were a beach ridge, but otherwise the soil is not very sandy. Boulders are abundant at a number of places, particularly on the alluvial slope southeast of Red Mountain. In a well in the SW. ¼ sec. 7, T. 30 S., R. 42 E. Mount Diablo meridian, about a mile from the mountain, boulders as much as 10 inches in diameter were abundant to a depth of 154 feet. These boulders are rounded, as if they had been waterworn. Placer gold and tungsten are found in the alluvium on the west side of the valley near Atolia.

The playa known as Cuddeback Dry Lake is hard and smooth except that it is traversed by cracks. The dumps around two wells on the playa consist entirely of clay. The water table lies at a depth of about 50 feet, and there are no water-indicating plants around it. In all respects it is a typical playa of the dry type. A short distance east of the playa, on the road from Atolia to Blackwater Well, occurs a belt of sandy soil which may be either an old shore line or a belt of sand dunes. There is no evidence that any large lake ever existed in the basin, however, and none would be expected, for the drainage area is not great.

MINERAL DEPOSITS

Valuable deposits of gold, silver, and tungsten have been mined on the western side of the valley near Atolia, but so far as the writer knows no deposits of commercial value have been found in any other part of the region.

The production of gold has been of the least value. The gold occurs in fissure veins on the north slope of the Rand Mountains northwest of Atolia.[56] The veins are narrow and thus give rise to the name Stringer district. Most of the mines are small, but some of the ore has been rich. Some gold has also been taken from a mine near St. Elmo.

The tungsten deposits around Atolia are among the most valuable in the United States and in the world, and the total production from the district probably has been more than $10,000,000.[57] (See p. 27.)

[56] Hess, F. L., op. cit., pp. 42–45.

[57] Considerable information on the geology and production of the Atolia district is scattered through the annual reports of the California State Mining Bureau on mineral production and in the annual volumes of Mineral Resources of the United States since 1905. The following are the more useful references on which the notes in this report are based: Cloudman, H. C., and others, Mines and mineral resources of San Bernardino County: California State Mineralogist Rept. for 1915–16, pp. 56–65, 1917. Bradley, W. W., California mineral production for 1920: California State Min. Bur. Bull. 90, pp. 79–80, 1921. Hess, F. L., Tungsten: U. S. Geol. Survey Mineral Resources, 1909, pt. 1, pp. 577–578, 1911; 1915, pt. 1, pp. 824–825, 1917; 1916, pt. 1, pp. 791–792, 1919; 1917, pt. 1, pp. 939–940, 1921; 1918, pt. 1, pp. 979–981, 1921. See also Nevius, J. N., Notes on the Randsburg tungsten district: Min. and Eng. Jour., vol. 45, No. 1, pp. 7–8, 1916. Glasgow, J. W., Tungsten mining at Atolia, Calif.: Min. and Oil Bull., vol. 2, No. 2, pp. 31–32, 1916. Nevius, J. N., Notes on the Randsburg tungsten district: Min. and Oil Bull., vol. 2, No. 6, pp. 126–128, 1916. Hulin, C. D., Geology and ore deposits of the Randsburg quadrangle: California State Min. Bur. Bull. 95, 1925.

The first commercial production of tungsten in this region was made in 1905, in the Stringer gold district, on the extreme western edge of the basin near the summit of the Rand Mountains. Here the tungsten occurs as scheelite in narrow veins or stringers in schist.[58] It is associated with gold, but the gold and tungsten generally do not occur in the same veins.

In 1906 production began from the Atolia district proper, which has since been the larger producer. The productive area seems to be a zone about half a mile wide which extends approximately east and west for a mile or two on each side of Atolia. The ore occurs as scheelite in veins in granite. On the slope between the Stringer district and the Atolia granite area both gold and tungsten occur in placer deposits. In the granite area the granite is decomposed into sand in which occur pieces of scheelite. Of this nature was the "spud patch" of the Atolia Mining Co., east of the town. The name is derived from the fact that the pieces of scheelite were mined much as potatoes are dug from the ground. Masses of scheelite weighing as much as 100 pounds were obtained from the spud patch. The placer deposits extend for only a little more than a mile east of Atolia.

From 1905 to 1914 the production of tungsten was comparatively small and the total production for the entire State, which was practically all from the Atolia district, was only about $1,500,000. In 1915, however, as a result of the war demands, the production increased rapidly. In the four years 1915 to 1918 the production of tungsten in San Bernardino County was valued at about $9,000,000, and most of it came from the Atolia district. The peak was reached in 1916, when, under the influence of prices as much as 10 times the previous normal price,[59] tungsten worth nearly $4,000,000 was produced. The high prices offered a great inducement to "high graders," who made money by carrying rich pieces of ore from the mines or by stealing concentrates from stock piles or cars.

The stimulation of high prices soon resulted in overproduction, and the price dropped greatly. The production in 1917 and 1918 was much less than in 1916, although it amounted to considerably more than $1,000,000 in each year. Since the end of the war tungsten produced by coolie labor in Asiatic countries has been imported into the United States so cheaply that it has been unprofitable to operate the mines in this country. Only a small quantity was sold in 1919, and none in 1920.[60] The greatest part of the production has been made by the Atolia Mining Co. In the 11 years from 1908 to

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[58] Cloudman, H. C., and others, op. cit., p. 56.
[59] Hess, F. L., U. S. Geol. Survey Mineral Resources, 1916, pt. 1, pp. 794–795, 1919.
[60] Bradley, W. W., op. cit., p. 80.

1918 the company produced tungsten valued at more than $9,000,000, and since 1907 it has paid dividends of more than $5,000,000.[61]

In April, 1919, rich silver deposits were discovered about 2 miles north of Atolia.[62] As a result of the discoveries of valuable gold and tungsten ores, the entire region had previously been carefully covered by prospectors, and yet the rich silver deposit had remained unknown. The discovery was made within a few hundred feet of a main road traveled by hundreds of persons, on a ledge that apparently had been blasted as a part of assessment work on a claim which was still valid and on which there was a shaft 130 feet deep. But the men who did the assessment work were looking for gold and did not recognize the silver ore, which was horn silver (silver chloride or cerargyrite). It is said that the ore was so rich that for a long time every bit mined was shipped, and the mine was without a dump until dividends amounting to $96,000 had been paid.

The silver ore is found at the contact between schist and granite.[63] According to published descriptions the ore is in the schist, which is cut by a siliceous or porphyritic dike. A fault zone, above which there is no ore, has cut off all surface indication of silver-bearing veins except the discovery outcrop, and that is almost hidden. If erosion had stopped a short time (in the geologic sense) before it did, or if it had gone on more slowly, the discovery vein also would still be covered and this rich silver deposit would not have been found. The discovery and development of these deposits furnish an excellent example of the way in which Dame Fortune once in a long while smiles upon the desert prospector.

WATER RESOURCES

GENERAL FEATURES

There are no streams in the drainage basin of Golden Valley, and so far as the writer is aware no springs now exist. Squaw Spring, in sec. 34, T. 29 S., R. 41 E. Mount Diablo meridian, ceased to flow when its supply was tapped by a well and tunnel. All water used in the valley is obtained from wells or shafts or is hauled in on the railroad.

In recent years considerable water, both for domestic use and for milling, has been required in the tungsten and silver district around Atolia, and the lack of a good supply has been a great disadvantage to mining activity. For a number of years the water for all uses, including the water for the Atolia mill, was hauled in tank cars from

[61] Hess, F. L., U. S. Geol. Survey Mineral Resources, 1918, pt. 1, p. 979, 1921.

[62] Parsons, A. B., The California Rand silver mine: Min. and Sci. Press, vol. 123, No. 20, pp. 667-675, 1921 (the story of the enterprise); idem, No. 25, pp. 855-859, 1921 (geology, development, and mining); idem, vol. 124, No. 1, pp. 11-17, 1922 (metallurgy, concentration by flotation). Wray, J. C., The Rand silver zone: Min. and Oil Bull., vol. 7, No. 13, pp. 783-786, 1921.

[63] Parsons, A. B., op. cit., p. 855.

Hinkley, a station on the Atchison, Topeka & Santa Fe Railway, at a distance of 47 miles. Until August, 1909, the water cost $15 a car of 9,406 gallons, but at that time the rate was raised to $24.30 a car.[64] In 1915 water was reached at a depth of 500 feet in a mine near Randsburg, and this was piped 5 miles to the concentration mill of the Atolia Mining Co. The company also caught all possible water from the scanty rainfall by means of gutters on its buildings. The tailings were run to settling ponds, and the water was used again. It was still necessary to haul some water by railroad from Hinkley, and in 1916 the cost was $18.40 a car of 10,500 gallons. In 1917 the pipe line of the Randsburg Water Co. was being extended to Atolia, and this helped out in some measure. It is understood, however, that the supply from this source is failing, and that in 1920, if it had not been for a decrease in the population, the system would not have been able to meet the demands on it. (See p. 210.) In 1921 water was hauled from Hinkley for use at the silver mines at the rate of $28 a car.[65]

As a result of the scarcity of water several types of dry concentrators and "dry washers" were used.[66] It is probable, however, that if sufficient water were available for more efficient washing, a considerable amount of gold and tungsten could be recovered from placer ground that could not be worked under present conditions.

The mines and mills are in or near the mountains, several miles from the nearest place where water is obtained from alluvium. In view of this fact any information on the possibility of obtaining ground water in the area underlain by bedrock is valuable, and the occurrence of ground water in rock and in the alluvium is discussed under separate headings.

WATER IN BEDROCK

Only two wells in the valley are known to be dug in bedrock. Blackwater Well, near the line between secs. 2 and 3, T. 30 S., R. 43 E. Mount Diablo meridian, is apparently dug in granite. Rock hills stand near by, and if the well does not reach rock it can not be far below the surface. The well is dug and is about 5 by 7 feet in diameter. On October 5, 1917, it was 32.6 feet deep, and the depth to water was 31.6 feet. On January 24, 1920, the depth to water was only 21 feet—that is, 10 feet higher than in 1917. At the time of the writer's first visit the well had apparently just been pumped a short time before his arrival. If so, the water supply is not abundant, as the water level had not risen very far. In 1917 the well was equipped with a small gasoline engine and pump, but in 1920 there

[64] Hess, F. L., U. S. Geol. Survey Mineral Resources, 1909, pt. 1, p. 576, 1911.
[65] Parsons, A. B., op. cit., p. 12.
[66] Cloudman, H. C., and others, op. cit., pp. 59–62.

was no pump in the well. An iron tank in a corral on lower ground about 500 feet north of the well had water in it. A ditch led from this tank toward the well, and although no pipe was visible the tank is doubtless fed from the well, the supply being regulated by a float valve. There was no other means of obtaining water unless one had a rope and bucket. The well is used for watering cattle. It is also a watering place for travelers. The water is of good quality for domestic use. (See analysis 3, p. 236.) It is a sodium carbonate water and contains 416 parts per million of total solids. The name Blackwater is said to have come from the fact that the water becomes dark after standing, but this feature was not observed in a sample collected by the writer.

The only other well known to be dug in bedrock is the Squaw Spring Well, on the northeast slope of Red Mountain in T. 29 S., R. 41 E. Mount Diablo meridian. According to C. S. Knight, manager of the Randsburg Water Co., this well is in the NW. ¼ sec. 27, but on the General Land Office township plat it is in the SE. ¼ sec. 34. This well is one of several wells from which the Randsburg Water Co. obtains its supply. (See p. 210.) Originally Squaw Spring, in the bottom of a wash, is said to have had a small flow throughout the year. In order to avoid damage from cloudburst, the water company sunk a shaft at a point about 50 feet higher than the spring. This shaft is 7 by 9 feet in diameter and is 180 feet deep. At the bottom a drift is cut toward the spring. The shaft was dug all the way through a rock described as porphyritic "malpais," which is doubtless a Tertiary volcanic rock. When the well is not being pumped the water stands about 50 feet below the surface, at about the same level as the old spring, which ceased to flow after the well was dug. The surface altitude at the well is about 3,400 feet. In 1917 the well was pumped with an Ames deep-well pump driven by a 15-horsepower Lambert gas engine. The supply is not great, for the well can be pumped only 4½ hours daily, or 9 hours every other day. The yield when so pumped is about 4,800 gallons a day, or 18 gallons a minute. A reservoir cemented in solid rock, which has an estimated capacity of 100,000 gallons, is situated 535 feet higher than the well and about a quarter of a mile distant. No sample was taken of the water, but it is said to be soft and of good quality, slightly better than the water from the Mountain Well, which furnishes part of the supply for Randsburg. (See p. 211.)

In addition to the Squaw Spring Well the Randsburg Water Co. obtains water from other deep wells or shafts in lava on the southwest side of Klinker Mountain, several hundred feet above the valley floor. All these wells, except possibly one, are situated in the drainage basin of Fremont Valley, but close to the divide separating it from Golden Valley. (See p. 210.) Water was also struck at a depth of about 500 feet in a shaft of the Consolidated Mining Co. at the southeast end of Randsburg, just outside of the Golden Valley drainage basin. (See p. 212.) The surface altitude is about 3,700 feet and the water level is about 3,200 feet.

The occurrence of water in rock at the wells and shafts just described suggests that water may be obtained from rock in other mountainous parts of the basin. However, although water has been obtained from rock at two or three places the prospects are not bright that any large quantity can be obtained in this way. The shaft of the No. 1 mine of the Atolia Mining Co., about a mile west of Atolia, is reported to have been bone-dry at a depth of 900 feet. The shaft is probably sunk in granite. If a continuous body of ground water extended from the alluvium of the valley to the wells and shafts described, it would be expected that water would be found in the No. 1 shaft considerably above the bottom. The fact that it is not so found shows that there is no such continuous body of ground water and that the water at the other localities occurs under special conditions and is probably present only in small quantities.

The water at the Squaw Spring Well and Mountain Wells of the Randsburg Water Co. comes from lavas which are badly fissured. The water in the Consolidated shaft comes from schist, which doubtless is also more or less fissured. The granite of the No. 1 shaft, except near the surface, is probably very tight, with few cracks along which the water can move. Although the water in the Blackwater Well presumably comes from granite, it probably occurs only in a thin zone at the top, or it may occur along the contact between the residual soil and the underlying solid rock. At any rate the quantity is small. Doubtless in the granitic area around the No. 1 mine a small quantity of water occurs along the contact between the soil and the rock, but if encountered in the No. 1 shaft, it was so small as to have been scarcely noticed.

Although water may be obtained from the bedrock in some places it is not likely to occur in sufficient quantities to supply the demand for milling. The supply of the Mountain Wells of the Randsburg Water Co. has been failing, requiring new development work, and the yield from the other wells and shafts is also small. The conditions as a whole are so unfavorable that they do not warrant prospecting for water alone. Possibly more water will be found in some shafts, but its presence can not be predicted.

WATER IN THE ALLUVIUM

At least 10 wells have been put down in the alluvium that fills the lower part of the drainage basin. Unfortunately, all but two of the homesteads visited by the writer in the fall of 1917 were deserted, and no definite information could be obtained as to the materials penetrated, yield of wells, or success in irrigation. Most of the wells for which any data were obtained are northwest of the playa. The principal data are given in the accompanying table, which also includes data on the Squaw Spring Well and Blackwater Well.

Records of wells in Golden Valley, Calif.

No. on Fig. 6	Name of owner or of well	Location (Mount Diablo meridian)				Depth of well (feet)	Diameter of well (inches)
		Quarter	Sec.	T. S.	R. E.		
1	Randsburg Water Co. (Squaw Spring Well)	SE.?	[a] 34?	29	41	180	84 by 108
2		SW.?	4	30	42	225	12
3	W. E. Gaines	SW	7	30	42	162	36
4		NW.?	17?	30	42	90.6	48
5	Jos. Stehuck	SE.?	18?	30	42	160	10
6		SW.?	21?	30	42	117.5	
7		NE.?	22?	30	42	59.6	48 by 60
8	Blackwater Well	NE	3?	30	42	32.6	60 by 84
9	Blackhawk Well	NE	13	30	41	[c] 140	

No. on Fig. 6	Depth to water (feet)	Date of measurement	Reference point for measurement	Remarks
1	50			In rock. See p. 231.
2	[b] 107.3	Oct. 5, 1917	Top of casing	No pump; abandoned.
3	159			Dug well. Can be pumped dry by hand.
4	[b] 89.3	Oct. 6, 1917	Surface of ground	No pump. Uncased below 5 feet.
5	100			Hand pump. See analysis, p. 236.
6	[b] 46.9	Oct. 6, 1917	Top of casing 1 foot above playa.	At edge of playa. Abandoned. No pump.
7	[b] 49.5	do	Top of cover level with ground	Dug well at edge of playa. Equipped with windmill. See analysis, p. 236.
8	[b] 31.6 [b] 20.9	Oct. 5, 1917 Jan. 24, 1920	Top of wood casing	See description, p. 230, and analysis, p. 236.
9	140(?)			Good water at 140 feet; bad water in lower strata. See p. 235.

[a] See p. 231.
[b] Measured by the writer; other depths are those reported by owner or other person.
[c] Exact depth not known, except that it is greater than 140 feet.

Two wells are located on the playa in the lowest part of the ba One of these (No. 7), near the northeast edge of the playa, is a dug well 60 feet deep. The depth to water when measured was 49.5 feet. This well is on a mound about 3 feet above the playa. In the past this well has been a watering place for travelers on the road from Mojave and Atolia to Blackwater Well and Granite Wells. The well was equipped with a windmill, but it was out of order when visited. The dump around the well indicates that the material penetrated was all clay, similar to that on the surface of the playa. An abandoned drilled well (No. 6), 117.5 feet deep, is located on the west side of the lake near the road from Atolia to Blackwater Well. The depth to water in it was 46.9 feet. The water table in the two wells is apparently at about the same altitude. The dump around this well was also all clay.

Three wells were visited northwest of the playa. In these wells the depth to water was increasingly greater away from the playa.

The maximum depth to water is 159 feet in a well (No. 3) in the SW. ¼ sec. 7, T. 30 S., R. 42 E. This is a dug well 162 feet deep. Boulders as much as 10 inches in diameter and rounded as if by moving water were found in it to a depth of 154 feet. Below that depth there was 7 inches of clay, followed by 5 feet of gravel, which was mostly composed of pebbles less than half an inch in diameter. The Blackhawk Well, a shaft sunk to obtain water for milling in the NE. ¼ sec. 13, T. 30 S., R. 41 E. Mount Diablo meridian, is said to have struck water of good quality at 140 feet. This well is probably situated on a little lower ground than the Gaines Well. No data are available as to the materials penetrated in it. Two wells are said to have been drilled on the southeast side of the playa, and the depth to water in each was about 100 feet. No accurate data are available in regard to the surface altitude of the wells measured, but an approximate estimate from the topographic map shows that the water table at well 3 is at about the same altitude as it is beneath the playa.

No data of value were obtained as to the yield of any of the wells. The Gaines Well (No. 3), in the SW. ¼ sec. 7, T. 30 S., R. 42 E., can be pumped dry in a few minutes with a hand pump. After about a barrel has been pumped it is necessary to wait about 10 minutes, and then a similar quantity can be pumped. One other well was equipped with a hand pump, and the supply was apparently sufficient for it. One well on the southeast side of the valley is reported to have yielded between 180 and 270 gallons a minute (20 to 30 miner's inches). A shaft sunk about 5 miles east of the Rand Silver mine is reported to yield only 1,500 gallons a day (about 1 gallon a minute) at a depth of 130 feet.[67] This shaft was sunk by the California Rand Co. in an attempt to get water for milling. The exact location is not known, but it is believed to be near the Gaines Well (No. 3).

Analyses were made of samples of water from two wells in the alluvium. One of these samples came from the dug well (No. 7) on the east side of the playa. (See analysis 2, below.) The well apparently had not been used recently, and as the sample was drawn by hand it might not represent the character of the water after the well had been pumped for some time. It is a highly mineralized sodium chloride water that can, however, be used for drinking and cooking. It is considered very bad for boiler use and poor for irrigation. The second sample came from the well of Joseph Stehuck (No. 5), probably in the SE. ¼ sec. 18, T. 30 S., R. 42 E. (See analysis 1, p. 236.) Although the well is 1½ miles from the playa and some distance up the alluvial slope, where the water would be expected to be better, it is even poorer than the other sample. It is a sodium chloride water

[67] Parsons, A. B., The California Rand silver mine: Min. and Sci. Press, vol. 124, No. 1, p. 12, 1922.

but is also unusually high in calcium. It has a slightly alkaline taste and is poor for domestic use because of the hardness, high chloride, and high total solids. It is very bad for boiler use and poor for irrigation. W. E. Gaines states that the water from his well (No. 3) northwest of the Stehuck well is better than that from either of the two wells sampled. It is said that the water from other wells in the valley is somewhat alkaline, and that in one well at least, it was so concentrated that it killed grain which was irrigated with it. It is reported that when the Blackhawk Well, in the NE. ¼ sec. 13, T. 30 S., R. 41 E. Mount Diablo meridian, was being dug, water of good quality was reached at a depth of 140 feet. Subsequently, when it was deepened, the water in the lower strata was so bad as to be unfit for domestic and boiler use. The well, which was then used to furnish a supply for milling, was abandoned because of the poor quality of the water. Several homesteaders have relinquished their claims because of their failure to get good water. The data at hand are insufficient to show whether or not water of poor quality is obtained throughout the valley.

The two samples of water analyzed from wells in the alluvium are high in chloride and in total dissolved solids. They are considerably different from a sample from Superior Valley, the adjoining valley on the east, where the general conditions that affect the occurrence of ground water seem to be about the same. The sample from the B. B. Crutts well (see analysis, p. 252), which is near one of the playas in Superior Valley, contained less than one-fifth as much total solids as the Stehuck well, and the chloride was only 28 parts per million, as compared to 888 in the Stehuck well. The reason for this difference is not known. So far as is known, the rocks of the Golden Valley basin are chiefly granite or volcanic rocks, and these should not contribute unusually large quantities of soluble material.

The analyses of samples from Blackwater Well (No. 1, p.236), which is in granite, and of the Mountain Wells (No. 1, p. 223), just outside the basin, which are in lava, show that these waters are entirely different from the water in the alluvium, and they are much better. So far as the writer is aware, no unusual amounts of soluble salts occur in the basin. If the salt in the water in Superior Valley and in Golden Valley is the result of ordinary concentration of material dissolved by the ground water, some condition must have been present in Golden Valley to cause a considerably greater concentration. The greater extent of the area in Golden Valley in which the water is poor suggests that the playa beds at an earlier period were more extensive than at present.

Analyses of ground waters from Golden Valley, Calif.

[Collected Oct. 6, 1917. Parts per million]

	1	2	3
Silica (SiO_2)	66	85	66
Iron (Fe)	1.4	.05	.14
Calcium (Ca)	171	69	33
Magnesium (Mg)	31	12	8.1
Sodium and potassium (Na+K)	401	336	[a] 72
Carbonate radicle (CO_3)	0	0	3.4
Bicarbonate radicle (HCO_3)	138	188	154
Sulphate radicle (SO_4)	35	74	56
Chloride radicle (Cl)	888	500	58
Nitrate radicle (NO_3)	7.8	3.5	.94
Total dissolved solids at 180° C	1,720	1,194	416
Total hardness as $CaCO_3$ (calculated)	555	222	116

[a] Calculated.

Analysts: 1 and 2, Addie T. Geiger and C. H. Kidwell, U. S. Geological Survey; 3, Margaret D. Foster, U. S. Geological Survey.
1. Well 5, table on p. 233; Joseph Stehuck, owner.
2. Well 7, table on p. 233.
3. Blackwater Well, No. 8, table on p. 233.

The total area of the drainage basin is not great nor is the area of the mountains that would furnish most of the water to the ground reservoir. Furthermore, the fact that the water table lies 50 feet below the playa is believed to indicate that there is leakage of ground water from the basin. The adjoining valleys are lower on all sides except the east, and the divide in that direction is apparently composed of impervious granitic rocks. The divide east of Fremont Peak, on the south side of the basin, may be composed of alluvium, and there may be leakage at that place or possibly through alluvium south of Atolia or in passes between the lava mountains on the north side of the valley. Perhaps there is even some leakage beneath the lava of Red Mountain or Klinker Mountain, on the northwest, as some lavas permit the ready passage of ground water. At any rate, the considerable depth to the water table is believed to indicate that the quantity of water that can be withdrawn annually is not great. It is probable, however, that water in sufficient quantity for use in milling can be obtained from the alluvium. An undertaking to obtain water in this way would have two disadvantages. In the first place, if the mills were located near Atolia the water would have to be lifted from 100 to 200 feet to the surface and at least 500 feet more for a distance of probably at least 3 to 5 miles to the town. It is uncertain whether such a project would be less expensive than the present method of hauling water from Hinkley. The Yellow Aster Mining Co. has for a number of years pumped water for its mills a distance of about 7 miles, lifting the water nearly 500 feet to the surface and more than 1,000 feet to the mine. (See p. 213.)

A factor which may prove a serious drawback is the quality of the water. It would seem, however, that the water from wells driven on the alluvial slope ought to be better than that from wells in the bottom of the basin. For that reason in putting down wells it would be desirable to drill them as far west of the playa as possible without having them too far west to encounter bedrock before the water table is reached. No data are available as to how far west water may be found in the alluvium, but it can probably be found at least as far west as secs. 24 and 25, T. 30 S., R. 41 E., and perhaps a mile farther west.

The conditions in the valley do not seem to be favorable for any great development of irrigation. The minimum lift is near the economic limit of pumping for alfalfa. Doubtless properly constructed wells would yield enough water for fruit trees, but it remains to be seen whether the water is good enough for irrigation. The area that can be irrigated is not great. It is limited on the one hand by the pumping lift and in some places probably by the fact that wells close to the mountains may strike bedrock before sufficient water is obtained, and on the other hand by the fact that the total quantity available is probably not great. As indicated by the well of W. E. Gaines, in which the depth to water is 159 feet, the pumping lift is probably at least 200 feet wherever the land is 2,700 feet above sea level. It is doubtful whether water can be pumped this high economically for fruit growing in the valley.

SUPERIOR VALLEY

GENERAL FEATURES

Superior Valley is a small valley about 25 miles due north of Barstow. (See pl. 7.) Conditions in this valley, in so far as settlement and future development are concerned, are typical of many valleys in the desert. The valley has a large area of gently sloping land that requires but little effort to make it ready for farming. It is practically undeveloped, and to the prospective rancher who may be ignorant of the difficulties of desert farming it seems to offer a great opportunity. During the last 8 or 10 years a number of persons have settled in the valley, and in January, 1918, 20 or more wells had been drilled. Several homesteaders had set out orchards or planted grain, but for one reason or another most of the crops failed, and a number of the settlers moved out of the valley. When the writer passed through it in January, 1920, there was no evidence of any successful development, but on the contrary several deserted homesteads were seen. A study of the water resources of the region shows that no great development may be expected.

As a result of the apparently favorable conditions in the valley it has been easy for the so-called "land locators" to make money by "locating" prospective homesteaders on land that is open to entry. For this service fees as high as $100 a quarter section or 50 cents an acre for larger areas are charged. In Superior Valley, locators are said to have told prospective settlers that water for irrigation could be obtained at depths of 60 to 75 feet, whereas in no well so far put down was it less than 90 feet to water. Although the prospects for Superior Valley are not bright, it is probable that from time to time new settlers will arrive in the valley. Some of them may succeed on the most favorably situated land, but many of them will be disappointed.

Most of the data on which the following report of conditions in Superior Valley is based were collected by the writer in September,

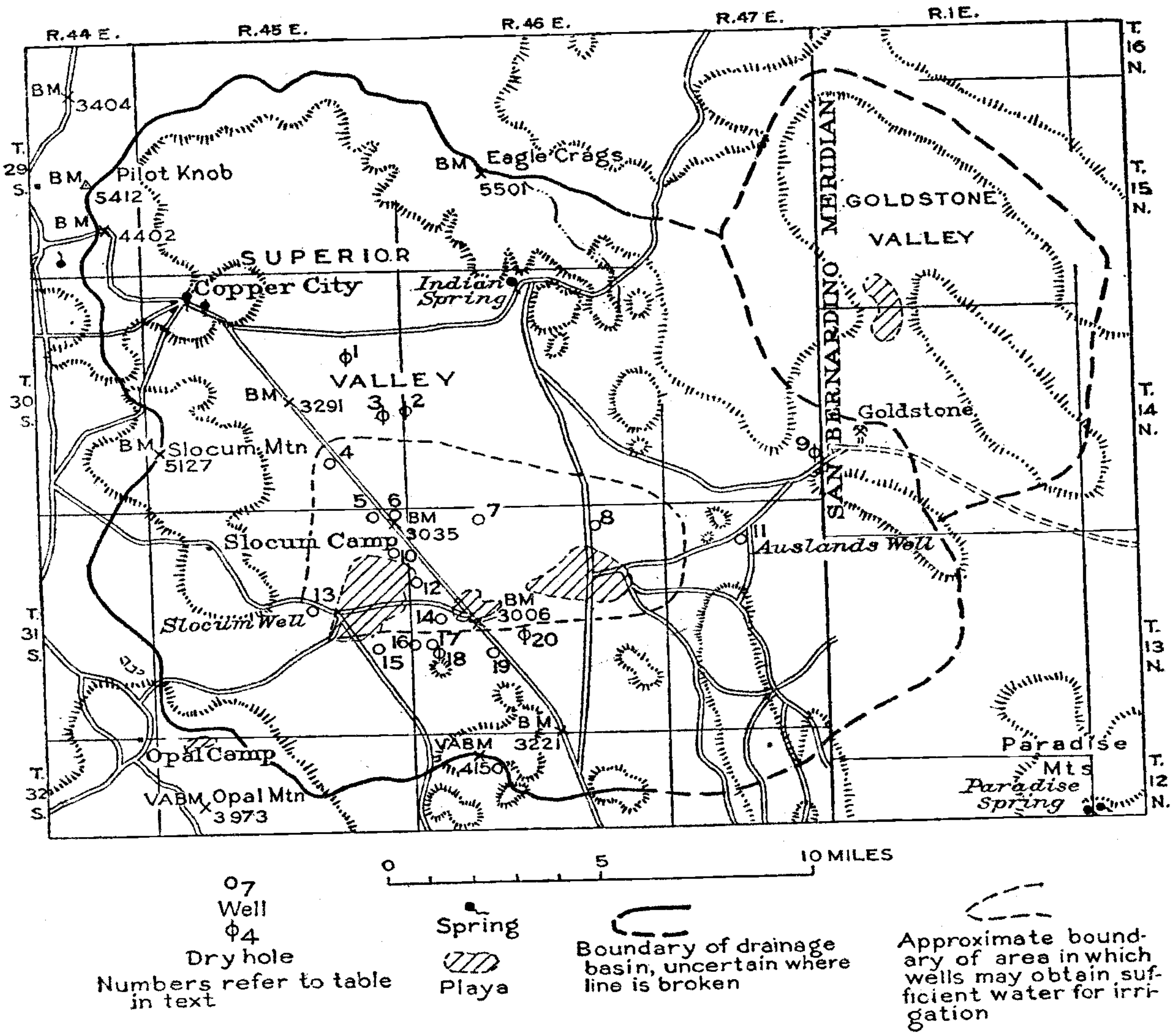

FIGURE 7.—Map of Superior and Goldstone Valleys, showing boundaries of drainage basins and location of wells

1917. Some information incorporated in the report was obtained by G. A. Waring, of the United States Geological Survey, in the fall of 1916. Most of the well data were furnished by D. K. Crutts, who drilled nearly all the wells in the valley.

Part of the basin of Superior Valley is shown on the Searles Lake topographic map, and on this map the divide is shown fairly definitely. On the north, northwest, and west it is formed by mountains and low connecting hills, the principal peaks of which are Eagle Crags, Pilot

Knob, and Slocum Mountain. On the southwest it is more indefinite. Opal Mountain forms a definite boundary, but between that mountain and Slocum Mountain the divide can not be accurately determined from the topographic map. It is possible that an area of 25 square miles or more on the west side of Slocum Mountain drains to Superior Valley. On the map of the valley (fig. 7) it has not been included in the drainage basin. On the south the divide is formed in part by low hills and in part by a gently sloping plain. On this plain the divide is indefinite.

On the east and southeast the divide is not definitely known. A rock ridge extends approximately from Lane Mountain, in T. 32 S., R. 47 E. Mount Diablo meridian, northward as far as sec. 17, T. 31 S., R. 47 E. To the north, in sec. 5 of the same township and approximately in line with the ridge, stand two isolated buttes, and farther north and northwest rise low mountains. From the west the ridge and the buttes north of it seem to form the eastern border of the drainage basin, but east of the buttes and the ridge lies a considerable area of nearly level land. Part of this eastern area probably drains southeast to Coyote Lake, and part probably lies in the drainage basin of Superior Valley, but this was not definitely determined. The eastern boundary of the drainage basin as shown on Plate 7 and Figure 7 may be somewhat in error.

The total area of the drainage basin as shown on Plate 7 is 280 square miles, of which approximately 30 square miles is occupied by mountains, 245 square miles by alluvial slopes, and 5 square miles by playas.

The valley is reached by a good road from Barstow, which crosses the valley from southeast to northwest. On the northwest this road leads to Randsburg and points north, and to Ballarat and the northern part of Death Valley. A branch road leads north on the east side of the valley to Indian Spring and thence to Leach Spring and to South Death Valley. These two roads are connected on the north by a road that stretches east and west. Numerous minor roads lead to all parts of the valley and to adjoining valleys.

Along the principal routes of travel water is obtainable at Indian Spring, at a poorly protected well or spring at Copper City, and possibly at several homesteads. Along the main road from Barstow to Copper City in January, 1920, water could be obtained by hand pump at the Crutts ranch, although there was no one at the place when visited by the writer. The other ranches along this road were apparently abandoned, and the pumps had either been pulled up or were not in working order.

There are no towns in the valley. Mail was brought from Barstow to Crutts post office, which was located in a rancher's house in the south-central part of the valley, but the post office was discontinued in 1922. Settlers' cabins are scattered throughout the valley. In 1916 a town site was laid out at the mining camp of Goldstone, on the northeast border of the valley, but in the fall of 1917 all mining activity had ceased. So far as is known mineral deposits have not been developed at any other place in the drainage basin, although some prospecting has been done in the vicinity of Copper City, an abandoned prospector's camp, now marked only by a well.

PHYSICAL FEATURES

Superior Valley is an elevated valley which consists mostly of nearly level land that slopes to a central depression and is surrounded by a relatively narrow border of mountainous territory. The lowest part of the valley is slightly elongated along an eastward-trending axis, which is somewhat south of the center of the drainage basin.

The lowest part of the valley lies at an altitude of about 3,000 feet, which is from 400 to 1,000 feet higher than the lowest part of adjacent drainage basins, except perhaps a small drainage basin on the northeast, which in this report is called the Goldstone Basin. From the lowest part of the valley the land rises gradually in all directions to rock hills and mountains. The valley lands rise more steeply on the north and west sides of the valley than on the south and east. The mountains on the north and west likewise are steeper and rise to greater altitudes than those on the opposite sides. The border of the basin on the east and south is formed of several more or less isolated buttes and ridges, none of which reach altitudes much greater than about 4,000 feet, and these are separated by much lower areas that are underlain by unconsolidated alluvium. On the north and west most of the divide is above 4,000 feet and several peaks rise above 5,000 feet. In that part of the basin the divide is apparently entirely formed by bedrock. Slocum Mountain and the Eagle Crags are the only large mountains, however. Most of the border on the north and west is formed by a relatively narrow ridge from which rise numerous knobs.

From the lowest part of the valley the land rises southward with a rather gentle uniform slope above which several isolated rock buttes rise steeply. The slope seems to be a typical alluvial slope, but at a number of places rock crops out in shallow washes, and in dry placer workings near the Williams well, a short distance south of the divide, bedrock is found at a depth of 3 or 4 feet. Apparently the slope on the south side of the valley is not an alluvial slope due to deposition but rather an erosional slope or mountain pediment, beveled across rocks and covered with a thin veneer of alluvium. Well records show that in even the lower part of the valley the alluvium is not very thick. On the north side of the valley rock was struck at a depth of 85 feet in well 1 (see table on p. 247 and fig. 7), in the NE. ¼ sec.14,

T. 30 N., R. 45 E. Mount Diablo meridian; at the same depth in well 3, in the SE. ¼ sec. 24 of the same township; and at 99 feet in well 2, in the SW. ¼ sec. 19, T. 30 S., R. 46 E.[68]

On the south side of the valley rock was struck at 135 feet at the Crutts ranch well (No. 19), in the SW. ¼ sec. 21, T. 31 S., R. 46 E.; at 95 feet in well 20, in the NE. ¼ of the same section; and at 60 feet in well 18, in the SE. ¼ sec. 19 of the same township. A well (No. 9) at Goldstone reached rock at a depth of 50 feet. Rock was not reached in wells in the center of the valley, but the deepest well is only 306 feet deep.

The central portion of the valley is occupied by three playas, which lie almost in an east-west line. According to the topographic map the west playa is 3,015 feet above sea level, the middle playa 3,000 feet (bench mark 3006, at the south side of the playa is about 5 feet above the playa surface), and the east playa 2,980 feet. In some other valleys where several playas occupy the same basin, as in Antelope Valley, the altitude of the playas is practically the same. In such places the different playas have been formed by the dismemberment of a single large playa through the formation of sand dunes or the building out of alluvial fans. The difference in altitude of the three playas in Superior Valley suggests a slope of the land to the east before the drainage was cut off, probably owing to the building out of the alluvial slopes from the north or south.

The borders of the playas in most places are marked by a rather abrupt rise of about 5 feet. This rise is doubtless a poorly developed bench that was cut when the playas were covered with sufficient water to permit wave action. No beach ridges or other ancient shore features were observed, and the drainage area is so small that it is not likely that a perennial lake existed here during Pleistocene time.

The surface of the playas in dry weather is hard and smooth. It is said to be covered by water each winter, but the water is generally so shallow that it is frequently blown from one side of the playas to the other. It is said that when the water is thus blown to one side the recently uncovered surface is so hard that one can walk across it. This condition is in contrast to that of many playa surfaces, which become plastic and muddy under similar circumstances. It may be due to the fineness of the clay, or perhaps to the fact that the soil of the playa deposits, as shown by a sample from the middle playa, contains a high percentage of calcium carbonate, which cements

[68] According to the official township plats of recent resurveys in Superior Valley by the General Land Office, the township lines on the Searles Lake topographic map are about a quarter of a mile too far east. The data are not sufficient to locate the township lines correctly on Figure 7, which is compiled from the Searles Lake map, and they are shown as on that map. The wells, however, are located as accurately as possible with respect to topographic features and roads as shown on the township plat. For this reason they do not appear to be located properly with respect to the township lines on the Searles Lake map.

much of the fine material into minute concretions and renders it impervious. (See analysis, p. 67.) The ground-water level lies nearly 100 feet below the playas, and in every respect they are good examples of the dry type of playa. (See p. 125.) Near the southwest border of the basin, in the southeastern part of T. 31 S., R. 44 E., and T. 32 S., R. 45 E., are three small playas. These seem to occupy small distinct basins of their own, but for convenience one of them is included in Superior Valley and the other two in Harper Valley. None of them were seen by the writer.

GEOLOGY

STRATIGRAPHY

The rocks exposed in the region consist of granitic rocks, volcanic rocks of both Tertiary and Pleistocene age, a pre-Tertiary sedimentary series, a sedimentary series that is probably Tertiary or Pleistocene, and Recent alluvium.

Near Copper City the rocks are principally granitic or dioritic intrusives. West and northwest of that place, especially at Pilot Knob, the granite is overlain by isolated patches of volcanic rocks of Tertiary age, which stand out as prominent knobs. Numerous small knobs shown on the topographic map in the territory northeast of Pilot Knob are doubtless also composed of volcanic rocks that rest on a basement of intrusive rocks. Slocum Mountain, as seen from a distance, is apparently composed of the same intrusive rocks as those that occur near Copper City. The ridge that extends north and south in Tps. 31 and 32 S., R. 47 E., consists of granitic rocks. West of the ridge, where the conditions suggest a mountain pediment, granite of the same series probably occurs at a depth of a few feet. The buttes that rise above the pediment in several places are apparently formed of rocks of the same series as those at Pilot Knob (see below), and they probably likewise rest on the eroded surface of the granite. Well logs indicate that rocks of the same intrusive series underlie a large part of the valley. The age of the intrusive rocks is not known, but the dioritic character of the rocks in some places shows that it is doubtless Mesozoic.

Volcanic rocks of probable Tertiary age occur at a number of places as steep-sided buttes. The most prominent of these is Pilot Knob, approximately in sec. 24, T. 29 S., R. 44 E. Mount Diablo meridian. The knob is a nearly flat-topped butte composed of bedded rocks, red above and white and greenish below, which rest on granitic rocks. (See pl. 14, *B*.) The butte was not visited by the writer, but according to Gilbert [69] and Spurr,[70] the capping of the knob is

[69] Gilbert, G. K., Report on the geology of portions of Nevada, Utah, California, and Arizona examined in the years 1871 and 1872: U. S. Geog. and Geol. Surveys W. 100th Mer. Rept., vol. 3, p. 124, 1875.

[70] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California: U. S. Geol. Survey Bull. 208, pp. 216-217, 1903.

basaltic lava and the underlying rocks are volcanic products, probably tuffs. Pilot Knob is one of the highest peaks for many miles, and its characteristic shape and color make it a landmark that can be seen from nearly all points within a radius of 25 miles. On clear days it may be recognized from the north base of the San Gabriel Mountains, about 75 miles away.

Other steep-sided buttes at different places in the drainage basin, especially on the south side, are composed of volcanic rocks that probably belong to the same general series as those of Pilot Knob. The rocks of the Eagle Crags, in the northeastern part of the basin, are also believed to belong to the same series. These crags were not visited, but as observed from the road near Indian Spring the mountain mass that forms them consists of high, steep-sided ridges made by the cutting of several large canyons. In these ridges are exposed a series of purplish, reddish, and grayish bedded rocks. On the south, where the beds appear in almost vertical cliffs, they dip about 15° W.

Lava, probably of Quaternary age, is found in at least two places in the region. A lava flow lies west of the north-south road that is near the east line of T. 32 S., R. 45 E. This flow apparently extends some miles to the northwest and may reach Opal Mountain. This mountain, however, as seen from a distance, is composed of purplish-red rock at the top with white below, and these may be Tertiary volcanic rocks. The lava flow near the road mentioned above is rather fresh in appearance, although it seems to be more weathered than the lava flow near Lavic, along the Atchison, Topeka & Santa Fe Railway. (See p. 653.) The basaltic lava that forms Black Mountain, a few miles farther west, is considered to be Quaternary, and the lava flow that borders Superior Valley is doubtless related to it. A small tongue of lava was observed north of the road about midway between Copper City and Indian Spring. From its black color and unweathered appearance it is probably of Quaternary age.

A series of sedimentary rocks older than Tertiary occurs in the northeastern part of the drainage basin around Goldstone. According to C. C. Jones,[71] the rocks in the vicinity of Goldstone consist of a series of limestone, quartzite, slate, sericite schist, and shale that has a total thickness of at least 10,000 feet. The strike of the beds is approximately northwest, and they dip 25°–35° NE. The rocks are cut by a series of altered dikes, probably originally diorite, which are approximately parallel to the bedding. The following log shows the rocks struck in a well drilled near the Goldstone town site. (See p. 250.)

[71] Jones, C. C., editorial note in article by A. E. Rau, Goldstone district, San Bernardino County, Calif.: Min. and Oil Bull., vol. 2, No. 7, pp. 149–155, 1916.

Log of well near Goldstone, Calif.

[Drilled for Goldstone Mining Co. by D. K. Crutts]

	Thickness (feet)	Depth (feet)
Lime shale	23	23
Gravel, sand, boulders	22	45
Lime shale	5	50
Lime shale with quartz stringers	37	87
Blue limestone	30	117
Shale (90 per cent), limestone (5 per cent), quartz (5 per cent)	178	295
Siliceous blue limestone, with pyrite	13	308
Black hornstone and pyrite, with traces of copper	12	320
Diorite, very hard	25	345

Traces of gold were found at a number of places in the well. Water was not found.

The rocks contain gold, silver, lead, and copper bearing minerals, but mining has been done principally for the gold. So far as the writer is aware, no evidence has been found as to the age of the rocks. No fossils were found during a hasty search of the dump pile from a shaft 325 feet deep. The rock in this dump was principally a dense blue limestone. Jones states that the sedimentary series was laid down on a basement of granitic rocks. These rocks may be either the pre-Cambrian or the Mesozoic granite. However, as the sedimentary series is cut by dioritic dikes and as the Mesozoic intrusive masses in the region contain dioritic phases the sediments are probably Paleozoic.

Sedimentary beds of probable Tertiary or Pleistocene age are exposed on the south flank of the Eagle Crags, where wide, deep washes have been cut in what is apparently an ancient alluvial fan built out from the mountains. The age of these beds is uncertain, but they are certainly older than the recent alluvium and may be as old as Tertiary. A prominent outcrop of a well-consolidated conglomerate at the road junction a quarter of a mile east of Indian Spring may belong to the same series, but it is more consolidated and probably is somewhat older.

The alluvial deposits, which occur in the central portion of the valley are essentially similar to those in other valleys and consist of sand, gravel, and clay. Apparently there is more coarse material than in some of the other valleys, for beds of boulders are reported in several well logs. The clay deposits do not form so large a proportion of the beds as elsewhere. The clay beds of the playas and the soil around the playas apparently contain more calcium carbonate than is found in most of the other valleys.

STRUCTURE

As previously stated, on the southeastern border of the valley stands a more or less continuous ridge that extends northward from Lane Mountain. The ridge gradually becomes lower toward the north and ends in sec. 17, T. 31 S., R. 47 E. Mount Diablo meridian, about 2 miles south of the Ausland ranch, but buttes and low hills northwest of that place are in line with the ridge. In its southern part the ridge does not rise very high above the mountain pediment on the west, but on the east there is a steep descent to a valley that drains to Coyote Dry Lake. Canyons that drain to Coyote Dry Lake by headward erosion have cut westward entirely through the ridge and have captured small areas that formerly drained westward. The topographic features suggest strongly that the ridge has been faulted upward with respect to the valley east of it. There is further evidence of a fault along the line of the ridge and near-by buttes in the depth to water on each side of the buttes near the Ausland ranch. As shown in the section on ground water, the water table at the Ausland ranch is nearly 150 feet lower than at ranches west of the buttes. Apparently the change in the water level is abrupt, as if there were a barrier or dam which held the water higher on the west side.

The steep cliffs of the Eagle Crags, the dip of the beds exposed in the cliffs of those mountains, and the dissection of the alluvial beds on the south side of the mountains suggest that this mass is an upfaulted block, but there was no opportunity to look for critical evidence. The numerous isolated buttes composed of Tertiary volcanic rocks may be faulted blocks. However, they do not seem to be greatly disturbed, and it is quite likely that they are remnants of flows which covered a much larger area and which have now been nearly all eroded.

CLIMATE

No reliable climatic data are available for Superior Valley. According to measurements by D. K. Crutts the rainfall was 16 inches in 1915–16 and less than 7 inches in the following year. His measurements, however, were made in an open pan and probably were subject to error. There is no large mountain mass that would greatly influence precipitation, and it is doubtful whether the normal rainfall is as great as 12 inches. It is believed that the average amount is not more than 5 to 7 inches.

On account of the comparatively high altitude of the valley the temperature both in summer and in winter is probably somewhat lower than that in most of the other desert valleys. Mr. Crutts reports a minimum temperature as low as 6° above zero in the winter of 1916–17, and as low as 10° in the two preceding winters. Winter morning temperatures several degrees below freezing are common. A maximum summer temperature of 116° has been recorded, but in 1915 the maximum was only 98°, and in 1916 it was 106°.

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SOILS

A sample of soil from the central playa contained much calcium carbonate. (See p. 67.) Although no other samples were collected, the soils of the lower part of the alluvial slope for some distance around the playas also seem to be high in this constituent, and some of the soil is in a hardened form similar to caliche. Farther away from the playas the soils in the valley seem to be of the usual type of compact sandy soil derived from the mechanical disintegration of granitic rocks.

VEGETATION

Creosote bush, the common desert plant, is found on the alluvial slopes but not near the playas. Ground water is not close to the surface, and the soil apparently is not alkaline, as is common where creosote is absent near playas. Its absence near the playas is not due to ground water and apparently not to alkali in the soil, but it may be due to the high content of calcium carbonate in the soil.

A good growth of bunch grass, better than that in most parts of the Mohave Desert region, was observed at several places in the valley, especially in the northwestern part. Some cattle are fed on this grass, but the forage is not sufficient to support any large number. A few yuccas grow in the valley. No water-indicating plants were observed except in a wash near Indian Spring, where ground water may occur close to the surface beneath a small area.

WATER RESOURCES

GENERAL FEATURES

There are no streams in Superior Valley, and all the water supply is derived from underground sources. Data were collected in regard to 20 wells that have been drilled in the valley, and these give a good idea as to the ground-water conditions. The location of these wells is shown on Figure 7, and data in regard to them are given in the accompanying table. In brief, the data show that the depth to water everywhere in the valley is nearly 100 feet or more. In a large part of the valley rock is likely to be encountered before ground water is struck, and the quantity of water available is not great.

As stated in the description of the physical features, the valley is partly divided by a ridge that extends approximately north and south through T. 31 S., R. 47 E., and by buttes north of this ridge, which are possibly a continuation of it. The ground-water conditions east of the buttes are somewhat different from those west of it, and for convenience the conditions west of the buttes are discussed first.

Records of wells in Superior Valley, Calif.[a]

No. on fig. 7	Location (Mount Diablo meridian)				Owner	Depth of well (feet)	Diameter of well (inches)	Depth to water (feet)	Draw-down (feet)	Method of lift	Reported yield (gallons per minute)	Date of completion of well	Remarks
	Quarter	Sec.	T. N.	R. E.									
1	NE.	14	30	45	H. C. Darrah	105	8	Dry.	------	------	------	Aug., 1916	Rock at 85 feet.
2	SW.	19	30	46	Peter Hopman	99	8	Dry.	------	------	------	Oct., 1916	Rock at 99 feet.
3	SE.	24	30	45	E. V. Edmonds	85	8	Dry.	------	------	------	Sept., 1916	Rock at 85 feet.
4	?	26	30	45	E. W. Brown	209	------	175	------	------	6	May, 1917	Dug 174 feet.
5	NW.	1	31	45	------	230	8	[b] 118	------	Windmill	------	------	
6	NE.	1	31	45	E. V. Edmonds	250	8	125	------	------	180	Feb., 1917	
7	NE.	5	31	46	D. W. Longwell	306	12	105	11	Turbine	[c] 450	------	Water struck at 118 feet and rose to 105 feet. A second well here 230 feet deep.
8	NE.	2	31	46	L. H. Baker	225	8	105	------	------	7	July, 1915	Water struck at 110 feet, said later to have risen to 105 feet.
9	------	([d])	30	47	Goldstone Mining Co.	345	8	Dry.	------	------	------	Apr., 1916	Rock at 50 feet. See log.
10	NE.	12	31	45	O. J. Eckley	201	12	[e] 95.6	16	Turbine	720	Nov., 1916	See descriptive notes.
11	SE.	5	31	47	K. T. Ausland	278	8	249	------	Jack pump	6	Feb., 1915	See p. 250.
12	SW.	7	31	46	Mrs. M. A. Moffat	136	8	113	------	Hand bailer	------	------	
13	SE.	15	31	45	P. P. Correll	220	12	115	12	------	[c] 225	Aug., 1917	
14	SE.	18	31	46	C. N. King	200	8	113	------	------	------	Mar., 1915	Another well 25 feet distant about same depth.
15	SW.	24	31	45	D. K. Crutts	208	8	122	------	------	[c] 180	Mar., 1917	
16	SW.	19	31	46	Mrs. Kate Knoxen	120	8	112	8	------	7½	Oct., 1914	Pumps dry in 10 minutes. Rock or boulder at 112 feet.
17	SE.	19	31	46	W. R. Knoxen	150	------	135	------	------	------	------	
18	SE.	19	31	46	do	192	8	Dry.	------	------	------	Aug., 1914	Rock at 70 feet. A second well 300 feet northwest struck rock at 60 feet.
19	SW.	21	31	46	B. B. Crutts	150	8	121	------	Lift	9	Mar., 1915	Rock at 135 feet. See p. 252 for analysis.
20	NE.	21	31	46	Charles Bird	135	------	Dry?	------	------	------	Oct., 1916	Rock at 95 feet. Abandoned.

[a] Al lmeasurements, unless otherwise stated in footnotes are those given by owner, well driller, or other person; the reference point and date of such measurements are generally not known.

[b] Measured by D. G. Thompson, Jan. 24, 1920; reference point for measurement, top of casing, 2 feet above surface.

[c] Measured by D. K. Crutts by means of weir.

[d] Exact location uncertain. Well said to be near township line and presumably near Goldstone town site.

[e] Measured by D. G. Thompson, Jan. 24, 1920; reference point for measurement, top of casing level with ground.

GROUND WATER IN WESTERN PART OF VALLEY

In only one well (No. 10), in the NE. ¼ sec. 12, T. 31 S., R. 45 E., is the depth to water less than 100 feet, and in that well it was 95.6 feet when measured. This well is in the central part of the valley. In other wells in the central part of the valley, where the water should be nearest the surface, the depth to the water table is at least 100 feet. Except in one well, however, the depth to water is not more than 125 feet. In well 4, in sec. 26, T. 30 S., R. 45 E., the depth to water is reported to have been 175 feet when the well was drilled. This well is at least 50 to 75 feet higher than the other wells in which water has been reached.

Approximate altitudes determined from the topographic map show that the water table in the valley as far east as the township line between Rs. 46 and 47 E., is probably nearly flat, although perhaps it rises slightly toward the north and south.

The materials penetrated in the wells consist of alternating beds of clay, sand, and gravel, in places with large boulders, and some of the wells penetrated bedrock. In some places the boulders seem to be mixed with clay, in others they are mixed in the gravel, and in still others there seem to be boulder beds that contain practically no fine material. In several wells clay similar to the clay of the playas was encountered. Such clay beds were thin, and except in one well they were near the surface. The logs of the wells do not show that the playa deposits are very thick or extend far beyond the surface limits of the present flats.

Although local inhabitants have considered that the alluvium contains water at two distinct horizons, there is no evidence in the well logs that such is the condition over any large area. In some wells gravel extends nearly all the way from the surface to a depth of 200 feet, and in other wells a mile or two distant the gravel beds may be separated by two or more clay beds. The beds are apparently all deposited by wash from the mountains, and it is to be expected that no distinct beds would extend over a large area.

Bedrock was struck in at least eight wells in the western part of the drainage basin. In several the rock was struck before water was reached, and these wells are dry. Rock was reached at depths of 60 and 70 feet in two wells in the SE. ¼ sec. 19, T. 31 S., R. 46 E. No water was obtained in either well, although one of them (No. 18) was drilled to a depth of 192 feet. In another well (No. 17), about a quarter of a mile north of No. 18, rock described as quartzite was struck at 54 feet, and water was struck at 135 feet. The water-bearing bed, which was only 6 inches thick, was reported as gravel, but it probably was really only a crevice in the rock. In well 16, in the SW. ¼ of the same section, rock was struck in the bottom of the well at a depth of 120 feet. Water was found in this well in gravel at 112 feet. The wells just mentioned are a short distance north and northwest of a low rock hill. In well 20, in the NE. ¼ sec. 21, T. 31 S., R. 46 E., rock described by the driller as quartzite was struck at 95 feet and extended to 130 feet, and below that for 5 feet rock described as gabbro was penetrated. No water was found and the well was abandoned. In the lowest part of the valley, around the playas and for a mile or two north of them, rock has not been reached in wells, but the deepest well (No. 7) is only 306 feet deep. On the north side of the valley rock has been reached in three wells (Nos. 1, 2, and 3) at depths of 85 to 100 feet. The relation of the water table to the alluvium and bedrock is shown in Figure 8.

The information obtained from the few wells that have been drilled shows that throughout a large part of the valley the bedrock lies at a depth of 50 to 150 feet, and rock may be struck before the water table is reached. In this territory water might be obtained from crevices in the rock if the wells are drilled deep enough, but this is not certain. The rocks are apparently crystalline rocks, which are not porous, so that even if water were obtained from them the quantity would be sufficient only for household use or to water a few head of cattle. It is therefore evident that a large part of the land that is otherwise suitable for farming can not be irrigated because there is no water supply for it.

The area in which it is believed that sufficient water for irrigation may be obtained before rock is struck is outlined approximately on Figure 7. Except near wells 14 to 18 the location of the boundary may be in error by a mile or two, but nevertheless it gives some idea of the restricted area in which water may be obtained for irrigation.

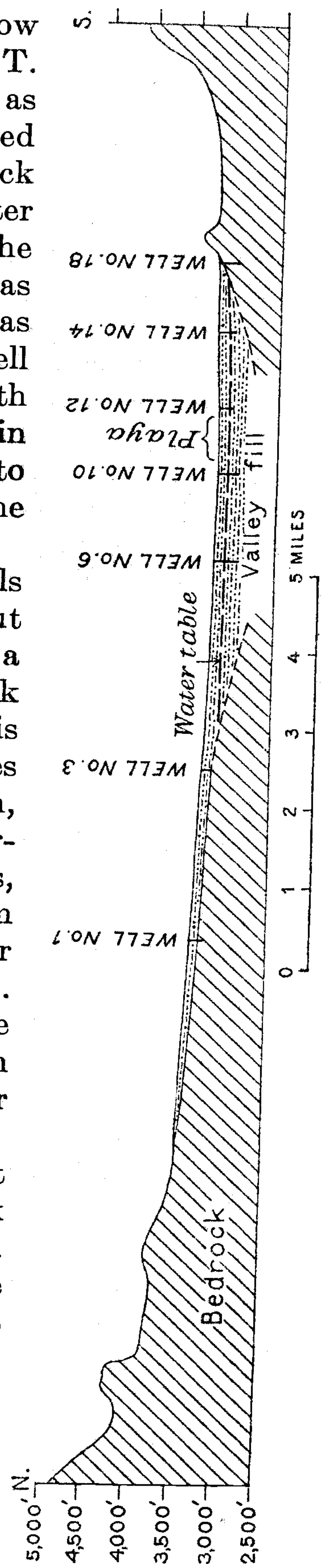

FIGURE 8.—Section along a north-south line through Superior Valley

GROUND WATER IN EASTERN PART OF VALLEY

The data available in regard to ground-water conditions in the eastern part of the drainage basin are meager. So far as is known only one well, the Ausland well (No. 11), reached water. This well, which is about half a mile southeast of two rock buttes, is 278 feet deep. Water was apparently found only near the bottom, but when the water-bearing stratum was reached the water rose in the well and stands about 249 feet from the top. The materials penetrated are said to have been compact sand or gravel like the soil formed of decomposed granite, which is found throughout a large part of the desert. Although boulders were found in a number of the wells in the western part of the valley, they were absent in the Ausland well. This fact is rather surprising, in view of the closeness of the well to rock buttes about half a mile to the northwest. It suggests that the buried slope of the buttes must descend rather steeply to the east.

The water level in the Ausland well is more than 100 feet lower than the water table in the western part of the valley. Apparently the change in the altitude of the water table is not gradual. In a well (No. 3) in the NE. ¼ sec. 2, T. 31 S., R. 46 E., about 3½ miles west of the Ausland well, the depth to water is only 105 feet. The altitude of the water table there is about the same as farther west, whereas if the water table sloped eastward to the Ausland well, it should be considerably lower at well 3. The two rock buttes about half a mile west of the Ausland well are in line with the long ridge that forms the southeast boundary of the basin. As suggested in the section on geology this ridge may be a block raised by faulting, and the buttes west of the Ausland well may be a continuation of this uplifted block. A buried dam formed in this way would explain the difference in the altitude of the water table in the eastern and central parts of the basin.

The only other well in the eastern part of the valley is one drilled for the Goldstone Mining Co. In this well rock was struck at 45 feet, and the well was drilled to a depth of 345 feet without finding water. (See log, p. 244.) The exact location of this well is not known, but it is said to be near the east line of T. 30 S., R. 47 E. Mount Diablo meridian, near the town site of Goldstone. This location would place it in a small arm of the valley almost entirely surrounded by rock hills, and it is not surprising that rock was struck so close to the surface. The surface at the well is approximately 300 feet above the Ausland well, where the depth to water is 249 feet. Thus the bottom of the Goldstone well is about 200 feet above the water table in the lower part of the valley. Possibly water might have been obtained if the well had been drilled to that depth, but the rocks may be so tight that they contain no water.

YIELD OF WELLS

The yield of wells in the central part of the valley seems to be sufficient for irrigation, although actual tests are available for only one or two wells. The well of O. J. Eckley (No. 3), in the NE. ¼ sec. 12, T. 31 S., R. 45 E., is said to have yielded approximately 720 gallons a minute (80 miner's inches), with a drawdown of 16 feet. The pumping plant at this well was dismantled in 1918. The well of D. W. Longwell (No. 7), in the NE. ¼ sec. 5, T. 31 S., R. 46 E., yielded 450 gallons a minute (50 miner's inches) with a drawdown of 11 feet when tested with a weir by D. K. Crutts. The driller estimated that the well of Paul P. Covell (No. 13) would yield 225 gallons a minute (25 miner's inches). The yield of two other wells (Nos. 6 and 15) was estimated by the driller at 180 gallons a minute (20 miner's inches) each, but they had not been tested when the field data were obtained. The yield of several other wells was given as less than 10 gallons each. Most of the wells with small yield are those which struck rock. These wells are on the border of the water-containing beds, or in some places the water comes from the rock itself.

QUALITY OF WATER

The quality of water in the three springs on the borders of the valley is discussed elsewhere. (See p. 254.) Only one analysis (No. 1, p. 252) is available for the water from a deep well in the central part of the valley. This analysis represents a sample collected by G. A. Waring from the well of B. B. Crutts (No. 19), in sec. 21, T. 31 S., R. 46 E. Mount Diablo meridian. The water is a sodium carbonate water that contains 334 parts of total dissolved solids per million. It is good for domestic use and fair for use in boilers and for irrigation. Although no other analyses are available of water from wells in the central part of the valley, the water is probably in general of as good quality, for no bad water was reported in the wells for which logs were obtained. The samples from Indian Springs and from the well at Copper City are of the same general character as that from the Crutts Well. The more concentrated water from the spring half a mile east of Copper City apparently comes from a formation of small extent. There is no reason to believe that water in most of the valley should be of other than good quality.

Analyses of ground waters from Superior Valley, Calif.

[Parts per million]

	1	2	3	4
Silica (SiO_2)	30	107	46	58
Iron (Fe)	Trace.	.05	.33	.20
Calcium (Ca)	22	13	21	122
Magnesium (Mg)	8.3	7.8	3.3	38
Sodium and potassium (Na+K)	[a] 77	[a] 39	117	310
Carbonate radicle (CO_3)	0	12	0	0
Bicarbonate radicle (HCO_3)	197	96	138	456
Sulphate radicle (SO_4)	42	21	97	405
Chloride radicle (Cl)	28	12	58	216
Nitrate radicle (NO_3)	14	14	3.2	6.4
Total dissolved solids at 180° C	334	289	421	1,406
Total hardness as $CaCO_3$ (calculated)	89	65	66	461
Date of collection	(b)	(c)	(c)	(d)

[a] Calculated.
[b] Aug. 21, 1916.
[c] Sept. 22, 1917.
[d] Jan. 10, 1918.

Analysts: 1, S. C. Dinsmore; 2 and 4, Margaret D. Foster, U. S. Geological Survey; 3, Addie T. Geiger and C. H. Kidwell, U. S. Geological Survey.

1. Well 19, Figure 7 and table on page 247; B. B. Crutts, owner.
2. Indian Spring, in sec. 4, T. 30 S., R. 46 E. Mount Diablo meridian. (See p. 253.)
3. Well at Copper City, in sec. 6, T. 30 S., R. 45 E. Mount Diablo meridian. (See p. 254.)
4. Unnamed spring in sec. 5, T. 30 S., R. 45 E. Mount Diablo meridian. (See p. 254.)

QUANTITY OF GROUND WATER AVAILABLE

The quantity of ground water available for use in Superior Valley is apparently not great, because the precipitation is low and the drainage area is relatively small, so that the initial supply is not large, and because apparently much of the water that is absorbed by the alluvium drains to adjacent basins.

The average annual rainfall is probably not more than 5 inches. Most of the drainage area is nearly level land with a mantle of alluvium, and in this part much of the rain is evaporated before it has penetrated far into the soil. The mountainous part of the drainage area covers only 30 square miles and is composed largely of isolated hills. As a result there is very little concentration of the run-off. The conditions are not favorable for the absorption of a large quantity of water.

The fact that the water table lies at a depth of nearly 100 feet or even more throughout the valley is significant. If a basin is watertight the water table will stand within a few feet of the surface. If, however, the water table lies at a considerable depth it is reasonably certain that there is an underground leakage from the basin. This is apparently the condition in Superior Valley. The valley is several hundred feet above the valleys that adjoin it, and there are at least two places where, it is believed, underground drainage is possible. The border of the southwest corner of the basin, in T. 32 S., R. 45 E., is composed of a basaltic lava flow of Quaternary age In other places where such lava is found it is much fractured, and water passes through it freely. It therefore seems possible that ground water can drain from Superior Valley southwestward to Harper Valley, nearly 1,000 feet lower, where the water table is close to the surface and in places is under artesian pressure. The southeastern border of the valley, in the northeastern part of T. 13 N., R. 1 E. San Bernardino meridian, is apparently composed of alluvium, but this has not been definitely ascertained. If it is, the ground water could drain southward on the east side of Lane Mountain and thence southeastward to Coyote Dry Lake, on the west side of which the ground water is under sufficient artesian pressure to produce flowing wells. It seems certain that there is underground drainage in the eastern part of the basin, for if there were not the water level in the Ausland well should be at least as high as that in the wells farther west. This condition would exist because even if the eastern part of the valley forms an independent ground-water basin, in the absence of an underground outlet the water table would rise until it reached the surface or found an outlet into the western part of the valley. The fact that the water table is so much lower in the eastern part of the valley points very strongly to an outlet from that part of the basin, even if there is no outlet in the southwest. It is possible that there may be underground leakage at other places not suspected.

If there is underground leakage from the valley most of the water that reaches the water table annually must drain out of the underground reservoir and is not available for use in the valley. This loss from the valley could doubtless be prevented if the water table could be lowered below the lowest point of the buried impervious rim by pumping.

WATERING PLACES

Data were obtained in regard to three springs in the valley. They are all near the border of the valley and are useful only as roadside watering places or for watering cattle.

Indian Spring, situated approximately in sec. 4, T. 30 S., R. 46 E. Mount Diablo meridian, is a valuable watering place on the road from Barstow to South Death Valley by way of Leach Spring. It is the last reliable watering place before Leach Spring is reached, a distance of about 25 miles. The spring is in a low wash about a fifth of a mile west of the junction of roads from Copper City and from Barstow. It is about 100 feet north of the road, and when visited by the writer the brush was so high that one would not suspect the presence of a spring. The wash in which it lies is marked by many boulders and is just at the point where the road to Copper City bends to the southwest. The spring is in a low mound of gravel and boulders. When visited it was well boxed and covered. (See pl. 15, *B*.) The water was about 2½ feet deep, and it stood about level with the bottom of the wash. There was no apparent outflow. The source apparently is the gravelly wash that reaches out from the Eagle Crags. Probably water is close to the surface for some distance along the wash. An analysis of the water (No. 2 in table, p. 252) shows that it contains only 289 parts of total dissolved solids per million and is of good quality for domestic use.

A watering place known as Copper City is approximately in the SE. ¼ sec. 6, T. 30 S., R. 45 E. Mount Diablo meridian. Formerly there were several houses at this place, but these are now destroyed. The well is about 100 yards north of the junction of the road between Barstow and Granite Wells and roads leading westward to Blackwater Well and southward on the west side of Slocum Mountain. The junction is marked by signs erected by the United States Geological Survey and the Automobile Club of Southern California. The watering place is perhaps more truly a well than a spring, for it is a hole about 5 feet in diameter dug to a depth of 13 feet in a small gulch eroded in a granitic rock. It is partly walled in on the downhill side but not cemented, so that when filled by rain water it can overflow, but animals can not reach it. Although the hole is probably filled by surface run-off during storms some water doubtless enters it in dry periods by seeping in from fractures in the rock. When visited on September 22, 1917, the water stood 8 feet below the surface, but on January 24, 1920, it was 2 or 3 feet higher. It was necessary to use a rope and bucket to reach the water. An analysis of a sample (No. 3, p. 252) collected in September, 1917, showed the water to be good for household use. It is a sodium carbonate water that contains 421 parts of dissolved solids per million. When the sample was taken the water was clear, but when the spring was visited in January, 1920, the water was dirty and covered with a green scum, which made it uninviting.

About 0.6 mile east of Copper City and 0.3 mile north of the road to Barstow is an unnamed spring. The water comes from a trench dug into the hillside in white clay that contains angular pebbles of a dark crystalline rock. The exact nature and origin of the formation were not ascertained. In January, 1920, the water was carried by a small pipe to a trough near by. Water trickled from the pipe at the rate of about a pint a minute, but the trough was nearly full. This spring is used for watering stock, as considerable good bunch grass grows near by. An analysis of a sample (No. 4, p. 252) taken from the spring in September, 1917, showed the water to be of only fair quality for domestic use. It contains 1,406 parts of total solids and is a sodium sulphate water.

IRRIGATION

At the time the field work was done, in September, 1917, there had not been sufficient development in the valley to determine its agricultural possibilities. The first homesteaders entered the valley in

1914, and the progress of development shortly thereafter was doubtless hindered by the adverse economic and other conditions incident to the World War. Only two pumping plants large enough for irrigation had been installed in 1917, and one of these was later dismantled. At both plants small tracts of fruit trees and grain had been planted with varying degrees of success. At one of the places, where 36 acres of fruit trees had been set out, 60 per cent of the trees were said to have been lost the first year. These trees were replaced, but many were lost again. Apparently the loss was due to improper care in cultivation and irrigation.

The pumping lift throughout the valley is at least 100 feet. This lift is so great that water can not be pumped economically for alfalfa or other crops that yield low returns. In some places in southern California, however, water is pumped considerably higher than this for irrigating fruits. The winters in Superior Valley are too cold for citrus fruits but deciduous fruits could be raised.

The valley is 25 miles from Barstow, the nearest shipping point, and the long haul over desert roads would involve considerable expense. The area that can be irrigated is so small that no large community can be developed.

GOLDSTONE VALLEY

PHYSICAL FEATURES AND GEOLOGY

The name "Goldstone Valley" is given in this report to a small valley northeast of Superior Valley. The town site of Goldstone is in the drainage basin of Superior Valley, but the Goldstone mine is in low hills that form the south border of this valley.

The valley was not visited but was observed from the hills at Goldstone. So far as the writer knows, there are no regularly traveled roads in it. The only signs of habitation were two or three small areas of cleared land on the south side of the valley. The physical conditions are unfavorable to any great development of the valley.

On the south the valley is separated by low rocky hills from the arm of Superior Valley in which Goldstone is located. On the west it is separated by low mountains from Superior Valley and a long wash that drains to Panamint Valley. On the north and east the boundary is not definitely known. About 2 miles northeast of the Goldstone mine there is a long ridge which extends northwestward for several miles and which may form the divide on the east side of the basin. The township plats of the General Land Office, however, show another mountain ridge 2 or 3 miles farther northeast that is approximately parallel with the one just mentioned. As seen from the hills at Goldstone it seemed to form the divide, and it is so shown on Figure 7. The area of the drainage basin as outlined on the map is 70 square miles, of which approximately 30 square miles consists of mountains and 40 square miles of gently sloping valley lands.

The lowest part of the basin, several miles north of the Goldstone Hills, is covered by a playa. This playa is wedged in between hills on the east and west that reach to its edge. On the south the land rises very gradually to the low hills at Goldstone. On the north the rise seems more abrupt. On the east the playa is bordered by the long ridge mentioned above that lies 2 or 3 miles northeast of Goldstone.

The physical aspect of the ridge, as seen from the Goldstone Hills, and its relation to the playa are very striking. It is several hundred feet high at its southeast end, but it slopes northwestward and disappears under the playa. A small outlier that rises out of the playa shows that the rocks of the ridge do not lie far beneath the playa surface. The top of the ridge appears to be rather smooth. The southwest face of the ridge is steep in places and is marked by a series of declivities. These steep slopes are suggestive of fault scarps. From a distance the ridge seemed to be formed by a lava flow. If it is a flow the steep slopes may be original surface forms due to rapid cooling of the lava or to erosion of soft beds overlain by a harder cap.

The rocks of the Goldstone Hills, on the south border of the drainage basin, are a series of pre-Tertiary sediments, more or less metamorphosed and intruded by dikes. (See p. 243.) Probably some of the same series also occur in the low mountains on the west side of the basin. The rocks on the northwest side of the basin are probably Tertiary volcanic rocks, more or less similar to those of Pilot Knob and the Eagle Crags. Such rocks were observed along the road hat runs just west of the basin. The mountains on the northeast side of the basin had the characteristic appearance of mountains formed of granitic rocks, but they were seen only from so great a distance that nothing definite can be said as to their composition.

The land between the Goldstone Hills and the long ridge northeast of them does not seem to be very high above the lowest part of the basin. The general impression the writer got by observing the valley from the Goldstone Hills was that it had at one time drained southeastward to either Langford or Coyote Basin and that it had been closed by the formation of the long ridge northeast of Goldstone. Apparently this change came about by an outpouring of lava, but it may have been due to faulting. The building of alluvial fans from the hills on each side probably helped to close the gap.

Climatic conditions in the valley are presumably about the same as in Superior Valley. The soil at the south end of the valley near the Goldstone Hills is rocky, as if the bedrock were not far below the surface. The vegetation appeared to be scantier than in some other desert valleys, and there was no evidence of good forage.

GROUND WATER

No information was obtainable as to whether there are any wells or springs in the drainage basin. There is no reason to believe that water is close to the surface. No clumps of mesquite, such as those that grow where water is near the surface, were observed around the playa in the basin. The bottom of the basin is apparently higher than that of the adjacent basins except Superior Valley. The boundary of the basin on the southeast is apparently composed of lava and alluvium, through which ground water might readily move from the valley. Some water could perhaps be obtained from deep wells, but it would not be surprising if rock were struck before water was reached.

BICYCLE VALLEY

GENERAL FEATURES

The name Bicycle Valley is given in this report to the valley that drains to a small playa, Bicycle Dry Lake, in the southeastern part of T. 14 N., R. 3 E. San Bernardino meridian. On some of the old maps this playa is called Garlic Lake, but current usage favors Bicycle Lake. Garlic Spring, about 2 miles south of the playa, is not in the drainage basin of Bicycle Lake.

On the east the boundary of the drainage basin is formed by a high, rather steep mountain known as Tiefort Mountain. The southern boundary is formed by low hills that are continuous with Tiefort Mountain. On the west the divide apparently is formed partly by a low ridge along the west boundary of T. 14 N., R. 3 E., and partly by the alluvial slope from mountains to the north. The divide on the northwest and north is formed by an unnamed mountain range, which is connected by low hills with the east end of the Granite Mountains. On the east it probably passes through low hills on the south-central part of T. 15 N., R. 4 E. San Bernardino meridian.

On the northwest Bicycle Valley is separated from Granite Valley by low hills that connect the Granite Mountains with a range on the southwest. This basin was not visited, and it is not known whether there is any surface or underground drainage from it to Bicycle Valley. (See p. 201.)

According to approximate barometric observations made independently by G. A. Waring, of the United States Geological Survey, and by E. T. Ham, county surveyor of San Bernardino County, the altitude of Bicycle Lake is between 2,250 and 2,500 feet above sea level, and the summit of the Granite Mountains where it is crossed by the Barstow-Silver Lake road is between 3,700 and 4,000 feet. A large part of the valley is probably less than 3,000 feet above sea level.

The valley was entirely uninhabited in 1918. It is crossed by the road from Barstow and Daggett to Silver Lake and Death Valley. From the north side of Bicycle Dry Lake a poorly defined road to the southwest and west is said to lead to Goldstone. This road is reported to be almost impassable for automobiles. An old road also leads eastward around the north end of Tiefort Mountain. There are no watering places along the roads in the valley.

The valley apparently has no valuable resources. No mines or prospects were seen, and there was no evidence that conditions are favorable for cattle raising or irrigation.

Most of the valley area within the mountain borders is a long slope that extends southward from the Granite Mountains and mountains west of them to Tiefort Mountain. Tiefort Mountain and the low hills adjoining it on the west form a broad V in which the drainage of the alluvial slope collects, forming Bicycle Dry Lake. On the east and west rise low hills which apparently form the divide on those sides of the basin, but this was not definitely determined. In the northeastern part of the basin the slope may drain eastward to an adjoining basin.

The slope between the Granite Mountains and Bicycle Lake is an excellent example of the long slopes that extend from many of the mountains in the Mohave Desert region. (See pl. 23, *B*.) From the north end of Bicycle Lake, northeastward along the Barstow Silver Lake road, the slope rises 150 feet in about 4½ miles, or about 35 feet to the mile, according to barometric observations by G. A. Waring. In the next 5 miles to the place where the road crosses the summit the rise is about 1,300 feet or about 260 feet per mile. The steepness of the grade increases gradually from the base of the slope to the summit of the mountains. The slope is apparently composed of alluvium, but areas of gently sloping land extend back into the mountains and the upper part is doubtless a mountain pediment composed of hard rocks beveled by erosion.

The Granite Mountains, as the name implies, are composed of granite rocks. Tiefort Mountain is probably composed of Tertiary volcanic rocks, as débris of a reddish vesicular lava is spread over Bicycle Lake. Along the road south of the playa lies a purplish-brown lava. A little farther south, along the road to Barstow, there are exposures of gneiss and schist cut by granite.

GROUND WATER

So far as is known no wells now exist in Bicycle Valley, and the indications are that no reliable supplies of either surface water or ground water can be obtained. A well reported to have been dry many years ago was situated near the Death Valley road, at the northeast edge of "No. 4 Dry Lake" (evidently Bicycle Dry Lake), near the southwest end of Tiefort Mountain.[72] An old hole, which is doubtless the remains of this well, was found close to the road on the north side of the playa. It was caved and filled within 15 feet of the top and showed no indications of moisture.

There are no indications of ground water near the surface. The playa is smooth and hard and belongs to the dry type. There is no salt grass around it nor any other indications of ground-water discharge. According to surface appearances the basin is not watertight. The border of the basin north of Tiefort Mountain and in the southwest corner is composed of alluvium, and probably there is underground leakage either to the east or southwest. It is possible that the water appearing at Garlic Springs, on the south side of the hills that form the southern border of the valley, comes from Bicycle Valley.

The prospects of obtaining water for irrigation in the valley are poor. The precipitation throughout the valley probably does not exceed 5 inches. The mountainous area is not great, and as a result there is little concentration of the run-off, and absorption of ground water is doubtless slight. Probably some water could be obtained in the lower part of the valley, but the yield would be very small. Although a large part of the land is otherwise well adapted to agriculture except for the lack of water, all indications show that neither irrigation nor dry farming is possible.

LANGFORD VALLEY

GENERAL FEATURES

Langford Valley is a short distance northwest of the center of San Bernardino County and about 30 miles northeast of Barstow. The name is taken from Langford Dry Lake, a playa in the lowest part of the valley, and Langford Well, a well-known roadside watering place. The principal features of the valley are shown on Plate 11 and Figure 9.

The valley is uninhabited except that a stockman occasionally lives at Garlic Springs. It is crossed by the road from Barstow to Silver Lake and Death Valley, which on the northeast side of the valley is joined by a road from Daggett.[72a] The road from Barstow is most commonly used, partly on account of a sandy stretch on the Daggett road. A road leads eastward from the Daggett road to Bitter Spring and thence to Silver Lake. This route is a short cut to Silver Lake, but it is seldom used because of heavy sand at several places. A poor road leads westward from the Barstow road near Garlic Springs to Goldstone.

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[72] Mendenhall, W. C., Some desert watering places in southeastern California and southwestern Nevada: U. S. Geol. Survey Water-Supply Paper 224, p. 54 (well No. 101), 1909.

[72a] See p. 555 for note in regard to new road from Barstow to Silver Lake.

The valley has no valuable resources. No mines or prospects were observed. A few cattle are grazed occasionally. The conditions are unfavorable for irrigation.

The lowest part of the basin lies at an altitude between 2,000 and 2,500 feet, and the surrounding hills probably do not rise more than

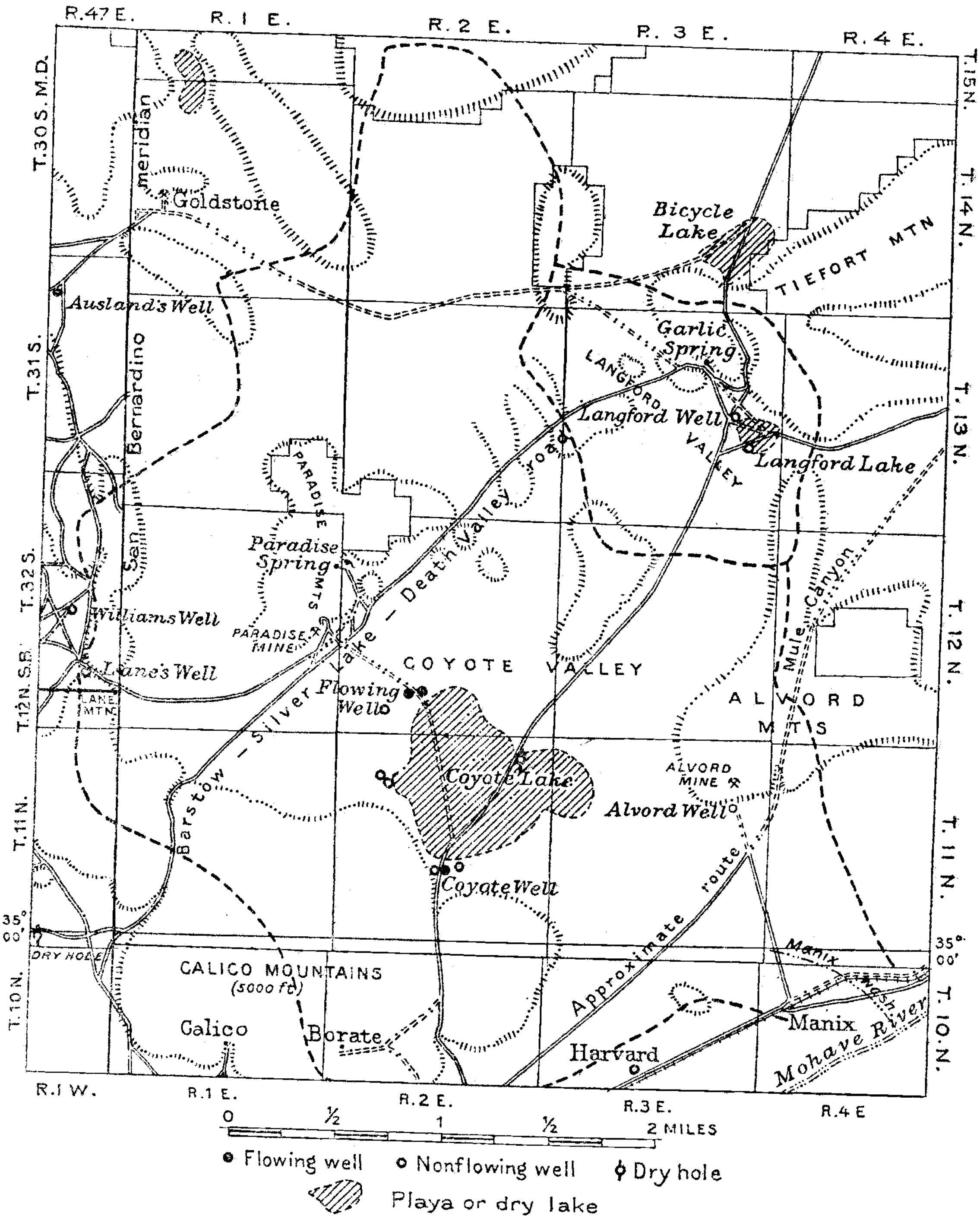


FIGURE 9.—Map of Coyote and Langford Valleys, showing boundaries of drainage basins and location of wells and springs

500 feet higher. Accordingly there is no reason for believing the average annual precipitation to be great, and it is probably not more than that at Barstow, about 4 inches.

The characteristic vegetation of most of the valley is the creosote bush and its common associates. There is no salt grass or other vegetation indicative of water except near Garlic Springs. For a distance of several hundred yards around the playa creosote bush is lacking, and there the dominant vegetation is a species of salt bush.

PHYSICAL FEATURES AND GEOLOGY

Langford Valley is a small valley separated from the adjoining valleys by high hills or low mountains. The boundary of the drainage basin as shown on Figure 9 is based on a hasty sketch map prepared from compass observations and the township plats of the General Land Office.

The divide on the northeast side of the valley is formed by rock ridges that extend from Tiefort Mountain, but the main part of the mountain apparently does not lie in the drainage basin. At Garlic Springs and northeast of that place the rocks are principally gneiss and schist intruded by granitic rocks. Near the divide along the road between Garlic Springs and Bicycle Dry Lake, on the north side of these hills, is a purplish lava, and this rock may form the south end of Tiefort Mountain. West of Garlic Springs the divide is low and apparently formed of alluvium. The southwest border of the basin is formed of high hills of granitic rock. Southward from Langford Lake a long slope rises for several miles to the divide that separates the basin from Coyote Valley. The slope appears to be a typical alluvial slope, but west of the Daggett road near the summit stands a granite hill, and possibly most of the south side of the valley is a mountain pediment or erosion surface with bedrock at a depth of only a few feet. The southwestern part of the valley as a whole appears to be a maturely eroded surface on which granite appears only on the higher hills, but doubtless the granite is close to the surface in much of the area.

The eastern divide is formed in part by a long, low ridge that extends northward from the Alvord Mountains and in part by hills that stretch southward from Tiefort Mountain. On the east side of Langford Lake there is a break in these hills through which the road leads to Bitter Spring. The divide is almost imperceptible and probably not more than 20 feet above the bed of the playa. It is partly filled with wind-blown sand, and unconsolidated alluvium apparently extends to a considerable depth. As pointed out on page 263, it is probable that there is now underground leakage through this pass, and very likely the entire Langford Valley was at one time tributary to West Cronise Valley, to the east.

Langford Lake is a small playa, hard and smooth in dry weather, that merges very gradually into the alluvial slope. The water table is about 50 feet below the surface, and the playa is in every way one of the dry type.

GROUND WATER

Two dug wells and a spring are the only sources of water in Langford Valley.

Langford well is near the west edge of Langford Dry Lake, probably in sec. 23, T. 13 N., R. 3 E. San Bernardino meridian. It is close to the Daggett road and is easily found. The well is 4 feet in diameter. In September, 1917, its total depth was 55 feet, and the depth to water was 49.5 feet below the platform of the curb, about 1 foot above the surface. The material on the dump around the well is a pebbly clay, and some of the pebbles are as large as an inch in diameter. The well was equipped with a substantial windlass and chain and a strong iron bucket. The temperature of the water was 66° F. An analysis of the water, given on page 263, shows it to be good for domestic use but poor for irrigation and very bad for use in boilers. The well is of use only as a roadside watering place.

A second well is situated on the south edge of Langford Lake, about a mile southeast of Langford well. This well is 53 feet deep, and on February 25, 1918, the depth to water was 48.8 feet. The well was equipped with a good windmill, but when the power was turned on it did not pump water, perhaps because the pump needed priming. There was no bucket or rope, but one might obtain water by descending a ladder in the well. This well apparently is used to water cattle, for two watering troughs stand near by.

Garlic Springs are on the north side of the valley, close to the south foot of the hills that extend westward from Tiefort Mountain. They are on the Barstow road about 1½ miles west of its junction with the Daggett road, approximately in sec. 10, T. 13 N., R. 3 E. The locality is marked by a cattleman's house. The two springs are about 350 feet north of the road and 100 feet back of the house. They are about 25 feet apart. The westerly spring, covered with boards and in good condition, is about 3 feet deep and 4 feet in diameter. The other is about 1 foot deep and 3 feet in diameter. The springs are apparently dug in alluvium which lies against granitic rocks that form the low hills on the north. The water is piped to wooden troughs at the road, and an automatic valve keeps the troughs full without waste of water. The springs flow 2 or 3 gallons a minute. The temperature of the water, as determined by G. A. Waring on August 22, 1916, was 72°.

In an earlier report on desert watering places it was stated that the water from Garlic Springs is strong with sulphur and sodium and magnesium sulphate.[73] Analyses of two separate samples collected

[73] Mendenhall, W. C., Some desert watering places in southeastern California and southwestern Nevada: U. S. Geol. Survey Water-Supply Paper 224, p. 61, 1909.

in August, 1916, and February, 1918, do not bear out this statement. (See table below.) The water is a sodium bicarbonate water, and the total solids in the two samples amount to 599 and 592 parts per million. The water is good for domestic use but poor for irrigation and very bad for boilers. The springs are occasionally used to water a few head of cattle, but they are principally used as a watering place for travelers. The nearest watering place on the road to Death Valley is Cave Springs, 30 miles to the north.

The occurrence of Garlic Springs on the edge of low hills which do not furnish a large drainage area, in a region where the precipitation is evidently small, is striking. According to barometric observations furnished by E. T. Ham, county surveyor of San Bernardino County, the springs are fully 150 feet lower than Bicycle Dry Lake, in the lowest part of the valley immediately north of Garlic Springs. It is therefore possible that the water emerging at the springs is seeping from Bicycle Valley.

It is not likely that a large quantity of water sufficient for irrigation can be obtained from wells in Langford Valley. The drainage area is small and the precipitation is low, so that little water reaches the water table. The fact that the water table is about 50 feet below the surface of Langford Dry Lake is believed to indicate that there is underground leakage from the basin. The most likely point for such leakage is on the east side of the playa, where a low pass in the divide that is probably less than 25 feet above the playa is apparently filled with alluvium to a sufficient depth to permit underflow.

Analyses of ground waters from Langford Valley, Calif.

[Parts per million]

	1	2	3
Silica (SiO_2)	52	56	45
Iron (Fe)	.48	.08	Trace.
Calcium (Ca)	18	22	24
Magnesium (Mg)	7.9	4.9	7.6
Sodium and potassium (Na+K)	[a] 181	178	[a] 162
Carbonate radicle (CO_3)	22	0	0
Bicarbonate radicle (HCO_3)	282	240	244
Sulphate radicle (SO_4)	102	140	144
Chloride radicle (Cl)	62	60	64
Nitrate radicle (NO_3)	12	2.1	3.0
Total dissolved solids at 180° C	624	592	599
Total hardness as $CaCO_3$ (calculated)	77	75	91
Date of collection	([b])	([c])	([d])

[a] Calculated.
[b] Sept. 7, 1917.
[c] Feb. 12, 1918.
[d] Aug. 22, 1916.

Analysts: 1, Addie T. Geiger, U. S. Geological Survey; 2, Margaret D. Foster, U. S. Geological Survey; 3, S. C. Dinsmore.

1. Langford well, in sec. 23 or 26, T. 13 N., R. 3 E. San Bernardino meridian. See p. 262.
2. Garlic Springs, in sec. 10 or 15, T. 13 N., R. 3 E. San Bernardino meridian. See p. 262.
3. Same as 2; collected by G. A. Waring about 17 months earlier.

RED PASS VALLEY

GENERAL FEATURES

Red Pass Valley is a little northwest of the central part of San Bernardino County and is bordered by Cronise Valley on the south, Bicycle Valley on the west, and parts of the Amargosa (Death Valley) and South Amargosa drainage basins on the north and east. (See pl. 7.) No name has been given previously to this valley, and the name assigned here is taken from a pass on the eastern border of the valley. The valley was observed only from the Silver Lake-Randsburg road and the Barstow-Death Valley road, which pass along its northern and northwestern borders, and very little information concerning it is available.

No one lives in the valley. The road from Barstow and Daggett to Cave Springs and Death Valley crosses its northwest corner. From this road another road leading to Silver Lake leads southeastward across the northeast side of the valley. This road was formerly the main route to Silver Lake and the eastern part of the Mohave Desert region, but since the opening of a shorter route farther south it is less traveled. It is also used for travel between Randsburg and Silver Lake. An alternative road, seldom used, leads a mile or two south of the main Randsburg-Silver Lake road, goes through Red Pass, and joins the main road again about 5 miles west of Silver Lake. (See pl. 11.) Another road from Barstow follows the route of the old Salt Lake road and crosses the valley from Bitter Spring to Red Pass.

PHYSICAL FEATURES AND GEOLOGY

On the south Red Pass Valley is separated from Cronise Valley by a low divide. On the west it is bordered by Tiefort Mountain the east end of the Granite Mountains, and the intervening low hills. The northern border is formed by the high Avawatz Mountains. The eastern divide is formed in part of low mountains and in part of alluvium. The mountains that border the valley are probably in large part pre-Tertiary igneous or metamorphic rocks.

The valley is essentially a large alluvial slope that descends southward from the base of the Avawatz Mountains, from which most of the alluvium has been brought. As compared to the Avawatz Mountains the other ranges are relatively low, and the alluvial slopes built out from them are short and do not cover large areas. In consequence of these relations, most of the drainage is toward the south. In the northwestern part of the basin the drainage from the Avawatz Mountains flows southward to a long ridge that extends diagonally northwestward across T. 16 N., R. 5 E. From the base of this ridge the drainage turns toward the southeast until the end of the ridge is reached, whence it continues southward. The lowest part of the valley, marked by a playa, lies on the extreme south side of the basin.

According to barometric data furnished by E. T. Ham, the alluvial slope descends from an altitude of about 3,500 feet or more above sea level at the base of the Avawatz Mountains to about 2,000 feet at the playa.

The divide of the basin where it is crossed by the Randsburg-Silver Lake road in the northeastern part of T. 15 N., R. 6 E., is composed of alluvium forming part of the long slope that extends southward from the Avawatz Mountains. A great wash that drains eastward into Riggs Valley is cutting the divide back toward the west by headward erosion and capturing part of Red Pass Valley. Just east of the divide it has exposed low hills of granite and other pre-Tertiary rocks, and it is not improbable that west of the divide similar rocks lie at no great depth below the alluvial covering.

On the northeast side of the ridge mentioned above that trends northwestward in T. 16 N., R. 5 E., there are suggestions of faulting in the steepness of the slope and in a cliff about 25 feet high at the base of the ridge which truncates spurs from it.

In the southwest half of T. 16 N., R. 5 E., and the east half of T. 16 N., R. 4 E., lies an area that is almost or completely separated from the Red Pass Valley. If it is a completely closed basin the divide at its east side that separates it from Red Pass Valley is only a few feet high. A small barren tract lies in the lowest part of the area, but it does not seem to be a distinct playa. If the surface drainage for this area does not reach Red Pass Valley, undoubtedly there is underdrainage into it.

GROUND WATER

No springs or wells are known by the writer to exist in Red Pass Valley. A well is said to have been dug in or near Red Pass, but according to recent information it has been filled with material washed in by storm waters.

No definite information is available in regard to ground-water conditions beneath the playa in the lowest part of the valley. As seen from a distance the south border of the basin seems to be composed of alluvium through which there might easily be underdrainage into Cronise Valley. The presence of Bitter Spring tends to strengthen this theory. If there were underdrainage the water would probably be considerably below the surface. The fact that there are no wells around the playa in T. 14 N., R. 6 E., which lay close to the old Salt Lake road, is pretty good evidence in itself that the depth to water in the lowest part of the basin is great, for if there were any indications of water near the surface wells would undoubtedly have been dug.

In the upper part of the alluvial slope the depth to water is undoubtedly very great because of the height of the land above the lowest part of the basin.

HARPER VALLEY

GENERAL FEATURES

Harper Valley, in the west-central part of San Bernardino County, derives its name from Harper Dry Lake, a playa which occupies the lowest part of the basin. (See pl. 7.) The ground-water conditions in the extreme southeastern part of the basin, around Hinkley, are closely related to conditions in the adjoining part of Mohave River basin, and that part of the area is described more fully on pages 425, 428–429.

The south side of the valley is crossed from east to west by the San Francisco line of the Atchison, Topeka & Santa Fe Railway, and a branch line from Kramer to Johannesburg crosses the west side. A fairly good road that leads from Barstow to Kramer, Mojave, and San Joaquin Valley parallels the main line of the railroad. A road leads from Hinkley northwestward across the valley to Atolia and Randsburg, but most travelers to those towns go westward to Kramer and thence on a better road that leads nearly due north to Atolia. Hinkley and Kramer each have a small store, and Hinkley has a post office. A railroad section crew lives at Hawes. Water is obtainable at these three places and at a number of ranches in the valley. Other railroad stations shown on the map are only sidings.

Except for some stock raising and irrigation farming there are no industrial activities in the region. There are no mineral deposits of great value in the basin. Some placer gold has been mined at the Coolgardie camp, in the southwest part of T. 32 S., R. 46 E. Mount Diablo meridian, and at another locality several miles northeast of Coolgardie, but in recent years only one or two persons have been working these deposits. "Dry washers" are used in recovering the placer gold. (See p. 30.)

During the last 20 years sporadic attempts have been made to find oil in the valley despite an adverse report on the area by R. W. Pack, published by the United States Geological Survey in 1913.[74] At least two wells have been drilled, and from time to time efforts have been made to arouse sufficient interest for further work. The most persistent attempt is discussed on pages 36 and 274. There is little hope that oil in commercial quantities can be obtained in the valley, although here, as elsewhere in the desert alluvium, small pockets of oil or gas may be struck.

SOIL AND VEGETATION

The soil in the lowest part of Harper Valley, particularly at its southeast end, is rather clayey. On the east side of the valley the soil is sandy, and in some places the roads are difficult to travel because of the sand. It is not known whether this condition also exists on

[74] Pack, R. W., Reconnaissance of the Barstow-Kramer region, Calif.: U. S. Geol. Survey Bull. 541, pp. 141–154, 1913.

the west side of the valley. On the alluvial slopes in the southwestern part of the valley the soil is generally the typical soil that results from the disintegration of granitic rocks.

On the alluvial slopes creosote bush is the characteristic plant. Around Harper Dry Lake salt grass is abundant over a considerable area. At the southeast end of the valley, rabbit brush (*Chrysothamnus mohavensis*) grows abundantly in the outer part of the salt-grass zone and extends for about half a mile farther away from the playa. This plant is considered to indicate that ground water lies within 10 or 15 feet of the surface. Mesquite grows at Black's ranch, but this plant, which generally indicates water near the surface, was not observed elsewhere in the valley. The vegetation north and west of the playa was not observed.

PRECIPITATION

No data in regard to precipitation are available for Harper Valley. The altitude of most of the valley is about the same as that of Barstow, and the average annual precipitation is doubtless about the same as at that place. The highest peak stands only 4,600 feet above sea level, and most of the mountainous areas do not rise more than 3,500 to 4,000 feet above sea level, so that they do not exert much influence on the precipitation. The average annual precipitation is probably not more than 5 inches.

PHYSICAL FEATURES AND GEOLOGY

The geology of the eastern part of the drainage basin, particularly of the Tertiary rocks, has been studied by Baker,[75] Pack,[76] and others.

The drainage basin tributary to Harper Dry Lake is roughly rectangular and is elongated slightly from east to west. At several places the basin presents unusual relations between the relief and the drainage, especially in the fact that mountains which at first glance appear to form the divide lie almost entirely within the drainage basin. (See pls. 10 and 17.) This is shown especially on the topographic map of the Searles Lake quadrangle, which covers the northern half of the valley.

The lowest part of the basin is occupied by a playa called Harper Dry Lake and a smaller playa less than a mile northeast of it. The area around the smaller playa is called Water Valley. In the southeastern part of T. 31 S., R. 44 E., and in T. 32 S., R. 45 E., are three small playas which seem to lie in distinct basins. However, probably there is underdrainage from them to the adjoining basins of Superior and Harper Valleys, and for convenience on Plate 7 the one in R.

[75] Baker, C. L., Notes on the later Cenozoic history of the Mohave Desert region, in southeastern California: California Univ. Dept. Geology Bull., vol. 6, pp. 342–348, 1911.

[76] Pack, R. W., Reconnaissance of the Barstow-Kramer region, Calif.: U. S. Geol. Survey Bull. 541, pp. 141–154, 1913.

44 E. is included in the drainage basin of Superior Valley and the other two in the basin of Harper Valley.

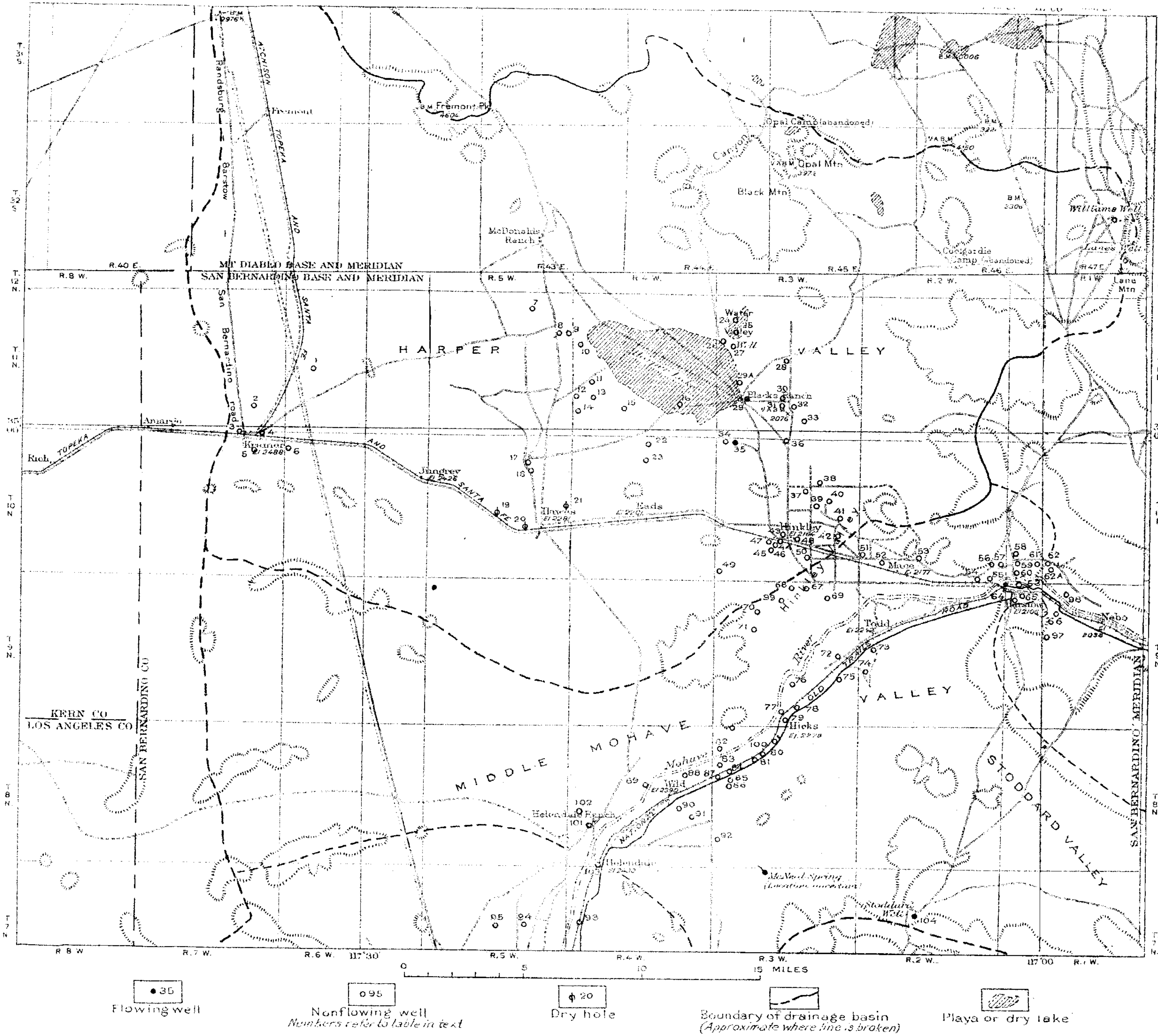
From Harper Dry Lake typical alluvial slopes rise gradually in all directions. On the north and east sides of the basin the slopes extend only a few miles to high hills and low mountains which form an almost continuous range that has a general northwest trend. A mountain at the east end of the valley is formed in part of a series of volcanic and sedimentary rocks of Tertiary age. Farther to the northwest stands Black Mountain, so called because it is formed of black basaltic lava of Quaternary age. Northwest of Black Mountain the rocks belong to the same Tertiary series as that at the east side of the valley. Pre-Tertiary crystalline rocks occur at the extreme northwest end of the ridge.

At several places in the mountains northeast of the playas drainage channels have cut back far beyond the summit, so that for a considerable distance the drainage divide is beyond the farther base of the mountains, and they are drained entirely into Harper Valley. This condition exists particularly where Black Canyon cuts the west end of Black Mountain. Also in the northeast corner of the basin drainage lines reach back beyond the buttes north of Coolgardie to a long, gentle slope which rises eastward for several miles, nearly to Lane Mountain. This slope has the appearance of an alluvial slope, but at Coolgardie camp and elsewhere bedrock is reached at a depth of a few feet. Most of the slope is probably an eroded rock surface or mountain pediment.

The rocks in the mountains north and northeast of Harper Lake are considerably faulted and folded. The nearly straight front of the mountains, which cuts northwestward across the Quaternary, Tertiary, and pre-Tertiary rocks, and its relation to the trough occupied by Harper Dry Lake, which is lower than the surrounding basins, suggest that a great fault may cut northwestward across the basin.

Northwest of Harper Dry Lake a ridge extends northwestward and culminates in Fremont Peak, which reaches an altitude of 4,600 feet, the highest point in the drainage basin. This ridge is composed of pre-Tertiary crystalline rocks. Between Fremont Peak and the mountains farther east is a pass leading to Golden Valley on the north.

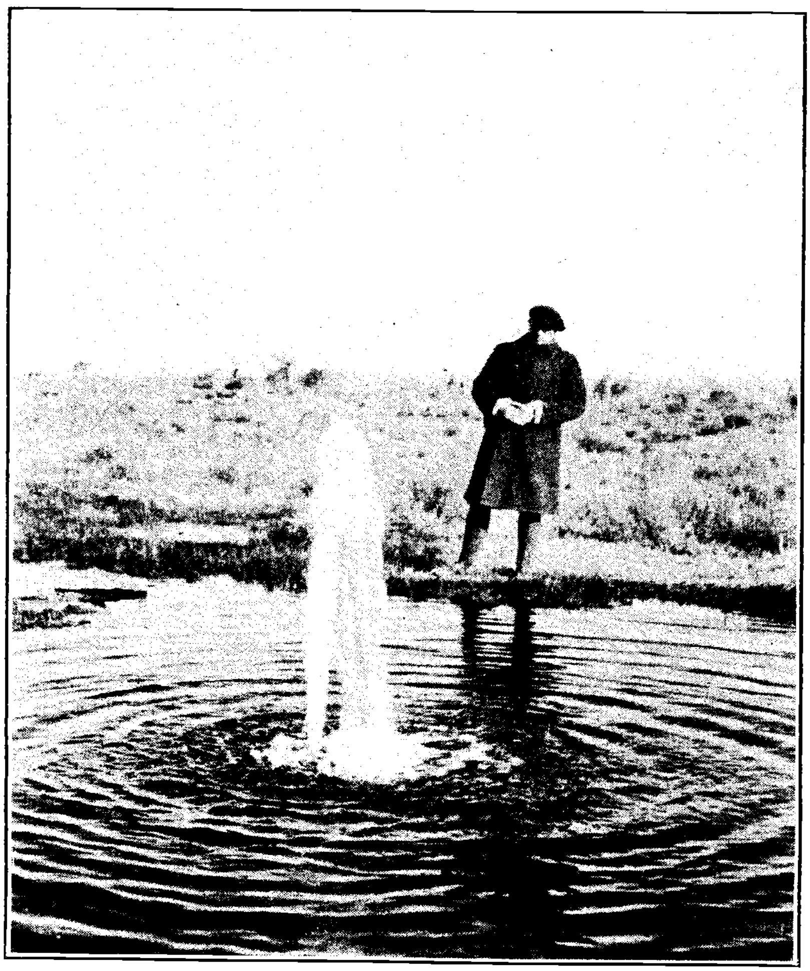
On the west and south sides of the basin there are no mountains, but the land rises gently for 10 to 15 miles to high hills on the border of the basin. The gentle slope is interrupted at a number of places by low knobs, and about 5 miles southwest of Harper Dry Lake the slope is somewhat steeper for a distance of about a mile. The hills along the western border of the basin north of Kramer are composed of granite, and probably all the knobs that rise from the gentle slope are formed of the same rock.



MAP OF HARPER VALLEY AND MIDDLE MOHAVE VALLEY SHOWING BOUNDARIES OF DRAINAGE BASINS AND LOCATION OF WELLS

A. SURFACE OF HARPER DRY LAKE

Shows ridge of alkali-covered "self-rising" ground and less alkaline smooth ground



B. WASTE FROM UNCAPPED WELL IN THE SE. ¼ SEC. 16, T. 7 N., R. 12 W., ANTELOPE VALLEY

The gentle slope that rises westward and southwestward from Harper Dry Lake appears to be an alluvial slope, but it is doubtful whether the alluvium is very thick. Probably a large part of it, except within 3 or 4 miles of the playa, is an erosional surface or mountain pediment, which is beveled across the bedrock. The low rock hills that rise above the slope suggest a rather mature erosion surface. Over a large area the rock at the surface is so disintegrated as to appear like alluvium, but in several prospect holes rock was observed within a few feet of the surface. On the other hand, according to a log furnished by the Atchison, Topeka & Santa Fe Railway, a well drilled at Kramer penetrated sand and boulders to a depth of 871 feet.

As described more fully on page 425, an area of about 20 square miles around Hinkley lies within the drainage basin of Harper Dry Lake, but it is almost completely shut off from the main part of the basin by low hills, and the divide that separates it from the Mohave River Basin is very low. Drainage channels from this area lead to Harper Dry Lake through a pass near the center of T. 10 N., R. 2 W. San Bernardino meridian. About 3 miles west of Hinkley there is a similar pass, but it is closed to surface drainage by a low divide that rises about 20 feet above Hinkley.

Harper Dry Lake, where seen at its southeast end, near Black's ranch, appears to be a playa of the wet type. Southeast of Black's ranch salt grass is abundant for at least a mile from the edge of the playa, and rabbit brush (*Chrysothamnus mohavensis*), a plant that indicates water, reaches beyond the salt grass zone for about half a mile. On the playa itself there are patches of alkali-covered "self-rising ground." About a mile west of Black's ranch one such belt rises abruptly about 2 feet above the general playa surface, which is level but mud-cracked and has practically no alkali on the surface. (See pl. 18, *A*.) When visited in November, 1919, the alkali-covered ground was soft and moist. The ground without alkali was cracked to a depth of 6 or 8 inches, and the soil was hard and dry to that depth, but below that, although very compact, it was slightly moist. Analyses of soil from the alkali-covered belt of "self-rising ground" and from the smooth mud-cracked ground show that the "self-rising ground" as a whole contains more salts than the smooth ground (see analyses, p. 67), apparently owing to rapid discharge of ground water by evaporation in the "self-rising ground," resulting in the deposition of the salts. Mechanical analyses of samples of soil from a depth of about 1 foot in each kind of ground show that the smooth ground contains a considerably higher percentage of very fine material. Perhaps the fine material prevents or greatly retards the upward capillary movement of the ground water.

The small playa in Water Valley northeast of Harper Dry Lake is separated from the main playa by low clay knolls. Doubtless the two were at one time joined together.

The divide that now separates the Mohave River valley from Harper Valley east of Hinkley is so low that in the past some discharge from the river possibly reached Harper Valley. In that event a lake would doubtless have been formed. No outstanding evidence of any lake was observed by the writer in the very short time that he spent in the valley, but certain features are suggestive. H. A. Briggs, of Hinkley, reports that shells were found at a depth of 200 feet in a well on or near Harper Dry Lake. Blue clay, which is believed to indicate deposition in a lake, was penetrated from 102 to 169 feet in a well about a mile north of the Black ranch. Clayey soil, such as might be deposited in a lake, extends for some distance from the southeast edge of the present playa. Farther from the playa for several miles the soil is unusually sandy, as might be expected if blown from ancient beaches.

GROUND WATER

CONDITIONS IN DIFFERENT PARTS OF THE VALLEY

Ground water is the only source of water supply in Harper Valley. Data in regard to 50 wells in the drainage basin are given in the following table, and the locations of the wells are shown on Plate 17. Many of the data were collected by G. A. Waring in August, 1916. Data in regard to several wells were furnished by H. A. Briggs, who has drilled many of the wells in the valley.

In the lower part of the valley, around Harper Dry Lake, ground water is reached at a depth of a few feet. In well 96, in sec. 19, T. 11 N., R. 3 W. San Bernardino meridian, the depth to water is 5 feet, and at Black's ranch (No. 29), in sec. 30 of the same township, it is 11 feet. At the P. E. McDonald ranch (No. 34), in sec. 6, T. 10 N., R. 3 W. San Bernardino meridian, some distance from Harper Dry Lake, in one well it is 12 feet, although two other wells in the vicinity flow. In Water Valley (Nos. 25, 26, and 27) water is obtained at depths of 10 to 20 feet. On the west side of the playa water is obtained at depths of 15 to 25 feet.

The depth to water increases away from Harper Dry Lake. The alluvial slope is gentle for 2 or 3 miles from the playa, and within that distance the water is less than 100 feet below the surface in all except two wells. In well 28, in sec. 16, T. 11 N., R. 3 E. San Bernardino meridian, the depth to water is 110 feet, and in well 7, in sec. 2, T. 11 N., R. 5 W., the depth to water is said to be 165 feet.

In nearly all the wells where the depth to water is less than 100 feet, except in very shallow wells, the water is under more or less

Record of wells in Harper Valley, Calif.[a]

No. on pl. 17	Location				Owner or name	Type of well or spring	Depth of well (feet)	Diameter of well (inches)	Depth to water (feet)	Date of measurement	Yield (gallons per minute)	Remarks
	Quarter	Sec.	T. N.	R. W.								
1	N. ½	20	11	6	Miss Rice	Drilled	300		280?			See log, p. 275.
2	SE	26	11	7		do	310		250			
3	NW	2	10	7		do	200	8	165		5	Windmill.
4	NE.?	2	10	7	Atchison, Topeka & Santa Fe Ry.		871	10 and 6	200		5	Abandoned. See p. 275.
5	SE	2	10	7			300		200			
6		6	10	6			200		Dry.			
7		2	11	5					165			Water did not rise when struck.
8		12	11	5	David Hanley		58		48			Water struck at 58 feet, below 15-foot layer of clay, rose to 48 feet.
9		12	11	5	H. J. Saecker		150		25			Salty water at 43 feet. Better water at 101 feet rose to 37 feet. Good water at 140 feet rose to 25 feet.
10		18	11	4	Estella C. Saecker		105		25			Salt water at 32 feet. Better water at 101 feet rose to 25 feet.
11		19	11	4	E. H. Benson		150		53			Salt water struck first. Better water at 145 feet rose to 53 feet.
12		30	11	4			108		60			
13		30	11	4			70		30			
14	SW	30	11	4			221		16		450	
15	SW	28	11	4			180+?		18			Water at 180 feet rose to 18 feet.
16		26	11	4	H. F. Spenker		222		16			
17	NW	11	10	5	Kramer Consolidated Oil Co.		800		280			See p. 274; analyses, p. 278.
18	NW	11	10	5	do		2,940		230		25	Depth to water when pumping is 400 feet. See p. 274; analyses, p. 278.
19	NE	21	10	5		Drilled	200		Dry			
20	SW	23	10	5		do	400		Dry			
21	SE	14	10	5		do	410		Dry			
22	NW	3	10	4		do	230	8	94		400	
23	SW	3	10	4		do	200+	8	80			Water struck at 200 feet rose to 80 feet.
24	NE	7	11	3			100		40			
25		7	11	3	W. T. Cann				15			
26		7	11	3	do				19			
27		20	11	3	J. G. Haskins				10			
28		16	11	3					110			
29		30	11	3	L. C. Stuckey	Dug	15		11			
30		28	11	3	E. M. Rush				40			Also two wells yielding small flows. Depth unknown, but believed to be less than 200 feet. See analysis, p. 278.

[a] Data on depth of well, depth to water, and yield are those reported by the owner, driller, or other person, except that where a date of measurement is given the depth to water was measured by D. G. Thompson.

Record of wells in Harper Valley, Calif.—Continued

No. on pl. 17	Location: Quarter	Location: Sec.	Location: T. N.	Location: R. W.	Owner or name	Type of well or spring	Depth of well (feet)	Diameter of well (inches)	Depth to water (feet)	Date of measurement	Yield (gallons per minute)	Remarks
31		28	11	3	J. Harmon		45		20			
32		27	11	3	—— Bagley				28			
33		34	11	3	E. J. Bitley				40			
34	NW	6	10	3	P. E. McDonald		36	12	[b] 12.7	Nov. 8, 1919		Not perforated and not used.
35	NE	6	10	3	do		43	4	Flows.		[c] 22	Two wells about same depth. Flow struck at about 33 feet. See analysis, p. 278.
36		[d] 3?	10	3		Drilled	56	12	[b] 34.6	Nov. 8, 1919		
37	NE	15	10	3			95		32		675	
38	S. ½	11	10	3			61		27		225	
39	SW	14	10	3	H. Harlow	Drilled	80	72 and 20	[e] 25.7	Nov. 28, 1919	360	
40	(?)	28	10	3	G. A. Harper				25			
41	NW	24	10	3	Robert V. Wallace	Drilled	200	10 and 8	25		675	
42	SW.?	24?	10	3			43	18	[f] 19	Nov. 28, 1919		Water struck at 16 feet rose to 11 feet. See analysis, p. 278.
43		28	10	3	H. A. Briggs				11			
44		28	10	3	Atchison, Topeka & Santa Fe Ry.	Dug	29	96	11		125	Drawdown about 10 feet.
45		28	10	3	G. F. Whitcom				19			
46		28	10	3	H. M. Henning		20		12			
47		28	10	3	do				13			
48		27	10	3	Anna L. Ritchie				12			
49		31	10	3	F. M. Leasure				75			
50		27	10	3	A. P. Fillpot		70		17			

[b] Reference point, top of casing.
[c] Flows at surface. Yield measured by D. G. Thompson, Nov. 8, 1919.
[d] Location uncertain. Well is at house about 0.4 mile northwest of road forks.
[e] Reference point for measurement, 3 notches cut in top of 12 by 12 inch beam on east side of well.
[f] Reference point, top of well curb.

artesian pressure, and flowing wells have been obtained at two places. Two 6-inch wells at Black's ranch, in sec. 30, T. 11 N., R. 3 W., yield small flows, which, according to report, were struck at a depth of less than 200 feet, but the depth to water in a shallow dug well at Black's ranch, is 11 feet. Two 4-inch wells, about 43 feet deep, on the P. E. McDonald ranch, in the NW. ¼ NE. ¼ sec. 6, T. 10 N., R. 3 W., also overflow, the artesian water having been struck at 33 feet. In November, 1919, the flow from one of these wells was about 2 gallons a minute. The water in wells at the west end of the valley appears to be under considerable pressure. In the wells of H. J. Saecker (No. 9), in sec. 12, T. 11 N., R. 5 W. San Bernardino meridian, water was struck at 43 feet, but it was of poor quality. Better water was struck at 101 feet, and it rose within 25 feet of the surface. In the well of E. C. Saecker (No. 10), in sec. 18, T. 11 N., R. 4 W., the first water, which was salty, was struck at 43 feet. Better water was struck at 101 feet and rose within 37 feet of the surface, and good water, which was struck at 140 feet, rose within 25 feet of the surface. It is said that in well 15, in the SW. ¼ sec. 28, T. 11 N., R. 4 W. San Bernardino meridian, water struck at 180 feet rose within 18 feet of the surface. It is reported that well 7, in sec. 2, T. 11 N., R. 5 W., is the only well within 2 or 3 miles of the west end of Harper Dry Lake in which the water did not rise when struck.

Little information is available in regard to the yield of the wells near the playa in which the water is under pressure. The yield of the flowing wells at Black's ranch and the McDonald ranch is not great. On the other hand, well 14, in the SW. ¼ sec. 30, T. 11 N., R. 4 W., is said to yield 450 gallons a minute, and well 22, in the NW. ¼ sec. 3, T. 10 N., R. 4 W., is reported to yield 400 gallons a minute. It is probable that wells within 2 or 3 miles of the playa, if properly constructed, will yield at least 300 gallons a minute, except on the north side of the playa, where the yield may be small.

Ground-water conditions around Hinkley and in the pass between Hinkley and Harper Dry Lake are closely related to those in the adjoining part of the Mohave River valley and are described in detail on pages 428–429. Around Hinkley the depth to water is about 10 feet, northeast of that place, toward the pass, the depth gradually increases, but nowhere is it as much as 50 feet. The greatest depth to water recorded is 35 feet, which was found in well 36, probably in sec. 3, T. 10 N., R. 3 W. The yield of the few wells for which data are available ranges between 360 and 675 gallons a minute. It is believed that properly constructed wells will obtain sufficient water for irrigation at a reasonable depth nearly everywhere in this part of Harper Valley. Wells that are drilled too near the hills, however, may strike rock before reaching a good supply of water.

Except in the pass southeast of Harper Dry Lake and around Hinkley, wells more than 2 or 3 miles from the playa have not obtained much water, and the depth to water is great. In two wells of the Kramer Consolidated Oil Co. (Nos. 17 and 18), in the NW. ¼ sec. 11, T. 10 N., R. 5 W. San Bernardino meridian, the depth to water is 230 and 280 feet, respectively. Well 18 was drilled for oil. (See p. 30.) No log of this well could be obtained, but workmen at the well said that the bottom, at a depth of 2,940 feet, was in dolomitic limestone. It is not known at what depth bedrock was reached. At the time of the writer's visit the well had been pumped steadily for several months with the hope that, if sufficient water were pumped out, oil would come in. It is said that before the pumping was begun the depth to water was 230 feet, but that during pumping the water level was 400 feet below the surface. The well was pumped at the rate of 25 gallons a minute. All water above a depth of 2,000 feet is supposed to be cemented off. The temperature of the water ranges from 106° to 112° F. As shown by analysis 1 the water is very highly mineralized and unfit for use. Another well about 20 feet away yields better water and is used for domestic supplies and for boilers. (See analysis 2, p. 278.) This well is reported to be about 800 feet deep. There are no perforations in the casing, but it is rotted open at about 400 feet, so that water enters at about that depth. It is said that originally the depth to water was about 235 feet—that is, about the same as in the deep well. When pumping of the deep well was begun the water level in the 800-foot well dropped to 280 feet and it is constant at that level. The temperature of the water from this well is 72° F.

Three holes drilled in the vicinity of Hawes are reported to be dry at depths of 200 to 410 feet. One of these holes (No. 19), in the NE. ¼ sec. 21, T. 10 N., R. 5 W., is reported to be 200 feet deep, another (No. 20), in the SW. ¼ sec. 23 of the same township, to be 400 feet deep, and the third (No. 21), in the SE. ¼ sec. 14, to be 410 feet deep. Another well (No. 6), in sec. 6, T. 10 N., R. 6 W., is reported to be dry at a depth of 200 feet. According to data furnished by the Atchison, Topeka & Santa Fe Railway, water was struck at a depth of 200 feet in the company's well (No. 4) in sec. 2, T. 10 N., R. 7 W., at Kramer. The well yielded only 7,200 gallons a day of 24 hours (5 gallons a minute), and probably for this reason it was abandoned. Water for railroad use at Kramer is hauled from Hinkley.

Water is reported at a depth of 250 feet in well No. 2, in the SE. ¼ sec. 26, T. 11 N., R. 7 W., and at a depth of 280 feet in well No. 1, in the N. ½ sec. 20, T. 11 N., R. 6 W. In the driller's log of well No. 1 (see table) "strong flows" are reported at two horizons.

Little information is available in regard to the conditions that govern the occurrence of the ground water in the western part of the

Harper Valley drainage basin near Hawes and Kramer. The presence of rock buttes at a number of places suggests that bedrock lies at no great depth. On the other hand, according to a log furnished by the Atchison, Topeka & Santa Fe Railway, the well of that company at Kramer penetrated cemented sand from the surface to a depth of 400 feet and cemented sand and boulders from 400 to 871 feet. The driller's log of the well of Miss Rice (well No. 1, pl. 17), in the N. ½ sec. 20, T. 11 N., R. 6 W., is given below:

Log of well of Miss Rice, in the N. ½ sec. 20, T. 11 N., R. 6 W. San Bernardino meridian

[Furnished by H. A. Briggs, driller]

	Thickness (feet)	Depth (feet)
Loose "granite formation"	60	60
Gray granite and quartz	1	61
Boulders, very hard	11	72
Gray granite and boulders	6	78
Granite and cement, decomposed	90	168
Mixture of granite and quartz, some sand	12	180
Clay with lime deposits	100	280
Gravel; strong flow of water	10	290
Clay	3	293
Sand and boulders; strong flow of water	7	300
Clay and broken quartz	8	308

Apparently there is an error in the interpretation of materials taken from the well, as clay does not generally occur below granite. Mr. Briggs has informed the writer by letter that he used the sand bucket in the part of the well from 78 to 168 feet, which is recorded as "granite and cement." There is little doubt that the material was unconsolidated alluvium, which doubtless was originally derived from granitic rocks and therefore looked like drill cuttings of granite.

There is little reason to expect large yields from any wells on the upper slopes of the valley in the area between Hawes, Kramer, and Fremont Peak. The rainfall is low and the slopes are gentle, so that there is not much concentration of drainage, and the rainfall is probably mostly evaporated before it can percolate into the ground. The conditions in this area are unfavorable to development of the ground water.

SOURCE OF GROUND WATER

The drainage area of Harper Valley is not large and the mountains are not very high and do not cover a large part of the basin. Unless ground water is contributed to the valley from some outside source the quantity available can not be great. There is evidence, however, that ground water enters the drainage basin from the Mohave River Basin and perhaps from other adjoining basins.

The water table apparently has a continuous slope northward from Mohave River near Todd station through the pass to Harper Dry

Lake. The fact that salt grass and rabbit brush reach so far southeastward from Harper Lake toward the pass to Hinkley points to a considerable supply of water from that direction. It is quite probable that the artesian pressure in wells at the east end of the playa is due to the fact that between the playa and Hinkley the water enters beds that are overlain by impervious beds deposited either in a lake or on the present playa.

The occurrence of water under pressure at the west and southwest sides of the playa raises a question as to its source. The low pass to the main valley about 3 miles west of Hinkley appears to be filled with alluvium, and this may be deep enough to permit underflow from Hinkley Valley to the southwest side of Harper Lake. Ground water moving through this pass might be impounded beneath impervious beds under considerable pressure. On the other hand, the water may pass under the retaining beds from the southwest.

Ground water may percolate into Harper Valley from both Golden Valley and Superior Valley, which adjoin Harper Valley on the northwest and northeast, respectively. In Golden Valley the water table is about 500 feet above Harper Dry Lake (see p. 236), and there may be movement to Harper Valley, possibly at the pass between the two valleys on the east side of Fremont Peak, which is believed to be filled with alluvium, or perhaps around the west side of Fremont Peak. In Superior Valley the water table is more than 800 feet above Harper Dry Lake (see p. 253), and at least part of the divide between Superior Valley and Harper Valley is composed of basaltic lava, through which, it is believed, water can pass freely.

It is believed that the underflow to Harper Valley from the Mohave River Basin is the principal source of ground water in the valley. If on account of future developments in the upper part of Mohave Valley the surface flow of the river or underflow reaching Hinkley Valley should be greatly decreased, the ground-water supply in the vicinity of Hinkley and the southeast end of Harper Dry Lake would probably be correspondingly decreased. (See pp. 434, 497.)

WATERING PLACES

Water may be obtained at many of the numerous ranches at which there are wells, as shown in the table on pages 271–272 and Plate 17. However, in the absence of specific information the traveler should not depend on finding water at all these places, for where conditions have been found unfavorable the wells may have been abandoned and pumps removed. Outside of the more settled part of the valley and except for the railroad stations at Hinkley, Hawes, and Kramer, only two watering places are known in the valley. One of these is the McDonald ranch, approximately in sec. 28, T. 32 S., R. 43 E. Mount Diablo meridian. The ranch was not visited, but it is believed that water is available there. The only other watering place of value to travelers is Williams Well, in the extreme northeast corner of the drainage basin, in T. 32 S., R. 47 E. Mount Diablo meridian. The well is on one of a network of roads near which are abandoned dry placer workings. It is dug, 4 by 5 feet in cross section, and is 88 feet deep. In October, 1917, the depth to water was 82.5 feet. When visited the well was equipped with a pump, but the pump was out of order. There was a windlass with sufficient rope to reach the water, but no bucket. The material penetrated by the well was weathered rock of a granitic type below a depth of about 6 feet. Because the water is derived from bedrock the yield of the well doubtless is not large. As shown by analysis 6 on page 278 the mineral content is high, the total solids being 882 parts per million. The water is fair for domestic use and irrigation and very bad for boilers.

QUALITY OF WATER

Analyses of water from five wells in Harper Valley are tabulated on page 278. Two of the samples (3 and 4) are from flowing wells near Harper Dry Lake, at the Black ranch and the P. E. McDonald ranch, respectively. The mineralization of the water from each of these wells is moderate; sample 3 contains 329 parts per million of total solids, and sample 4 contains 328 parts per million. The two waters are similar in character, for both are carbonate waters, but sample 3 contains more calcium than the other. Both are good for domestic use and fair for boilers. Samples 3 and 4 are respectively good and fair for irrigation.

A sample from the well of H. A. Briggs (analysis 5) is somewhat more mineralized than the water from the wells near the playa, as it contains 413 parts per million of total solids. The water is a calcium carbonate water. It is good for domestic use and irrigation and fair for boilers. It is probable that water of good or fair quality for domestic use and irrigation can be obtained practically everywhere in the region around Hinkley and around Harper Dry Lake, where the depth to water is low enough to permit pumping for irrigation. It is said that the first water struck in wells on the west side of the playa is salty but that water obtained from deeper strata is of better quality.

The two other samples analyzed (1 and 2) are from the two wells of the Kramer Consolidated Oil Co., in sec. 11, T. 10 N., R. 5 W. The sample from the deep well drilled for oil is very highly mineralized, as it contains 14,672 parts per million of total solids. It is a sodium chloride water but also contains much calcium. The water from the 800-foot well is much less concentrated, for it contains only 1,168 parts per million of total solids. It is also a sodium chloride water, but the percentage of chloride is much smaller and of sulphate and carbonate much larger, which indicates that the water from the two wells does not have a common source. The high concentration of the water from the deep well, especially with respect to chloride, raises a question as to the source of the water. A large quantity of chloride might come either from saline lake or playa beds of Quaternary or Tertiary age or from older sedimentary rocks that were laid down in the sea, which still contained salt from sea water that was inclosed at the time of their formation. The well is 2,940 feet deep, and all water above 2,000 feet is supposed to be cemented off. No definite information is available as to the strata penetrated by the well, except that the bottom is said to be in limestone. No salt-bearing rocks are known near the well. The low mineral content of the samples from the wells at the east end of the playa shows that the high concentration of the water can hardly come from the playa beds that are near the surface.

No analyses are available of water from wells in the higher part of Harper Valley except Williams Well, which is described on page 277. The little information available in regard to the geology of the region indicates that the water in most of the wells is probably of good enough quality for domestic use.

Analyses of ground waters in Harper Valley

[Parts per million]

	1	2	3	4	5	6
Silica (SiO_2)	62	48	26	43	50	104
Iron (Fe)	2.0	1.7	.50	.16	.55	.13
Calcium (Ca)	2,070	63	42	24	29	94
Magnesium (Mg)	36	15	6.9	5.7	25	31
Sodium and potassium (Na+K)	[a] 3,324	[b] 320	[b] 57	[b] 80	[b] 72	175
Carbonate radicle (CO_3)	0	0	0	0	0	15
Bicarbonate radicle (HCO_3)	28	257	197	199	165	520
Sulphate radicle (SO_4)	153	261	54	43	94	54
Chloride radicle (Cl)	8,636	303	28	34	70	195
Nitrate radicle (NO_3)	1.9	5.4	.0	.21	Trace.	Trace.
Total dissolved solids at 180° C	14,672	1,168	329	328	413	882
Total hardness as $CaCO_3$ (calculated)	5,320	219	133	83	175	362
Date of collection	([c])	([c])	([d])	([e])	([f])	([g])

[a] Na, 3,286 parts per million; K, 38 parts per million.
[b] Calculated.
[c] Dec. 14, 1917.
[d] Aug. 17, 1916.
[e] Nov. 8, 1919.
[f] Aug. 18, 1916.
[g] Oct. 12, 1917.

Analysts: 1, C. H. Kidwell, U. S. Geological Survey; 2, Addie T. Geiger, U. S. Geological Survey; 3 and 5, S. C. Dinsmore; 4 and 6, Margaret D. Foster, U. S. Geological Survey.

1. Well No. 18, pl. 17 and table on p. 271; well drilled for oil by Kramer Consolidated Oil Co. (See p. 274).
2. Well No. 17, pl. 17 and table on p. 271; Kramer Consolidated Oil Co., owner. Water well a few feet from well No. 18.
3. Well No. 29, pl. 17 and table on p. 271; at Black ranch; L. C. Stuckey, owner. Collected by G. A. Waring.
4. Well No. 35, pl. 17 and table on p. 272; P. E. McDonald, owner.
5. Well No. 43, pl. 17 and table on p. 272; H. A. Briggs, owner.
6. Williams Well, T. 32 S., R. 47 E. Mount Diablo meridian. (See p. 277.)

IRRIGATION

In December, 1919, besides small garden patches, there was practically no land irrigated in Harper Valley except near Hinkley, where alfalfa was being raised at several places. Some experimental farming, however, was being done in other parts of the valley. Ground water can apparently be obtained for irrigation at moderate depths almost everywhere within 1 to 3 miles of Harper Dry Lake, and unless the soil is too poor, it seems that irrigation should be feasible. Doubtless a market for some produce could be found at Barstow and, as long as the mining activities continue, in the Randsburg district. If there were any extensive development, however, most of the products would have to be shipped by rail to larger cities.

In a large part of the valley the depth to water is so great that pumping for irrigation is probably not feasible on account of the cost.

COYOTE VALLEY

GENERAL FEATURES

Coyote Valley lies a little west of the central part of San Bernardino County and adjoins the Lower Mohave Valley on the south. Possibly the valley drains into Mohave River through Manix Wash, and it is so shown on Plate 7 and Figure 9, but that is not certain, and the valley is accordingly described as a separate unit.

There are no towns in the valley. From time to time a few persons live at the Paradise mine, in the western part of the valley, at the Alvord mine, in the eastern part, or at homesteads on the borders of Coyote Dry Lake. However, the work at the mines and by the homesteaders has been very sporadic, and one should not count on obtaining help in an emergency at any of these places.

The road from Barstow to Death Valley leads northeastward across the west side of the valley. A road from Daggett and Yermo leads northeastward across the central part of the valley and joins the road from Barstow 1½ miles east of Garlic Springs, in Langford Valley. (See p. 259.) Both these roads also lead to Silver Lake, either by way of Bicycle Valley and the Randsburg road or by way of Bitter Spring and Red Pass. However, in 1923 a shorter route to Silver Lake by way of Manix and East Cronise Valley was opened, and much of the travel now follows this road.

Besides these main roads a road leads from the Barstow road near the Paradise mine westward to Lane Mountain and up a canyon in the mountains, past Lane's well to roads in the eastern part of Harper Valley and Superior Valley. This road may be in bad condition in Lane Mountain. Several roads lead southeastward from the Paradise Mountains to Coyote Dry Lake and Coyote Well and eastward across the playa to the Alvord Well and mine. Other roads lead to homesteads and prospects.

The principal watering places in the valley are Paradise Springs, Lane's Well, and Coyote Well. (See pp. 282–288.)

The climate of the valley is doubtless much the same as that at Barstow. The lowest part of the valley is 200 to 300 feet lower than Barstow and lies on the leeward side of low mountains. These two conditions may make the average annual precipitation a little less than that at Barstow.

Throughout most of the valley the vegetation consists of the creosote bush and the species commonly associated with it. Some mesquite grows on the northwest side of Coyote Dry Lake. Trees that appeared to be mesquite or willow were observed in a wash northwest of Paradise Springs, but as they were seen from a distance of half a mile or more their identity is not certain. Salt grass grows around Paradise Springs and in small patches around the western border of Coyote Dry Lake.

PHYSICAL FEATURES AND GEOLOGY

The boundaries of the Coyote drainage basin were not definitely determined at several places. The divide of the valley as the writer believes it to be situated and the principal geographic features are shown in Figure 9. On the northeast the drainage divide is formed by the Alvord Mountains and low hills that continue northwest from them for at least several miles beyond the Barstow-Death Valley road. A large wash that crosses the road probably in sec. 34, T. 13 N., R. 2 E., apparently receives the drainage from an area extending as far northwest as a large lava hill in the southeastern part of T. 14 N., R. 1 E. It may also receive the drainage from mountains at the north end of T. 14 N., R. 2 E. The western border of the valley is formed by a more or less continuous ridge that extends north and south, the highest part of which is Lane Mountain. The southern border of the western part of the valley consists of the Calico Mountains, which rise to an altitude of 5,000 feet. Farther east the valley is separated from the Lower Mohave Valley by a low, broad ridge. Although throughout a considerable area this ridge appears to be of alluvium, rock hills rise from it in several places, and the entire ridge is probably underlain by bedrock at no great depth.

In the extreme southeastern part of the valley a large wash known as Manix Wash extends from Mohave River northwestward toward Coyote Dry Lake. The writer did not have an opportunity to trace the course of this wash and is without definite information as to whether it reaches back to and drains Coyote Dry Lake. Some persons report that it drains the playa and others that there is a divide between the playa and the wash. According to readings on an aneroid barometer made by the writer at Coyote Well and a short time afterward at Kouns siding, on the Los Angeles & Salt Lake Railroad, Coyote Dry Lake is about 100 feet below the railroad and the playa is about 1,775 feet above sea level. According to other barometric observations furnished by E. T. Ham the playa along the Daggett-Death Valley road is at least 25 feet lower than the altitude determined by the writer. The playa according to Ham's data would be at about the same altitude as Manix Wash where it is crossed by the Los Angeles & Salt Lake Railroad, or possibly a little lower. The playa therefore could not be drained by the wash. However, as is well known, barometric observations without frequent checking at points of known altitude may be considerably in error. Even though the east end of Coyote Dry Lake is drained by the wash it is improbable that the surface drainage from the western part of the valley crosses the playa. Nevertheless, if the surface drainage does not reach Mohave River through Manix Wash the divide east of the playa is undoubtedly formed by alluvium, so that the body of ground water in Coyote Valley is continuous with that beneath the valley drained by Manix Wash. For that reason Coyote Valley is considered as continuing to Mohave River, as shown on Figure 9. However, data on several wells near Manix are given in the section on the Lower Mohave Valley.

The divide of Coyote Valley is apparently composed of alluvium at several other places, particularly between the Alvord Mountains and the Daggett-Death Valley road, north of the Paradise Mountains, and in the northwest corner of the valley east of the Ausland Well. In the first two localities low rock hills at several places make it seem probable that bedrock lies near the surface. As shown by ground-water conditions in Superior Valley, however, it is probable that east of the Ausland Well the divide is composed of alluvium and there is drainage of ground water from Superior Valley. (See pp. 250–253.)

Numerous rock hills and low mountains rise from the floor of the valley within its borders. The largest of these are the Paradise Mountains. Northeast and north of these mountains are several large hills with more rounded outlines in which granite crops out at many places. Undoubtedly most of this part of the valley is underlain by rocks at a depth of a few feet, although it has the appearance of being filled with alluvium. Between the southwest end of the Paradise Mountains and Lane Mountain rock crops out along washes, and part of the slope that is apparently of alluvial origin is undoubtedly an eroded rock surface or mountain pediment.

The Calico Mountains are composed of a series of Tertiary volcanic rocks. (See p. 442.) West of the Barstow-Death Valley road there is in addition greenish clay of Tertiary age which is a part of the Barstow formation. Elsewhere in the region the rocks observed are nearly all granitic intrusives. The Paradise Mountains and the hills north and northeast of them apparently are composed entirely of these rocks. The lower part of Lane Mountain is composed mostly of granitic rocks, but the upper part is a reddish volcanic rock, probably rhyolite of Tertiary age. The contact between the two rocks may be seen very distinctly from the road a mile or two east of the mountain.

Lane Mountain rises very steeply to a considerable height from Coyote Valley, but on the west side of the mountain in the upper part of the valley the slopes of Harper Valley are several hundred feet above Coyote Valley, and the mountain does not rise much above the rest of Harper Valley. Lane Mountain is part of a long ridge that extends almost due north and south. These features are suggestive of a northward-trending fault by which Coyote Valley has been dropped downward with respect to Lane Mountain and the valley west of it. The steep slope along the east side continues southward and southeastward to the Calico Mountains, and the nearly level upland valley occupied by the Barstow formation lies several hundred feet above Coyote Valley.

The southwestern part of Coyote Dry Lake presents features characteristic of the wet type of playa. Puffy soil or "self-rising ground" occurs especially near Coyote Well, and there are small patches of salt grass around the border of the playa. The water level in Coyote Well in February, 1918, was 13 feet below the surface, and as the surface at the well is a few feet above the playa the water table beneath the playa is undoubtedly near enough for the water to rise by capillary action. In contrast to the southwest side of the playa the northeast side presents features that are characteristic of playas of the dry type. The surface is hard and smooth. That the water table lies at a greater depth is shown by a hole along the Daggett–Death Valley road near the northeastern edge of the playa, which in September, 1917, was dry at a depth of 73 feet.

GROUND WATER

WELLS NEAR COYOTE DRY LAKE

Several wells have been dug or drilled near Coyote Dry Lake, but no very definite information was obtained in regard to them except for the depths to water as measured by the writer. The location of the wells is shown in Figure 9.

A flowing well is situated on the homestead entry of L. S. Jones in the S. ½ sec. 28, T. 12 N., R. 2 E. San Bernardino meridian. The well is nearly a quarter of a mile west of Coyote Dry Lake. It is 6 inches in diameter and in February, 1918, was 90 feet deep. It is said that the depth originally was 100 feet. When visited, the water was flowing from the casing about 2½ feet above the surface at a rate between 5 and 10 gallons a minute. The stream flowed for some distance toward the playa before it all percolated into the soil.

No sample was taken of the water, but it apparently contains a considerable amount of salts in solution, for alkali stands along the channels where the water has flowed. The water is warm. No thermometer was available, but the temperature was estimated to be at least 75° or 80° F. The well is about 4 miles southeast of Paradise Springs, where the water from one outlet has a temperature of about 102°. (See p. 286.) It is altogether probable that the heat of the water in the well and springs comes from the same source.

Several hundred feet east of the flowing well described above and within 200 feet of the playa is another drilled well, 6 inches in diameter. When visited the well had a wooden plug in the top so that it could not be measured. An inch pipe had been inserted in the side of the 6-inch casing, and from it water was trickling at the rate of about a gallon a minute. About 300 feet north of this well water was seeping up around a wooden pipe sunk in the side of a low sand dune. Mesquite grows near the playa for some distance, and evidently the water table is close to the surface.

When the writer visited the locality in February, 1918, E. E. Barr was drilling a well 10 inches in diameter near the northwest corner of the SE. ¼ sec. 8, T. 11 N., R. 2 E., but the well was not then completed. Water was struck at a depth of 17 feet, and it rose a short distance in the casing. At a depth of 22 feet another water-bearing bed was struck, and the water rose within 3½ feet of the surface. The well is on the alluvial slope north of the Calico Mountains and is about 15 feet above Coyote Dry Lake. No test had been made as to the yield of the well.

About a quarter of a mile northwest of the Barr Well is a dug well, 17.5 feet deep, in which the depth to water on February 26, 1918, was 7.8 feet. This well is about 10 or 15 feet above Coyote Dry Lake and probably a little below the Barr Well.

J. T. Burns has a drilled well in the NW. ¼ sec. 32, T. 12 N., R. 2 E. San Bernardino meridian. The total depth is not known, but the depth to water is reported to be about 8 feet. The water is said to be of poor quality.

Several wells have been drilled or dug on the south side of Coyote Dry Lake. Coyote Well, probably in sec. 22, T. 11 N., R. 2 E. San Bernardino meridian, near the Daggett-Death Valley road, has been a watering place for many years. The well is dug to a total depth of 18 feet and is about 2 feet 8 inches in diameter. On September 6, 1917, the depth to water was 15.7 feet, and on February 26, 1918, it was 13.4 feet from the top of the tile casing, 8 inches above the ground. In 1918 the well was equipped with a good windlass and bucket. As shown by analysis 1 (p. 288), the water is highly mineralized, and contains 2,482 parts per million of total dissolved solids. More than 95 per cent of the basic constituents are sodium and potassium. The predominating acid constituent is the sulphate radicle. The water tastes and smells of hydrogen sulphide. It is not suitable for domestic use and should not be drunk unless necessary. In an emergency it could doubtless be used without serious consequences until better water was obtained. It is poor for irrigation. The temperature of the water on September 6, 1917, was 71° F.

On the east side of the road, 200 or 300 feet from Coyote Well, a 6-inch well was drilled in the winter of 1917–18 to a depth of 50 feet. In February, 1918, the water, which had a brackish taste, was trickling from the casing through a slit cut at the ground level.

About half a mile east of Coyote Well is a 6-inch drilled well. The well measured only 18 feet deep, and there was only 2 or 3 inches of water in it. This water may have come from a rainstorm that occurred only a few hours before the visit, and the measurement may not represent the true depth to water. This well is several feet above the playa.

On the northeast edge of Coyote Dry Lake, a few feet east of the Daggett-Death Valley road, there is a dry hole 73 feet deep. This hole is sunk on the playa, and the material on the dump pile around it is mostly a gray clay with very few pebbles. There is a well in sec. 12 or 13, T. 11 N., R. 3 E., near the Alvord mine, but no data are available in regard to it.

The available data show that water is near the surface near the southwest and west borders of Coyote Dry Lake, and in a small area within a short distance of the playa it is under sufficient pressure to cause it to rise above the surface in drilled wells. On the other hand, the depth to water on the northeast side of the playa is considerably greater, as is shown both by the dry hole along the Daggett-Death Valley road referred to above and by the absence of any water-indicating vegetation, such as salt grass or mesquite, which is present on the west side of the playa. It is not certain whether this difference in depth to water is due to a difference in altitude of the playa. It may perhaps be due to other conditions. The drainage area on the west side of the playa is several times larger than the area northeast of the playa. Consequently, the contribution to the ground-water reservoir west of the playa would be much larger. The clay beds of the playa may be so impervious that they prevent the ground water west of the playa from moving toward the northeast.

If a divide exists between the east end of Coyote Dry Lake and Mohave River it is undoubtedly composed of alluvium, and ground water must drain from Coyote Valley to the Mohave Valley. If the playa is level, as is true of most playas, the gradient of the water table eastward would itself be sufficient reason for the water table to lie at a greater depth at the east side of the playa. However, it does not seem that the great difference in the depth to water in Coyote Well and in the dry hole at the northeast edge of the playa can be due alone to the slope of the water table. Perhaps, in addition to the conditions suggested, the playa may rise in altitude toward the northeast, or there may be a buried barrier which causes an abrupt drop in the water table between the two wells.

No data are available as to the yield of any of the wells. The alluvium around the wells visited is not coarse, and it seems doubtful if any of the wells would yield very much water. At the western border of Coyote Dry Lake carefully constructed wells might yield enough water to be used for irrigating small areas. It is believed, however, that the conditions are not very favorable for irrigation, partly because of the poor quality of the water. The gradient of the land is not great, and as the water table is already near the surface the land might easily become "water-logged" and spoiled by alkali.

WATERING PLACES IN THE MOUNTAINS

Paradise Springs.—The Paradise Springs are noteworthy because the water from them has a higher temperature than that from any other springs known in the Mohave Desert region. They are in a broad canyon on the east side of the Paradise Mountains, in sec. 7, T. 12 N., R. 2 E. San Bernardino meridian (see fig. 9), and are reached by a road that turns northwestward from the Barstow-Death Valley road 23.8 miles northeast of Barstow. Near the southeast end of the mountains several roads turn north or northwest to the Paradise mine, which is about 1½ miles south of the springs. If one of these roads is followed in order to reach the springs the traveler should turn northeast along the base of the mountain. The most direct road to the springs branches from the main road a short distance south of a rock hill that lies on the south side of a large canyon but is partly separated from the main mountain. The road ascends a wash south of this hill to a low divide, beyond which there is an abrupt drop of several feet to the large, broad canyon mentioned above. Westward from this divide there may be seen a terrace-like flat several acres in extent, which slopes slightly northeastward toward the main canyon. This flat area is partly covered with salt grass and partly with alkali. Near the middle of the flat is a barrel, from which two collecting ditches and pipe lines lead back to the springs, one group of which is about 300 feet west of the barrel and the other about 600 feet to the northwest. (See fig. 10.)

The water is collected by several short ditches, from a few inches to several feet deep, which lead to the two main ditches mentioned above. At the southern group of ditches the water comes wholly from the sandy clay that forms the terrace-like flat, but within 25 feet farther west rises a bedrock hill. The rock at this place appears to be a metamorphosed sediment. At the north group of ditches the water comes mostly from the clay, but at one place it issues directly from cracks in the rock. In a prospect cut a short distance south of this group the rock is pegmatite.

The temperature of the water from the different seepages has a range of about 20°. On October 11, 1917, the highest temperature of

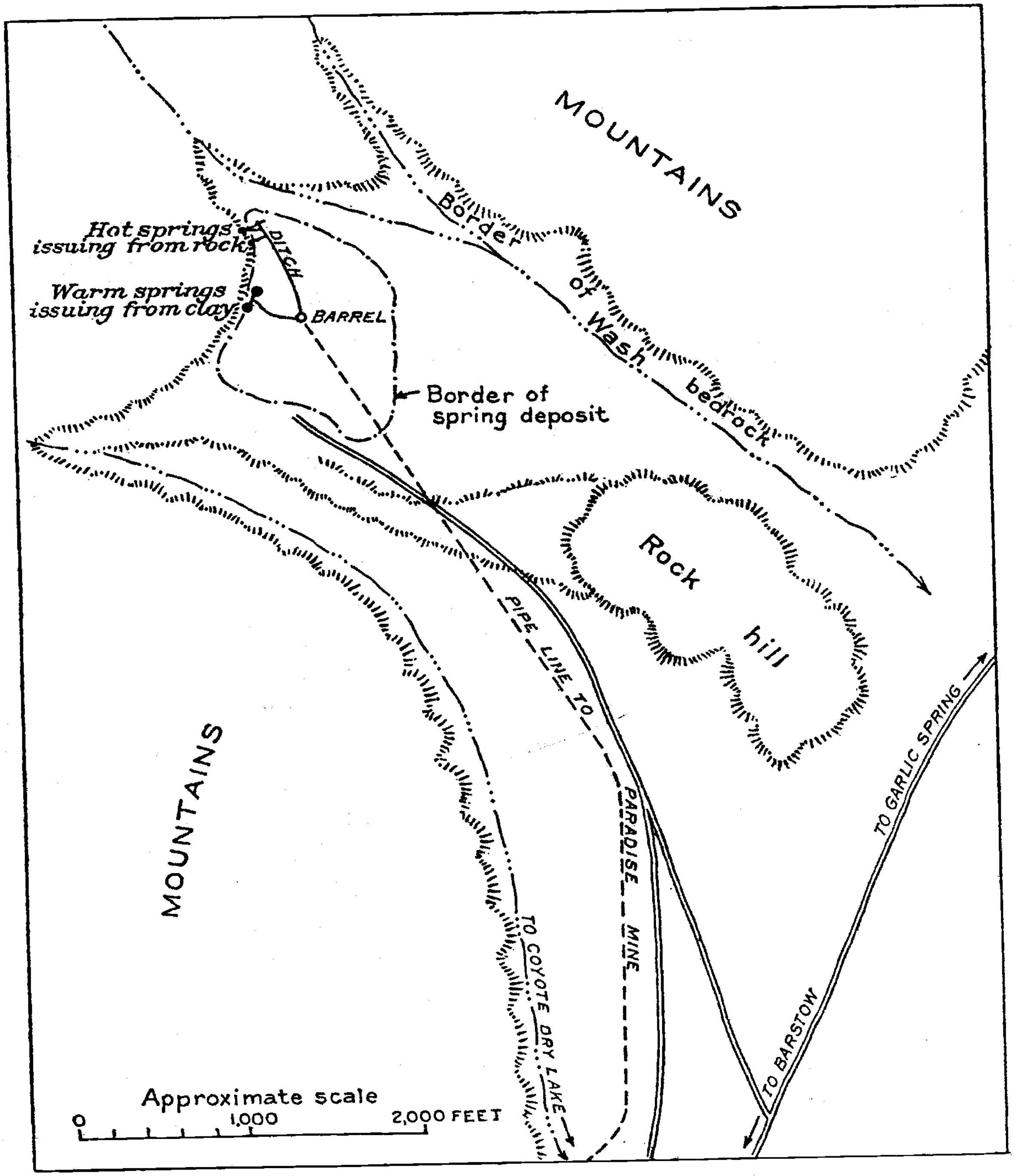


FIGURE 10.—Sketch map of the vicinity of Paradise Springs

water emerging from the cracks in rock was 106.5°. On February 12, 1918, the highest temperature observed at this same place was 102°.

On two occasions G. A. Waring recorded maximum temperatures of 102°, first in 1908 [77] and later on August 22, 1916.[78] The temperature of the water flowing from the clay at points 10 or 15 feet from the seepage from the rock ranged from 90° to 95°. The temperature

[77] Waring, G. A., Springs of California: U. S. Geol. Survey Water-Supply Paper 338, p. 52, 1915.
[78] Unpublished field notes.

of the water at the southern group of seepages, where the water comes entirely from the clay, ranged from 82 to 84°.

Most of the water comes from the ditches dug in the sandy clay that forms the terrace at the base of the rock hills. However, as some water comes from cracks in the rock and as this water is the hottest in this locality it is believed that the ultimate source of the water is the bedrock; the water in the clay is believed to percolate from the rock below the surface, cooling as it passes through the clay.

The water doubtless originally emerged on a bare rock surface, which was later covered by the terrace of sandy clay. The terrace appears to have been built up partly from material in solution, which was precipitated as the water emerged from the rock. However, as shown by analyses 2 and 3 (p. 288), the water is not very highly mineralized, and it is improbable that the material thus laid down forms a large part of the deposit. Doubtless most of the deposit is wind-blown sand and clay, which has been held where it fell by the moisture from the springs.

The original source of the water and of its heat is entirely a matter of conjecture. The rocks in the Paradise Mountains are largely granitic, with perhaps areas of metamorphosed sedimentary rocks in addition to the quartzite west of the southern group of springs. So far as is known there are no volcanic rocks in the mountains, but such rocks are abundant within 5 or 6 miles to the south. Water from a flowing well about 4 miles southeast of the springs is warm. It is possible that this water may move underground in the alluvium from the springs, but the distance is so great that it would seem that the temperature would be lowered nearer to the normal. More probably the rocks which furnish the heat lie below the well and also below the springs.

The total quantity of water discharged at the collecting barrel in October, 1917, was between 25 and 30 gallons a minute. A considerable quantity of water that was flowing in the ditches did not enter the barrel. Probably by clearing out the ditches and digging additional ones the supply could be increased considerably. From the collecting barrel a pipe line leads southeastward and southward to the Paradise mine, a distance of about 1½ miles. The pipe line descends to an altitude below the mine, so that the water is forced up to the mine by the pressure in the upper part of the line. In October, 1917, however, there were so many leaks in the lower part of the line that no water reached the mine, which was then closed. Later a new pipe line was laid at a higher level. It is said that the water corrodes the pipe very rapidly.

Two samples of water were collected from the springs—one of the hot water at the northern group of ditches and the other of the cooler water at the southern group. The mineral content is fairly moderate in both samples, but the hot water contains about 150 parts per million of dissolved solids more than the cooler water. The predominant constituents in each sample are sodium and sulphate. The cooler water is good for domestic use, but the hot water is only fair. Both waters are fair for irrigation.

Lane's well.—Lane's well is near the head of a canyon that cuts through Lane Mountain and is probably in sec. 33, T. 32 S., R. 47 E. Mount Diablo meridian. (See fig. 9.) The well is reached by several roads in the eastern part of Harper Valley, which unite at the head of the canyon about a tenth of a mile west of the well. A road, which may be washed out in the canyon after heavy rains, also leads to the well from the Barstow-Death Valley road in Coyote Valley, 5 or 6 miles to the east.

The well is near an old shack in the bottom of a small canyon. It is dug, 4 by 5 feet in area, and is 41 feet deep. On October 12, 1917, the depth to water measured 24.3 feet. At that time there was a hand pump in the well, but it was out of order. There was over the well a windlass, with a rope and a gasoline can. About 200 feet down the canyon another dug well or shaft has been sunk 40 feet deep, and the depth to water in it was 28 feet. This well had no windlass. A large pile of granite around the well indicates that the lower part of the well is in that rock. The water from the upper well was hauled for use by prospectors at Coolgardie and homesteaders in the region west of the well.

The analysis of a sample of water from the upper well is given in column 4 of the table below. The water is rather highly mineralized and contains 757 parts per million of total dissolved solids. It is only fair for domestic use because of the high total hardness, which will require considerable soap in washing, but it can be used for drinking and cooking without serious difficulty. It is fair for irrigation use.

ANALYSES

Analyses of ground waters from Coyote Valley, Calif.

[Parts per million]

	1	2	3	4
Silica (SiO_2)	64	136	55	50
Iron (Fe)	.24	.22	.12	.86
Calcium (Ca)	13	8.0	7.9	48
Magnesium (Mg)	7.2	3.1	1.4	49
Sodium and potassium (Na+K) (calculated)	826	151	134	140
Carbonate radicle (CO_3)	18	58	0	Trace.
Bicarbonate radicle (HCO_3)	462	26	97	270
Sulphate radicle (SO_4)	890	169	161	167
Chloride radicle (Cl)	367	48	48	162
Nitrate radicle (NO_3)	4.0	Trace.	.70	1.2
Total dissolved solids at 180° C	2,482	623	468	757
Total hardness as $CaCO_3$ (calculated)	62	33	26	321
Date of collection	[a]	[b]	[c]	[d]

[a] Sept. 6, 1917. [b] Oct. 11, 1917. [c] Feb. 12, 1918. [d] Oct. 12, 1917.

Analysts: 1, Addie T. Geiger, U. S. Geological Survey; 2 and 4, Margaret D. Foster, U. S. Geologica Survey; 3, Addie T. Geiger, Margaret D. Foster, and C. H. Kidwell, U. S. Geological Survey.

1. Coyote well, sec. 22, T. 11 N., R. 2 E. San Bernardino meridian. (See p. 283.)
2. Hot spring (temperature 102° F.), northern group of outlets, Paradise Springs, sec. 7, T. 12 N., R. 2 E San Bernardino meridian. (See p. 286.)
3. Warm spring (temperature 82° F.), southern group of outlets, Paradise Springs, about 250 yards south of hot spring represented by analysis 2. (See p. 286.)
4. Lane's well, sec. 33 or 34, T. 32 S., R. 47 E. Mount Diablo meridian. (See above.)

ANTELOPE VALLEY

Antelope Valley is one of the few areas in the Mohave Desert region in which irrigation has been successful to a considerable extent. The water supply of the valley was described by Johnson [79] in 1911, but since that time many new wells have been drilled. The writer collected information in the valley in December, 1918, December, 1919, January, 1920, and April and May, 1921.

The writer is indebted to Messrs. H. A. Brodie and L. S. Tudor, of the Southern California Edison Co.; Burt Cole, engineer for the Palmdale irrigation district; J. W. Scott, engineer for the Little Rock irrigation district; and Harry Austin, R. H. Orr, C. L. Mason, and N. S. Abbott for information in regard to wells, acreage under irrigation, and other valuable data. W. R. Parkhill and C. H. West, engineers of the Federal Land Bank of Berkeley, also kindly furnished data.

In addition to the report by Johnson cited above, several other published reports [80] contain brief data in regard to Antelope Valley. The writer has also been permitted to examine several unpublished reports by engineers in regard to the utilization of the surface waters of certain parts of the valley for irrigation.

LOCATION AND SETTLEMENTS

Antelope Valley lies in Los Angeles and Kern Counties, in the southwest corner of the Mohave Desert region (see pl. 7), and is bounded on the south and west by the high San Gabriel and Tehachapi Mountains. These ranges serve as barriers to the rain-producing winds that blow from the Pacific Ocean in winter, and for that reason the precipitation is so low that in most parts of the valley crops can

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[79] Johnson, H. R., Water resources of Antelope Valley, Calif.: U. S. Geol. Survey Water-Supply Paper 278, 1911.

[80] Davis, A. P., Report of progress of stream measurements for the calendar year 1896: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 4, pp. 402–405, 1897. Describes a stream-gaging station on Little Rock Creek and gives the estimated discharge of the creek for 1896.

Schuyler, J. D., Reservoirs for irrigation: Idem, pp. 711–715, 737. Describes proposed reservoirs of the Antelope Valley Water Co. and the Alpine (now called Harold) reservoir of the South Antelope Valley Irrigation Co.

Operations at river stations, 1897, Part II: U. S. Geol. Survey Water-Supply Paper 16, p. 193, 1898. Gives record of daily gage height at gaging station on Little Rock Creek for 1897.

Newell, F. H., and others, Report of progress of stream measurements for the calendar year 1897: U. S. Geol. Survey Nineteenth Ann. Rept., pt. 4, p. 527, 1899. Gives estimated monthly discharge of Little Rock Creek for 1897.

Operations at river stations, 1898, Part II: U. S. Geol. Survey Water-Supply Paper 28, p. 189, 1899. Gives record of daily gage height at gaging station on Little Rock Creek for 1898.

Newell, F. H., Report of progress of stream measurements for the year 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 4, p. 540, 1900. Gives estimated monthly discharge for Little Rock Creek for 1898.

Newell, F. H., Report of progress of stream measurements for the year 1899: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 4, pp. 470–471, 1901. Gives estimated monthly discharge of Little Rock Creek for 1899.

Johnson, H. R., Water resources of Antelope Valley, Calif.: U. S. Geol. Survey Water-Supply Paper 278, 1911. Describes in considerable detail both the ground water and surface water supplies of the valley. Gives data in regard to 353 wells.

Tait, C. E., Irrigation resources of southern California: California Conservation Comm. Rept., pp. 322–324, 1912. Gives a brief outline of developments in the valley up to 1912.

Adams, Frank, Irrigation districts in California, 1887–1915: California Dept. Engineering Fifth Bienn. Rept., appendix B, pp. 10, 37–39, 91–93, 1917. (Originally printed as Bull. 2 of State Dept. Engineering, 1916.) Gives briefly the history of the different irrigation districts formed in the valley.

not be grown without irrigation. The more prominent topographic features of the region are shown on Plate 19 and on the relief maps, Plates 9 and 10.

The valley lies 40 miles north of Los Angeles, but the distance by railroad or highway is nearly twice as great, owing to the fact that high mountains necessitate a wide detour to the west. The line of the Southern Pacific Railroad that runs from Los Angeles to San Francisco by way of San Joaquin Valley crosses the valley from south to north, and the line of the Atchison, Topeka & Santa Fe Railway from Barstow to San Francisco crosses the northeast corner. The valley is also connected with Los Angeles by a good paved road, which is part of one of the roads that connects southern California with the Lincoln Highway between San Francisco and Salt Lake City.

The largest town is Lancaster, on the Southern Pacific Railroad near the center of the valley. The next in size is Palmdale, on the railroad 8 miles south of Lancaster, near the foot of the San Gabriel Mountains. The only other town on the railroad is Rosamond, 12 miles north of Lancaster. Lancaster and Palmdale are thriving towns, with hotels, good stores, and banks. Little Rock, 10 miles southeast of Palmdale; Del Sur, 9 miles west of Lancaster; and Fairmont, 19 miles west of Lancaster, are small communities, each with a post office and general store. Valyermo and Llano, each 20 miles southeast of Palmdale; Wilsona, about 20 miles northeast of Palmdale; Neenach, 28 miles northwest of Lancaster; Domino, 16 miles west of Rosamond; and Muroc, on the Atchison, Topeka & Santa Fe Railway, are post offices that serve scattered ranches.[81] All these communities are reached by automobile, and roads lead from the valley to desert towns lying to the north and east.

HISTORY OF IRRIGATION

Stock raising was probably the first agricultural activity of white men in this region. The first attempts at farming any large portion of the valley seem to have been made near the foot of the mountains along the south side of the valley, where the rainfall is somewhat greater than in the center of the valley. Some of the early settlers, especially those on the lands west of the Southern Pacific Railroad around Del Sur, Fairmont, and Neenach, tried to grow crops without irrigation. In years of abundant rainfall they seem to have been successful. For instance, it is said that 750 carloads of wheat was shipped from the valley in 1893,[82] most of it presumably from the region between Del Sur and Neenach. One man is said to have had 1,000 acres in wheat and barley. The following year, however, the rainfall was deficient, and the crop failed.

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[81] Runnington post office, shown in Plate 9, and Casa Desierto post office, shown on Plate 10, are not listed in the 1928 edition of the Postal Guide and apparently have been discontinued.

[82] Farm, Field, and Fireside, vol. 17, No. 16, pp. 524–527, Apr. 21, 1894.

During the early nineties a wave of schemes of land settlement swept over the Western States, and in California conditions were made favorable by the passage in 1887 of a law known as the Wright Act. This law "sought to confer on farming communities powers of municipalities in the purchase or construction and the operation of irrigation works." [83] In Antelope Valley six irrigation districts were organized under the Wright Act between 1890 and 1895, known as the Neenach, Manzana, Amargosa, Palmdale, Little Rock Creek, and Big Rock Creek districts. The Little Rock Creek district is the only one that can be said to have been entirely successful, after a hazardous career, and the Big Rock Creek district is the only other one that still exists. Recently a new Palmdale district, which embraces in part the lands of the old Palmdale district, has been organized under a new law.

One of the most pretentious projects was located on Rock Creek (often called Big Rock Creek), then called Rio del Llano (river of the plain). This project was fostered by a paper devoted to farming interests, which proposed the establishment of a colony where the colonists would have an opportunity to build homes for themselves.[84] The plan seems to have been a bona fide scheme, which promised no great profits to the promoters, and the land with water rights was sold much cheaper than in neighboring districts. Before the land was obtained by the colony several hundred acres of fruit trees, grapes, and alfalfa had been brought to a productive state by a few ranchers, who used water from the creek. The promoters of the colony obtained 8,000 acres of land, all of which was quickly sold under contracts, and steps were taken to obtain an additional area of 10,000 acres, but this area was in litigation and was not immediately obtainable.

During the same period that the Rio del Llano colony had its inception other colonies were being started along the north foot of the mountains. The Alpine Springs colony was located on the site of the present Little Rock Creek district. It contained 1,300 acres, planted mostly with almonds and prunes.[85] At Manzana 1,500 acres was sold and planted, mostly in almonds,[86] and at Almendro, at the west end of the valley, it was planned to set out 800 acres in 1895, mostly in almonds. Probably at least 1,000 acres additional had been set out by private parties. It is probable that during this period areas aggregating from 12,000 to 15,000 acres were bought in different parts of the valley by prospective colonists who expected

[83] Adams, Frank, Irrigation districts in California, 1887–1915: California Dept. Eng., Fifth Bienn. Rept., appendix B, p. 8, 1917. This report was also published as California Dept. Engineering Bull. 2, 1916.

[84] The information on the early history of this colony is gathered from numerous articles in different numbers of Farm, Field, and Fireside, vols. 17–20, 1894–1897.

[85] Farm, Field, and Fireside, vol. 17, p. 828, June 23, 1894.

[86] Idem, pp. 521–524, Apr. 21, 1894.

to set out orchards. Some idea of the magnitude of the developments may be obtained from the following quotation from Hinton:[87]

In the Antelope Valley proper, since April, 1889, some 10,000 acres have been brought under cultivation; this area can be readily increased to 25,000 acres. It is estimated that in all 50,000 acres are now under ditch. The surface supply is obtained from mountain streams, stored in three reservoirs, with a total capacity of 30,000,000 gallons.[88] The works include five dams, five headways, seven weirs, and six tunnels driven into the foothills. The main ditches are 50 miles in length, 5 feet wide at the top. There is an equal mileage of distributing and lateral ditches.

The colonization projects seem to have been started at what proved to be the most inopportune time in the history of the valley. During eight out of the eleven years from July 1, 1893, to June 30, 1904, the mean annual rainfall for the places at which precipitation records have been kept for a long period was considerably below the normal. (See table on p. 85 and pl. 6.) For two successive years, 1897–98 and 1898–99, the precipitation was the lowest yet recorded at several of the stations for which the records are given; the longest record covers a period of 50 years.

The colonists had hardly set out their orchards when they were hit by the unprecedented drought. The orchards on the west side of the valley, which depended almost entirely on rainfall for water, were the first to wither, but it was not long before Rock and Little Rock Creeks dwindled to a point where they did not carry enough water for the large acreage set out. Most of the settlers were forced to give up their new homes. A very few were able to continue on their places until years of more abundant rainfall. Tracts amounting to many hundreds of acres were abandoned, for in 1910 less than 5,000 acres was irrigated in the valley.

Mr. O. Lewis, of Little Rock, states that in the dry years of 1897–1899, as the flow of Little Rock Creek dwindled, family after family moved out until he was practically the only landowner left in the district. He installed a pumping plant in a well dug in the creek bottom and was thus able to keep his orchard from dying. After the drought had passed some of the settlers gradually drifted back, and eventually the Little Rock Creek district was placed on a sound basis. The original orchards were largely planted with almonds and olives, but these trees suffered greatly from the drought, and in the years since that period most of the orchards have been set out with pear trees and a smaller number of apple trees.

Since its beginning the Big Rock Creek Irrigation District has been divided into two parts, known as the East Side and the West Side, located respectively on the east and west side of Rock Creek Wash.

[87] Hinton, R. J., Progress report of irrigation in the United States, pt. 1, p. 50, U. S. Dept. Agr., 1891.

[88] About 90 acre-feet. Either the figure given by Hinton is wrong or the storage capacity was exceedingly small in comparison with the diversion works that had been built according to his statement.

When the lands were first colonized in 1894, the headquarters of the East Side were at Llano and of the West Side at Almondale.

In 1914 an attempt was made to rehabilitate the Rio del Llano project by a group of socialists, who established a cooperative colony. Several hundred members joined the colony, each contributing a certain amount of money. It was to be operated on ideal socialistic principles of equal division of work and of benefits accruing therefrom, and it was expected that the colony would eventually become nearly independent of the outside world. Internal troubles arose over the management of the colony. In the early part of 1918 most of the colonists were sent to Louisiana to form a new colony, and Llano was practically abandoned. In 1919 a large part of the area that was formerly irrigated was badly neglected.

Almondale was abandoned during the extreme drought of the nineties and has not been revived, but a community known as Longview has been established on some of the West Side lands, and several hundred acres of fruit trees are being irrigated. It is reasonable to believe that eventually the district may become as highly developed as the Little Rock Creek district.

The districts on the west side of the valley did not survive the drought of the nineties. It was found that the water supply that was to be used for irrigation was not sufficient except in seasons when the precipitation was above the normal, and the projects were abandoned. Hundreds of acres of almond and olive trees were allowed to die, but about 1,000 acres of trees at Manzana are still cultivated without irrigation and in some years produce good yields.

At about the time the Little Rock Creek Irrigation District was organized the South Antelope Valley Irrigation Co., later called the Palmdale Water Co., was organized as a private corporation, not under the Wright Act. This company also used water from Little Rock Creek, carrying it by open ditch to a natural depression, known as the Alpine or Harold Reservoir, about a mile south of Palmdale. Until recently no storage was provided on the creek. The Little Rock Creek district has used the flow of the stream only during the irrigation season, but the Palmdale Co. has stored some of the winter flow in the Harold Reservoir. This reservoir, however, has a capacity of only about 3,000 acre-feet, and in winter, when the run-off is greatest, much water has been lost. Recently the Palmdale Irrigation District has been organized. It covers practically the same territory that was served by the Palmdale Water Co., which has sold its holdings and water rights to the new district. The Palmdale district and the Little Rock Creek district joined on a project to build a concrete dam on Little Rock Creek with a view to impounding the greater part of the excess flow that is not diverted to the Harold Reservoir. In January, 1919, a bond issue of $580,000 was voted for this purpose.

In the Palmdale district about 700 acres has been irrigated, and in the Little Rock Creek district about 1,600 acres, practically all in pears or apples. When the new storage works are completed the plans provide for irrigating about 5,000 acres in the Palmdale district and about 3,000 acres in the Little Rock Creek district.[89]

While the southern margin of Antelope Valley has been developed by water from Rock and Little Rock Creeks, a large area in the central part has been developed by water from drilled wells. Early in the eighties it was discovered that flowing wells could be obtained in the lower part of the valley near Lancaster by drilling to depths of 200 to 500 feet.[90] The development of the ground-water resources at first was not rapid. Johnson's report gives a list of 353 wells that had been drilled up to January, 1909.[91] Only 23 wells are given in this list as being drilled during the 10-year period 1881 to 1890, but Hinton states that in 1890 more than 100 wells were in use, of which five were flowing wells.[92] Definite figures for the period since 1908, when the field work on Johnson's report was finished, are not available, but the rate at which wells have been drilled has apparently been somewhat greater than before 1908. One driller put down about 80 wells from 1912 to 1919, and another about 40 wells from 1917 to 1919. Other drillers have also put down a considerable number of wells. Probably at least 150 wells have been drilled since 1908, and the total number that have been drilled in the valley is not far from 500, but not all of these are now in use.

In the early years the land in the central part of the valley was devoted principally to cattle raising. Gradually, however, an increasing area was irrigated from wells. The water for irrigation was at first obtained almost entirely from flowing wells. Practically no pumping plants were used for irrigation prior to 1900. In the list of 353 wells given by Johnson less than 40 are indicated as equipped with pumping plants in 1908, including several that were used by railroads or for manufacturing. Since 1908 the number of pumping plants has increased greatly. In January, 1920, the Southern California Edison Co. was furnishing electric power to more than 200 pumping plants, and in addition there were 25 to 50 pumping plants operated by gasoline or oil engines.

The greatest development at first took place in the area of artesian flow because of the ease with which water could be obtained. In a large part of this area, however, there is so much alkali that the land

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[89] The dam has been completed since the above statement was written, but no information is available as to the results of its use. All statements in this report are based on conditions as they were in 1919, unaffected by storage of water which has since taken place.

[90] Hinton, R. J., Progress report of irrigation in the United States, p. 50, U. S. Dept. Agr., 1891. Johnson, H. R., Water resources of Antelope Valley, Calif.: U. S. Geol. Survey Water-Supply Paper 278, well No. 298, p. 86, 1911.

[91] Johnson, H. R., op. cit., pp. 70-88.

[92] Hinton, R. J., op. cit., p. 50.

is useless for crops. Nevertheless many wells were put down on land covered with alkali merely to get title to the land under the desert-land laws. At a number of places the settlers tried to grow crops, only to have them killed by alkali or by salt grass that got a better footing in the alkali soil.

The developments in recent years have been confined largely to raising alfalfa on land that lies near the margins of the area of artesian flow, where the alkali is not bad, and land that lies not more than a mile or two outside the area of artesian flow, where the pumping lift is not more than 50 feet. In the last few years a number of wells have been drilled higher up on the alluvial slope to be used in irrigating fruit orchards, which yield a sufficient return to warrant a high lift. The most notable development of fruit orchards has been between Palmdale and Little Rock and northwest of Palmdale, where several hundred acres of fruit trees, mostly pears, have been set out. Although some fruit trees are being grown in the alfalfa-producing region, fruit growing on a commercial scale is practically confined to the higher lands on the south side of the valley. In 1920 experiments were made in growing rice on the clay flat of Rosamond "Dry Lake" on the north side of the valley, but the results were not satisfactory.

In addition to the lands irrigated in Antelope Valley several hundred acres is under cultivation in mountain valleys that are tributary to the main valley. Near Valyermo 300 acres or more of pear and apple orchards are irrigated with water from Rock Creek and yield good returns. A few hundred acres is devoted to fruit and grain in Leonis Valley, a long, narrow valley drained by Amargosa Creek, west of Palmdale. The rainfall here is greater than in Antelope Valley and irrigation is not practiced. Some of the lands are naturally moist.

In the last few years the development of Antelope Valley has been rapid. In a report published in 1912 the area of irrigated land in the valley is given as 4,629 acres.[93] The following summary, compiled from information obtained by the writer from various sources in January, 1920, gives some indication as to the area irrigated in the valley in 1919.

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[93] Tait, C. E., Irrigation resources of southern California: California Conservation Comm. Rept., p. 326, 1912.

Estimated area irrigated in Antelope Valley in 1919

Locality and source of water	Nature of crop	Area (acres)
Water supply from surface streams:		
Valyermo and Pallett ranches	Fruit	300
Llano	Fruit and alfalfa	300
Longview	Fruit	350
Little Rock	do	1,600
Palmdale	do	700
Water supply from wells:		
Electric pumping plants [a]	do	1,555
	Alfalfa	[b] 6,855
Gasoline pumping plants and flowing wells	Fruit and alfalfa	300
		11,960

[a] The estimates of acreage irrigated by water from electrically driven pumping plants were obtained from H. S. Brody, district agent of the Southern California Edison Co., which furnishes power to probably 90 per cent of the pumping plants in the valley.

[b] Data received from Mr. N. S. Abbott, Lancaster, Calif., in December, 1924, show that the area of alfalfa irrigated as given in the above table may be too high. He stated that in 1919–20 the directors of the Alfalfa Growers Association of Antelope Valley made a careful survey and estimated the acreage then planted to be about 4,400 acres. He further stated that a careful compilation by L. S. Tudor, district agent of the Southern California Edison Co., showed an acreage planted to alfalfa in July, 1923, of 8,013 acres. Mr. Abbott stated that in recent years there had been a yearly increase in alfalfa acreage of about 1,000 acres.

The most rapid expansion probably occurred within the last year or two, to infer from shipments of certain products as given in the following table, furnished by the freight department of the Southern Pacific Railroad. Records for shipments prior to 1917 are not available.

Agricultural products shipped from stations in Antelope Valley, 1917–1919, in carloads

Station	Hay			Grain			Live stock			Deciduous fruit		
	1917	1918	1919	1917	1918	1919	1917	1918	1919	1917	1918	1919
Lancaster	333	809	1,479	2	2	3	54	73	63	8	3	1
Palmdale		17				3		10	5		72	102
Rosamond	2	20	57						1			
	335	846	1,536	2	2	6	54	83	69	8	75	103

The hay shipped from the valley is nearly all alfalfa. Most of it is shipped from Lancaster, and Rosamond ranks second. In addition to the shipments given in the table, an increasing tonnage of hay has been shipped to Los Angeles by motor truck. Mr. R. C. Hitte, of the Lancaster Feed & Fuel Co., estimates that in 1919 from 2,000 to 3,000 tons (equivalent to 180 to 270 carloads) was shipped by truck.[94]

About 80 per cent of the shipments of fruit consists of pears, and most of the remainder of apples. Practically all the fruit is shipped from Palmdale—that is, from the more elevated valley lands, where the orchards are irrigated from the mountain streams or where the

[94] Statistics furnished by the Southern Pacific Co. for shipments from 1920 to 1926 show that shipments of hay by railroad have decreased to almost nothing, apparently as a result of increasing shipments by automobile truck. The data are obviously of no value as an indication of agricultural production in the valley and hence have not been added to the table.

pumping lift is great. The small quantity of grain shipped comes principally from the dry-farm district between Del Sur and Neenach. In this connection the statement that 750 cars of grain was shipped in 1893 is of interest.

SOILS

A soil survey has been made of a large part of the Antelope Valley region.[95] The soils are composed essentially of detrital material washed into the valley from the mountains—that is, of fragments of granite, schist, gneiss, limestone, and volcanic and other rocks. On the alluvial slopes the materials range in coarseness from clay to sand, gravel, and boulders. In the lower part of the valley, around the playas, the soil contains a large amount of clay and silt and a proportionately smaller percentage of sand and gravel. The material that underlies the playas is practically all clay or silt.

Throughout the greater part of the alluvial slopes the soil seems to be fairly productive when provided with water, but on the lower land which surrounds the playas and extends for several miles from them the soil contains more or less alkali. Although alfalfa and other crops are grown in some places on the alkali soil, most of this land is not cultivated. In some places where low mounds of wind-blown sand are scattered over the surface alkali may not show at the surface, but when the land is leveled for irrigation alkali may later appear. This condition apparently exists only near the outer edge of the area of alkali soil, for elsewhere if there is much alkali it will rise to the surface of the sandy areas. The alkali in the soil in the lower part of the valley seems to be due principally to evaporation of ground water that has reached the surface by upward capillary movement.

As a result of the evaporation of the lakes that once existed in some of the closed basins of the Mohave Desert region common salt and other alkali salts were deposited with the clay and silt of the lake bottoms and the soils in such places, as well as the ground waters, are highly impregnated with alkali. This does not seem to have happened in Antelope Valley, for no extensive salt deposits have been found, and the water from wells drilled on or close to the playas is rather low in mineral matter. No data are available as to the depth to which the alkali extends. However, as it is due to evaporation, it is probably most abundant in the uppermost foot or two.

In the present investigation the boundary of the area of alkali soils was determined approximately at several places on the south side of the valley east and west of Lancaster. Where thus defined it agreed closely with the limit of the area in which flowing wells existed at the time of the investigation, which is shown on Plate 19, and doubt-

[95] Carpenter, E. J., and Cosby, S. W., Soil survey of the Lancaster area, Calif.: U. S. Dept. Agr. Bur. Soils Field Operations for 1922, advance sheets, 1926.

less the boundaries for the two areas are approximately the same throughout the valley. On this assumption it is estimated that the valley includes 75,000 to 100,000 acres in which the soil contains more or less alkali. In this area the cost of obtaining water from wells is less than in any other part of the valley, but unfortunately the topographic and soil conditions are not favorable to methods used to reduce alkali in other arid areas. In view of the fact that there is a vast acreage of land with better soil elsewhere in the valley much of the low land will doubtless remain uncultivated.

NATIVE VEGETATION

Many kinds of native plants grow in Antelope Valley, although the variety in any one locality is more or less restricted. The distribution of the different plant species is determined by a combination of factors that include variations in soil, moisture, and temperature. Hence there are plant zones the boundaries of which follow approximately the contour of the land.

The plant forms over most of the valley proper are desert shrub varieties, the large species being confined to the mountains or upper slopes of the valley. In the high mountains coniferous trees are found. These areas are included in national forests and are difficult of access, and hence these trees are used very little. The most noticeable treelike form in the valley is the Joshua tree, or giant yucca, which grows principally on the upper parts of the alluvial slopes and is rare below altitudes of 2,500 feet above sea level. The piñon or juniper is found in the upper part of the yucca zone and extends upward on the mountains. Between Fairmont and Neenach these two forms grow in greater abundance than has been observed by the writer at any other place in the Mohave Desert region. The yucca is the only large tree in the valley that can be easily obtained for fuel. It is composed of rather pithy material, however, which, although it gives much heat, burns out quickly. Deciduous trees are very rare in the valley, except where they have been planted by ranchers.

Some of the native plants are good indicators of the nature of the soil or the depth to ground water. Salt grass (*Distichlis spicata*) is one of the best of these indicators. It grows where the depth to ground water is shallow and also generally indicates some alkali in the soil. In some places in the alkali-soil area it is abundant; in others it is very sparsely distributed. Other types, commonly known as salt brush, grow in the alkali soil of the lower part of the valley. Mesquite trees, which are usually good indicators of shallow ground water, grow at places in the area of artesian flow and along the wash of Rock Creek southwest of Lovejoy Buttes.[96] Sagebrush

[96] Johnson, H. R., op. cit., p. 19.

(*Artemisia tridentata*) was observed on the intermediate part of the alluvial slope, the growth being particularly dense south and southwest of the Portland ranch, 6 or 7 miles west of Lancaster, at an altitude of about 2,400 feet above sea level. It is unusual to find this species growing at so low an altitude in the Mohave Desert region. There is probably no relation between the distribution of this plant and the shallow-water zone, but it is said to indicate good agricultural land. The creosote bush (*Covillea tridentata*), which is the dominant plant over most of the Mohave Desert region, is almost entirely absent throughout a large part of Antelope Valley and grows in abundance only around the borders of the valley.

PHYSICAL FEATURES

GENERAL FEATURES

Antelope Valley lies in a closed basin—that is, a basin which has no outlet for its surface streams. All the storm water either sinks into the ground or collects in the lower parts of the valley, where it is disposed of by evaporation.

The boundary of the drainage basin of the valley is shown on Plate 19. It is roughly triangular, like a huge arrowhead. On the south and southwest the valley is separated from a region that drains to the Pacific Ocean by the San Gabriel Mountains (on some maps named the Sierra Madre) and their westward extension—Sawmill Mountain and Liebre Mountain. The trend of these mountains is approximately N. 70° W. The San Gabriel Mountains are very steep and high. North Baldy, the highest peak in the divide of Antelope Valley, rises 9,389 feet above sea level, and several other peaks attain altitudes of more than 6,000 feet. The peaks of Sawmill and Liebre Mountains, however, are less than 6,000 feet above sea level.

On the northwest the valley is separated from the south end of San Joaquin Valley by the Tehachapi Mountains, the highest peak of which is Double Mountain, 7,950 feet above sea level. The trend of the Tehachapi Range is N. 65° E.

The divide between Antelope Valley and adjacent regions on the north and east is not so distinct as that formed by the San Gabriel and Tehachapi Mountains. In these directions the divide is marked in some places by low rock ridges or isolated buttes, but in other places it lies on slopes of alluvial material which have so gentle a grade that it is difficult to determine just where the divide is situated except by careful leveling or observation on the flood run-off. A large fan built out in front of Oak Creek, west of Mojave, slopes both southeastward toward Antelope Valley and northeastward to Fremont Valley, and the exact boundary between the two valleys is not known. It is probable that flood waters of Oak Creek at one time or another flow in both directions. The boundary north of the railroad between Bissel and Kramer is located with comparative accuracy. Topographic maps are not available for the east side of the valley, and it is not certain that the boundary of the basin from Kramer southward to the northern part of T. 6 N. is correct as it is represented in the map. South of T. 6 N. it is reasonably accurate, but at the extreme southeast corner of the basin a large alluvial fan has been built at the mouth of Sheep Creek, and it is impossible to determine accurately from the topographic map into which drainage basin that stream empties. The divide on the east and north is much lower than that on the southwest and northwest, the maximum altitude being not much over 3,500 feet above sea level.

Antelope Valley lies at a higher altitude than any of the valleys beyond the mountains that surround it, with one exception. The valley of Mohave River, on the east, is higher at its upper end than Antelope Valley, but toward the north it drops to an altitude between 2,100 and 2,200 feet. The lowest part of Antelope Valley is about 2,275 feet above sea level. The lowest part of Fremont Valley, to the north, is about 1,900 feet above sea level. The south end of San Joaquin Valley, which lies west of the Tehachapi Mountains, is only about 1,000 feet above sea level. San Fernando Valley and San Gabriel Valley, on the south side of the San Gabriel Mountains, do not reach altitudes of more than 1,000 feet.

The drainage basin of Antelope Valley includes topographic features of three principal kinds—mountains, alluvial slopes, and playas. The alluvial slopes and the playas form the valley proper. The alluvial slopes contain most of the area that is devoted to agriculture, but nearly all the water that is available for irrigation comes from the mountains.

The playas, usually called "dry lakes," occupy the lower parts of the valley and are nearly flat expanses underlain by clay or silt. The alluvial slopes are underlain by sand, gravel, and clay. They rise gradually from the playas and become steeper as they approach the mountains. From the upper limit of the alluvial slopes the mountains rise very steeply, and their sides are generally rough and rocky. The origin of the three kinds of features is described briefly in the following paragraphs. Their relation to the water resources of the valley will be discussed on subsequent pages.

MOUNTAINS

The San Gabriel Mountains and probably the Tehachapi Mountains have been raised to a great altitude by faulting—that is, they are huge blocks of the earth's crust that have been broken from the surrounding rocks and pushed up to a great height. This movement was probably very slow and it was probably accompanied by earthquakes. After being elevated, part of the mountains have been worn away by streams and other agents until now they are much dissected and very rugged.

Since the main mass of the San Gabriel Mountains and the western continuation of that range, the Sawmill and Liebre Mountains, were elevated, faulting of lesser magnitude has occurred along the north base of the range. The most obvious evidence of this later faulting is a succession of long, narrow valleys that have a northwesterly trend, separated from the main valley by narrow ridges. The outer ridge that adjoins the valley has been lifted up, or the valley behind it is a block that has dropped down. Several of these valleys stand out prominently on the relief maps (pls. 9 and 10); the most notable is the one occupied by Elizabeth and Hughes Lakes (Leonis Valley), which is drained by Amargosa Creek, Swartout Valley, and Lone Pine Canyon. The ditch of the Palmdale irrigation district from Little Rock Creek to the Harold Reservoir follows one of the valleys which is less prominently shown on the map but which is nevertheless a distinct valley. The Harold Reservoir also occupies one of these valleys. The direct road from Little Rock to Valyermo follows in a general way the fault line. Portal Ridge is a prominent ridge that separates Elizabeth and Leonis Valleys from the main valley. Careful observation shows less notable features that indicate the continuation of the fault line at other points along the north base of the San Gabriel Range.[97]

The succession of valleys and ridges or other features that indicate the fault zone can be traced northwestward and northward to San Francisco and beyond and southeastward through Cajon Pass and San Gorgonio Pass to the Salton Sea Basin. This long zone of faulting has been called the San Andreas rift. Movement along this rift farther northwest, particularly near San Francisco, caused the earthquake of April 18, 1906, which did so much damage in that city and elsewhere. There apparently was no movement along the San Andreas rift in Antelope Valley in 1906, but faulting along the rift has occurred in the region at least as recently as 1857.[98] Evidences of faulting are found at other places in the San Gabriel Range; the fault lines are approximately parallel to the San Andreas rift, but none of them are as continuous as the rift.

The origin of the rock hills on the north and east sides of Antelope Valley is somewhat obscure. There is evidence that the hills at the north end of the valley west of Rosamond have been faulted, but the extent of this faulting is not known. However, definite evidence of faulting has not been found in the hills on the east side. These hills are low, and their appearance suggests that they represent an old land surface that had been worn down nearly to a plain. They are now almost buried by alluvium.

[97] Lawson, A. C., and others, The California earthquake of April 18, 1906 (report of the State Earthquake Investigation Commission): Carnegie Inst. Washington Pub. 87, vol. 1, pp. 43–44, pls. 24–28, maps 7–10 in atlas, 1908.

[98] Idem, pp. 43, 52, 449.

ALLUVIAL SLOPES

Antelope Valley is underlain by a large amount of rock débris, which has been washed down from the surrounding mountains. By the process known as weathering the surface rocks of the mountains are being continually though slowly broken into fragments that range in size from mintue particles to boulders several feet in diameter. This débris is carried to the valley by the mountain streams. At flood stage the streams may carry very coarse material, including boulders a foot or more in diameter. In the mountains, where the grade of a stream is steep, its carrying power is great, but when the stream reaches the foot of the mountains its grade becomes less, the velocity of the water decreases, and it therefore drops some of its load. It deposits the coarsest material first and carries the silt and clay farthest.

Most of the débris is deposited in front of the mouth of the canyon, where the stream leaves the mountains, because the velocity of the stream usually decreases most rapidly at that place. It often happens that so much débris is deposited in the channel that the stream overflows on either side, giving rise to distributary streams, which also deposit sand and gravel. By this process a sloping fan-shaped plain, called an alluvial fan, underlain to great depths by coarse alluvium, is formed at the foot of the mountains. The fans built by several streams along the foot of the mountains may coalesce, forming a more or less continuous alluvial slope.

PLAYAS

If the mountain streams furnish enough water ponds or lakes may be formed in the lower parts of a closed basin. When the streams carrying débris flow into such a lake their velocity is further lessened and all material is dropped close to the shore, except the very finest silt or clay, which may remain in suspension for some time but finally settles to the bottom. In the Antelope Valley region, as in many other desert valleys, the rainfall is so slight and the evaporation is so great that not enough water is carried to the bottom of the valley to form a lake except after heavy rains in the mountains. The lake that is formed during great floods usually contains only a few inches of water which evaporates in a few weeks or months, leaving a bare, smooth flat of clay or silt which is locally known as a "dry lake" but which geologists call a playa.

There are several playas in the lowest parts of Antelope Valley, of which the largest are Rosamond, Rogers (Rodriguez), and Buckhorn Dry Lakes. It is probable that at one time all three formed a single large playa, but they are now separated by low sand dunes. There is also reason to believe that at an earlier period a perennial lake covered these playas. Along the Atchison, Topeka & Santa Fe Railway about 5 miles northeast of Muroc, in T. 10 N., R. 8 W., Rogers Dry Lake is separated from a smaller playa by a low ridge of gravel about 5 feet high which was evidently deposited in standing water as a beach ridge. A well-defined beach ridge, the top of which is 10 or 15 feet above the surface of the playa, was observed on the northeast side of Rosamond Dry Lake. At most places around Rogers Dry Lake there is a sharp rise of 1 to 6 feet or more from the clay flat to the surrounding land, suggesting a wave-cut cliff. These features may be due to wave action in a temporary lake formed by unusually heavy floods from the mountains, the lake disappearing after a few months or a year or two at the longest. Other higher and more prominent cliffs were observed from a distance by the writer on the north side of Rosamond Dry Lake, about 5 miles east of Rosamond. He did not have an opportunity to examine them closely, and as a fault, which might account for them, was observed in this locality only a mile or two farther west, it was not definitely established that they are wave-cut cliffs. The presence of a considerable thickness of blue clay, which is generally considered to indicate deposition under water, in wells in the lowest part of the valley (see p. 306) further suggests the existence of a lake.

It is known that in the Pleistocene epoch perennial lakes existed in other basins in the Mohave Desert region that now contain only playas,[99] and it is not improbable that further examination will show that a perennial lake once covered the playas in Antelope Valley. It is generally believed by geologists that these ancient lakes were due to slightly greater precipitation and less evaporation throughout the desert region than at present. If the difference in rainfall was sufficient to produce lakes in other parts of the Mohave Desert region, the rainfall in the San Gabriel and Tehachapi Mountains must have been sufficient to produce a perennial lake in Antelope Valley.

If a perennial lake did exist in Antelope Valley covering the area of the three playas mentioned, it probably overflowed northward into another basin, known as Fremont Valley, by a channel extending from the north end of Rogers Dry Lake along the west side of T. 11 N., R. 9 W. San Bernardino meridian. It has been stated that in the Pleistocene epoch Rogers Dry Lake drained to Mohave River.[1] The writer does not believe that this was the case. So far as is known, the lowest point in the divide on the east side of the playa is along the Atchison, Topeka & Santa Fe Railway a mile or two west of Kramer, where the altitude, according to levels run by the topo-

[99] Gale, H. S., Salines in the Owens, Searles, and Panamint Basins, southeastern California: U. S. Geol. Survey Bull. 580, pp. 251–323, 1914. Buwalda, J. P., Pleistocene beds at Manix, in the eastern Mohave Desert region: California Univ. Dept. Geology Bull., vol. 7, pp. 443–464, 1914. Thompson, D. G., Pleistocene lakes along Mohave River, Calif.: Washington Acad. Sci. Jour., vol. 11, pp. 423–424, 1921 (abstract of paper read before Geological Society of Washington, April 28, 1920).

[1] Free, E. E., The topographic features of the desert basins of the United States with reference to the possible occurrence of potash: U. S. Dept. Agr. Bull. 54, p. 45, 1914.

graphic branch of the United States Geological Survey, is slightly more than 2,500 feet above sea level.[2] At the north end of Rogers Dry Lake, however, the altitude of the divide between Antelope Valley and Fremont Valley, according to the Searles Lake topographic map, is less than 2,400 feet. The exact altitude is not known, but apparently it is not much over 2,300 feet. Unless there is a low point on the rim on the east side of Rogers Dry Lake not observed by the writer, it would be natural for any overflow to go northward. A very marked channel extends northward from the south side of T. 32 S., R. 38 E. Mount Diablo meridian, between Desert Butte and Castle Butte, to a playa in Fremont Valley. Where this channel is crossed on the road from Mojave to Atolia, near the north line of sec. 20, T. 32 S., R. 38 E., it is fully 500 feet wide and from 10 to 15 feet below the surrounding territory. It is apparently much too large to have been cut by the drainage from the territory that is now tributary to it and strongly suggests an outlet channel from Rogers Lake. About 4 miles farther southeast, almost due east of Desert Butte, on the lowest part of the divide, however, there is no noticeable channel of any sort. The conditions here are not clear, and the writer did not have opportunity to determine definitely whether or not an outlet existed at the north end of Rogers Dry Lake.

GEOLOGY

KINDS OF ROCKS

The rocks of the mountains and hills that form the border of Antelope Valley are as a rule not water-bearing or yield only meager supplies, whereas most of the deposits that underlie the valley yield water, some of them very freely.

The rocks which yield little or no water comprise (1) limestone, (2) granite and rocks of a similar nature, (3) metamorphosed rocks, such as slate, schist, and gneiss, and (4) volcanic rocks. These rocks are compact and hard and contain almost no pore spaces that can hold water. Practically the only water that is contained in them exists in fissures. The fissures are usually small and form only a small percentage of the entire rock mass, so that the quantity of water that these rocks can yield is very small.

The main water-bearing formation is the valley fill, which consists chiefly of the alluvial gravel, sand, and clay that underlie the greater part of Antelope Valley. These deposits are very porous and are capable of holding large quantities of water, but the pores in the clay are so minute that they yield their water very slowly.

The following brief notes on the rocks of the valley, based on observations by the writer, on previously published reports, or on personal communications from L. F. Noble and J. P. Buwalda, both

[2] Spirit leveling in California, 1896 to 1923, inclusive: U. S. Geol. Survey Bull. 766, p. 86, 1925.

of the United States Geological Survey, will be of value in interpreting conditions. Mr. Noble has studied in detail the geology in the vicinity of Little Rock and Valyermo, and Mr. Buwalda has studied the geology of the mountains on the west side of Antelope Valley.

DISTRIBUTION OF NON WATER-BEARING ROCKS

The rocks of the Tehachapi and San Gabriel Ranges and the hills on the east side of the valley consist principally of granite, together with some limestone and schist or gneiss. The rocks of the buttes on the north side of the valley and the buttes northeast of Rosamond are principally volcanic rocks with some sandstone. Although these rocks are more porous than the granite, they will yield little water and may be considered practically impervious.

The fill of the valley is probably underlain by crystalline or volcanic rocks. The chief evidence in support of this belief is the presence of such buttes as the Antelope or Fairmont Buttes, the Little Buttes, northeast of Fairmont, and Quartz Hill, northwest of Palmdale, which are composed of volcanic or granitic rocks. Hard rock has also been encountered in several wells in the valley. (See wells 24, 97, and 107 in table, p. 356, and map, pl. 19.) On the other hand, the depth to solid rock in some parts of the valley is great. A well was drilled for oil in sec. 11, T. 7 N., R. 12 W., to a depth of 2,000 feet, apparently without having reached bedrock. Shale struck at about 1,300 feet probably represents a consolidated phase of the valley fill.

Non water-bearing rocks practically surround and underlie the valley, forming an essentially water-tight basin in which lie the water-bearing beds. At two places and possibly elsewhere the rim of the basin is composed of porous materials, but it is evident that impervious rocks underlie them at no great depth. (See pp. 324–325.)

DISTRIBUTION OF WATER-BEARING FORMATIONS

The water-bearing formations may be separated into two divisions—those that occur in the mountains and hills and those that underlie the valley.

Small areas of water-bearing formations occur at several places in the mountains. Sandstone occurs at the extreme west end of the valley, near the junction of the Tehachapi Mountains and the northwest continuation of the San Gabriel Range. It is overlain by less consolidated beds of sand and gravel.[3] Other deposits of more or less consolidated gravel and sand cover a considerable area near the north base of the San Gabriel Mountains. Good exposures of them occur south of Valyermo post office, where they have been broken and tilted by faulting along the San Andreas rift zone.

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[3] Johnson, H. R., op. cit., p. 25.

These sedimentary rocks belong to the group of water-bearing formations, but they are of little economic value. Around Valyermo they occur only in the mountains, where they are so dissected by steep valleys that the land is practically worthless for agriculture. They are separated from the water-bearing rocks of the valley by non water-bearing rocks. The water-bearing rocks in the hills at the west end of the valley occur under somewhat similar conditions, but they may continue out into the valley beneath the valley fill that forms the alluvial slope. Their outcrops cover small areas, however, and they are of no great value as sources of water. The water-bearing rocks of the mountains absorb more water during heavy rains than the less porous rocks, such as granite, but much of their water is later returned slowly to the surface through springs or seeps and is evaporated.

The notable water-bearing formation in Antelope Valley is the alluvium that underlies the valley. It is composed of gravel, sand, and clay washed down from the surrounding mountains. A study of well logs and of samples from wells indicates that the water-bearing beds that are penetrated in the wells are much like the materials that lie immediately below the surface and were deposited by processes that may be observed at the present time.

A peculiar type of water-bearing rock, locally called "honeycomb cement" or simply "cement," is encountered in many wells in the alluvium in Antelope Valley. It is so named because of its resemblance to artificial cement and because of its porous texture. According to Johnson [4] it is a limy hardpan, either in clay or in sand, which has a more or less cellular texture, apparently due to water dissolving out some of the constituent material.

Deposition of clay, either on a large playa or in a perennial lake, occurred for a long period in the lowest part of Antelope Valley, for a thick body of clay is encountered in wells north and northeast of Lancaster. Mr. Harry Austin states that in a well on the Morgan ranch, in the NE. ¼ sec. 3, T. 7 N., R. 12 W., blue clay was penetrated from a depth of 120 feet to 240 feet, practically without any change to coarser material. In a well in the SE. ¼ sec. 34, T. 9 N., R. 12 W., blue clay was struck at about 100 feet and was about 80 feet thick. Near Redman School blue clay is reached at a depth of about 265 feet and is about 200 feet thick.

CLIMATE

TEMPERATURE, WINDS, AND EVAPORATION

High temperatures are common in summer, the thermometer rising above 100° F. on many days each season and frequently reaching 110° or 115°. Records kept at Mojave, a few miles north of the north

[4] Johnson, H. R., Water resources of Antelope Valley, Calif.: U. S. Geol. Survey Water-Supply Paper 278, p. 39, 1911.

side of the valley, for the 16-year period 1891 to 1906 give the maximum temperature as 115° F.[5] During this period the annual maximum was never below 105°, and for 7 out of the 16 years it was above 110°. The air usually cools rapidly after the sun sets, with the result that there is generally a large daily range of temperature, frequently amounting to 30° and sometimes to 45°. The summer evenings are nearly always delightfully cool, and the heat seldom prevents sleep.

The winter temperatures are somewhat higher than those in regions of the same latitude and altitude farther inland. The thermometer frequently rises to 60° or more in the day and usually drops only a few degrees below freezing at night, although it sometimes goes as low as 15° above zero or even lower. The lowest minimum temperature recorded at Mojave during the 16-year period mentioned above was 15°. It is said that on December 30, 1895, the temperature fell to 6° above zero near Lancaster.[6] The daily range is probably somewhat less in winter than in summer.

It is generally believed that along the foot of the mountains on the south side of the valley the winter temperature is usually several degrees higher and the summer temperature a few degrees lower than in the lower part of the valley. Mr. Dickey, who for a number of years has been in charge of large almond orchards at Manzana, in the west end of the valley, states that in many years freezing temperatures occur at Lancaster six weeks earlier than at Manzana.

Strong winds blow across the valley at times. Such winds frequently carry fine sand and clay, which gather into low dunes in some parts of the valley, principally on its east side. The fine sand is at times blown against young plants with such force that they are cut off as if by a knife, and it is necessary to protect newly sown alfalfa or other crops by windbreaks.

Data in regard to evaporation from a floating pan on Harold Reservoir are given on page 76.

PRECIPITATION

Records of precipitation have been kept for periods of 1 to 13 years at a number of places in the valley, as follows:[7] Monterio (Knecht's ranch), on Cottonwood Creek about 30 miles northwest of Lancaster; the Liebre ranch, about 30 miles west of Lancaster; the E. T. Earl ranch, about 5 miles southwest of Lancaster, in sec. 36, T. 7 N., R. 13 W.; Palmdale; Palmdale headworks, at head of ditch on Little Rock Creek; Valyermo, on Rock Creek, 20 miles southwest of Palmdale; Llano, 20 miles east and a little south of Palmdale, in sec. 21, T. 5 N., R. 9 W.; Fairmont; Manzano; and Lancaster. (See pp. 78–80.)

[5] Johnson, H. R., op. cit., p. 17.
[6] Idem. p. 17.
[7] The records w re compiled in 1920-21, and subsequent records have not been obtained.

The corrected long-term average annual precipitation of the stations in Antelope Valley has been calculated by the method described on page 83 and is given in the table on page 87.

The data in these tables must be used with some caution, for there are great differences between the indexes of the several control stations in some years, though for most of the years the differences are not great.

A study of the data on precipitation shows certain dominant features. (1) There is a distinct seasonal distribution of the precipitation, most of it coming in the winter; (2) the precipitation differs in different parts of the valley, being affected by topographic features, but in general it is least in the low central part of the valley and greatest in the high mountains; (3) the mean annual precipitation in most of the valley is less than 10 inches, an amount so small that irrigation is necessary for successful agriculture.

The seasonal distribution of the precipitation is very marked. According to the records from 70 to 85 per cent or more falls from November to March. The greatest precipitation usually occurs in January, February, and March.

The winter precipitation comes from storms that cover large areas. These storms move, in general, from the Pacific Ocean eastward. The precipitation from such storms is more or less steady, continuing from several hours to two or three days, and an inch or more may fall during a storm. Most of the precipitation in the valley is in the form of rain. Snow falls occasionally, but it usually melts within a few hours. In the high San Gabriel and Tehachapi Mountains much of the winter precipitation occurs as snow, which remains on the ground for longer periods.

The precipitation during the dry season is irregular. It usually occurs in thunderstorms in which the fall may be only a fraction of an inch, but occasionally the fall is very great in a short time. The summer rainfall is not of much value to crops, because it is so slight and irregular, and the severe thunderstorms may do more damage than good. As the greatest precipitation occurs in the winter, when the plants use a minimum quantity of water, the water must be stored either in the soil, in artificial surface reservoirs, or in the natural underground reservoir composed of the water-bearing sand and gravel that underlie the valley.

The records, as adjusted to the long-term period, for stations in and near the valley show that the mean annual precipitation differs considerably at different points, ranging from 18.10 inches at Monterio to 3.96 inches at Gray Mountain. It is a striking fact, however, that the mean annual precipitation is greater at stations high above sea level than at lower stations. The moisture-laden winds from the ocean, after passing over the mountains, descend to lower levels and, becoming warmer, can absorb more moisture, so that evaporation rather than precipitation takes place, or, if the air is still oversaturated, the rainfall becomes less and less at successively lower altitudes. Because of these conditions the rainfall at a given altitude in Antelope Valley is somewhat less than that at a corresponding altitude on the oceanward side of the mountains that border the valley.

Although in general the higher the altitude the greater the precipitation, this relation is not uniform for all parts of the basin. This discrepancy can best be shown by dividing the number of inches of the corrected long-term average annual precipitation for a given station by the altitude of the station in feet. The ratios thus obtained for all the stations in the basin and for the control stations around it are given in the last column of the table on page 87. These results show that the precipitation at the stations on the south side of San Gabriel Mountains and the west side of the Tehachapi Mountains (Bakersfield, Tejon ranch, Fort Tejon, Newhall, Los Angeles, and San Bernardino) is greater than at the corresponding altitudes in Antelope Valley or on the mountain slopes tributary to it, primarily because these stations are on the windward side of the mountains with respect to the moisture-bearing winds from the ocean.

Among the stations in Antelope Valley the rainfall per foot of altitude is greatest at Fairmont, and it decreases eastward and westward from that point. At the Liebre ranch, for instance, if altitude were the only factor affecting the rainfall, the average annual precipitation should be greater than at Fairmont, but in reality it is considerably less. On the east, the rainfall at Valyermo is likewise much less than at Fairmont, although the altitude is greater. The north side of the valley as a whole is much drier than the south side. These variations are probably due to local topographic features that influence the course of the rain-bearing winds from the ocean. Mr. William Dickey, of Manzana, states that the rain-bearing clouds at that place generally move from the southeast, and Mr. J. C. Knecht, of the Liebre ranch, states that the best rains there come from the south. On the other hand, near Little Rock the rain clouds generally come from the direction of the head of Soledad Canyon.

According to the theory that precipitation increases with altitude, the mean annual rainfall in the San Gabriel and Tehachapi Mountains should be considerably greater than is recorded at the nearest stations. If, for instance, the precipitation on North Baldy Peak bears the same ratio to the altitude as that at Valyermo, the mean annual precipitation at the summit would be about 28 inches. There is no means of determining the accuracy of this estimate, but it seems reasonable. The corrected long-term average annual precipitation

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in Little Bear Valley, in the San Bernardino Mountains, about 50 miles southeast of Antelope Valley, at an altitude of 5,200 feet, is 33.72 inches, and that at Bear Valley, a short distance farther southeast, at an altitude of 6,500 feet, is 36.18 inches. The ratio of precipitation to altitude at these points is greater than at Valyermo, but it is believed that the topographic conditions in the San Bernardino Mountains are more favorable for heavy precipitation than those in the region between North Baldy and Valyermo. It is considered that 30 inches is a fair figure to assume for the maximum average annual precipitation on the leeward side of the highest part of the San Gabriel Mountains. For most of the north side of the mountains it would be much less than that amount. On this basis the average annual precipitation for the entire area between Valyermo and North Baldy would be about 20 inches.

RUN-OFF

In the drainage basin of Antelope Valley perennial streams are found only in the mountains. Where the streams emerge from their mountain canyons upon the alluvial slopes most of the water is absorbed. It is only during the flood run-off following heavy rains that the streams flow very far down into the valley. Occasionally some of the water may flow to the playas (dry lakes) in the lower part of the valley, from which it disappears principally by evaporation.

Rock Creek and Little Rock Creek, which rise in the high San Gabriel Mountains, are the two largest streams in the valley. Cottonwood Creek, which rises in the Tehachapi Mountains, is probably next in size. These creeks are all mountain streams with steep grades. Amargosa Creek, which drains Leonis Valley, is probably perennial for part of its course. It is not a typical mountain stream but flows in a flat-bottomed alluvium-filled valley in which it has cut a narrow trench 10 to 20 feet deep with nearly vertical walls. This trench has been cut recently, probably as a result of uplift along the San Andreas rift. Several minor streams at the extreme west end of the valley are said to have a small perennial flow. Oak Creek, which rises in the Tehachapi Mountains, is said to be a perennial stream of fair size, but where it emerges from the mountains it is on the summit of a large alluvial fan that slopes both northeast and southeast, and it is not known whether the surface run-off goes to Antelope Valley or to Fremont Valley. Similar conditions exist in the extreme southeastern part of the valley, at the mouth of Sheep Creek Canyon.

Stream-flow measurements have been made on Rock and Little Rock Creeks. Daily gage-height readings were made on Little Rock Creek during 1896–1899, from which the run-off for these years has been computed.[8] The monthly discharge is given in the following

[8] U. S. Geol. Survey Water-Supply Paper 300, pp. 402-405, 1913.

table. The run-off year is considered as extending from October 1 to September 30. Inasmuch as the run-off for July, August, and September is small the records can be compared without great error with the precipitation records, which are given for years beginning July 1.

Monthly discharge of Little Rock Creek for 1896–1899

[Drainage area, 65 square miles]

Month	Acre-feet	Month	Acre-feet
1896		1897–98—Continued	
January	1,144	January	373
February	1,070	February	389
March	3,332	March	371
April	470	April	364
May	110	May	319
June	30	June	0
July	12	July	0
August	12	August	10
September	30	September	0
The period [a]	6,210	The year	2,930
1896–97		1898–99	
October	61	October	0
November	89	November	0
December	234	December	0
January	879	January	318
February	2,894	February	245
March	4,187	March	472
April	6,284	April	268
May	2,189	May	166
June	399	June	119
July	22.1	July	12
August	12.3	August	12
September	11.9	September	12
The year	17,300	The year	1,620
1897–98		1899	
October	338	October	0
November	411	November	0
December	350	December	61

[a] The record for October, November, and December, 1895, is lacking.

The record is complete for the three years 1896–97, 1897–98, and 1898–99. Reference to the average precipitation indices for these years in the table (p. 85) shows that in the first year, when the run-off was 17,300 acre-feet, the precipitation in the region was about 113 per cent of the long-time average but that in the other two years it was less than half of the average. A gaging station has been maintained on San Gabriel River near Azusa, Calif., from which complete records of run-off from a drainage area of 222 square miles are available from 1896 to 1926. This drainage area comprises part of the same mountain range as that drained by Little Rock Creek but lies on the Pacific slope of the range, where the rainfall is materially higher. The annual variation, however, should be roughly comparable in the two areas. The run-off during the 3-year period 1897 to 1899 on San Gabriel River was 34 per cent of the mean for the 31-year period ending September 30, 1926. On this basis the average annual run-off of Little Rock Creek would be approximately 21,000 acre-feet, or 323 acre-feet to the square mile.

Measurements of the discharge of Rock Creek have been made regularly since January 17, 1923. The monthly summaries of the records are given in the accompanying table.[9] The gaging station is in the NE. ¼ sec. 20, T. 4 N., R. 9 W., about a quarter of a mile south of the boundary line of the Angeles National Forest and about 1¾ miles southeast of Valyermo. It is above the point where Pallett Creek discharges into Rock Creek. A number of miscellaneous measurements have also been made on Pallett Creek and Rock Creek below the regular station.[10]

Monthly discharge of Rock Creek near Valyermo, January, 1923, to September, 1926

[Drainage area, 23 square miles]

1923	Acre-feet
January 17–21	391
February	844
March	1, 060
April	1, 210
May	1, 010
June	827
July	664
August	453
September	372
The period	6, 830

1923–24	Acre-feet
October	409
November	412
December	430
January	324
February	258
March	244
April	702
May	612
June	305
July	183
August	149
September	155
The year	4, 180

1924–25	Acre-feet
October	170
November	145
December	206
January	217
February	174
March	239
April	508
May	486
June	294
July	148
August	134
September	142
The year	2, 860

1925–26	Acre-feet
October	143
November	159
December	186
January	188
February	245
March	414
April	4, 680
May	2, 810
June	1, 520
July	922
August	534
September	376
The year	12, 200

The precipitation was below normal in both the years 1923–24 and 1924–25, as is indicated by the fact that precipitation indices at Los Angeles, San Bernardino, Bakersfield, and Tejon ranch ranged from only 43 to 87 per cent of the normal in 1923–24 and from 51 to 83 per

[9] Daily records are given in U. S. Geol. Survey Water-Supply Paper 570, pp. 82–83, 1923; Water-Supply Paper 590, pp. 84–85, 1928; Water-Supply Paper 610 (in press); and Water-Supply Paper 630 (in preparation).

[10] The records of these miscellaneous measurements are contained in Water-Supply Papers 531, p. 295, 1925; 610 (in press); 630 (in preparation).

cent in 1924–25. The discharge of Rock Creek in these years was undoubtedly far below the true average. In 1925–26, when the run-off was 12,200 acre-feet, the precipitation was 127 per cent of the normal at San Bernardino and 113 per cent at Los Angeles, but only 90 per cent at Bakersfield and 67 per cent at Tejon ranch. A comparison of concurrent records on Rock Creek and San Gabriel River indicates that the mean run-off of Rock Creek for the 3-year period ending September 30, 1926, was approximately 45 per cent of the long-term mean. On this basis the average annual run-off of Rock Creek would be approximately 14,500 acre-feet, or 630 acre-feet to the square mile.

Amargosa Creek, which drains Leonis Valley, is a perennial stream, but no data are available in regard to its discharge. Its drainage basin, of about 40 square miles, differs considerably from those of any of the other perennial streams, and the flow of the creek is probably affected accordingly. The highest point in the basin is more than 5,000 feet above sea level, but the slopes are on the whole much more gentle than those in the basins of Rock and Little Rock Creeks. The bottom of the valley is wide, nearly flat, and underlain by a considerable thickness of alluvial material or of disintegrated rock that is capable of absorbing much of the rain. The water table beneath much of the land in the bottom of the valley is so close to the surface that the soil is more or less moist, and evaporation takes place. Although the precipitation in Leonis Valley is doubtless as great as in any other part of Antelope Valley that lies at the same altitude, the run-off per square mile is probably not more than half as great as in the basins of Rock and Little Rock Creeks.

Estimates of the run-off of several streams in the Tehachapi Mountains were given to the writer by Mr. John C. Knecht, foreman of the Liebre ranch, and by Messrs. Leeds & Barnard, consulting engineers in charge of the construction of a reservoir on the ranch. These estimates lead to the conclusion that the total annual flow of all the streams in the Tehachapi Mountains from Oak Creek southward, which drain an area of about 65 square miles, is about 2,500 acre-feet. The run-off per square mile of Cottonwood Creek and probably of Oak Creek is believed to be somewhat greater than the average of the other streams. However, an examination of these two creeks by F. C. Ebert, hydraulic engineer, of the United States Geological Survey, and the writer showed that the run-off to the square mile is doubtless much less in the Tehachapi Mountains than in the basins of Rock Creek and Little Rock Creek. The Tehachapi Mountains are much lower than the San Gabriel Mountains and have much less precipitation. The surface slope over a large part of the southwest end of the mountains is much less than that in the Little Rock Creek and Rock Creek basins. In addition it is believed that a considerable area in the mountains at the west end is underlain by porous rocks, which absorb much of the rain, whereas in the two main drainage basins at the east end of the valley the rocks are mostly granite, which is incapable of absorbing much of the rain.

East of Rock Creek there is an area of about 45 square miles of mountainous country tributary to Antelope Valley that reaches altitudes as great as 8,000 feet. The principal drainage basin in this region is Swartout Valley, drained by Sheep Creek. It is believed that the region is sheltered from the rain-bearing winds by high mountains, such as North Baldy and Old Baldy, and that the precipitation is not as great as in the basins of Rock and Little Rock Creeks. The run-off per square mile from this region is perhaps only half as much as that from the two basins west of it.

Between Rock and Little Rock Creeks there is an area of about 20 square miles of mountainous country. This region is not very high, and its run-off per square mile is very much less than that in the Little Rock Creek basin.

Between Little Rock Creek and Amargosa Creek is another area drained by several intermittent or ephemeral streams. Most of this drainage is prevented from reaching the valley proper by a long, low ridge that lies north of the valley, along the San Andreas fault line. Some of it reaches the natural depression occupied by the Harold Reservoir and another small basin to the east. Farther east most of the run-off is absorbed by porous material in the fault valley, producing ciénaga conditions in an area where much of the water evaporates. It is believed that there is a small flow from the ciénaga lands into the main part of Antelope Valley. The run-off per square mile from this area is small. Several short intermittent or ephemeral streams drain the north slopes of Sawmill and Liebre Mountains, and the run-off from this area likewise is small.

Fairmont, the point in the valley at which the greatest average annual precipitation is recorded according to the table on page 87, is situated at the northwest end of Portal Ridge. The streams that drain Portal Ridge are short, and the contribution per square mile from this ridge is not great.

The average annual run-off from all parts of the mountainous area that surrounds Antelope Valley is roughly estimated, on the basis of the fragmentary information above given, to be about 75,000 acre-feet.

GROUND WATER

IMPORTANCE OF GROUND-WATER SUPPLY

About 80 per cent of the land at present irrigated in Antelope Valley receives its water supply from wells. (See p. 326.) The total area of land in the valley that is level enough to be farmed is about

500,000 acres. Ground water—that is, water recovered by means of wells—is contained in the alluvial deposits that underlie practically the whole of this large area, but in about half of the area the depth to water is so great that under present economic conditions the water can not be profitably pumped for irrigation. It is estimated that in about 275,000 acres the depth to the water table is not more than 150 feet. Under present economic conditions in southern California, however, only products that bring high cash returns per acre, such as apples, pears, and other fruits, can be raised where the pump lift is greater than 100 feet.

The ultimate limiting factor, however, is not the depth to the water table, but the quantity of water that is available. A great volume of water is stored in the alluvial deposits that underlie the valley, but if enough water were pumped from this ground-water reservoir to irrigate 275,000 acres the water level would soon be lowered so far that pumping for irrigation would be unprofitable. In the long run pumping must not exceed intake.

OCCURRENCE OF GROUND WATER

The water that is pumped for irrigation in Antelope Valley occurs in the alluvial deposits—clay, sand, and gravel. The mountains and hills that surround the valley are composed of rocks that are practically impervious to water. These rocks form a basin which is nearly water-tight and which contains a great accumulation of porous alluvial deposits that are capable of holding a large volume of water. A part of the water that falls as rain on the alluvial deposits or that is carried by the mountain streams upon these deposits sinks into them and becomes ground water. The alluvium is essentially a great underground reservoir in which the run-off from the mountains is stored.

It is believed by some people that the ground-water supply of the valley comes from some distant source, such as the Sierra Nevada, north of the valley. In particular it has been said that the water comes from Mount Whitney, 125 miles north of Lancaster, and other high mountains that are tributary to Owens Valley, reaching Antelope Valley by underground channels that are supposed to exist in the rocks which lie between that region and Antelope Valley. Despite efforts made in the previous report by the Geological Survey [11] to correct these mistaken ideas as to the source of the water supply, the erroneous notions have persisted and are still advocated by some persons. It is therefore considered necessary to point out again why they are fallacious.

[11] Johnson, H. R., Water resources of Antelope Valley, Calif.: U. S. Geol. Survey Water-Supply Paper 278, pp. 59–61, 1911.

Practically all the run-off on the west side of the high Sierra is carried by Kings, Kaweah, Tule, and Kern Rivers and other streams into San Joaquin Valley. That on the east side is carried to Owens Valley and farther south to Indian Wells Valley and Fremont Valley. Each of these valleys is inclosed by rocks that are as impervious as those that surround Antelope Valley. The water table is 100 to 300 feet lower in Fremont and Indian Wells Valleys than in Antelope Valley. (See pp. 162, 217.) Therefore, even if the rocks between the basins were permeable the ground water in Antelope Valley would drain into Fremont Valley rather than receive any acquisition from that valley or from Indian Wells Valley. It is true that the water table in Owens Valley is several hundred feet higher than in Antelope Valley, but there is no way for water from Owens Valley to reach Antelope Valley unless it follows channels that penetrate the solid rock mass of the Sierra Nevada. It is inconceivable that fissures or other channels sufficiently large to carry water to Antelope Valley could exist in the granitic rocks that compose the Sierra, parallel to the trend of the range, without the coexistence of fissures in other directions that would permit the leakage of the water to the lower lands on the east, or to San Joaquin Valley on the west, which is more than 1,000 feet below Antelope Valley.

Similarly, the valleys that lie south and east of Antelope Valley are lower than this valley, so that if the rocks that surround the valley were not impervious, the movement of water would be away from it and not toward it. It is obvious that there can be no contribution of any consequence to the ground-water reservoir of Antelope Valley from sources outside of its drainage basin. Essentially all of its supply comes from the rain and snow that fall within the boundaries of its own basin.

Much of the water is absorbed by the alluvium and sinks downward until it reaches a level below which the alluvium is completely saturated, all the interstices between the rock particles being filled with water. If a hole is sunk into this zone of saturation water will flow into the hole, making it a well. The upper surface of the zone of saturation is called the water table.

The water table is not a horizontal surface. Its shape is governed by the nature and structure of the alluvium, the source of the water, the areas of discharge, and other conditions. Well data indicate that the water table is nearly horizontal in the central part of Antelope Valley but that it rises gradually toward the mountains. It is highest in the alluvial fans near the mouths of the canyons from which emerge such streams as Rock Creek and Little Rock Creek. (See pp. 336–338 and figs. 11 and 13.)

The water table is highest beneath the upper parts of the principal alluvial fans because the greatest supply of water is added to the ground-water reservoir where the principal streams pour out from the mountain canyons upon the porous gravel. The body of ground water seeks to reach a uniform level and moves from these upper levels toward the central part of the valley. Its movement through the alluvium is very slow, and consequently the water table does not quickly become a level surface. If there were no precipitation in any part of the valley for a number of years, so that there would be no addition to the ground water, it would have an opportunity to reach an equal level throughout the valley, and the water table would become practically horizontal. As a result of precipitation, however, a new supply of water is added each year, and as the greatest addition occurs on the fans of such streams as Little Rock Creek the water table stands highest in such places. During the dry summer the ground water of the alluvial fans moves slowly toward the center of the valley and the water table beneath the upper parts of the fans falls, only to rise again when the ground-water supply is replenished by the heavy rains of the following winter. Fluctuations of the water table are discussed further on pages 326–335.

ARTESIAN CONDITIONS

In the lower parts of Antelope Valley, the beds near the surface are composed of clay and silt, which act as a nearly water-tight cover over the underlying water-bearing beds and tend to prevent the water from rising to the surface. These beds extend for some distance up the alluvial slopes, confining the ground water under them. As the water table is higher beneath the alluvial slopes than in the bottom of the valley it exerts hydrostatic pressure on the water beneath the confining beds. If a well is drilled through the confining beds to the water-bearing beds the water will rise in the well under hydrostatic pressure. If the well is in the lower part of the valley the water may rise high enough to overflow at the surface, producing a flowing well, or if the casing is extended upward the water may rise to a level several feet above the surface. If the well is drilled on the alluvial slope a short distance above the lowest part of the valley, the water may rise in the well but not high enough to reach the surface. The conditions that give rise to wells of either kind are called artesian conditions. The conditions that result in flowing wells are shown in Figure 11.

Many flowing wells have been obtained in Antelope Valley, some of which yield large quantities of water without pumping. Wells near Rosamond Dry Lake are reported to flow at the rate of 100 miner's inches (about 2 second-feet, or 900 gallons a minute). In a well drilled for the Southern Pacific Co. at Oban, 5 miles north of Lancaster, the water rose 22.5 feet above the surface upon its completion in 1910. Artesian conditions in the valley are described in some detail in Water-Supply Paper 278.

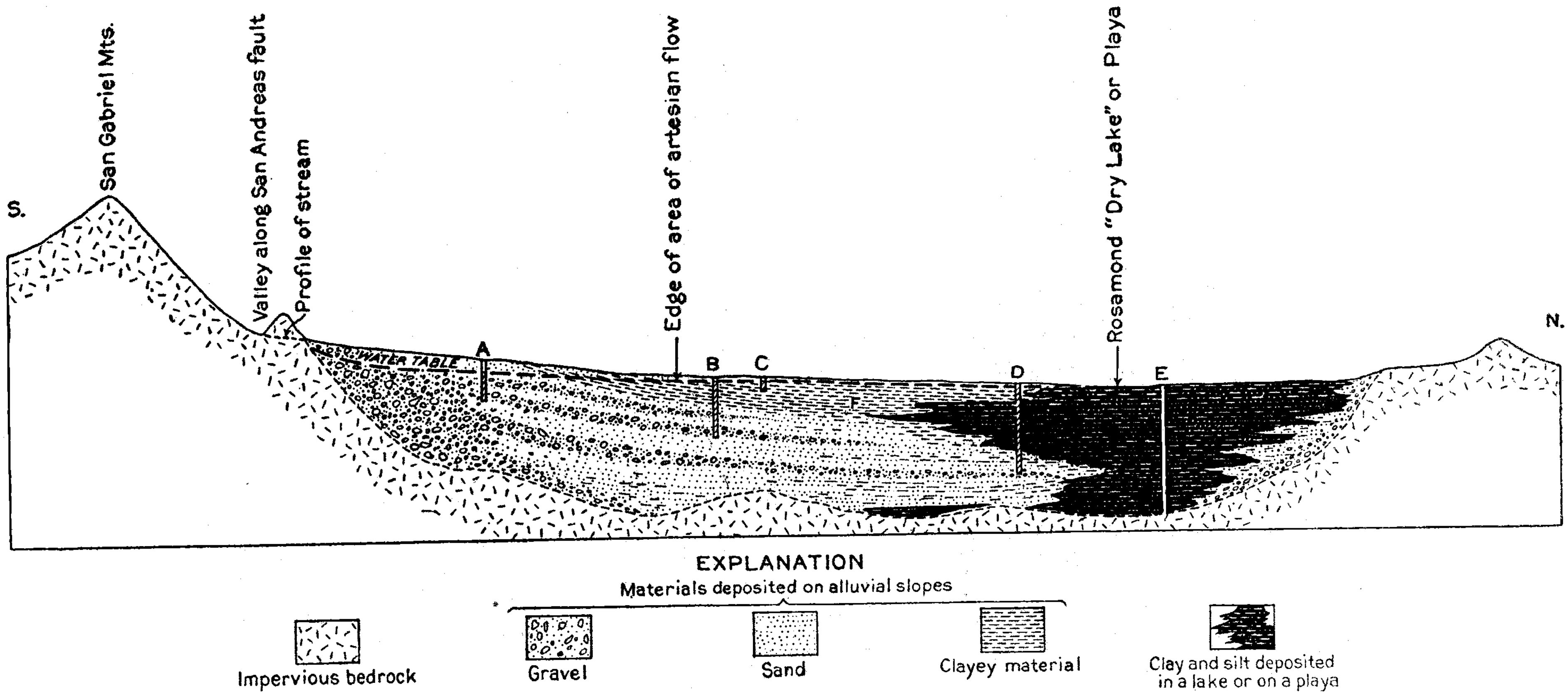


FIGURE 11.—Diagrammatic section across Antelope Valley from south to north, showing occurrence of ground water. Heavy dashed line is water table. The bed of clayey material, F, is relatively impervious and holds the water beneath it under pressure. A is an ordinary pump well. B is a flowing well near the edge of the area of artesian flow, penetrating gravel below the playa clay. C is a shallow well in the area of artesian flow, but it will not flow because it does not reach a water-bearing bed below F. D is a flowing well that obtains its supply from a deep gravel bed. E is a dry hole, drilled to bedrock entirely through silt and clay too impervious to yield any water

In Plate 19 the approximate boundary of the area of artesian flow is given. In part of the region two lines are shown—one the boundary as it was in 1909, as shown on the map in Water-Supply Paper 278, and the other the boundary as indicated by data obtained by the writer in December, 1919, and January, 1920. There is some uncertainty as to the original boundary northwest of Lancaster, for several wells that were represented on the map in Water-Supply Paper 278 as being situated in the area of artesian flow are said never to have flowed. The position of the boundary in the winter of 1919–20 was not determined for the entire area.

The water level in artesian wells is subject to fluctuations, like that in other wells. If the pressure is weak the well may cease to flow during the summer and begin to flow again in the fall or winter. If the pressure is strong the only evidence of fluctuation may be a slight decrease in the volume of flow.

QUANTITY OF GROUND WATER AVAILABLE

The alluvium-filled basin of Antelope Valley has already been likened to a surface reservoir. In any surface reservoir there is discharge by surface outflow, underground leakage, or evaporation, and the same is true of a ground-water reservoir. During a long period of years the average annual inflow into the ground-water reservoir, which may be called the recharge, will be about equal to the average annual discharge. Although there may be minor fluctuations from season to season, if the average inflow is greater than the quantity used for economic purposes and that lost by leakage in various ways, the reservoir will overflow, and if it is less the reservoir will be drained. The most desirable condition is that as much water be used as possible without exceeding the average annual recharge.

GROUND-WATER RECHARGE

SOURCES

The conditions that affect the recharge of the ground-water reservoir may best be summarized by the following quotation from Meinzer:[12]

> Contributions to the underground supply are made at the localities where the following three conditions exist: (1) The formations lying between the surface and the water table are not water-tight; (2) the water from rain or snow is applied in sufficient quantity to percolate to the water table without being entirely absorbed by the capillary pores of the dry zone between the surface and the water table; and (3) the water table is not already at the surface. These three conditions are provided most fully on the upper parts of the alluvial fans, where water is poured from the mountains upon gravelly deposits through which it can percolate freely to the water table. They are largely wanting in the

[12] Meinzer, O. E., Geology and water resources of Big Smoky, Clayton, and Alkali Spring Valleys, Nev.: U. S. Geol. Survey Water-Supply Paper 423, pp. 78–79, 1917.

mountains, where nearly impervious bedrocks are near the surface, and in the lower parts of the valley, where the soil is too tight to admit water freely and where over large areas the water table is so near the surface that water is being discharged from the valley fill instead of being taken in.

Contributions to the water in the valley fill are made by (1) the perennial streams that flow out of the larger canyons; (2) the floods discharged at long intervals from the canyons which are normally dry; (3) the underflow of some of the canyons; (4) the rain that falls in the valley; and (5) water discharged underground from openings in the bedrocks.

CONTRIBUTIONS FROM RUN-OFF

The water that is carried by the streams from the mountains out upon the alluvial slopes is disposed of in two ways—some of it percolates to the water table and replenishes the ground-water supply, and the remainder evaporates before it reaches the water table. As Antelope Valley is a closed basin no water is carried away from the valley on the surface. However, in wet years considerable surface water may reach the playas, where it evaporates without getting below the surface.

The largest contribution to the ground water comes from the perennial streams, most of it from Rock Creek and Little Rock Creek (see fig. 13) and less from Amargosa Creek and several streams at the west end of the valley. Although the run-off from Sheep Creek is probably considerable, the position of the alluvial fan upon which it empties is such that a large part of the water, either surface or underground flow, goes eastward toward Mohave River and does not reach Antelope Valley.

The run-off from more than half of the mountainous area is not carried by perennial streams but by streams that flow only after rains. The flow from these streams largely sinks beneath the surface, but most of it goes to wet the soil and is evaporated or taken up by plants before it reaches the water table. In ordinary years the contribution to the ground-water reservoir by these intermittent or ephemeral streams is very small, but in exceptionally wet years they may furnish an appreciable amount of ground water. About 7,000 acre-feet of the flow of the perennial streams was used in 1919 for irrigation and was not available for recharge except as it percolated downward after it had been applied to the irrigated land. (See p. 326.)

CONTRIBUTIONS FROM UNDERFLOW

The coarse water-bearing alluvium extends some distance up the canyons and fills them to considerable depths. Surface water may enter the alluvium several miles above the mouth of the canyon, percolate down the canyon, and reach the main ground-water reservoir without again appearing at the surface. Evidence of the existence of this underflow is seen about a mile above the mouth of the canyon of Little Rock Creek, where the Little Rock Irrigation District has built a low concrete dam that presumably reaches bedrock. At times when the creek is dry for a long distance above and below the dam a small pool of water stands just behind the dam and a considerable stream flows continually from this pool into the irrigating ditches.

Measurements made by J. B. Lippincott in June, 1896, near the place where the submerged dam was later built showed that at that time the water was percolating through the gravel at the rate of about 2.16 feet an hour, or 3.53 miles a year.[13] The submerged dam is 368 feet wide and 11 feet 8 inches high. If the cross section through which the water percolates were equal to that of the dam and the rate of flow were that given above, the underflow in one year would be a little less than 2,000 acre-feet. As the dam extends above the creek bed, the cross section of the underflow is probably not as great as that of the dam, but, on the other hand, the season of 1895–96, when the measurements were made, was unusually dry.

It is probable that a considerable quantity of water is discharged as underflow by Rock Creek. The lower mile of its canyon is filled with coarse alluvium, which must contain a large quantity of water. Attempts have been made at various times to recover some of this underflow by a tunnel driven through solid rock to a point near the place where the road from Little Rock to Valyermo crosses the creek, where it is turned under the gravels. The yield from this tunnel is said to be about 100 miner's inches (about 1,500 acre-feet a year), but the underflow has never been developed to its full capacity.

There is probably some underflow in the canyons of Oak, Cottonwood, and Amargosa Creeks. It is said that in the summer water ceases to flow at the surface in Cottonwood Canyon as far upstream as Knecht's ranch, 6 miles or more above the mouth of the canyon. Much of it sinks into the alluvium and continues downstream as underflow. The exact conditions in Oak Canyon are not known, but it is understood that most of the surface flow enters the alluvium some distance above the mouth of the canyon. In January, 1920, practically no water was flowing in Amargosa Creek where it emerges from the pass at the east end of Portal Ridge, although a stream was flowing farther up the canyon. It is probable that most of the runoff from Swartout Valley, east of Rock Creek, enters the alluvium of the main part of the valley as underflow, for Sheep Creek is shown on the topographic map as an intermittent stream, and the alluvial deposits extend for some distance up the canyon.

CONTRIBUTIONS FROM PRECIPITATION IN THE VALLEY

Some of the rain that falls on the valley may percolate to the water table. The rainfall on the valley lands is low, and the quantity that falls in a single storm is ordinarily not great. The lower part of the

[13] Schuyler, J. D., Reservoirs for irrigation: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 4, p. 714, 1897

valley is largely underlain by a clayey soil which absorbs water very slowly, and most of the rain that falls on such soil remains near the surface until it evaporates. Furthermore, in most of the area in which flowing wells exist the water table is so close to the surface that discharge rather than absorption is the dominant process. Outside the area of artesian flow the soil is more permeable, and percolation may occur. A large part of the precipitation that enters the soil is, however, taken up by the yuccas and other plants that cover the alluvial slopes. After exceptionally heavy storms some of the precipitation doubtless reaches the zone of saturation.

CONTRIBUTIONS FROM BEDROCK

The rock formations in the mountains are nearly impervious, and the quantity of water that enters them is so small that any contribution to the ground-water reservoir by percolation from this source is probably negligible. The only region where there might be much percolation is on the south side of the valley, where faulting has produced a series of valleys, some of them undrained, behind Portal Ridge and the low hills that form a continuation of this ridge toward the east. Although the surface material of Portal Ridge consists of comparatively loose, porous soil, exposures at several points indicate that solid rock occurs at no great depth. It has been suggested that the faulting might have so greatly shattered the rock ridges that separate the valleys along the fault line from the main part of the valley that water from these closed valleys could percolate into the alluvium of the main valley. The very fact, however, that ciénagas are found at several points in the fault valley and especially the presence of Elizabeth and Hughes Lakes constitute evidence that there is not much seepage, for otherwise the lakes and ciénagas would be drained.

CONCLUSION

It has been estimated that the total run-off from the mountain areas into Antelope Valley averages about 75,000 acre-feet a year. A large part of the run-off from perennial streams is added to the ground-water supply, but only small quantities of water from the ephemeral streams and from rainfall in the valley reach the water table. It is roughly estimated that from all sources an average of about 50,000 acre-feet a year is added to the ground water.

GROUND-WATER DISCHARGE

The contributions to the ground-water supply are about balanced during a period of years by losses from the ground-water reservoir. The natural losses occur chiefly in three ways—by evaporation where the water is brought to the surface in springs or by capillary action; by transpiration by plants; or by percolation out of the basin through underground passages. Moreover, water is withdrawn from the ground-water reservoir through flowing wells and by pumping. Estimates of the amount of discharge by the different processes would serve as a basis for estimating the quantity available for irrigation.

DISCHARGE FROM SPRINGS

A number of springs exist in the drainage basin of Antelope Valley. Many are in the mountains on the south and west sides of the valley, but the water from these mountain springs does not come from the main ground-water reservoir beneath the valley, and hence their discharge does not represent a loss from the main ground-water supply.

Several springs discharge water from the main ground-water reservoir. The Willow Springs, about 8 miles west of Rosamond, which probably form the largest group of springs in the valley, are estimated to flow about 100 acre-feet a year. Other springs are Buckhorn Springs, about 12 miles east of Rosamond; Lovejoy Springs, about 16 miles east of Palmdale; and Moody Spring, about 20 miles east of Palmdale.

DISCHARGE FROM SOIL AND PLANTS

To determine accurately the area in which discharge by evaporation is occurring, it would be necessary to make numerous borings with a soil auger or to measure shallow wells to find where the water was close enough to the surface to be within the limit of capillary rise. The writer did not have opportunity to do this work. Studies in other regions of the desert, however, have shown that certain surface conditions are fairly reliable evidence of discharge by evaporation, and some of these conditions are present in Antelope Valley.

Where evaporation has continued for a long time deposits of alkali may be seen at the surface. The alkali was held in solution in the ground water, and as the result of long-continued evaporation the mineral matter has been left on the surface as a deposit.

The presence of the water table within a few feet of the surface is also shown by certain plants which are found almost exclusively in areas where the water table is near the surface. One of the most reliable of these plant indicators is salt grass (*Distichlis spicata*). Where salt grass is the predominating vegetation the depth to water is usually not more than 8 feet. Such plants discharge ground water. The plant roots reach down to the capillary fringe and perhaps even to the water table and draw up the water, giving it off into the air through pores in the leaves, a process known as transpiration.

The presence of alkali on the surface and of salt grass shows that discharge of ground water by evaporation and transpiration is taking place at a number of places, involving a large acreage in the lower part of Antelope Valley. It is noteworthy that evidence of such discharge is found at many places within the area of artesian flow but with minor exceptions is generally absent outside of that area. There is, therefore, some suggestion that the discharge is related to the artesian conditions. However, the fact that the indications of discharge are not everywhere present in the area of artesian flow raises a question as to whether the loss is from the artesian supply or only from the surface zone that is separated from the artesian aquifers by relatively impervious clay. If it is a loss from the artesian aquifers it will probably be reduced as the head on them is lowered by an increase in the use of water for irrigation. On the other hand, if it is a loss from the surface zone no great reduction may result with greater use of water, and conceivably it may increase; for the water level may be raised by additional return seepage from irrigation which the underlying clay will prevent from reaching the artesian aquifer.

On the south side of Lovejoy Buttes, about 15 miles east of Palmdale, the water table is close to the surface and there is evidence of discharge, but the area of discharge is not great. Salt grass was observed at a number of places in Leonis Valley, in the fruit valley between the Harold Reservoir and Little Rock Creek, and at other places, but at these places the discharge is not from the ground-water reservoir of the main part of the valley.

In experiments in Owens Valley Lee [14] found that when the water table was at the surface the evaporation and transpiration from a salt-grass area in one year was about 62 inches and that the evaporation decreased at a nearly uniform rate with the depth of the water table and ceased entirely at a depth of about 7½ feet. Climatic records indicate that the evaporation is fully as high in Antelope Valley as in Owens Valley. The total area in Antelope Valley in which there is discharge by evaporation and transpiration is unknown, but from the writer's observations it is considerable, and there must be a substantial loss of ground water by these processes.

PERCOLATION OUT OF THE BASIN

North of Rogers Dry Lake, the divide between Antelope Valley and Fremont Valley is not very high above the dry lake, and although rock hills are present on both sides, the divide for a distance of about a mile is probably composed of alluvium. If a perennial lake ever covered Rogers Dry Lake it may have overflowed at this point into Fremont Valley.

At Muroc the water table is lower than it is farther south in the valley, and at the north end of the playa, as nearly as can be deter-

[14] Lee, C. H., The determination of safe yield of underground reservoirs of the closed basin type: Am. Soc. Civil Eng. Trans., vol. 78, pp. 181–196, 1915; An intensive study of the water resources of a part of Owens Valley, Calif.; U. S. Geol. Survey Water-Supply Paper 294, pp. 53–64, 1912.

mined in several wells, it is still lower, indicating that the water table slopes toward the north. In the vicinity of Redman School, in T. 8 N., R. 10 W., where the altitude is more than 2,300 feet the water rises to the surface. In December, 1917, it flowed several feet above the ground in a test hole for potash (well 6 in table on p. 348 and pl. 19) drilled on Rogers Dry Lake near the center of sec. 20, T. 9 N., R. 9 W., where the altitude is about 2,275 feet above sea level. The depth to water in the Atchison, Topeka & Santa Fe Railway well at Muroc is about 33 feet and the altitude of the ground about 2,285 feet; the altitude of the water table is about 2,255 feet. In well 4, in the northeast corner of the NW. ¼ sec. 6, T. 19 N., R. 9 W., the depth to water is about 90 feet, and it is about the same in well 3, in northeast corner of sec. 34, T. 11 N., R. 9 W. As nearly as can be determined the altitude of the surface at these wells is not much over 2,300 feet, and the altitude of the water table is probably between 2,210 and 2,240 feet. These conditions are shown in Figure 5. The slope of the water table toward the north seems to indicate that the water is percolating northward under the alluvium into Fremont Valley.

The water table in Fremont Valley is much lower than in Antelope Valley. The depth to water in well 55 (see pl. 16 and table on p. 222), about 2 miles east of Desert Butte, in T. 12 N., R. 10 W., in January, 1920, measured 199 feet. The surface at this well is believed to be not more than 2,375 feet above sea level and the altitude of the water table not more than 2,175 feet. The water table in wells northwest of this well is even lower. (See fig. 5.) It is therefore evident that a rock barrier exists below the alluvial surface at the divide which acts as a submerged dam holding up the water table in Antelope Valley but which may allow some ground water from Antelope Valley to waste underground into the valley to the north.

The boundary of the drainage basin at the northwest corner of the valley is formed by an alluvial fan that has been built out in front of the canyon of Oak Creek, and at the southeast corner of the valley it is formed by a similar fan in front of the canyon of Sheep Creek. In each region, however, the water table, as shown by depth to water in wells, is higher than it is in the lower part of the valley, indicating that the ground water moves toward the lower level in the valley and not out of the drainage basin.

QUANTITY OF WATER USED FOR IRRIGATION

Estimates of total consumption of water for irrigation in Antelope Valley, from both surface and underground sources, are summarized in the accompanying table. The figures for quantity of water applied in irrigation, commonly called duty of water, are based on information given by a number of ranchers. They are average figures and do not represent extreme quantities used on different tracts of land.

Estimate of water used for irrigation in the drainage basin of Antelope Valley, 1919

Source of supply and locality	Area (acres)	Principal crop	Quantity applied in irrigation (acre-feet per acre)	Total consumption of water (acre-feet)
Supply obtained from wells				
Electric power plants mostly near Palmdale	1, 555	Fruit	1⅓	2, 100
Electric power plants mostly near Lancaster	6, 855	Alfalfa	4	27, 400
Gasoline power plants	300	do	4	1, 200
Supply obtained from streams:				
Little Rock district	1, 600	Fruit	1⅓	2, 100
Palmdale district	700	do	1⅓	900
Longview	350	do	1⅓	500
Llano	150	do	1⅓	200
	150	Alfalfa	4	600
Valyermo and Pallett ranches	300 (?)	Fruit	([a])	3, 100
	11, 960			38, 100

[a] Total quantity used is based on statement of estimated continuous flow diverted during irrigation season.

The water obtained from flowing wells for irrigation is not included in the above estimates, but the quantity is probably not great. Where the flowing wells have sufficient head to yield supplies adequate for irrigation without pumping, the soil generally contains so much alkali that not much land is under cultivation. Much artesian water, however, is wasted. This waste probably amounts to several thousand acre-feet a year.

According to the data presented above, in 1919 about 31,000 acre-feet of ground water was pumped annually for irrigation, and about 7,000 acre-feet was obtained from streams. Some of the water, however, percolated downward and returned to the water table, so that the net draft on the ground-water reservoir was not as great as stated.

FLUCTUATIONS OF THE WATER TABLE

ANNUAL FLUCTUATIONS

The water table rises during or shortly after the rainy season. The rise is generally greatest on the higher portions of the alluvial fans near the mouths of the mountain canyons, where the water is added to the alluvium in the rainy season faster than it can move through the sand and gravel to lower levels, and it is least in the lower central part of the basin. The nature and amount of these seasonal fluctuations are illustrated by measurements made in four wells at approximately monthly intervals from November, 1915, to November, 1916, by E. W. Martin, of Little Rock, which are given on page 327. The fluctuations are shown graphically in Figure 12. All these wells are in or near the wash of Little Rock Creek, near the point where it emerges from its mountain canyon upon the alluvial slope.

Water levels in wells near Little Rock Creek

[Measurements by E. W. Martin]

Date	Depth to water below reference point (feet)			
	Littleton well [a]	Kellerman well [b]	Keyes well [c]	Holloway well [d]
1915				
Nov. 6	33.3	52.6	13.5	15.4
Dec. 2	43.3	[b] 54	Dry.	15.7
1916				
Jan. 4	35	[b] Dry.	1.6	10.7
Feb. 1	21.8	26.3	(c)	10.5
Mar. 17	20.7	28.3	0	10.7
Apr. 3	19.3	27.4	------	10.3
May 2	18	32	2	11
June 6	23	40	5	14
July 1	23	45	10	15
Aug. 1	30	50	13.5	15.5
Sept. 8	23.8	52	Dry.	16.5
Nov. 6	37	47	Dry.	15.3

[a] Littleton well (No. 139 on pl. 19), in southeast corner SW. ¼ NW. ¼ sec. 14, T. 5 N., R. 11 W. A drilled well 1.3 feet in diameter, about 43 feet deep. Reference point for measurements, top of casing 1.5 feet above ground. On Jan. 9, 1920, the depth to water, measured by the writer, was 39.8 feet below the reference point.

[b] Kellerman well (No. 140), approximately in NE. ¼ SW. ¼ sec. 14, T. 5 N., R. 11 W., about 75 feet from bank of Little Rock Creek. The well is dug 54 feet deep. It was nearly dry on Dec. 2, 1915, and completely dry on Jan. 4, 1916. Reference point, nail in curb about 18 inches above surface of ground.

[c] Keyes well (No. 141), near northeast corner of sec. 22, T. 5 N., R. 11 W., close to bank of creek. Reference point is a piece of pipe that projects from curb about 15 inches below surface of ground. Well could not be measured Feb. 1, 1915, because of high water in creek. Well is 14 feet deep.

[d] Holloway well (No. 142), near northwest corner of sec. 23, T. 5 N., R. 11 W., close to bank of creek. Reference point, surface of ground.

The measurements were made during a year of unusually heavy rainfall, and hence both the high and low water levels were probably higher than during normal years. Nevertheless they show the general fluctuation, the water being highest in the winter or early spring and lowest in the late summer or fall. The marked rise in the Keyes well between December 2 and January 4 was due to heavy rains in the later part of December. From 6 to 8 second-feet of water was flowing in the creek at that time. The well is close to the creek bank and practically within the canyon, being dug in the alluvium that fills the canyon. It responds very quickly to the flow of the stream. In contrast to it is the Kellerman well, which on January 4 was dry. It is farther from the stream channel, and the water that percolated through the alluvium from the stream had not reached the well. Water ceased flowing in the stream as far as the Littleton well about April 11. Annual fluctuations are shown by somewhat less detailed observations on a number of wells, the records of which are given on pages 364–371.

Ranchers in different parts of the valley have observed fluctuations of the water table in the different seasons of the year. A. C. Whidden stated that on his ranch in secs. 9 and 16, T. 7 N., R. 13 W., the difference between the maximum and minimum height of the water table is about 12 feet.

The water table reaches its highest and lowest levels in different parts of the valley at different times, but in general it is highest late in winter or in spring just before irrigation is begun and lowest in the late summer or fall, near the end of the irrigation period, when

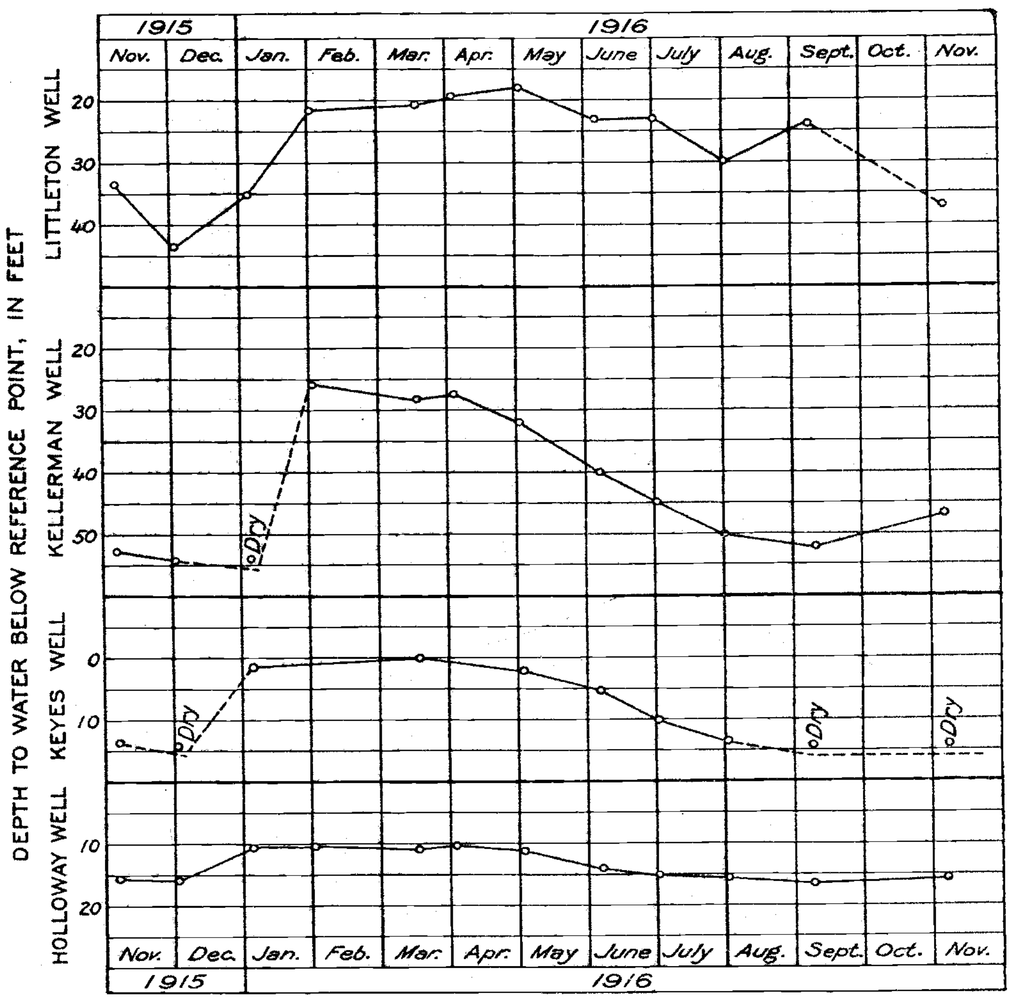


FIGURE 12.—Fluctuation of water table in wells near Little Rock Creek, Antelope Valley, November, 1915, to November, 1916

the heavy pumping produces some of the change in level. There are, however, exceptions to this statement.

E. B. Wargren, whose ranch is in the SW. ¼ NE. ¼ sec. 21, T. 7 N., R. 12 W., stated that the water in his well reaches its lowest level and begins to rise about the later part of September. A. Z. Wilson stated that at his ranch in the southeast corner of sec. 2, T. 7 N., R. 11 W., the water begins to rise in the pump pit in June, although at the same time the pumping lift apparently continues to increase and the yield decreases for several weeks. The apparent rise in the water table is evidently due to the return seepage of water from irrigation. Such a condition has been observed in other irrigated regions. This seepage water may be prevented from reaching the principal water-bearing bed by impervious layers. In support of the theory that this rise is due to seepage from the surface Mr. Wilson gave the following evidence. A reservoir a few hundred feet from Mr. Wilson's well does not hold water readily. When the reservoir was filled the water seeped out, and in one week the water in Mr. Wilson's pump pit rose 2 feet. In a well at the reservoir the water rose 4 feet. It subsided in both wells after the reservoir was empty. A. C. Whidden stated that in his wells in secs. 9 and 16, T. 7 N., R. 13 W., the lowest level is reached during July and the water begins to rise during the later part of that month, while the pumping is the neighborhood is as heavy as at any time. The conditions here are probably similar to those cited by Mr. Wilson. In the wells near the mouth of Rock Creek Canyon the lowest level was not reached until December—that is, later than in most parts of the valley. This lag may be partly accounted for by the fact that no wells are pumped within a radius of several miles, and hence the effect of reduced pumping is eliminated.

SECULAR FLUCTUATIONS

Fluctuations before 1920.—In addition to its annual fluctuations the water table moves slowly up and down during longer and more irregular periods, owing chiefly to series of wet and dry years. Heavy pumping tends to lower it.

The testimony of well owners in the valley as to whether there has been any marked change in the water table during recent years is to a certain extent conflicting. Some stated definitely that there has been a gradual lowering of the water level; others stated that they have noticed no change; and a few stated that the water level in 1919 was higher than during the preceding few years. Many well owners did not know whether the water level in their wells had changed and apparently had not given the matter any thought, although it really is of much importance. Usually the pumps are installed in such a manner that the depth to water can not be readily observed. If the water rises the owner has no indication of the fact, nor even if it falls, unless the drop is so great as to reach the suction limit or is revealed by a great increase in his power bill or a decrease in the discharge of the pump. Even if any of these indications are observed they are sometimes attributed to mechanical trouble in the pump and not to a lowering of the water level. The desirability of measuring the depth to the water level, from time to time, can not be too strongly urged on the owner.

Several well owners have observed that the water in pump pits rose earlier or to a higher level than in past years. The return seepage of irrigation water causes a rise of the ground water in the upper beds while at the same time the level of water in the beds that yield the strongest supply may still be low. In a dry season irrigation is often begun earlier than in normal years and more water is applied to the land. It would therefore not be surprising that in a a dry year like 1919 the level of the water in the upper beds would rise earlier or to a higher level than during normal years. On the whole, the information from well owners indicates a lowering of the water table both within and outside the area of artesian flow.

The proprietor of the hotel at Rosamond stated that in 1919 the water was about 2 feet lower in his well (No. 21) than in 1918. The depth to water, as measured by the writer on January 12, 1920, was 25 feet below the top of the casing, about 8 inches above the ground. This well probably is No. 69 in Water-Supply Paper 278, for which the depth to water was given as 15 feet. If not the same well it is very close to that well, and evidently the water table has dropped. A few hundred feet south of it a well at an old saloon, which is said to have been owned formerly by a Mr. Simpson and to be the well designated No. 267 in Water-Supply Paper 278, was dry in January, 1920, at a depth of 19 feet below the surface. The depth to water in 1909 was given as 16 feet. This well apparently has been partly filled up.

The Southern Pacific Railroad has a flowing well (No. 37) at Oban, in the NE. ¼ sec. 21 or NW. ¼ sec. 22, T. 8 N., R. 12 W., which is so arranged that the water rises naturally into an elevated tank for supplying engines. F. M. Worthington, division superintendent of the railroad, stated in a letter that in 1910 the water in this well rose 22 feet 6 inches above the surface of the ground, in 1918 it rose 19 feet, and in 1920 it rose 17 feet 6 inches. He did not say whether the tests were made at approximately the same time each year, but presumably the height given for each year is the maximum height at which the water stood at any time during that year. The railroad also has a well at Lancaster in which the water stood at the surface when drilled in 1914 and 2 feet below the surface in 1920.

Mr. L. M. Huntington, superintendent of the P. D. Gaskill ranch, in the SW. ¼ sec. 35, T. 8 N., R. 13 W., stated that in 1919 the water in the well (No. 20) was about 8 feet lower than in previous years. This year was the first in which it was necessary to prime the pumps. When the well is not being pumped the water stands about 22 feet below the surface. On the map in Water-Supply Paper 278 this place is shown as inside the area of artesian flow. If this map was correct when made, the drop in the water level since 1909 would be more than 22 feet, but there is some question whether this part of the region was within the area of artesian flow. Two wells in the section that adjoins the Gaskill ranch on the south, Nos. 88 and 89 in

Water-Supply Paper 278, were indicated on the map in that report as flowing wells, but in the table on pages 74 and 75 of that report the depth to water is given as 7 and 7¾ feet, respectively, and they are both referred to as "nonflowing artesian" wells. Mr. Huntington stated that the depth to water in well 89 (in Water-Supply Paper 278), owned by F. A. Ingersoll, is now 22 feet. Evidently the water table in this well has dropped considerably.

Mr. A. C. Whidden, owner of the Portland ranch, in the NE. ¼ sec. 16 and the N. ½ sec. 9, T. 7 N., R. 13 W., stated that, as far as he could determine, the water table dropped on the average about 1 foot a year in the nine years prior to 1920. It was not possible to measure his wells (Nos. 51, 52, and 53), but there is evidence that the drawdown increases each year. It has become necessary to prime the pumps earlier in the year than formerly.

Mr. Harry Austin, who has drilled many wells in the valley, stated that wells 42*a* to 42*c* (in Water-Supply Paper 278), in the N. ½ sec. 2, T. 7 N., R. 13 W., ceased flowing for the first time in 1919. On the Reese Snowden ranch, in the NW. ¼ sec. 11, a short distance south of the wells mentioned above, the depth to water in a well 225 feet deep (No. 56) was 3 feet 8 inches when measured on January 16, 1920. In Water-Supply Paper 278 wells on this ranch and also wells farther west were noted as flowing wells. Evidently the area of artesian flow has been reduced in size in this vicinity.

Mr. H. A. Prendel, whose well (No. 62) is in the SW. ¼ NE. ¼ sec. 24, T. 7 N., R. 13 W., stated that his well began to flow later in the fall of 1919, the flow was smaller than usual, and the pumping lift during the irrigation season was apparently greater. The maximum drawdown on the vacuum gage during the pumping season in 1928 was equivalent to 22 inches of mercury. In 1919 it was 23 inches, which indicates a difference in the water level of about 1 foot. In previous years the water rose high enough to begin flowing usually in October, but in 1918 it did not flow until the later part of November, and in 1919 not until the early part of December. About 1916 the well was changed so that the discharge pipe was about 4 feet above ground, and at that time it flowed from 10 to 15 gallons a minute. When visited by the writer on January 10, 1920, it flowed at the same level not more than 2 gallons a minute. This well is near the edge of the area of artesian flow. Mr. Prendel stated that when he came to the region about 1910 a well (No. 61) about half a mile west of his place flowed 5 or 6 miner's inches. On January 10, 1920, the water stood in this well about 6 inches below the surface. This well is evidently No. 247 in Water-Supply Paper 278. The well when measured by the writer was 211 feet deep.

Mr. E. B. Wargren, whose ranch is in the SW. ¼ NE. ¼ sec. 21, T. 7 N., R. 12 W., stated that when his well (No. 69) was drilled in

1914 the water barely flowed at the surface. In January, 1920, it was about 3 feet below the surface.

On January 14, 1920, the depth to water in an 8-inch well (No. 67) on the E. T. Earl ranch, near the northwest corner of sec. 36, T. 7 N., R. 13 W., as measured by the writer, was 79 feet below the floor of the pump house. Mr. J. A. White, superintendent of the ranch, stated that in April, 1918, the depth to water in a 16-inch well only a few feet from the 8-inch well was 72 feet. As the water in both wells is considered to stand at practically the same level it was about 7 feet lower in 1920. It should be noted, however, that the higher level was recorded in April, when the water table is probably at its maximum level, and perhaps in January, 1920, the water had not yet reached its highest point. Mr. White stated that in 1918 the 16-inch well was pumped dry several times. In 1919, however, the pump yielded more water. The low level of the water in 1918 was attributed to the effect of an earthquake. Although this may have been the cause it is more likely that the real cause was a lowering of the water table, which rose again in 1919.

Mr. Donald Graham, resident manager of the Guy C. Earl ranch, in the NW. ¼ sec. 35, T. 7 N., R. 13 W., stated that the drawdown of his wells during the irrigation season has gradually increased. As indicated by a vacuum gage in 1913, it was equivalent to 20 inches of mercury (about 23 feet) and in 1919 to 26 inches (about 29 feet), which is an average drop of about 1 foot a year.

The depth to water in well 48, near the center of sec. 14, T. 7 N., R. 14 W., as measured by the writer on December 18, 1919, was 147 feet below the top of the casing, which is about 1 foot above the surface. This is evidently well 35 of Water-Supply Paper 278, in which the depth to water is given as 120 feet.

Mr. J. L. Meder stated that on his brother's ranch, in the NE. ¼ NW. ¼ sec. 13, T. 7 N., R. 12 W., the crops were originally irrigated from flowing wells (No. 74) without pumping, but it is now necessary to pump. The wells still flow in the winter but not as much as formerly.

The depth to water in a well (No. 85) on the J. B. Nourse ranch, at the southwest corner of sec. 12, T. 7 N., R. 11 W., as measured by the writer on January 15, 1920, was 13 feet below the surface. This is well 77 of Water-Supply Paper 278 and flowed when it was drilled in 1906. Mr. Nourse believes that the pumping lift has increased in the last four years, basing his statement on his yearly power consumption since he began using electricity. In 1916 Mr. Nourse lowered his pump 8 or 9 feet.

Mr. A. Z. Wilson, whose ranch is in the southeast corner of sec. 2, T. 7 N., R. 11 W., stated that the water table in the summer is now about 10 feet lower than when he settled in the valley in 1907. One of his wells (No. 84), when it was drilled in July, 1907, flowed about 6 miner's inches. The well has flowed every winter until the season of 1919–20, but the flow was less each year. On January 15 the well had not begun to flow, and Mr. Wilson did not believe it would flow. Soon after the well was drilled a centrifugal pump was installed, being set at the ground level. It has since been necessary to lower the pump, setting it in a 12-foot pit. The writer was informed that it has been necessary to lower the pumps in several other wells in the vicinity of the Roosevelt School, but he did not have an opportunity to obtain detailed information in regard to conditions in that part of the valley.

Mr. Grant Frakes for several years irrigated about 5 acres of alfalfa in sec. 30, T. 8 N., R. 10 W., from a flowing well (No. 45) without pumping. For the last three years the flow has ceased during part of the summer. In 1919 there was no flow from about July 1 to about November 1. The flow from this well was originally about 25 miner's inches.

Mr. Charles Eberts, who has installed and repaired many pumps in the valley and hence has been in a position to observe conditions in different parts of it, expressed the opinion that the water table had been lowered from 3 to 10 feet in the six years ending in 1919, although the water in the upper alluvial beds had risen several feet in some wells, owing to the return seepage from irrigation.

Several other persons reported that the pumping lift had increased 10 to 12 feet since their wells were drilled. Two of these wells are situated several miles east of Lancaster, in the Roosevelt district, and two others about 4 miles southeast of Palmdale, in a region of comparatively new development.

Some of the lowering is doubtless due to deficient precipitation in the four years prior to 1919, but most of it is apparently due to the draft on the supply for irrigation. It is manifestly impossible for so great a quantity to be pumped from the ground-water reservoir without affecting the water table. The consumption has increased more or less regularly in recent years. The several years of deficient precipitation have had a cumulative effect in reducing the recharge in proportion to the discharge, for not only has the recharge each year been less than in normal years but the consumption has been greater for a given area because in dry years irrigation is usually begun earlier than in normal years.

Fluctuations in 1920–1926.—After the writer's investigation in January, 1920, it was realized that periodic measurements of the depth to water in a number of wells were necessary to determine the true nature of fluctuations of the water table. Unfortunately funds were not available to permit observations as frequently as desirable, but a considerable number of measurements have been made which yield valuable information. Mr. N. S. Abbott, a citizen of Lancaster who has installed many pumps in the valley, has measured about 25 wells from two to five times a year since 1921. The writer expresses his appreciation of the service thus rendered by Mr. Abbott. Beginning in October, 1924, measurements of the same wells have been made twice a year by F. C. Ebert or H. G. Troxell, of the United States Geological Survey. These observations have been made early in the spring, when the water table is about at its highest point, and in the fall, when it is about at its lowest point. The records of depth to water are given on pages 364–371. The locations of the wells, with numbers corresponding to those in the tables, are shown on Plate 19.

To judge from observations in other investigations in which automatic recorders were used to obtain a continuous record of water levels, the seasonal rise or fall of the water level may be interrupted by fluctuations as pumps on other wells are stopped or started. Furthermore, the lowest and highest levels reached each season are affected by several factors that vary from year to year, such as amount of precipitation and its time of occurrence. The difference in precipitation from year to year may affect the water level directly in so far as it affects recharge of the ground-water reservoir; and indirectly in that pumping for irrigation may be necessary earlier or later in some years than in others. Because of these variable conditions, it is unlikely that the water level reaches its lowest or highest level at exactly the same time each year. It is highly desirable that automatic water-level recorders be installed on several observation wells to obtain continuous records of the movement of the water level, from which the highest and lowest points reached each year can be determined.

All the wells show more or less seasonal fluctuation, the water level being lower in summer than in winter. The amount of fluctuation ranges from a few inches in wells 48 and 163, to 41 feet in well 160. Several of the wells have a seasonal range of more than 10 feet, notably Nos. 59, 61, 155a, 160, and 169. These are all near wells that are pumped regularly during the irrigation season, and the great lowering of the water level in them in the summer is obviously due to pumping of the near-by wells. There is no conclusive evidence of any definite trend from 1921 to 1925. In the summer of 1926, however, lower water levels were observed in every well for which the records are complete than at any previous time during the period of the observations with the exception of well 48. Furthermore, in 8 out of 17 wells measured in 1927, including well 48, the water level was lower than in any previous year.

The difference between the lowest level in the summer of 1926 and the previous lowest level ranged in different wells from 0.6 foot to

12.8 feet. In three wells it was between 5 and 10 feet, in six wells it was between 1 and 5 feet, and in four wells it was 1 foot or less. The difference between the low levels of 1927 and those of 1926 was mostly less than 1 foot.

It appears that only a moderate decline in the water level occurred in 1926 and 1927, and this is believed to be due in part to some increase in draft and in part to deficient precipitation.

RECENT DEVELOPMENTS OF GROUND WATER

Many new wells have been drilled in different parts of Antelope Valley since the first report on the water resources of the valley was published.[15] As a result of the drilling of some of these wells conditions were revealed that had not been previously known. The trend of the new developments in different parts of the region is given briefly in the following pages.

In the central part of the valley the new developments have taken place largely around the border of the area of artesian flow, either extending a short distance inside the boundary of the area or reaching a mile or two away from it. In this territory alfalfa is the principal crop. Few new wells have been drilled in the interior of the area of artesian flow doubtless because it is not adapted to alfalfa. The greatest lift observed by the writer where water was pumped for alfalfa was about 70 feet, in the northwestern part of T. 8 N., R. 13 W., but throughout most of the valley water for alfalfa is not pumped more than 50 feet. The land rises more gradually toward the east and west than toward the south, and it is perhaps for this reason that more new wells have been drilled around the east and west margins of the flowing-well area. A large number of wells have been drilled west, northwest, and north of Esperanza School. Many have been drilled 4 or 5 miles east and southeast of Lancaster, and a large number within a radius of several miles of the Roosevelt and Redman Schools. The depth to water directly east of the flowing-well area is nowhere very great.

The depth to water in the well of William H. Brooks (No. 89), in the SE. ¼ sec. 10, T. 7 N., R. 10 W., is only 25 feet. In well 91, in the NW. ¼ sec. 20, T. 7 N., R. 9 W., belonging to W. T. Graham, it is about 80 feet. This is nearly at the eastern limit of the irrigable area, for rock hills rise beyond it. Few wells seem to have been drilled southwest of Lancaster, probably because the land rises more rapidly in that direction, and the pumping lift increases rapidly. In the lower part of the valley most of the wells drilled years ago were only 4, 6, or 8 inches in diameter. At many places new wells of larger diameter have been drilled to replace the old ones.

[15] Johnson, H. R., Water resources of Antelope Valley, Calif.: U. S. Geol. Survey Water-Supply Paper 278, 1911.

Many new wells have been drilled northeast of Palmdale and between that town and Little Rock. In Water-Supply Paper 278 only a few wells were shown in and near Palmdale, and these were used principally only for domestic purposes or manufacturing. The depth to water was supposed to be too great to permit the use of the wells for irrigation. In recent years several wells have been drilled between Palmdale and Little Rock in which the depth to water was found to be much less than was supposed. The depth to water in the upper part of the alluvial fan of Little Rock Creek is slight near the mouth of the canyon of the creek and increases for some distance to the northwest, north, and northeast of the mouth of the canyon. In well 39, the Littleton well, a few feet northwest of the bridge over Little Rock Creek, in the NW. ¼ sec. 14, T. 5 N., R. 11 W., the depth to water on January 9, 1920, was 38 feet. (See p. 327 for data on fluctuations of the water level in this well.) The depth to water increases for some distance to the northwest, north, and northeast. West of Little Rock Creek, in the NE. ¼ sec. 9, T. 5 N., R. 11 W., the depth to water in well 138, belonging to Robert Stuart, is reported to be about 90 feet. In well 111, owned by John Boyle, in the southeast corner of the SW. ¼ sec. 32, T. 6 N., R. 11 W., the depth to water is said to be about 100 feet. In well 110, near the southwest corner of the NW. ¼ sec. 31, T. 6 N., R. 11 W., owned by Carl W. Lorenz, the depth to water is reported to be 146 feet, and in well 101, in Palmdale, just east of the Palmdale Inn, owned by the Palmdale Land Co., the depth to water as measured by the writer on January 7, 1920, was 245 feet.

Not only does the depth to water increase northwestward from the mouth of the canyon of Little Rock Creek, but it also increases to the north and northeast, for some distance. The depth to water in well 107, in the SE. ¼ sec. 21, T. 6 N., R. 11 W., owned by George B. Otis, is reported to be about 165 feet, and in other wells near this the depth to water is nearly as great. It is worthy of note that granite was struck in this well at a depth of about 300 feet. So far as is known rock was not reached in any other wells in this vicinity. On the Rowland ranch, in sec. 14, T. 6 N., R. 11 W., about 5 miles north of the Littleton well, the depth to water is reported to be 117 feet. In the well of E. W. Martin (No. 143), in the NW. ¼ sec. 12, T. 5 N., R. 11 W., about a mile northeast of well 39, the depth to water when drilled in August, 1918, was 86 feet. The depth to water in well 16, in the NW. ¼ sec. 28, T. 6 N., R. 10 W., owned by J. Hintermann, is said to be 125 feet. About 1½ miles northeast of this the depth to water in well 117, in sec. 22, owned by Mr. Bowland, is said to be about 75 feet. Many other wells have been drilled east and southeast of Palmdale, but these need not be discussed in detail.

The water table is so close to the surface near the mouth of the canyon of Little Rock Creek apparently because so much water is poured out onto the gravel and absorbed near the head of the alluvial fan. The water after it reaches the saturated zone does not move rapidly toward the lower part of the basin, and the result is a piling up, so to speak, of the water near the mouth of the canyon. If no water were added to the ground water beneath the fan for several years, it would have an opportunity to spread out and reach a uniform level. Because the water table stands so much higher under the alluvial fan of Little Rock Creek it is probable that during a period of extra dry years the water level will drop more in that locality than in the lower part of the valley, where the water table is more nearly level. It is also possible that the water table would return to or nearly to the original level in a single winter of exceptionally heavy and advantageously distributed rainfall.

The influence of discharge from the water table of Little Rock Creek in building up the water level beneath its fan are shown in three profiles in Figure 13. Profile B extends along a line almost due north from the mouth of Little Rock Creek, and shows how the water table beneath the alluvial cone rises more than 400 feet above its level in the lower part of the valley. Along profile A, which extends from the mouth of the creek northwestward through Palmdale, the water table slopes rather steeply for some distance from the mouth of the cone. In this profile the water table in well 96 is represented to be slightly higher than in well 101. This may be due partly to inadequate data in regard to the altitude of the surface at the wells. However, it is also probably due in part to the fact that there is a buried rock ridge, of which Quartz Hill is a part, which acts as a barrier to the northward movement of water, so that the water stands at a higher level behind it than at corresponding altitudes farther to the east and west. Profile C extends along a line extending from the San Gabriel Mountains northward through Palmdale—that is, it is between the mouths of Little Rock and Amargosa Creeks.[16] In contrast to the other two profiles, which extend from the mouth of Little Rock Creek, profile C shows that the water table does not rise steeply near the mountains but has only a gradual slope, with little doubt because there is no important contribution to the ground-water reservoir in this part of the valley.

The recent development of the ground-water supply on the upper part of the alluvial slope, between Palmdale and Little Rock, has been due in a large measure to the high returns received from the pear and apple orchards in the Little Rock irrigation district, where the water supply is obtained from Little Rock Creek. The prices

[16] The contour interval on the Elizabeth topographic map, on which the surface profile is based, is so large that the valley occupied by the Harold Reservoir is not shown.

received for the fruits produced in these orchards are sufficient to justify high pumping lifts, much greater than can be borne in alfalfa growing. The lands nearer the mountains that are irrigated by ground water are therefore devoted almost entirely to pear and apple orchards. In the four or five years prior to 1919 several hundred acres of trees had been set out, and in 1919 the oldest were

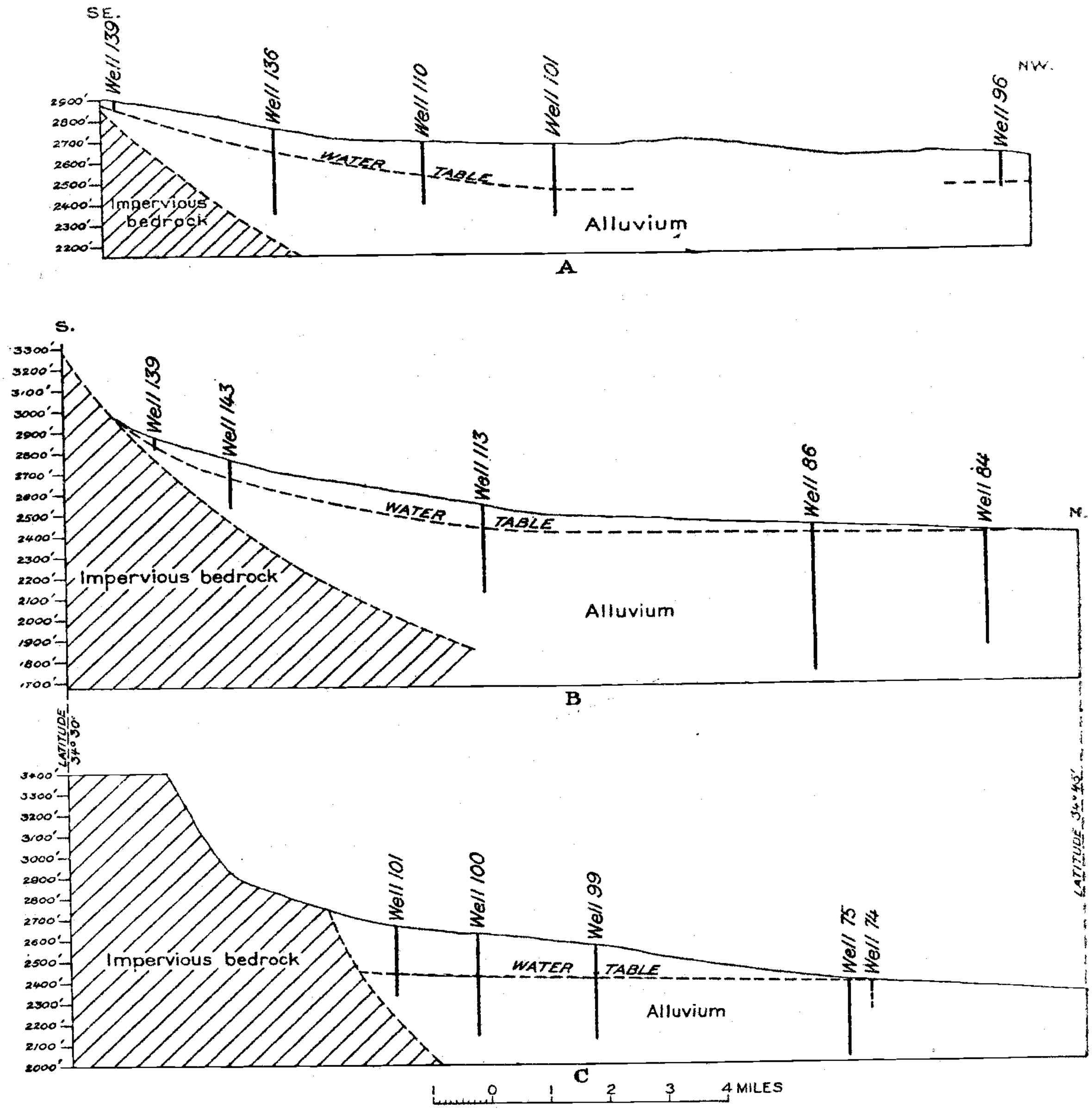


FIGURE 13.—Sections showing effect of discharge from Little Rock Creek, Antelope Valley, in building up the water table. A, Profile from mouth of Little Rock Creek northwestward through Palmdale; B, profile northward approximately along longitude 118°; C, profile along a line from north to south through Palmdale

just reaching the bearing stage. The pumping lifts in this part of the valley range from 100 feet to as much as 160 feet.

Conditions similar to those on the fan on Little Rock Creek probably exist on the fan of Rock Creek, but fewer data are available in regard to the latter region. The lift in well 145, in the Longview colony, owned by G. C. Chase and believed to be in sec. 25 or 26, T. 5 N.,

R. 10 W., is reported to be about 50 feet. The only other information obtained was in regard to wells nearer Lovejoy Buttes. The depth to water in well 120, in the S. ½ sec. 28, T. 6 N., R. 9 W., owned by E. E. Reinsberg, was reported to be about 28 feet. Farther north, near the south side of the buttes, the water stands very close to the surface, producing a ciénaga around Lovejoy Springs. One well near the springs, owned by Alexander Stewart, flows, and in another the depth to water is only 2 feet.

The nearness of the water table to the surface in this vicinity is evidently due to the presence of the Lovejoy Buttes, which act as a barrier behind which the water is held, for north of the buttes the depth to water is much greater. J. C. McGowan reports that in his well (No. 94), in the SE. ¼ SW. ¼ sec. 34, T. 7 N., R. 9 W., the depth to water is 100 feet. In the well of Aaron C. Huff (No. 121), near the northwest corner of sec. 18, T. 6 N., R. 8 W., the depth to water is 165 feet. The barrier apparently continues as a buried rock ridge eastward from the Lovejoy Buttes toward Gray Mountain, for data collected in 1917 by G. A. Waring, of the United States Geological Survey, show that the water table in secs. 13 and 14, T. 6 N., R. 8 W., was only 30 to 50 feet below the surface. (See wells 122–125, pp. 358–359.) Additional data are presented in a recent report on water for irrigation in Upper Mohave Valley,[17] which adjoins Antelope Valley on the east. On Plate 1 of that report, contours of the water table show that the water table is higher immediately south of Gray Mountain than to the east. Apparently a part of the ground water that comes from the flow of Sheep Creek is held back by the rock hills in the vicinity of Mirage Dry Lake and is diverted westward along the south side of the buried ridge between Gray Mountain and the Lovejoy Buttes. If this is true, the depth to water along the south side of T. 6 N., R. 8 W., would not be very great.

Northwest of Palmdale the distance between the flowing-well area and the foot of the mountains is short and the land rises rapidly. Accordingly, the depth to water increases rapidly from the flowing-well area toward the mountains. In well 98, owned by W. R. Cowan, in the southeast corner of the NE. ¼ NE. ¼ sec. 4, T. 6 N., R. 12 W., only 3 miles from the flowing-well area, the depth to water was 150 feet when the well was drilled in 1914. The pumping lift in this well was estimated by the driller to be 180 feet when the yield was 30 miner's inches (270 gallons a minute). In well 67, on the E. T. Earl estate, in the northwest corner of sec. 36, T. 7 N., R. 13 W., the depth to water, as measured by the writer on January 14, 1920, was 79 feet.

[17] McClure, W. F., and others, Report on the utilization of Mojave River for irrigation in Victor Valley, Calif.: California Dept. Engineering Bull. 5, pp. 54–55, pl. 1, 1918.

South of Quartz Hill, in sec. 6, T. 6 N., R. 12 W., no good wells have been obtained. Well 97, near the northeast corner of the NE. ¼ sec. 1, T. 6 N., R. 13 W., south of Quartz Hill, struck hard rock at 77 feet. Water was found at 76 feet, but the quantity is small, and it was estimated by the driller that the well would not pump more than 5 or 6 miner's inches (45 to 54 gallons a minute). In well 96, about 1½ miles southwest of this, probably in the SW. ¼ sec. 2, T. 6 N., R. 13 W., on the ranch of Dr. W. Winnard, hard rock was struck at about 125 feet. The water stood about 130 feet from the surface when the well was completed in January, 1920. The quantity was said to be only enough for domestic use. About half a mile northwest of Doctor Winnard's well hard material was struck in well 95, on the place of Fred Godde, at a depth of 137 feet. Water was found at 96 feet, and when drilling was finished it stood at about that depth. The quantity available is apparently not great.

It is not certain whether the material called "rock" in the Winnard and Godde wells is granite, or other unweathered igneous rock, or whether it is material derived from the weathering of such rocks, which has been cemented together. At any rate, it apparently is not very porous and does not yield much water. It is also perhaps significant that there is no stream in this locality like Little Rock Creek which might pour out a large quantity of water to build up the water table.

There has been practically no development by irrigation in the west or northwest part of the valley. In January, 1920, the writer observed only one or two ranches that were irrigated west of the road between Del Sur and Willow Springs. This condition is due largely to the fact that the depth of water increases toward the mountains. The depth to water in well 30, near the northeast corner of sec. 30, T. 8 N., R. 13 W., as measured by the writer on January 16, 1920, was 56 feet. The depth to water in well 26, owned by R. A. George, near the southeast corner of sec. 14, T. 8 N., R. 14 W., is reported by the driller to have been 90 feet when the well was finished in August, 1918. According to the report by Johnson,[18] the depth to water in a well in the NW. ¼ sec. 6, T. 8 N., R. 14 W., is 140 feet. In the same report the depth to water in a well (No. 25 on pl. 19) in sec. 10, T. 8 N., R. 16 W., is given as 200 feet. The depth to water in a well 2½ miles west of that well, in sec. 6 of the same township (well 24, pl. 19), is given as only 94 feet. The reason for this difference is not known, but it is believed that in the well where the depth to water is only 94 feet the supply comes from a local bed which is perched above the main water table. This belief is supported by information supplied by C. H. Windham in

[18] Johnson, H. R., Water resources of Antelope Valley, Calif.: U. S. Geol. Survey Water-Supply Paper 278, p. 70, well 9, 1911.

regard to a well drilled for oil (No. 23, pl. 19) on the Liebre ranch, approximately near the center of sec. 27, T. 9 N., R. 17 W. Water was not encountered in this well until a depth of 530 feet was reached, and it rose within about 400 feet of the surface but could be bailed down. According to the topographic map this well is not more than 300 feet above the well in sec. 6, T. 8 N., R. 16 W., and yet the altitude of the water table is apparently lower than in the well on lower ground. Normally it would be more likely that the water table would be higher nearer the mountains. It has been shown earlier in this report that there is no great contribution to the water table by streams at the west end of the valley, and for this reason it is not surprising that the depth to water is great, for there is no "piling up," so to speak, of the water such as occurs on the alluvial fan of Little Rock Creek.

Several wells have been drilled west and northwest of Willow Springs, but so far as is known none of them have been used for irrigation. Mr. Fred M. Hamilton, owner of Willow Springs, states that in well 15, drilled by him in the SE. ¼ SE. ¼ sec. 1, T. 9 N., R. 14 W., water was struck at 67 feet and rose within 57 feet of the surface. In well 13, on the place of John Lane, in the NE. ¼ sec. 4 of the same township, the first water was struck at 275 feet. Another water-bearing bed was struck at 550 feet, and the water rose within 250 feet of the surface. On Mr. Naquin's place, in the NW. ¼ sec. 8, T. 9 N., R. 13 W., north of the lava butte that lies east of Willow Springs, the depth to water in well 16 is said to have been 47 feet.

A number of wells have been drilled on the nearly level lands that lie between the lava buttes north of Rosamond (called the Rosamond Buttes), Soledad Mountain, and hills north of the Atchison, Topeka & Santa Fe Railway. So far as can be determined from the topographic maps the region is a part of the Antelope Valley drainage basin, but the ground-water conditions are probably not comparable with those in the main part of the valley. It is likely that the depth to impervious non water-bearing rocks is at no place very great, and the topography is such that there is no source for any large contribution to the ground-water supply. Besides the rainfall in the immediate region, the only other possible contribution may be a part of the run-off from Oak Creek.

Near the southwest corner of sec. 24, T. 10 N., R. 12 W., the depth to water in an 8-inch well (No. 10) owned by I. J. Sopp, is about 40 feet, and the total depth of the well is 75 feet. The well is equipped only with a windmill and is used for irrigating a small patch of alfalfa. Another well (No. 11), on the D. H. Walker ranch, in the NW. ¼ NE. ¼ sec. 26 of the same township, is reported to yield 30 miner's inches, with a lift of about 90 feet. The water is used to irrigate 20 acres of apple trees. A well (No. 9) on the place of R. A. Canning, near the northwest corner of sec. 18, T. 10 N., R. 11 W., is 150 feet deep, and the depth to water is about 50 feet. The well is equipped with a windmill, and the water is used to irrigate about 5 acres of fruit trees and a small patch of alfalfa. On the place of Mr. Rathbun, in sec. 34, T. 11 N., R. 11 W., in well 8, which is 300 feet deep, the depth to water is reported to be 70 feet. Rock was struck within 60 feet of the top, and the water comes in from crevices. The yield is small, estimated at about 100 barrels in 24 hours. In another well (No. 7) owned by Mr. Rathbun, probably in sec. 4, T. 10 N., R. 11 W., the depth to water is reported to be 70 feet. The total depth is 200 feet. The yield of this well is also small. It is reported that the water in both of Mr. Rathbun's wells is slightly salty. Other wells are located in this region, but no information was obtained in regard to them.

Several wells have been drilled at the north end of Rogers "Dry Lake," but not much information was obtained in regard to them. Well 3, on the place of H. M. Meckley, in the NE. ¼ sec. 34, T. 11 N., R. 9 W., is 260 feet deep, and the depth to water is reported to be 90 feet. With the pump running to its full capacity this well is said to have yielded 35 miner's inches with a 2-foot drawdown. The owner believes that the well will furnish 65 miner's inches if equipped with a larger pump. E. F. Edinburgh has a well (No. 4) in the northeast corner of the NW. ¼ sec. 6, T. 10 N., R. 9 W., which is 280 feet deep. The depth to water is 90 feet. The well had not been tested when the information was obtained by the writer in December, 1917. The depth to water in well 5, owned by the Atchison, Topeka & Santa Fe Railway, at Muroc, is only about 30 feet. Although definite information is not available in regard to the relative altitude of the ground surface at Muroc and at the wells at the north end of the "dry lake," it is believed that the water table is lower at the north end of the lake than at any other place in the valley, and that there is percolation northward into Fremont Valley. (See p. 325.)

The possible contribution to the water table from precipitation in the region around the north end of Rogers Dry Lake is small. It is not definitely known whether the deposits underlying the playa are all clay or silt, and therefore so impervious that ground water from the main part of the valley can not move to beds that underlie the north end of the playa. However, in well 6, drilled near the center of sec. 20, T. 9 N., R. 9 W., on the playa, as a test for potash, water-bearing gravel, which yielded a strong flow of water, was struck at a depth of less than 145 feet. It is quite probable that there is free communication between the water-bearing beds at the north end of the "dry lake" and those beneath the main part of the valley.

QUALITY OF WATER

Analyses of several samples of water are published in Water-Supply Paper 278 (p. 57), and analyses of 6 samples collected by the writer are given in the accompanying table. In addition, in Water-Supply Paper 278 (pp. 70–89) the total solids as determined by conductivity measurements are given for samples from 180 other wells. These analyses indicate that water suitable for domestic use and irrigation can be obtained from deep wells almost anywhere in the valley. All but two of the 12 waters analyzed are classed as either fair or good for domestic use, boilers, and irrigation. The total dissolved solids range from 158 to 766 parts per million, but only two samples contained more than 330 parts. The water which contained 766 parts per million (No. 69) was obtained from a shallow well only 15 feet deep, and alkali is abundant on the surface a short distance from the well. It is hard but not unsuitable for drinking or irrigation.

Analyses of ground waters in Antelope Valley, Calif.

[Parts per million]

No. on pl. 19 [a]	Date of collection	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total dissolved solids at 180° C.
6	Dec. 13, 1917	27	0.21	6.1	1.9	[b] 94	9.1	158	71	6.2	0.78	301
59	Jan. 10, 1920	39	.07	36	8.3	[b] 27	.0	150	9.5	16	33	255
65	Jan. 10, 1920	35	.06	46	11	[b] 48	.0	150	88	28	12	346
69	Jan. 14, 1920	40	.07	157	23	75	.0	364	127	77	61	766
86	Jan. 13, 1920	23	.07	21	2.2	[b] 29	1.7	107	19	10	.50	158
148	1908	45	.86	5.7	1.8	154	9.6	325	55	29	.0	460
149	1908	52	.84	5.1	6.2	102	19	196	54	65	.64	330
150	1908	16	.08	40	7.0	54	.0	176	44	25	7.0	283
151	1908	39	.05	36	12	41	.0	146	31	18	30	267
152	1908	39	.07	23	3.7	25	6.0	96	25	5.5	1.7	161
(c)	1908	25	.25	44	9.1	54	.0	155	101	19	-------	312
(d)	Dec. 13, 1917	46	.06	9.3	1.7	[b] 82	.0	164	59	8.6	.48	281

[a] For additional data see corresponding map number in table on pp. 348–363.
[b] Calculated.
[c] Not numbered on map. Willow Springs, sec. 11, T. 9 N., R. 14 W.
[d] Not numbered on map. Buckhorn Springs, sec. 27, T. 9 N., R. 10 W.

Analysts: No. 6 and Buckhorn Springs, A. T. Geiger; Nos. 59, 65, 69, and 86, M. D. Foster; Nos. 148–152 and Willow Springs, Walton Van Winkle.

Of the 185 samples from wells listed in Water-Supply Paper 278 only 19 contained more than 300 parts per million of total solids and only 2 contained more than 500 parts per million. In general, the water obtained from shallow wells is more highly mineralized than that from deeper wells. This is especially true in the area of artesian flow, where the water table is so close to the surface that more or less alkali has been deposited at and near the surface as the result of evaporation. The concentration of alkali in the soil may extend down a number of feet, or surface water containing alkali may seep into the well. The water from deep wells near and on the playas is nearly as good as that from wells some distance from them, despite the presence of alkali at the surface. Water that contained only 301 parts per million of solids was obtained at a depth of less than 150 feet in a well (No. 6) drilled as a test for potash near the center of sec. 20, T. 9 N., R. 9 W., on Rogers Dry Lake. This drilling did not penetrate any beds of salt or gypsum.

WELL CONSTRUCTION

Drilling in Antelope Valley is done by the hydraulic rotary and the mud-scow or California methods.

In the fine deposits that underlie the lower parts of the alluvial slopes the hydraulic rotary method is commonly used. The hole is not cased until it is drilled the entire depth or until the diameter is reduced. To prevent caving before the casing is inserted the water that is forced into the hole is laden with mud, which fills the porous alluvium and acts as a lining. Unperforated casing is usually inserted to a depth of 50 feet or more, and perforated casing of small diameter in the rest of the well. The casing is perforated before it is inserted.

In the coarse bouldery deposits that underlie the upper parts of the alluvial slope the mud-scow method is used. A sand bucket or mud scow, consisting of a long iron pipe with a sharpened edge, is commonly used for both loosening and removing the material, but if large boulders are encountered the drilling may be done with a heavy iron bit. To prevent caving the casing must be driven down as the hole progresses and is perforated after it is inserted in the well. It may be perforated throughout, but usually it is perforated only where good supplies of water were struck when the hole was drilled. If because of inaccurate measurements the casing is perforated a little too high or too low, the water supply may be much less than if the measurements were carefully made.

If the water is under artesian pressure and the casing is perforated for most of its length, the pressure at different horizons may be different and the water from one bed may be forced into another. In several wells 500 to 600 feet deep the water level stood 5 to 15 feet or more above the level of the water in wells only half as deep.

Most of the wells that were drilled during the early development of the valley were only 6 or 8 inches in diameter. In recent years most of them have been 10 or 12 inches, and a few as large as 16 inches. One reason for the larger wells has been the increase in the use of deep-well turbine pumps.

PUMPING PLANTS

Three general types of pumps are used in Antelope Valley. In the upper parts of the alluvial slopes, where the lift is great, reciprocating or cylinder pumps are much used. They are especially adapted to pumping rather small supplies of water for fruit orchards. In the lower parts of the alluvial slopes, where the lift is not great, and especially in the area of artesian flow centrifugal pumps of both horizontal and vertical types have been used to a great extent, the pumps usually being set in pits. In the last few years the drop of the water table has made it necessary to lower a number of the centrifugal pumps, and this required the deepening of the pump pits. To avoid additional expense from this trouble many of the well owners have installed deep-well turbine centrifugal pumps, which are placed in the well casing at any desired depth. These pumps are also well adapted to use where the lift is great, as in the fruit-raising districts.

Probably 90 per cent of the irrigation wells are pumped by electricity, most of the rest being too far from the transmission lines to warrant the expense of connecting them. Practically all the plants that are not operated by electricity are run by internal-combustion engines that use the cheaper grades of fuel known as "tops" and distillate.

CONSERVATION OF WATER SUPPLY

The information presented in this report shows that the available water supply is not sufficient to irrigate all the tillable land in the valley; but it is believed that the safe yield of the ground-water reservoir has not yet been reached. Nevertheless, conservation of the water supply is necessary if the maximum use of the water is to be obtained. In some other areas, notably the Santa Ana and San Gabriel Basins, the ground-water supply has been increased by a process called water spreading, which consists of spreading the flood water over a large territory, thus increasing the area of the surface where percolation may occur.[19] In Antelope Valley most of the run-off is spread naturally over the alluvial fans, so that the benefits to be attained by artificial spreading probably would not be great. Possibly some of the water that occasionally reached the playas, where it is evaporated, might be added to the ground-water reservoir by spreading.

Losses of ground water may be reduced by reducing the natural losses and the waste through wells. The natural loss by evaporation and transpiration probably will be reduced as increased pumpage causes the water level to be lowered. This condition will also reduce somewhat the loss by percolation out of the basin, if there is any. One very practical means of increasing the irrigation supply is by eliminating needless waste from flowing wells, many of which are allowed to flow freely throughout the year, although no use is made of the water. (See pl. 18, *B*.) This waste amounts to at least

[19] Lee, C. H., Subterranean storage of flood water by artificial methods in San Bernardino Valley, Calif.: California Conservation Comm. Rept., pp. 339–399, 1913. Tait, C. E., Preliminary report on conservation control of flood water in Coachella Valley, Calif.: California Dept. Eng. Fifth Bienn. Rept., appendix D, pp. 23–27, 1917.

several thousand acre-feet a year. The water thus wasted is probably to a large extent lost permanently, because much of the water is dissipated by evaporation and transpiration and probably only a very small part of it returns to the ground-water reservoir. Other uneconomic results of this waste have been pointed out in the report by Johnson.[20] When wells are allowed to flow freely the pressure head in near-by wells is reduced, and it may become necessary to install pumps. The waste of water increases the alkali in the soil.

Doubtless some water may be saved by a careful study of the distribution and application of water to the crops. Several reports on the elimination of waste in water applied in irrigation have been published by the United States Department of Agriculture or State experiment stations.[21] The quantity of water required for a unit area may be reduced by the growth of crops that require less water than alfalfa. Deciduous fruit trees require much less water than alfalfa, but it is said that the climatic conditions in the lower parts of the valley differ so greatly from those in the Palmdale and Little Rock fruit districts that fruit grown in the lowlands can not compete with the choice fruit produced on the higher lands to the south. The truth of this statement can best be determined by actual experimentation, and several persons on the lowlands are raising small orchards.

RECORDS OF WELLS

Detailed data in regard to many wells in Antelope Valley are given in the following table. The well numbers in the first column correspond to those on Plate 19.[22] Most of the wells listed have been drilled since the publication of Water-Supply Paper 278, but a few which are listed in that report, and which are mentioned specifically in the text of the present report, are included in the table. The reader is referred to Water-Supply Paper 278 for data in regard to many wells drilled prior to 1909. Some wells in the valley are not listed in either report.

The well data were obtained from a number of sources. The information in regard to about one-third of the wells was obtained from drillers' logs, which did not give information in regard to the pumping plants. Some of the data were reported by the owners of the wells or by other persons. The data obtained from so many sources are of various degrees of accuracy. In the tables so far as possible the

[20] Johnson, H. R., op. cit., pp. 66–67.

[21] Etcheverry, B. A., Increasing the duty of water: California Univ. Coll. Agr. Exper. Sta. Circ. 114, 1914. Smith, G. E. P., Use and waste of irrigation water: Arizona Univ. Coll. Agr. Exper. Sta. Bull. 88, 1919. Fortier, Samuel, Irrigation of alfalfa: U. S. Dept. Agr. Farmers Bull. 865, 1917. Adams, Frank, Robertson, R. D., Beckett, S. H., Hutchins, W. A., and Israelsen, O. W., Investigations of the economical duty of water for alfalfa in Sacramento Valley, Calif., 1910–1915: California Dept., Eng. Fifth Bienn. Rept., appendix C, 1917; also printed as California State Dept. Eng. Bull. 3.

[22] Owing to a necessary rearrangement of the well numbers after Plate 19 was drawn, certain numbers have been omitted from the map.

source of the data has been indicated by means of footnotes. In general, the information in regard to the depth to water can be considered of value only for the few places where the date of measurement is given, in order that the relation of the water level at the time of measurement to the seasonal fluctuation may be known. In the drillers' records of a number of wells that apparently are located within the area of artesian flow the depth to water is given as several feet below the surface. It is probable that the depth given is the depth at which shallow ground water not under artesian pressure was struck and that at greater depths water under artesian pressure probably rose to the surface, but this fact was not stated in the records. In many places the depth to water is based on measurements made several years ago, and the water level has since changed considerably.

Records of wells in and near Antelope Valley, Calif.

No. on map (pl. 19)	Location				Owner or name	Depth of well (feet)	Diameter of well (inches)	Type of casing and depth at which it is perforated
	Quarter	Section	T. N.	R. W.				
1	SW	24	[b]	[b]	C. C. Conklin	337	12	
2	(?)	35(?)	12	10	(?)	[c] 378	10	
3	NE	34	11	9	H. M. Meckley	260	10	
4	NW	6	10	9	E. F. Edinburgh	280	10	
5	NW.(?)	31(?)	10	9	Atchison, Topeka & Santa Fe Railway (Muroc station).	218	12½	
6	(?)	20	9	9	California Kali Co.	150(?)		
7	(?)	34(?)	11	11	—— Rathbun	300		
8	(?)	4(?)	10	11	do	200		
9	NW	18	10	11	R. A. Canning	150		
10	SW	24	10	12	I. J. Sopp	75	8	
11	NE	26	10	12	D. H. Walker	(?)	16	
12	N½	12	11	12	George A. Arper	(?)		
13	NE	4	9	14	John Lane	550	12	
14	SW	2	9	14	L. A. Turner	155	7	
15	SE	1	9	14	F. M. Hamilton(?)	186		
16	NW	8	9	13	—— Naquin	(?)	12	
17	NE	14	9	14	John Hammond	100		
18	NW	29	9	13		[c] 54	42	
19	SE	31	9	13	Arden Dairy	443	12	12-inch screw casing, 0–118 feet; 10-inch perforated stovepipe casing, 117–443 feet.
20	SW	34	9	13	P. D. Gaskill	420 350	8 10	
21	NW	21	9	12	W. S. Webb	[c] 89	6	
22	SE	16	9	12	Mitchell, Erickson & Johnson	254	14	14-inch screw casing, 0–84 feet; perforated stovepipe casing, 71–251 feet.
23	(?)	27(?)	9	17	C. H. Windham	1,395		

[b] Well 1 is in T. 32 S., R. 37 E. Mount Diablo base and meridian. All other townships are located with respect to the San Bernardino base and meridian.
[c] Measured by writer. Unless otherwise stated all other figures on total depth or depth to water were reported by the owner, driller, or other person.

No. on map (pl. 19)	Water level: Above (+) or below (−) surface or reference point [a] (feet)	Water level: Date of measurement	Method of lift	Yield (gallons per minute): Flow	Yield (gallons per minute): Pump	Yield (gallons per minute): Date of measurement	Date of completion of well	Remarks
1	−242		Deep-well cylinder					In drainage basin of Fremont Valley.
2	[c]−199	Feb. 6, 1920	Cylinder					In drainage basin of Fremont Valley. Reference point for measurement, top of pump support, 1 foot above surface.
3	−90		Vertical centrifugal		[d] 305		1915	Pit dug 90 feet. Estimated capacity of well, 65 inches.
4	−90				[e] 40		1915	Sandy clay, 0-100 feet; good water-bearing gravel, 100-280 feet.
5	[f]−33	Dec., 1913	Deep-well cylinder		[f] 110	Dec., 1913	1913	Used for locomotives.
6	+4	Dec. 13, 1917		(?)			Dec., 1917	Test hole for potash. Artesian flow obtained at about 125 feet. For analysis see p. 343.
7	−70		Hand		Small.			Struck rock at about 60 feet. Water a little salty.
8	−70				Small.			Water a little salty.
9	−52		Windmill		Small.			
10	−40		do		Small.		1910	
11	−90		Deep-well turbine		270			In drainage basin of Fremont Valley.
12	−400							
13	−250							Water struck at 275 feet and rose to 250 feet.
24	−145							
15	−57							Water struck at 67 feet and rose to 57 feet.
16	−47							
17	(?)							Pump cylinder is 86 feet from surface.
18	[c]−53.1	Jan. 16, 1920	None					Dug well. Reference point for measurement, top of curb 6 inches above surface.
19	[g]−63		([h])		[i] 765		Apr., 1917	
20	−22		Centrifugal		1,125		Oct., 1915	Two wells pumped together; pump set at 22 feet. Drawdown in 1919 was 24 inches on vacuum gage.
21	[c]−25.0	Jan. 12, 1920	Windmill		Small.			Reference point, top of casing, 8 inches above surface. See p. 364 for additional measurements of depths to water.
22	(?)		([h])		[i] 450		June, 1917	
23	−400							Drilled for oil. Water struck at about 530 feet; rose to 400 feet; stands at 400 feet.

[a] Depth to water is from surface unless a specific reference point is described in the column of "Remarks."
[c] Measured by writer. Unless otherwise stated all other figures on total depth or depth to water were reported by the owner, driller, or other person.
[d] Capacity of pump. Capacity of well believed to be greater.
[e] No pumping test had been made when data were collected. The figure is estimated by driller or owner.
[f] Measurements of depth to water, yield, and other data furnished by Atchison, Topeka & Santa Fe Railway.
[g] Data furnished by driller. Although the reported depth to water is probably that at the time of completion it is not always clear from the driller's log whether it was that figure or the depth at which water was first struck, later rising under artesian pressure.
[h] Data obtained from the drillers' records in January, 1920. Although pumps may have been installed on many of the wells at that time the record did not so state.
[i] Estimated by driller, generally before installation of pump.

Records of wells in and near Antelope Valley, Calif.—Continued

No. on map (pl. 19)	Location				Owner or name	Depth of well (feet)	Diameter of well (inches)	Type of casing and depth at which it is perforated
	Quarter	Section	T. N.	R. W.				
24		6	8	16	W. M. Fisher	(?)	8	
25		10	8	16	O. Caldwell	200+		
26	SE	14	8	14	R. A. George	252	16	8-inch screw casing, 0–146 feet; 6½-inch perforated stovepipe casing, 146–252 feet.
27	SW	6	8	13	J. Narod	301	8	Screw casing, 0–119 feet; perforated stovepipe casing, 119–301 feet.
28	NE	6	8	13	Gust Rottman	100	14	
29	SW	8	8	13	—— Brooks	350		
30	NE	30	8	13	—— Martin (?)	[a] 314	8	
31	NW	2	8	13	F. A. Ingersoll	336	6	
32	NW	2	8	13	L. M. Huntington	420	6	
33	NW	6	8	12	Mrs. M. Webber	334	10	
34	NW	4	8	12		(?)	12	
35	NE	4	8	12		(?)	10	
36	NE	4	8	12		[a] 56	6	
37	NW	22(?)	8	12	Southern Pacific Railroad (Oban siding).	371	6	
38	NW	22(?)	8	12	La Grande (?)	(?)	4	
39	SW	22	8	12	C. H. Lippincott	330	6	
40	NE.(?)	34(?)	8	12		(?)		
41	SW	28(?)	8	11	T. P. Breslin	272	10	Screw casing, 0–44 feet; perforated stovepipe casing, 38–272 feet.
42	SW	34	8	11	Hahn	200	10	Screw casing, 0–47 feet; perforated stovepipe casing, 41–200 feet.
43	NW	18	8	10	Harvard Ranch No. 1	295	12	Screw casing, 0–76 feet; perforated stovepipe casing, 69–293 feet.
44	SW	19	8	10	S. D. Longwell	283	6	6-inch screw casing, 0–62 feet; 4¾-inch perforated stovepipe casing, 51–283 feet.
45	NE. (?)	30	8	10	Grant Frakes	(?)	6	
46	NE	31	8	10	—— Hall	302	10	Screw casing, 0–64 feet; perforated stovepipe casing, 52–302 feet.
47	SW	32	8	10	John Demuth	350 772 200	6 6 6	

[a] Measured by writer. Unless otherwise stated all other figures on total depth or depth to water were reported by the owner, driller, or other person.

No. on map (pl. 19)	Water level: Above (+) or below (−) surface or reference point (feet)	Water level: Date of measurement	Method of lift	Yield (gallons per minute): Flow	Yield (gallons per minute): Pump	Yield (gallons per minute): Date of measurement	Date of completion of well	Remarks
24	−94							Well No. 2 in Water-Supply Paper 278.
25	−200							Well No. 4 in Water-Supply Paper 278.
26	[g]−90						Aug., 1918	Struck "tufa rock" at 165 feet, which reached to bottom.
27	[g]−72		([h])		[i]450		Nov., 1914	Pumping lift about 70 feet.
28	−56		Deep-well turbine		360			
29	−50		Turbine		630			
30	[c]−56.1	Jan. 16, 1920	None					Reference point, top of casing, 2 feet above surface.
31	−22		Vertical centrifugal		675			Drawdown 26 inches on vaccuum gage.
32	−18		do		675			Drawdown 26 inches on vacuum gage; pump set at 22 feet.
33	−14		([h])		450		Nov., 1914	
34	Flowing.	Jan. 12, 1920		(?)				Capped, but water coming up around casing.
35	Flowing.	do		[j]25		Jan. 12, 1920		Plug knocked out and water wasting.
36	[c]−5.3	do	None					Reference point top of casing level with surface.
37	[k]+17.6		do	(?)				See p.330. Probably same as well 228 in Water-Supply Paper 278.
38	[l]+4	Jan. 12, 1920		[j]270		Jan. 12, 1920		Probably same as well 271 in Water-Supply Paper 278.
39	At surface.[m]	do	None	(?)			Oct., 1915	
40	Flowing.	do	do	[j]20		Jan. 12, 1920		Poorly capped.
41	[n]−4			([h])	[i]450		Dec., 1914	
42	[n]−10		([h])		[i]450		June, 1914	Estimated lift 35 feet when pumping 450 gallons per minute.
43	[g] Flowing.		([h])		[i]720		May, 1916	
44	[g]−9		([h])		[i]270		Mar., 1918	
45	+2	Jan. 16, 1920	None	(?)				Did not flow from July to Oct., inclusive, 1919. See p. 333.
46	[g]−10.5		([h])		[i]630		June, 1914	
47	−7 −40 −12	1907 1907 1917	Vertical centrifugal		630	Jan., 1920	1907 1907 1917	Three wells pumped together. In summer yield is estimated to be only 450 gallons per minute. In the 772-foot well the water under greatest pressure is cased off.

[c] Measured by writer. Unless otherwise stated all other figures on total depth or depth to water were reported by the owner, driller, or other person.

[g] Data furnished by driller. Although the reported depth to water is probably that at the time of completion it is not always clear from the drillers' log whether it was that figure or the depth at which water was first struck, later rising under artesian pressure.

[h] Data obtained from the drillers' records in January, 1920. Although pumps may have been installed on many of the wells at that time the record did not so state.

[i] Estimated by driller, generally before installation of pump.

[j] Estimated by the writer.

[k] Reported by Southern Pacific Railroad in letter dated June 2, 1920.

[l] Water flows with considerable force at a height of 4 feet above surface. Will rise much higher.

[m] On the drillers' record the depth to water is given as 4½ feet. This is probably the depth at which water was struck. When the well was visited in January, 1920, water was leaking out at surface.

[n] Depth to water as given in driller's record. This is probably depth at which water was struck and not that at which it stood on completion of drilling, as the well is within the area of artesian flow.

Records of wells in and near Antelope Valley, Calif.—Continued

No. on map (pl. 19)	Location				Owner or name	Depth of well (feet)	Diameter of well (inches)	Type of casing and depth at which it is perforated
	Quarter	Section	T. N.	R. W.				
48	NW	14	7	14	George Marigold (?)	[c] 152	5	
49	SE	5	7	13	G. F. Weld	450	16	16-inch screw casing, 0–116 feet; 10-inch perforated stovepipe casing, 104–450 feet.
50	NW	3	7	13	Charles Pemberton [e]	400	12	12-inch screw casing, 0–75 feet; 10-inch perforated stovepipe casing, 69–400 feet.
51	NW	9	7	13	A. Whidden	501	18	18-inch stovepipe casing, not perforated, 0–118 feet; 10-inch perforated stovepipe casing, 110–500 feet.
52	NE	9	7	13	do	502	16	16-inch stovepipe casing, not perforated, 0–113 feet; 10-inch perforated stovepipe casing, 100–500 feet.
53	NE	16	7	13	do	{ 250 500	6 6	
54	NE	17	7	13	G. C. Earl	{ 600 270	8 10	Casing, not perforated, 0–275 feet; 6-inch perforated casing, 275–600 feet. Casing, not perforated, 0–100 feet; 8-inch perforated casing, 100–270 feet.
55	NW	11	7	13	R. O. Snowden	350	12	12-inch screw casing, 0–80 feet; 10-inch perforated stovepipe casing, 70–350 feet.
56	NW	11	7	13	do	{ 225 500 }	6	
57	NE	10	7	13	J. C. Clark	500	12	
58	N. ½	2	7	13	R. Riddell			
59	SE	15	7	13				
60		13(?)	7	13				
61	NE	23	7	13		[c] 211	7	
62	NE	24	7	13	H. A. Prendel	450	6	6-inch screw casing, 0–168 feet; 4⅞-inch perforated stovepipe casing, 168–450 feet.
63	SW	24	7	13	M. L. Berry	300		
64	NW	35	7	13	G. C. Earl	541	16	
65	NW	35	7	13	do	400	8	
66	SE	26	7	13	E. T. Earl estate	501	16	16-inch stovepipe casing, not perforated, 0–140 feet; 10-inch perforated stovepipe casing, 130–501 feet.

[c] Measured by writer. Unless otherwise stated all other figures on total depth or depth to water were reported by the owner, driller, or other person.
[e] Formerly owned by L. P. Burgess.

No. on map (pl. 19)	Water level: Above (+) or below (−) surface or reference point (feet)	Water level: Date of measurement	Method of lift	Yield (gallons per minute): Flow	Yield (gallons per minute): Pump	Yield (gallons per minute): Date of measurement	Date of completion of well	Remarks
48	[c]−147	Dec. 18, 1919	Windmill					Probably well No. 35 in Water-Supply Paper 278. See p. 364 for additional measurements of depth to water.
49	[g]−60		([h])		720		Mar., 1917	
50	[p]−32	Jan. 16, 1920	Deep-well turbine		[i]675		Aug., 1918	Estimated lift 60 feet when pumping 675 gallons per minute.
51	[g]−45		do		[q]1,625	Oct. 8, 1920	June, 1919	Lift 90 feet when pumping 1,625 gallons per minute.
52	[g]−33		do		[c]1,625		Dec., 1918	
53	−10		Vertical centrifugal		[c]630		1912	Two wells connected.
54	{−23 −27}		do		[c]1,000			Two wells pumped together. Drawdown 26 inches on vacuum gage.
55	[g]−16		([h])		[i]900		Jan., 1917	Two wells of same diameter, depth, etc.
56	[r]−3.75	Jan. 16, 1920	(?)				1918 (?)	Depth to surface water, 7.5 feet. Two wells connected. See p. 311.
57	−25		Deep-well turbine		720		July, 1914	Pumping lift, 47 feet; pump set at 67 feet.
58								Ceased flowing in 1919. See p. 331. Same as wells 42a to 42c in Water-Supply Paper 278.
59	[c]+3	Jan. 10, 1920	None	25		Jan. 10, 1920		Water wasting. See p. 364 for additional measurements of depth to water. For analysis see p. 343.
60	+6			250				Water wasting. Probably same as well 252 in Water-Supply Paper 278.
61	[c]−1.7	Jan. 10, 1920						Reference point for measurement top of casing, 1.1 feet above surface. Said to have flowed 50 gallons per minute in 1910. Same as well No. 247 in Water-Supply Paper 278. See p. 365 for additional measurements of depth to water.
62	[c]+4	do	Horizontal centrifugal	[c]2	315		1915	Drawdown 23 inches on vacuum gage. See p. 331.
63	−28		Vertical centrifugal					Pump set at 28 feet; must be primed.
64	−53	April, 1916	Deep-well turbine		[s]315		Nov., 1915	Estimated lift to surface 66 feet. Lift above surface 33 feet.
65	−85 −95	Spring, 1913 Summer, 1919	Deep-well cylinder		90		1912-13	Two wells 6 feet apart, each same depth, diameter, etc.; separate pumps run by same motor. For analysis see p. 343.
66	[g]−58		Deep-well turbine		900		Aug., 1919	

[c] Measured by writer. Unless otherwise stated all other figures on total or depth to water were reported by the owner, driller, or other person.
[g] Data furnished by driller. Although the reported depth to water is probably that at the time of completion it is not always clear from the driller's log whether it was that figure or the depth at which water was first struck, later rising under artesian pressure.
[h] Data obtained from the drillers' records in January, 1920. Although pumps may have been installed on many of the wells at that time the record did not so state.
[i] Estimated by driller, generally before installation of pump.
[p] Reported by W. R. Parkhill, of Federal Land Bank of Berkeley. Driller's log gives depth to water as 26 feet, indicating a probable drop since well was drilled.
[q] Result of weir measurement by Southern California Edison Co.
[r] Depth to water in 225-foot well measured by W. R. Parkhill, Federal Land Bank of Berkeley.
[s] Measured by pump manufacturer.

Records of wells in and near Antelope Valley, Calif.—Continued

No. on map (pl. 19)	Location				Owner or name	Depth of well (feet)	Diameter of well (inches)	Type of casing and depth at which it is perforated
	Quarter	Section	T. N.	R. W.				
67	NW	36	7	13	E. T. Earl estate	466	8	
67a	NW	36	7	13	do	460	16	
68	SE	16	7	12	(?)	------	------	
69	NE	21	7	12	E. B. Wargren	350	6	6-inch screw casing, 0–100 feet; 5-inch perforated stovepipe casing, 100–350 feet. See p. 331.
70	NE	21	7	12	—— Mason	254	8	Screw casing, 0–60 feet; perforated casing, 53–254 feet.
71	NE	21	7	12	C. E. Marble	301	10	10-inch screw casing, 0–63 feet; perforated stovepipe casing, 51–301 feet.
72	SE	11	7	12	Mott and Martin	300	8	8-inch screw casing, 0–79 feet; perforated casing, 69–300 feet.
73	NW	23	7	12	R. G. Donovan	153	8	Unperforated casing, 0–52 feet; perforated casing, 40–153 feet.
74	NW	13	7	12	—— Meder	------	------	
75	SE	13	7	12	J. L. Meder	363	12	Screw casing, 0–102 feet; perforated stovepipe casing, 102–363 feet.
76	NW	6	7	11	C. F. Nelson	302	12	Screw casing, 0–82 feet; perforated stovepipe casing, 70–300 feet.
77	SW	6	7	11	Oliver Miller	430	4½	
78	SW	18	7	11	C. Crapinell	300	10	10-inch screw casing, 0–80 feet; 6½-inch perforated stovepipe casing, 60–290 feet.
79	NW	30	7	11	—— Burris	298	10	Screw casing, 0–98 feet; not perforated, 0–98.4 feet; perforated stovepipe casing, 96–298 feet.
80	SE	32	7	11	Big Ten Ranch	550	6	
81	NE	16	7	11	W. W. Wurzburger	303	10	
82	SE	2	7	11	M. E. Felt	282	6	Casing, not perforated, 0–82 feet; perforated stovepipe casing, 70–279 feet.
83	NE	2	7	11	J. O. Eggen	301	10	Screw casing, 0–70 feet; perforated stovepipe casing, 60–300 feet.
84	SE	2	7	11	A. Z. Wilson	{250 {550	6 6	

No. on map (pl. 19)	Water level: Above (+) or below (−) surface or reference point (feet)	Water level: Date of measurement	Method of lift	Yield (gallons per minute): Flow	Yield (gallons per minute): Pump	Yield (gallons per minute): Date of measurement	Date of completion of well	Remarks
67	[e]−78.9	Jan. 14, 1920	Deep-well cylinder		100		Sept., 1914	Reference point for measurement, cement floor of pump house. Two wells, same depth, diameter, etc., together yield 200 gallons per minute.
67a	−72		Deep-well turbine		550		Jan., 1915	See p. 332.
68	+3.5			50–100				Water wasting.
69	−3	Jan., 1920	Horizontal centrifugal		450		Feb., 1914	Originally flowed. See p. 331. For analysis see p. 343.
70	[g]−20		([h])				Mar., 1916	
71	[g]−10		([h])		[i]450		Mar., 1915	
72	[g]−13		([h])		[i]450		Jan., 1918	
73	[g]−16		([h])		[i]180		Feb., 1911	
74	Flows.							Does not flow as strong as formerly. See p. 332.
75	−21	Jan., 1920	([h])		1,625		Jan., 1920	Has 2 other wells 240 and 550 feet deep.
76	Flows.[l]		Deep-well turbine		[j]200		Sept., 1919	
77	Flows.	Jan., 1920	Horizontal centrifugal	15	450		1905(?)	Originally flowed about 50 gallons per minute. Drawdown estimated at 20 feet.
78	[g]−32		([h])		[i]675		Dec., 1917	
79			([h])				Feb., 1916	
80	(?)		Centrifugal		540			Depth of pit 65 feet.
81	[g]−25		([h])		[i]450		Apr., 1916	
82	[g]−14		([h])				June, 1916	
83	[g]−12		([h])		[i]540		June, 1916	
84	See remarks.		Vertical centrifugal		800		July, 1907	550-foot well originally flowed 50 gallons per minute. Ceased flowing in 1919. See p. 332. Pumping yield of both wells in winter about 800 gallons per minute; in summer about 550 gallons per minute. 250-foot well not perforated to 100 feet; 550-foot well not perforated to 240 feet.

[e] Measured by writer. Unless otherwise stated all other figures on total depth or depth to water were reported by the owner, driller, or other person.
[g] Data furnished by driller. Although the reported depth to water is probably that at the time of completion it is not always clear from the driller's log whether it was that figure or the depth at which water was first struck, later rising under artesian pressure.
[h] Data obtained from the drillers' records in January, 1920. Although pumps may have been installed on many of the wells at that time the record did not so state.
[i] Estimated by driller, generally before installation of pump.
[j] Estimated by the writer.
[l] In the driller's log the depth to water is given as 10 feet. Apparently water was first struck at this depth and later rose to the surface, for the well is said to have flowed before the pump was installed.

Records of wells in and near Antelope Valley, Calif.—Continued

No. on map (pl. 19)	Location				Owner or name	Depth of well (feet)	Diameter of well (inches)	Type of casing and depth at which it is perforated
	Quarter	Section	T. N.	R. W.				
85	SW	12	7	11	J. B. Nourse	610	6	Casing not perforated, 0–240 feet.
85a	SW	12	7	11	do	203	8	
86	SW	23	7	11	George A. Niller	330	8	Screw casing, 0–200 feet; perforated stovepipe casing, 200–330 feet.
86a	SW	23	7	11	do	710	6	Screw casing, 0–376 feet; perforated stovepipe casing, 376–710 feet.
87	NE.(?)	11	7	11	George Edwards	225	8	
88	NW	10	7	10	C. A. Cleary	400	8	8-inch screw casing, 0–90 feet; perforated stovepipe casing, 80–400 feet.
89	SE	10	7	10	W. H. Brooks	300	10	
90	NE	32	7	10	C. S. Jones	350	10	10-inch screw casing, 0–120 feet; 8¼-inch perforated stovepipe casing, 110–250 feet.
91	NW	20	7	9	W. T. Graham	(?)	12	
92	E. ½	20	7	9	S. G. Bay	401	12	12-inch casing, not perforated, 0–105 feet; 8¼-inch perforated stovepipe casing, 100–400 feet.
93	E. ½	28	7	9	H. L. Graham	278	10	10-inch screw casing, 0–126 feet; 8½-inch perforated stovepipe casing, 120–278 feet.
94	SW	34	7	9	J. C. McGowan	158	12	
95	NW.(?)	2	6	13	Fred Godde	137	12	
96	SE.(?)	2(?)	6	13	W. L. Winnard	171	12	
97	NE	1	6	13	E. T. Earl estate	100	5⅝	
98	NE	4	6	12	W. R. Cowan	303	10	Casing, not perforated, 0–178 feet; perforated stovepipe casing, 174–303 feet.
99	SW	1	6	12	J. L. Davidson	451	12	Screw casing, 0–184 feet; perforated stovepipe casing, 168–448 feet.
100	SE	13	6	12	H. C. Fertig	490	10	Screw casing, 0–260 feet; perforated stovepipe casing, 252–489 feet.
101	NE	26	6	12	Palmdale Land Co.	[c] 344	6	
102	SW	6	6	11	F. Junquist	445	10	Casing, not perforated, 0–147 feet; perforated stovepipe casing, 140–445 feet.
103	NE	6	6	11	—— Copple	350	12	
104	SE	8	6	11	Orr & Baker	450	10	
105	NW	10	6	11	E. T. Earl estate	445	16	16-inch screw casing, 0–165 feet; 10-inch perforated stovepipe casing, 445 feet.
106	SE	20	6	11	C. L. Mason	260	12	
107	SE	21	6	11	G. B. Otis	502		

[c] Measured by writer. Unless otherwise stated all other figures on total depth or depth to water were reported by the owner, driller, or other person.

No. on map (pl. 19)	Water level: Above (+) or below (−) surface or reference point (feet)	Water level: Date of measurement	Method of lift	Yield (gallons per minute): Flow	Yield (gallons per minute): Pump	Yield (gallons per minute): Date of measurement	Date of completion of well	Remarks
85	[c] −13.5	Jan. 15, 1920	Horizontal centrifugal				1907	Reference point for measurement, 13.5 feet below joint in standpipe, 0.5 feet above surface. Well flowed when first drilled. See p. 332.
85a	[c] −19.2	do.						Reference point for measurement, top of casing level with ground. See p. 365 for additional measurements of depth to water.
86			Vertical centrifugal		900		Feb., 1910	Two wells pumped together. Depth to water in pit 30.0 feet below floor, Jan. 15, 1920. For analysis see p. 343.
86a	[c] −39.5	Jan. 13, 1920						Dug well. See p. 365 for additional measurements of depth to water.
87	[c] −17.0	Jan. 15, 1920					1919	Reference point for measurement, top of 10 by 12 inch frame, 1 foot above surface. Depth to surface water in pit 19.8 feet.
88	[g] −24		([h])		[i] 540		Apr., 1919	
89	−25							Pumping lift 50 feet.
90	[g] −91		([h])		[i] 675			
91	−80		Deep-well cylinder		450			
92	[g] −78		([h])				June, 1914	
93			([h])				May, 1914	Struck rock at bottom.
94	−100		Deep-well cylinder		450		1913	Drawdown 10 feet.
95	−95		([h])		Small.		Jan., 1920	
96	−130				Small.		Jan., 1920	Struck rock at 122 feet.
97	[g] −76		None		[i] 50		Aug., 1919	Struck rock at 77 feet.
98	[g] −150		([h])		[i] 270		Aug., 1914	Estimated lift 180 feet when pumping 270 gallons per minute.
99	[g] −130		([h])		[i] 540		May, 1917	
100	[g] −172		Deep-well turbine		[i] 360		Sept., 1915	
101	[c] −245.5	Jan. 7, 1920	None					Same as well No. 152 in Water-Supply Paper 278. Reference point for measurement top of cement floor of pump house.
102	[g] −92		([h])		[i] 400		March, 1915	
103	See remarks.		Deep-well turbine		675			Depth to water 120 feet when pumping.
104	−103		do.		675			
105	−78		do.		630		Feb., 1915	
106	−159		Deep-well cylinder		135		June, 1915	Principal water-bearing strata 227–260 feet.
107	−165		Air lift		[u] 225	Oct. 26, 1917		Granite reported to have been struck at 300 feet.

[c] Measured by writer. Unless otherwise stated all other figures on total depth or depth to water were reported by the owner, driller, or other person.
[g] Data furnished by driller. Although the reported depth to water is probably that at the time of completion it is not always clear from the driller's log whether it was that figure or the depth at which water was first struck, later rising under artesian pressure.
[h] Data obtained from the drillers' records in January, 1920. Although pumps may have been installed on many of the wells at that time the record did not so state.
[i] Estimated by driller, generally before installation of pump.
[u] Weir measurement by C. E. Tait.

Records of wells in and near Antelope Valley, Calif.—Continued

No. on map (pl. 19)	Location				Owner or name	Depth of well (feet)	Diameter of well (inches)	Type of casing and depth at which it is perforated
	Quarter	Section	T. N.	R. W.				
108	SW	28	6	11	George Coffman	260	12	
109	SE	28	6	11	C. Sigfriedson	237	12	
110	NW	31	6	11	C. W. Lorenz	105	12	Stovepipe casing, perforated at 212-215, 250-261, and 301-304 feet.
111	SW	32	6	11	J. Boyle	495	16	Stovepipe casing, perforated at 158-168, 188-196, 214-222, 224-248, and 258-268 feet.
112	SE	32	6	11	J. F. Jacobs	410	12	Perforated at 158-172 and 290-302 feet.
113	SE.(?)	14	6	11	P. A. Rowland	425	12	
114	NW	24	6	11	F. W. Comstock	(?)	(?)	
115	W. ½	18	6	10	J. M. Schissler	(?)	------	
116	NW	28	6	10	J. Hintermann	175	------	
117	(?)	22	6	10	—— Bowland (?)	181	------	
118	------	21(?)	6	9	Alexander Stewart	(?)	------	
119	NW.(?)	22	6	9	Mrs. A. Stewart	180	14	
120	NW	28	6	9	E. E. Reinsberg	(?)	12	
121	NW	18	6	8	A. C. Huff	215	9	
122	NE.(?)	14	6	8	W. W. Kent	(?)	------	
123	NW.(?)	13	6	8	J. S. Barton	(?)	------	
124	SE	14	6	8	E. Malcom	(?)	------	
125	SE	14	6	8	A. H. Tidd	(?)	------	
126	SE	13	6	8	J. O. W. Anderson	(?)	------	
127	SE.(?)	23	6	8	S. W. Moore	(?)	------	
128	NE	36	6	8	------	------	------	
[w] 129	SW	5	6	7	M. B. Charles	------	------	
[w] 130	NE	3	6	7	W. M. Gray	392	------	

[w] Located in Mirage Valley drainage basin. Data from C. E. Tait, Bureau Public Roads and Rural Engineering, U. S. Department Agriculture. Most of these data, with those in regard to other wells not listed in this report, are given in Report on the utilization of Mojave River for irrigation in Victor Valley, Calif.: California Dept. Engineering Bull. 5, 1918.

No. on map (pl. 19)	Water level: Above (+) or below (−) surface or reference point (feet)	Water level: Date of measurement	Method of lift	Yield (gallons per minute): Flow	Yield (gallons per minute): Pump	Yield (gallons per minute): Date of measurement	Date of completion of well	Remarks
108	−63		Windmill					Water said to have been struck first at 126 feet, rising to 63 feet. Perforated in gravel at 220 feet.
109	−7.3		None					Water struck at 140 feet; rose to 73 feet; cased to 196 feet.
110	−146		Deep-well cylinder		180			Pumping lift 175 feet.
111	−100		Deep-well turbine		600		May, 1917	See p. 366 for additional measurements of depth to water.
112	See remarks.		Deep-well cylinder		315		Nov., 1916	Lift 112 feet.
113	[g] −117		Deep-well turbine		450			Water rose a few feet when struck.
114	(?)		Deep-well cylinder		150			
115	(?)		(?)		450			Depth probably not more than 250 feet.
116	−125		Windmill					
117	−75				675			
118	Flows.			(?)				Near Lovejoy Springs. Combined flow of well and springs is about 60 gallons per minute. Depth to water in another well near by only 2 feet.
119	−17		Turbine		630			Drawdown 90 feet. Struck bedrock at 175 feet.
120	−28		(?)		720			
121	−165		Windmill		[i] 90			
122	[s] −33							Dug.
123	[s] −29							Do.
124	[s] −33							
125	[s] −48							Do.
126	[s] −56							
127	[s] −57							
128	[s] −112							
[w] 129	[c] −40.8	Dec. 16, 1919						Reference point top of curb. Depth to water measured 36 feet on Feb. 16, 1918. Well No. 253 in California Dept. Eng. Bull. 5, p. 90.
[w] 130	−16							Water struck at 165 feet; said to have overflowed. Water also found at other depths. Well No. 248 in California Dept. Eng. Bull. 5.

[c] Measured by writer. Unless otherwise stated all other figures on total depth or depth to water were reported by the owner, driller, or other person.

[g] Data furnished by driller. Although the reported depth to water is probably that at the time of completion it is not always clear from the driller's log whether it was that figure or the depth at which water was first struck, later rising under artesian pressure.

[i] Estimated by driller, generally before installation of pump.

[s] From data collected by G. A. Waring, U. S. Geological Survey, in August, 1917.

[w] Located in Mirage Valley drainage basin. Data from C. E. Tait, Bureau Public Roads and Rural Engineering, U. S. Department Agriculture. Most of these data, with those in regard to other wells not listed in this report, are given in Report on the utilization of Mojave River for irrigation in Victor Valley, Calif.: California Dept. Engineering Bull. 5, 1918.

Records of wells in and near Antelope Valley, Calif.—Continued

No. on map (pl. 19)	Location				Owner or name	Depth of well (feet)	Diameter of well (inches)	Type of casing and depth at which it is perforated
	Quarter	Section	T. N.	R. W.				
[w] 131	NW	11	6	7	K. McDonald	25	48	
[w] 132	NE	30	6	7	P. Showers	295	12	
[w] 133	SW	27	6	7	H. M. Engebritson	151	See remarks.	
134	SE	12	5	12	G. S. Lindley	[c] 180	8	
135	NW	5	5	11	C. K. Cook	[c] 403	12	Stovepipe casing, perforated at 175–179, 191–197, 205–225, 249–255, and 270–295 feet.
136	SW	4	5	11	Will McAdam	399	16	
137	SE	4	5	11	J. A. Martin and B. H. Martin	373	16	
138	NE	9	5	11	Robert Stuart	223	12	
139	NW	14	5	11	—— Littleton	[c] 44.3	16	
140	SW	14	5	11	—— Kellerman	54	(?)	
141	NE	22	5	11	—— Keyes	14	----------	
142	NW	23	5	11	—— Holloway	(?)	----------	
143	NW	12	5	11	E. W. Martin	226	12	Stovepipe casing, perforated at 96–104, 114–122, 128–158, 198–208 feet.
144	SE	21	5	10	H. J. Hammond	30	36	
145	SW	23	5	10	G. C. Chase	69	----------	
[v] 146	NE	9	5	7	O. W. Jessup	351	6	
[w] 147	SW	12	5	7	De Moville and Rowley	415	----------	
[x] 148	NW	26	9	12	John Mosby	165	4	
[x] 149	NE. (?)	14	8	12	S. J. Morford	300	5	
[x] 150	NE	10	7	13	C. N. Post	360	4	
[x] 151	NW	22	7	13	—— Vysette	227	2¾	

[c] Measured by writer. Unless otherwise stated all other figures on total depth or depth to water were reported by the owner, driller, or other person.
[u] Weir measurement by C. E. Taft.
[v] From data collected by G. A. Waring, U. S. Geological Survey, in August, 1917.
[w] Located in Mirage Valley drainage basin. Data from C. E. Tait, Bureau Public Roads and Rural Engineering, U. S. Department Agriculture. Most of these data, with those in regard to other wells not listed in this report, are given in Report on the utilization of Mojave River for irrigation in Victor Valley, Calif.: California Dept. Engineering Bull. 5, 1918.
[x] The data for wells Nos. 148 to 152, inclusive, are taken from Water-Supply Paper 278. They are included principally for use in the discussion on quality of waters.

No. on map (pl. 19)	Water level: Above (+) or below (−) surface or reference point (feet)	Water level: Date of measurement	Method of lift	Yield (gallons per minute): Flow	Yield (gallons per minute): Pump	Yield (gallons per minute): Date of measurement	Date of completion of well	Remarks
[w] 131	[i] −21.5	Feb. 21, 1918						Dug. Well No. 246 in California Dept. Eng. Bull. 5.
[w] 132	−80		Jack pump					Well No. 216 in California Dept. Eng. Bull. 5.
[w] 133	−135		do		[c] 10		1915	Dug 140 feet. 10-inch hole at bottom drilled 16 feet. Well No. 217 in California Dept. Eng. Bull. 5.
134	−4		Vertical centrifugal		[c] 180			In small valley along San Andreas fault line. No sand or gravel. Drawdown 15 feet; recovers in 5 hours.
135			Deep-well cylinder		[i] 360			First water struck at 145 feet.
136	[c] −88.9	Jan. 9, 1920	do		720		Jan., 1916	Reference point for measurement hole in casing head in pit, 3.5 feet below floor.
137	−84							Pumping lift said to be 115–120 feet.
138	−90		Deep-well turbine		360		1913	Pumping lift 109 feet.
139	[c] −39.8	Jan. 9, 1920	None					See pp. 327 and 366 for other measurements.
140								See p. 327 for measurements of depth to water.
141								Do.
142								Do.
143	−86		Deep-well cylinder		180		Aug., 1918	First water struck at 77-foot level, but later dropped to 86 feet.
144	−20		Windmill		Small			Dug well.
145	−42				75			
146	See remarks.		Deep well cylinder					Depth to water variously reported at 250 to 280 feet. Well No. 210 in California Dept. Eng. Bull. 5.
[v] 147	−315		None					Well No. 213 in California Dept. Eng. Bull. 5. In Mirage Valley drainage basin.
[x] 148	Flows(?)							Well No. 265 in Water-Supply Paper 278. For analysis, see p. 343.
[x] 149	Flows(?)							Well No. 270 in Water-Supply Paper 278. For analysis, see p. 343.
[x] 150	Flows(?)							Well No. 51 in Water-Supply Paper 278. For analysis, see p. 343.
[x] 151	Flows(?)							Well No. 253 in Water-Supply Paper 278. For analysis, see p. 343.

[c] Measured by writer. Unless otherwise stated all other figures on total depth or depth to water were reported by the owner, driller, or other person.
[i] Estimated by driller, generally before installation of pump.
[v] From data collected by G. A. Waring, U. S. Geological Survey, in August, 1917.
[w] Located in Mirage Valley drainage basin. Data from C. E. Tait, Bureau Public Roads and Rural Engineering, U. S. Department Agriculture. Most of these data, with those in regard to other wells not listed in this report, are given in Report on the utilization of Mojave River for irrigation in Victor Valley, Calif.: California Dept. Engineering Bull. 5, 1918.
[x] The data for wells Nos. 148 to 152, inclusive, are taken from Water-Supply Paper 278. They are included principally for use in the discussion on quality of waters.

Records of wells in and near Antelope Valley, Calif.—Continued

No. on map (pl. 19)	Location				Owner or name	Depth of well (feet)	Diameter of well (inches)	Type of casing and depth at which it is perforated
	Quarter	Section	T. N.	R. W.				
[a] 152	([b])	8	7	11	Ben. W. Hahn	350	5	
153	SE	30	7	10	J. L. Stone	532	14	14-inch double stovepipe casing, 0–140 feet; 10-inch perforated galvanized-iron casing, 130–492 feet.
154	SW	27	7	11	Robert B. Campbell	401	16	16-inch double stovepipe casing, 0–116 feet; 10-inch perforated galvanized-iron casing, 110–400 feet.
155	SW	5	7	10	Chris Larris	404	16	16-inch double stovepipe casing, 0–81 feet; black-iron perforated casing, 73–403 feet.
155–a	SW	5	7	10	do			
156	NW	21	6	11	Moller & Serritsler	350	12	12-inch screw casing, 0–199 feet; 4-inch perforated galvanized casing, 188–348 feet.
157	NE	20	9	13	Harry White	350	12	12-inch double stovepipe casing, 0–101 feet; perforated casing, 88–348 feet.
158	NW	11	8	13	—— Nebecker	452	16	16-inch double stovepipe casing, 0–99 feet; perforated 10-inch casing, 90–450 feet.
159	NW	30	7	11	E. A. Merritt	281	10	10-inch double stovepipe casing, 0–99 feet; perforated 8¼-inch galvanized-iron casing, 89–279 feet.
160	NE. (?)	2	7	11	—— Rice			
161	(?)	8	8	10				
162	SW	9	8	10	J. M. Hamilton	25±		
163	NE	24	8	14				
164	NE	30	8	13				
165	SE	20	7	13	—— Doll (?)			
166	SE	32	7	12	—— Lord			
167	NE	34	7	12				
168	SE	12	6	11	Harper & Paramore			
169	SW	10	7	11	C. B. Sharp			
170	NE	31	7	10				
171	SE	14	7	10	—— Adair			

[a] The data for wells Nos. 148 to 152, inclusive, are taken from Water-Supply Paper 278. They are included principally for use in the discussion on quality of waters.
[b] The exact location of this well is not given in Water-Supply Paper 278 and it is not shown on the map.

No. on map (pl. 19)	Water level: Above (+) or below (−) surface or reference point (feet)	Water level: Date of measurement	Method of lift	Yield (gallons per minute): Flow	Yield (gallons per minute): Pump	Yield (gallons per minute): Date of measurement	Date of completion of well	Remarks
[j] 152	Flows(?)							Well No. 146 in Water-Supply Paper 278. For analysis, see p. 343.
153	[g] −76		([h])		[i] 1,125		Apr. 3, 1920	
154	[g] −62		([h])		[i] 1,350		Mar. 25, 1921	
155	[g] −23		([h])		[i] 1,350		Mar. 4, 1921	Total lift 75 feet when pumping 1,350 gallons a minute.
155-a	[c] −28.9	May 29, 1921						See p. 366 for additional measurements of depth to water.
156	[g] −135		([h])		[i] 675		Feb. 17, 1921	
157	[c] −37.2	May 30, 1921	([h])		[i] 675		Nov. 30, 1920	See p. 367 for additional measurements of depth to water.
158	[g] −23		([h])				July 27, 1920	
159	[g] −44		([h])		[i] 585		May 15, 1920	
160	[c] 20.0	May 29, 1921						Do.
161	[k] 14.5	Aug. 21, 1921						Do.
162	[c] 11.25	May 29, 1921						See p. 368 for additional measurements of depth to water.
163	[c] 79.0	May 30, 1921						Do.
164	[k] 65.2	Oct. 3, 1921						Do.
165	[k] 39.9	Oct. 4, 1921						See p. 369 for additional measurements of depth to water.
166	[k] 116.1	Oct. 4, 1921						Do.
167	[k] 123.6	Oct. 4, 1921						Do.
168	[k] 113.0	Oct. 8, 1921						See p. 370 for additional measurements of depth to water.
169	[c] 19.0	May 29, 1921						Do.
170	[c] 81.2	May 29, 1921						Do.
171	[c] 62.05	May 29, 1921						See p. 371 for additional measurements of depth to water.

[c] Measured by writer. Unless otherwise stated all other figures on total depth or depth to water were reported by the owner, driller, or other person.

[g] Data furnished by driller. Although the reported depth to water is probably that at the time of completion it is not always clear from the driller's log whether it was that figure or the depth at which water was first struck, later rising under artesian pressure.

[h] Data obtained from the drillers' records in January, 1920. Although pumps may have been installed on many of the wells at that time the record did not so state.

[i] Estimated by driller, generally before installation of pump.

[j] The data for wells Nos. 148 to 152, inclusive, are taken from Water-Supply Paper 278. They are included principally for use in the discussion on quality of waters.

[k] Measured by N. S. Abbott.

Measurements of depth to water in wells in Antelope Valley, Calif.

Well 21; W. S. Webb, owner; NW. 1/4 sec. 21, T. 9 N., R. 12 W.

[Well equipped with windmill, behind hotel at Rosamond. Reference point, top of casing 8 inches above surface of ground]

Date of measurement	Depth to water below reference point	Measured by	Date of measurement	Depth to water below reference point	Measured by
1920	*Feet*		1925	*Feet*	
Jan. 12	25.0	D. G. Thompson.	May 5	28.4	F. C. Ebert and H. G. Troxell.
1921			Oct. 6	29.9	Do.
May 30	26.2	D. G. Thompson and N. S. Abbott.	1926		
Oct. 3	28.6	N. S. Abbott.	Jan. 9	30.0	N. S. Abbott.
1922			May 13	29.5	F. C. Ebert.
Feb. 7	26.2	Do.	Aug. 25	32.0	N. S. Abbott.
1924			Oct. 15	[a] 32.0	F. C. Ebert.
Oct. 23	29.4	F. C. Ebert and H. G. Troxell.	1927		
			Jan. 19	30.0	N. S. Abbott.
			May 9	[a] 31.0	F. C. Ebert.
			Oct. 27	[b] 32.9	Do.

Well 48; George Marigold, owner (?); southeast corner NW. 1/4 sec. 14, T. 7 N., R. 14 W.

[Reference point, top of casing and few inches above surface of ground]

Date of measurement	Depth to water below reference point	Measured by	Date of measurement	Depth to water below reference point	Measured by
1919			1924		
Dec. 18	147.0	D. G. Thompson.	Nov. 15	146.2	N. S. Abbott.
1921			1925		
Apr. 30	146.5	D. G. Thompson and F. C. Ebert.	Feb. 17	145.7	Do.
Oct. 14	147.1	N. S. Abbott.	May 6	146.8	F. C. Ebert and H. G. Troxell.
1922					
Jan. 1	146.5	Do.	June 8	145.9	N. S. Abbott.
Apr. 30	147.4	Do.	July 21	146.3	Do.
May 24	146.5	Do.	Oct. 6	146.7	F. C. Ebert.
Oct. 26	147.0	Do.	1926		
1923			Jan. 9	145.8	N. S. Abbott.
Feb. 24	146.3	Do.	May 16	145.5	F. C. Ebert.
July 11	146.6	Do.	Aug. 30	146.6	N. S. Abbott.
1924			Oct. 15	146.8	F. C. Ebert.
Jan. 9	146.3	Do.	1927		
Mar. 28	146.05	Do.	Jan. 20	146.	N. S. Abbott.
July 4	146.3	Do.	May 9	146.3	F. C. Ebert.
Oct. 22	147.0	F. C. Ebert and H. G. Troxell.	Oct. 26	148.0	Do.

Well 59; owner unknown; SE. 1/4 sec. 15, T. 7 N., R. 13 W.

[Opposite ranch of Mr. Bonnefeux. Well inclosed above surface with sewer pipe. Reference point, top of sewer pipe about 5 feet above top of casing and surface of ground until 1924; thereafter top of casing. In 1924 well was plugged by débris at a depth of about 7 feet, but when high enough the water was able to percolate through the débris.]

Date of measurement	Depth to water below reference point	Measured by	Date of measurement	Depth to water below reference point	Measured by
1920			1923		
Jan. 10	([c])	D. G. Thompson.	July 11	22.1	N. S. Abbott.
1921			1924		
Apr. 30	17.5	D. G. Thompson and F. C. Ebert.	Oct. 20	[e] 3.4	Do.
May 30	10.4	D. G. Thompson and N. S. Abbott.	Oct. 22	[f] 2.5	F. C. Ebert and H. G. Troxell.
			1925		
Oct. 2	13.7	N. S. Abbott.	Jan. 22	([c])	N. S. Abbott.
1922			May 5	([g])	F. C. Ebert and H. G. Troxell.
Jan. 21	([c])	Do.	July 7	([g])	N. S. Abbott.
Apr. 30	15.1	Do.	Oct. 6	([g])	F. C. Ebert.
May 24	([c])	Do.	1926		
Oct. 26	6.1	Do.	Jan. 9	([c])	N. S. Abbott.
Nov. 20	([c])	Do.	Aug. 30	([g])	Do.
1923			1927		
Feb. 25	([d])	Do.	Jan. 20	([c])	Do.
May 14	16.9	Do.			

[a] Pumping very slowly.
[b] Not pumping.
[c] Flowing.
[d] Flowing about 40 gallons a minute.
[e] Measured from top of casing (?).
[f] Sewer pipe broken up. Reference point, top of casing about 5 feet lower than original reference point.
[g] Water below débris plug.

Measurements of depth to water in wells in Antelope Valley, Calif.—Continued

Well 61; owner unknown; NE. 1/4 sec. 23, T. 7 N., R. 13 W., probably near southeast corner

[Reference point, originally top of casing 1.1 feet above surface of ground until some time prior to Oct. 22, 1924, when top of casing was broken off level with surface of ground. Measurements prior to 1924 have been corrected to present reference point by subtracting 1.1 feet from the observed reading. Well plugged with débris at a depth of 21.5 feet, but in winter water rises above plug]

Date of measurement	Depth to water below reference point	Measured by	Date of measurement	Depth to water below reference point	Measured by
1920			1925		
Jan. 10	0.6	D. G. Thompson.	Jan. 22	4.0	N. S. Abbott.
1921			May 6	18.5	F. C. Ebert and H. G. Troxell.
Apr. 30	19.2	D. G. Thompson and F. C. Ebert.	July 17	(g)	N. S. Abbott.
May 30	13.0	D. G. Thompson and N. S. Abbott.	Oct. 6	19.9	F. C. Ebert.
Oct. 2	12.5	N. S. Abbott.	1926		
1923			Jan. 9	4.4	N. S. Abbott.
Feb. 25	2.5	Do.	May 13	24.2	F. C. Ebert.
May 14	15.6	Do.	Aug. 30	(g)	N. S. Abbott.
July 11	22.2	Do.	Oct. 15	20.3	F. C. Ebert.
1924			1927		
Sept. 29	20.5	Do.	Jan. 20	5.7	N. S. Abbott.
Oct. 22	9.6	F. C. Ebert and H. G. Troxell.	May 9	(h)	F. C. Ebert.
Nov. 15	8.8	N. S. Abbott.	Oct. 26	17.0	Do.

Well 85a; J. B. Nourse, owner; SW. 1/4 sec. 12, T. 7 N., R. 11 W.

[Unused well a few feet from well equipped with pump. Reference point, top of casing, level with surface of ground]

Date of measurement	Depth to water below reference point	Measured by	Date of measurement	Depth to water below reference point	Measured by
1920			1922		
Jan. 15	19.2	D. G. Thompson.	Feb. 8	20.3	N. S. Abbott.
1921			May 3	[j] 34.9	Do.
Apr. 27	[i] 29.3	Do.	1924		
May 29	[i] 28.8	D. G. Thompson and N. S. Abbott.	Oct. 23	(j)	F. C. Ebert and H. G. Troxell.
Aug. 21	[i] 31.6	N. S. Abbott.			
Oct. 2	26.3	Do.			

Well 86a; George A. Niller, owner; SW. 1/4 sec. 23, T. 7 N., R. 11 W.

[Dug well at house. Reference point, three notches cut in south side of curb, 1.7 feet above surface of ground]

Date of measurement	Depth to water below reference point	Measured by	Date of measurement	Depth to water below reference point	Measured by
1920			1924		
Jan. 13	39.5	D. G. Thompson.	Oct. 23	38.2	F. C. Ebert and H. G. Troxell.
1921			1925		
May 29	37.6	D. G. Thompson and N. S. Abbott.	May 6	37.5	Do.
Aug. 21	(k)	N. S. Abbott.	Oct. 6	38.3	F. C. Ebert.
Oct. 2	(k)	Do.	1926		
1922			May 13	(l)	Do.
May 23	38.3	Do.			

[g] Water below débris plug.
[h] Plugged and dry at 21.5 feet.
[i] Well 10 feet to south running.
[j] Pump installed in well.
[k] Dry at 40.5 feet.
[l] Filled in and dry at 33 feet.

Measurements of depth to water in wells in Antelope Valley, Calif.—Continued

Well 111; J. Boyle, owner; SW. 1/4 sec. 32, T. 6 N., R. 11 W.

[Reference point, bottom of pump base, level with surface of ground]

Date of measurement	Depth to water below reference point	Measured by	Date of measurement	Depth to water below reference point	Measured by
1919			1925		
September	114	J. Boyle.	May 5	137.1	F. C. Ebert and H. G. Troxell.
1921			Oct. 7	140.7	F. C. Ebert.
August	119	Do.	1926		
1921			May 12	[m] 136.5	Do.
Feb. 12	118.1	N. S. Abbott.	Oct. 16	([n])	Do.
1924			1927		
Oct. 24	134.5	F. C. Ebert and H. G. Troxell.	May 10	[o] 147.0	Do.
			Oct. 26	([p])	Do.

Well 139; Littleton well, on north side of road a short distance west of bridge over Little Rock Creek near town of Little Rock, probably near southwest corner of NE. 1/4 NW. 1/4 sec. 14, T. 5 W., R. 11 W.

[Reference point, top of casing 1.5 feet above surface of ground. See p. 327 for additional measurements]

Date of measurement	Depth to water below reference point	Measured by	Date of measurement	Depth to water below reference point	Measured by
1920			1924		
Jan. 9	39.8	D. G. Thompson.	Oct. 24	([r])	F. C. Ebert and H. G. Troxell.
1921			1925		
Apr. 29	35.2	D. G. Thompson and F. C. Ebert.	May 5	([s])	Do.
Oct. 9	36.4	N. S. Abbott.	Oct. 7	([s])	F. C. Ebert.
1922			1926		
Jan. 5	38.35	Do.	May 12	[t] 32.65	Do.
Oct. 21	35.3	Do.	Oct. 16	36.4	Do.
1923			1927		
July 14	34.1	Do.	May 10	23.7	Do.
1924			Oct. 26	32.4	Do.
July 16	[q] 44.4	Do.			

Well 155a; Chris Laras, owner; SW. 1/4 sec. 5, T. 7 N., R. 10 W.

[Abandoned well 25 feet north of pumping plant. Reference point, top of casing about level with surface of ground]

Date of measurement	Depth to water below reference point	Measured by	Date of measurement	Depth to water below reference point	Measured by
1921			1924		
May 29	28.9	D. G. Thompson and N. S. Abbott.	Nov. 13	25.3	N. S. Abbott.
Aug. 21	33.45	N. S. Abbott.	1925		
Oct. 1	35.6	Do.	Feb. 10	25.3	Do.
1922			May 6	[v] 46.7	F. C. Ebert and H. G. Troxell.
Feb. 8	21	Do.	Aug. 12	[v] 49.9	N. S. Abbott.
May 23	[u] 34.4	Do.	Oct. 6	[v] 46.4	F. C. Ebert.
Sept. 8	[u] 40.1	Do.	1926		
Oct. 30	23.8	Do.	Jan. 4	24.4	N. S. Abbott.
1923			Mar. 17	27.5	Do.
Feb. 26	23.1	Do.	May 13	[w] 46.3	F. C. Ebert.
May 13	[u] 36.9	Do.	Aug. 16	[x] 54.4	N. S. Abbott.
July 12	[u] 43.4	Do.	Oct. 16	[y] 34.4	F. C. Ebert.
Oct. 10	31.1	Do.	1927		
Dec. 12	23.5	Do.	Jan. 18	26.8	N. S. Abbott.
1924			May 9	[w] 52.2	F. C. Ebert.
Apr. 12	63.7	Do.	Oct. 27	35.8	Do.
July 8	45.1	Do.			
Oct. 23	28.5	F. C. Ebert and H. G. Troxell.			

[m] Pump pulled.
[n] Pumping.
[o] Pumping in the vicinity.
[p] New pump set, could not measure.
[q] Well cleaned out.
[r] Well dry at 44.5 feet.
[s] Well dry.
[t] Little Rock Reservoir filled; considerable water wasted down Little Rock Creek.
[u] Pump running near by.
[v] Well 25 feet to the south being pumped.
[w] Well to the south being pumped.
[x] Although the fact is not indicated in the record, a pump near by was probably running at the time this measurement was made.
[y] Near-by pumps not operating.

Measurements of depth to water in wells in Antelope Valley, Calif.—Continued

Well 157; Harry White, owner; NE. ¼ sec. 20, T. 9 N., R. 13 W.

[Reference point, top of casing level with surface of ground]

Date of measurement	Depth to water below reference point	Measured by
1921		
May 30	37.2	D. G. Thompson and N. S. Abbott.
Oct. 3	37.85	N. S. Abbott.
1922		
Jan. 21	36.6	Do.
Apr. 29	36.0	Do.
May 24	36.6	Do.
Oct. 17	38.5	Do.
1923		
Apr. 30	40.2	Do.
July 10	40.2	Do.
Aug. 8	40.4	Do.
1924		
Apr. 13	40.1	Do.
July 4	40.4	Do.
Oct. 23	38.7	F. C. Ebert and H. G. Troxell.
Dec. 31	37.4	N. S. Abbott.
1925		
Feb. 10	37.4	Do.
May 5	40.4	F. C. Ebert and H. G. Troxell.
May 8	40.9	N. S. Abbott.
July 21	41.8	Do.
1926		
Jan. 9	38.5	Do.
May 13	40.55	F. C. Ebert.
Aug. 20	42.8	N. S. Abbott.
Oct. 15	42.3	F. C. Ebert.
1927		
Jan. 19	41.0	N. S. Abbott.
May 9	43.1	F. C. Ebert.
Oct. 27	43.0	Do.

Well 160; Mr. Rice, owner, formerly owned by Mr. Chapman; southeast corner NE. ¼ (?) sec. 2, T. 7 N., R. 11 W. Old well 50 feet north of pumping plant. Reference point, 1921–22, top of curb, level with surface of ground. After July, 1923, top of casing about 1 foot above curb

Date of measurement	Depth to water below reference point	Measured by
1921		
May 29	20.0	D. G. Thompson and N. S. Abbott.
Aug. 21	26.9	N. S. Abbott.
Oct. 1	17.6	Do.
1922		
Feb. 7	([c])	Do.
Oct. 30	6.6	Do.
1923		
Feb. 26	2.7	Do.
May 13	25.0	Do.
July 12	([i])	Do.
Oct. 10	[s] 20.0	Do.
1924		
Jan. 10	0.00	Do.
Mar. 7	15.4	Do.
July 8	[u] 41.2	Do.
Oct. 23	15.0	F. C. Ebert and H. G. Troxell.
Nov. 13	7.2	N. S. Abbott.
1925		
Feb. 10	5.9	Do.
May 6	[z] 44.8	F. C. Ebert and H. G. Troxell.
Aug. 12	[z] 55.6	N. S. Abbott.
Oct. 6	12.7	F. C. Ebert.
1926		
Jan. 5	6.6	N. S. Abbott.
Mar. 17	11.9	Do.
May 13	[aa] 37.9	F. C. Ebert.
Aug. 20	[z] 66.5	N. S. Abbott.
Oct. 16	29.2	F. C. Ebert.
1927		
Jan. 18	8.5	N.S. Abbott.
Oct. 27	30.7	F. C. Ebert.

Well 161; owner unknown; dug well in sec. 8, T. 8 N., R. 10 W.

[At abandoned shack on west side of road to Buckhorn Springs and Muroc. Reference point not reported]

Date of measurement	Depth to water below reference point	Measured by
1921		
Aug. 21	14.5	N. S. Abbott.
Oct. 1	14.0	Do.
1922		
Feb. 7	12.3	Do.
Apr. 21	14.5	Do.
May 23	13.0	Do.
July 20	15.7	Do.
Oct. 30	13.7	Do.
1923		
Feb. 26	13.9	Do.
May 13	15.4	Do.
July 12	16.4	Do.
Oct. 10	15.2	Do.
Dec. 12	14.8	Do.
1924		
Jan. 10	12.4	N. S. Abbott.
Mar. 7	16.4	Do.
July 8	17.1	Do.
Nov. 13	13.3	Do.
1925		
Feb. 10	15.2	Do.
Aug. 10	17.8	Do.
1926		
Jan. 4	15.7	Do.
Mar. 17	16.0	Do.
Aug. 16	19.9	Do.
1927		
Jan. 18	16.6	Do.

[c] Flowing.
[i] Well 10 feet to south running.
[u] Pump running near by.
[z] Although the fact is not indicated in the record, a pump near by was probably running at the time this measurement was made.
[s] Pump removed; new reference point, top of casing about 1 foot above surface of ground.
[aa] Pump 50 feet away running.

Measurements of depth to water in wells in Antelope Valley, Calif.—Continued

Well 162; J. M. Hamilton, owner; NW. ¼ SW. ¼ sec. 9, T. 8 N., R. 10 W.

[A shallow well, with no perforations in casing. Reference point, top of casing about 1.8 feet above surface of ground]

Date of measurement	Depth to water below reference point	Measured by	Date of measurement	Depth to water below reference point	Measured by
1921					
May 29	11.25	D. G. Thompson and N. S. Abbott.	Oct. 23	12.5	F. C. Ebert and H. G. Troxell.
Aug. 21	12.9	N. S. Abbott.	Nov. 13	12.4	N. S. Abbott.
Oct. 1	11.4	Do.	1925		
1922			Feb. 10	12.2	Do.
Feb. 7	11.3	Do.	May 6	11.9	F. C. Ebert and H. G. Troxell.
Apr. 29	10.6	Do.	Aug. 10	12.6	N. S. Abbott.
July 20	11.3	Do.	Oct. 6	12.8	F. C. Ebert.
Oct. 30	11.8	Do.	1926		
1923			Jan. 4	12.6	N. S. Abbott.
Feb. 26	11.6	Do.	Mar. 17	12.5	Do.
May 13	11.6	Do.	May 13	12.45	F. C. Ebert.
July 12	11.9	Do.	Aug. 16	13.4	N. S. Abbott.
Oct. 10	12.0	Do.	Oct. 16	13.4	F. C. Ebert.
Dec. 12	11.7	Do.	1927		
1924			Jan. 18	13.2	N. S. Abbott.
Jan. 10	11.3	Do.	Mar. 9	12.8	F. C. Ebert.
Mar. 7	11.6	Do.			
July 8	12.0	Do.			

Well 163; owner unknown; probably near northeast corner of NE. ¼ sec. 24, T. 8 N., R. 14 W.

[Well with windmill at corral of cattle camp. Reference point, top of casing about 3 inches above surface of ground]

Date of measurement	Depth to water below reference point	Measured by	Date of measurement	Depth to water below reference point	Measured by
1921			1925		
May 30	79.0	D. G. Troxell and N. S. Abbott.	Feb. 11	78.5	N. S. Abbott.
Oct. 3	78.8	N. S. Abbott.	May 5	78.8	F. C. Ebert and H. G. Troxell.
1922			June 8	78.85	N. S. Abbott.
Jan. 5	[a] 80.2	Do.	July 21	79.2	Do.
May 24	79.4	Do.	Oct. 6	79.5	F. C. Ebert.
Oct. 17	79.1	Do.	1926		
1923			Jan. 9	79.0	N. S. Abbott.
July 10	78.85	Do.	May 13	79.1	F. C. Ebert.
1924			Aug. 25	79.9	N. S. Abbott.
July 27	78.9	Do.	Oct. 15	81.0	F. C. Ebert.
Oct. 20	78.95	Do.	1927		
Oct. 22	79.1	F. C. Ebert and H. G. Troxell.	Jan. 19	79.7	N. S. Abbott.
			May 9	79.5	F. C. Ebert.
			Oct. 27	80.3	Do.

Well 164; owner unknown; probably in NE. ¼ sec. 30, T. 8 N., R. 13 W.

[About 1,000 feet west of a well owned by H. L. Martin, which stands near road. Reference point, top of casing, 6 inches above surface of ground]

Date of measurement	Depth to water below reference point	Measured by	Date of measurement	Depth to water below reference point	Measured by
1921					
Oct. 3	65.2	N. S. Abbott.	Oct. 22	59.9	F. C. Ebert and H. G. Troxell.
1922			Feb. 11	56.9	N. S. Abbott.
Jan. 6	55.4	Do.	May 5	61.5	F. C. Ebert and H. G. Troxell.
Apr. 30	59.8	Do.	June 8	61.9	N. S. Abbott.
May 24	59.7	Do.	July 21	64.3	Do.
Aug. 23	61.6	Do.	Oct. 6	62.4	F. C. Ebert.
Oct. 17	59.3	Do.	1926		
1923			Jan. 9	58.5	N. S. Abbott.
Mar. 20	57.0	Do.	May 13	62.3	F. C. Ebert.
July 10	59.0	Do.	Aug. 25	66.7	N. S. Abbott.
July 26	62.4	Do.	Oct. 15	65.4	F. C. Ebert.
Aug. 9	62.6	Do.	1927		
1924			Jan. 19	60.9	N. S. Abbott.
July 4	62.6	Do.	May 9	65.0	F. C. Ebert.
Oct. 20	59.3	Do.	Oct. 27	66.2	Do.

[a] Pumping.

Measurements of depth to water in wells in Antelope Valley, Calif.—Continued

Well 165; Mr. Dall, owner (?); occupied by Mr. Krubsack; northeast corner SE. ¼ sec. 20, T. 7 N., R. 13 W.

[Dug well. Reference point, nail in curb about 3 feet from top of box]

Date of measurement	Depth to water below reference point	Measured by	Date of measurement	Depth to water below reference point	Measured by
1921			1923		
Oct. 4	39.9	N. S. Abbott.	Feb. 25	39.5	N. S. Abbott.
1922			July 10	40.1	Do.
Jan. 21	39.6	Do.	1924		
May 24	39.7	Do.	Jan. 10	39.7	Do.
Oct. 26	39.95	Do.	Oct. 22	([a])	F. C. Ebert and H. G. Troxell.

Well 166; Mr. Lord, owner; NE. ¼ SE. ¼ sec. 32, T. 7 N., R. 12 W.

[Reference point, hole drilled in pump base, about 1 foot above surface of ground]

Date of measurement	Depth to water below reference point	Measured by	Date of measurement	Depth to water below reference point	Measured by
1921			1925		
Oct. 4	116.1	N. S. Abbott.	Feb. 19	118.0	N. S. Abbott.
			May 5	118.1	F. C. Ebert and H. G Troxell.
1922					
Feb. 8	115.3	Do.	June 8	118.6	N. S. Abbott.
May 21	115.3	Do.	Aug. 12	118.4	Do.
Oct. 26	116.6	Do.	Oct. 6	119.5	F. C. Ebert.
			Dec. 29	119.2	N. S. Abbott.
1923			1926		
May 13	116.4	Do.	May 13	119.5	F. C. Ebert.
July 11	116.8	Do.	Aug. 25	121.3	N. S. Abbott.
			Oct. 15	121.6	F. C. Ebert.
1924					
Mar. 28	116.5	Do.	1927		
July 16	[bb] 117.8	Do.	Jan. 20	120.8	N. S. Abbott.
Oct. 22	118.5	F. C. Ebert and H. G. Troxell.	May 9	121.5	F. C. Ebert.
Nov. 15	118.4	N. S. Abbott.	Oct. 26	124.0	Do.

Well 167; Mr. Morrion, owner (?); SE. ¼ NE. ¼ sec. 34, T. 7 N., R. 12 W.

[Reference point, hole in casting resting on well]

Date of measurement	Depth to water below reference point	Measured by	Date of measurement	Depth to water below reference point	Measured by
1921			1925		
Oct. 4	123.6	N. S. Abbott.	June 8	125.9	N. S. Abbott.
			Aug. 12	126.7	Do.
1922			Oct. 6	127.2	F. C. Ebert.
Feb. 8	121.7	Do.	Dec. 29	126.9	N. S. Abbott.
May 21	122.5	Do.			
Oct. 26	125.1	Do.	1926		
			May 12	126.7	F. C. Ebert.
1923			Aug. 25	133.4	N. S. Abbott.
May 13	123.5	Do.	Oct. 15	128.5	F. C. Ebert.
July 11	124.5	Do.			
			1927		
1924			Jan. 20	130.0	N. S. Abbott.
July 16	125.4	Do.	May 9	128.5	F. C. Ebert.
Oct. 22	127.0	F. C. Ebert and H. G. Troxell.	Oct. 26	130.7	Do.
Nov. 14	126.1	N. S. Abbott			
1925					
Feb. 19	126.6	Do.			
May 5	125.5	F. C. Ebert and H. G. Troxell.			

[a] Well dry.
[bb] Windmill running.

Measurements of depth to water in wells in Antelope Valley, Calif.—Continued

Well 168; Harper & Paramore, owners; southeast corner SE. ¼ sec. 12, T. 6 N., R. 11 W.

[Reference point, top of casing 6 inches above surface of ground]

Date of measurement	Depth to water below reference point	Measured by	Date of measurement	Depth to water below reference point	Measured by
1921			1924		
Oct. 8	113.0	N. S. Abbott.	Nov. 14	114.0	N. S. Abbott.
1922			1925		
Feb. 12	112.6	Do.	Feb. 27	114.6	Do.
Oct. 21	116.6	Do.	June 9	115.6	Do.
			Nov. 4	116.9	Do.
1923			1926		
May 13	111.7	Do.	Jan. 4	117.4	Do.
July 12	112.8	Do.	Aug. 20	117.0	Do.
1924			1927		
Feb. 16	112.9	Do.	Jan. 17	120.6	Do.
July 15	113.9	Do.			

Well 169; C. B. Sharp, owner; SW. ¼ sec. 10, T. 7 N., R. 11 W.

[Well is 300 feet northeast of house. Reference point, top of casing]

Date of measurement	Depth to water below reference point	Measured by	Date of measurement	Depth to water below reference point	Measured by
1921			1924		
May 29	19.0	D. G. Thompson and N. S. Abbott.	Nov. 13	8.0	N. S. Abbott.
Oct. 2	18.5	N. S. Abbott.	1925		
			Feb. 10	6.1	Do.
1922			May 6	26.6	F. C. Ebert and H. G. Troxell.
Feb. 8	1.7	Do.			
Oct. 30	8.0	Do.	Aug. 12	34.2	N. S. Abbott.
1923			1926		
Feb. 26	2.9	Do.	Jan. 5	6.5	Do.
May 13	20.1	Do.	Mar. 17	11.0	Do.
July 12	27.9	Do.	May 13	([cc])	F. C. Ebert.
Oct. 10	21.7	Do.	Aug. 23	47.0	N. S. Abbott.
1924			1927		
Apr. 12	24.8	Do.	Jan. 18	9.7	Do.
July 8	33.2	Do.			
Oct. 23	13.7	F. C. Ebert and H. G. Troxell.			

Well 170; owner unknown; near northwest corner NE. ¼ sec. 31, T. 7 N., R. 10 W.

[Reference point, top of casing, about 2.5 feet above surface of ground]

Date of measurement	Depth to water below reference point	Measured by	Date of measurement	Depth to water below reference point	Measured by
1921			1924		
May 29	81.2	D. G. Thompson and N. S. Abbott.	Nov. 14	85.5	N. S. Abbott.
Aug. 2	82.5	N. S. Abbott.	1925		
Oct. 2	82.0	Do.	Feb. 10	84.8	Do.
			May 6	[ee] 87.3	F. C. Ebert and H. G. Troxell.
1922					
Jan. 23	81.2	Do.	June 9	[u] 87.9	N. S. Abbott.
May 1	83.0	Do.	July 17	[u] 89.2	Do.
Aug. 30	[u] 85.1	Do.	Oct. 6	89.4	F. C. Ebert.
Oct. 21	[u] 85.4	Do.	Oct. 30	89.0	N. S. Abbott.
1923			1926		
May 8	[u] 84.1	Do.	Jan. 4	87.0	Do.
July 12	[u] 85.9	Do.	Mar. 16	87.3	Do.
July 14	[dd] 85.4	Do.	May 13	89.9	F. C. Ebert.
Oct. 8	85.2	Do.	Aug. 16	94.8	N. S. Abbott.
Dec. 12	84.6	Do.	Oct. 15	[ee] 93.9	F. C. Ebert.
1924			1927		
Apr. 12	83.7	Do.	Jan. 17	90.2	Do.
July 10	87.3	Do.	May 9	[ee] 94.8	Do.
Oct. 23	86.7	F. C. Ebert and H. G. Troxell.	Oct. 27	96.1	Do.

[u] Pump running near by.
[cc] Well covered. Could not measure.
[dd] Pump not running.
[ee] Well 100 feet to north being pumped.

Measurements of depth to water in wells in Antelope Valley, Calif.—Continued

Well 171; Mr. Adair, owner; SE. ¼ SE. ¼ sec. 14, T. 7 N., R. 10 W.

[Reference point, top of cement pump base level with surface of ground. No pump in well]

Date of measurement	Depth to water below reference point	Measured by
1921		
May 29	62.05	D. G. Thompson and N. S. Abbott.
Aug. 21	62.2	N. S. Abbott.
Oct. 2	62.3	Do.
Dec. 30	62.3	Do.
1922		
May 1	63.4	Do.
Sept. 2	62.7	Do.
Oct. 17	62.8	Do.
1923		
May 8	62.9	Do.
July 12	63.1	Do.
Oct. 8	63.3	Do.
Dec. 7	63.2	Do.
1924		
Feb. 16	63.05	Do.
Apr. 12	63.4	Do.
July 9	64.0	Do.
Aug. 12	64.1	Do.
Oct. 23	64.3	F. C. Ebert and H. G. Troxell.
1924		
Nov. 13	64.1	N. S. Abbott.
1925		
Feb. 10	63.8	Do.
May 6	64.5	F. C. Ebert and H. G. Troxell.
June 9	64.8	N. S. Abbott.
Sept. 10	65.5	Do.
Oct. 6	65.6	F. C. Ebert.
Oct. 30	65.4	N. S. Abbott.
1926		
Jan. 4	64.8	Do.
Mar. 15	64.9	Do.
May 13	65.65	F. C. Ebert.
Aug. 16	66.9	N. S. Abbott.
Oct. 16	67.4	F. C. Ebert.
1927		
Jan. 17	66.3	N. S. Abbott.
May 9	67.6	F. C. Ebert.
Oct. 27	(1)	Do.

[1] Well 10 feet to south running.

MOHAVE RIVER BASIN

The drainage basin of Mohave River is one of the largest in the Mohave Desert region. Agricultural development has been greater in this basin and the prospects for future development are also greater than in any other basin of the region except, perhaps, Antelope Valley. Several projects to irrigate large areas in the basin have been proposed, but so far none of them have been completed. A number of reports, published and unpublished, have been made upon these different projects. The most comprehensive report is Bulletin 5 of the California State Department of Engineering, "Report on the utilization of Mohave River for irrigation in Victor Valley, Calif.," by W. F. McClure, J. A. Sourwine, and C. E. Tait. This report, like most of the others, considers principally problems concerned in the utilization of the surface flow of the river.

The basin contains several large areas where conditions are favorable to agricultural development, separated by less favorably situated areas. The physical and geologic conditions are such that there seems no doubt that the development of either the surface or ground-water supply in one part of the basin will affect the development in areas farther downstream. No report, so far as the writer is aware, has given more than passing consideration to the effect of developments in one part of the drainage basin on developments in another part. In the following pages attention is called to some of these problems, but their solution does not lie within the scope of this report. Because of the relation between conditions in different parts of the basin it is desirable first to describe certain features of the basin as a whole and then to discuss conditions in the different sections separately.

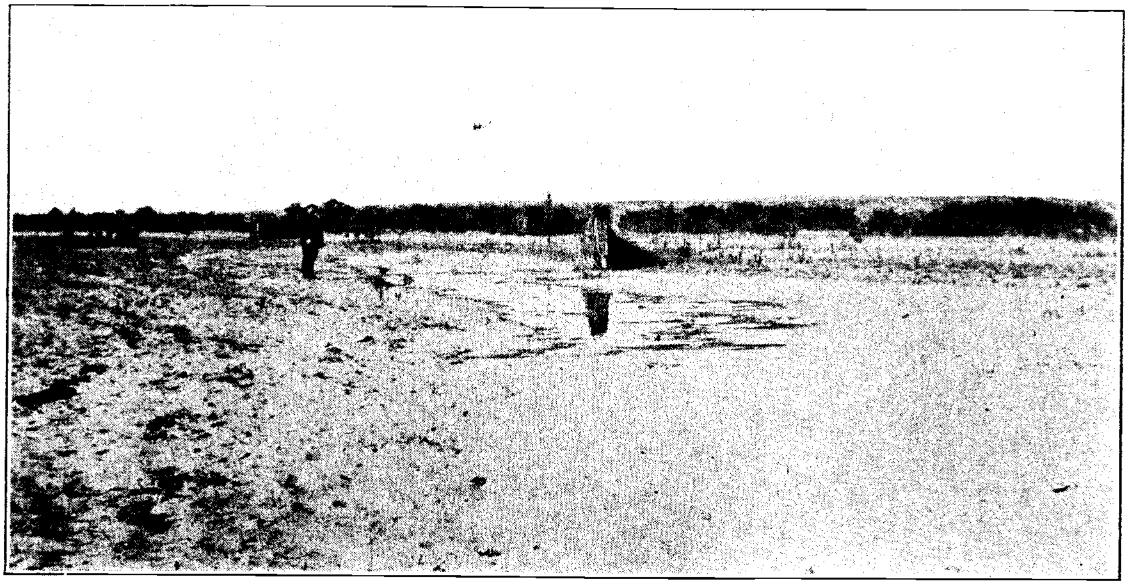
The data on the Mohave River Basin are based on information obtained from several sources. The writer has personally observed and collected some data in almost the entire drainage basin of the river, except the headwater region in the San Bernardino Mountains. His detailed studies, however, were confined to the area from Barstow eastward to the so-called "sink" of the Mohave. The late Mr. C. E. Tait, of the United States Bureau of Public Roads, kindly made available to the writer data in regard to more than 300 wells in the upper part of the drainage basin collected in connection with the investigation of the Mohave River Commission. Some of these data were published in the bulletin already cited,[23] but many of the data of value in the interpretation of ground-water conditions in that part of the region were not published. In the fall of 1916 G. A. Waring, of the United States Geological Survey, collected data on wells in the Mohave River Basin from the upper valley down as far as Minneola and Yermo, and these are incorporated with the other data.

In 1920 in response to requests for information in regard to groundwater conditions along Mohave River, a special preliminary report was prepared by the writer. Manuscript copies of this report were deposited in the branch office of the United States Geological Survey at Los Angeles, the office of the State water commission at San Francisco, and the office of the county surveyor of San Bernardino County. In that report it was possible to state briefly only the general features of the occurrence of ground water in the basin.

TRANSPORTATION AND SETTLEMENTS

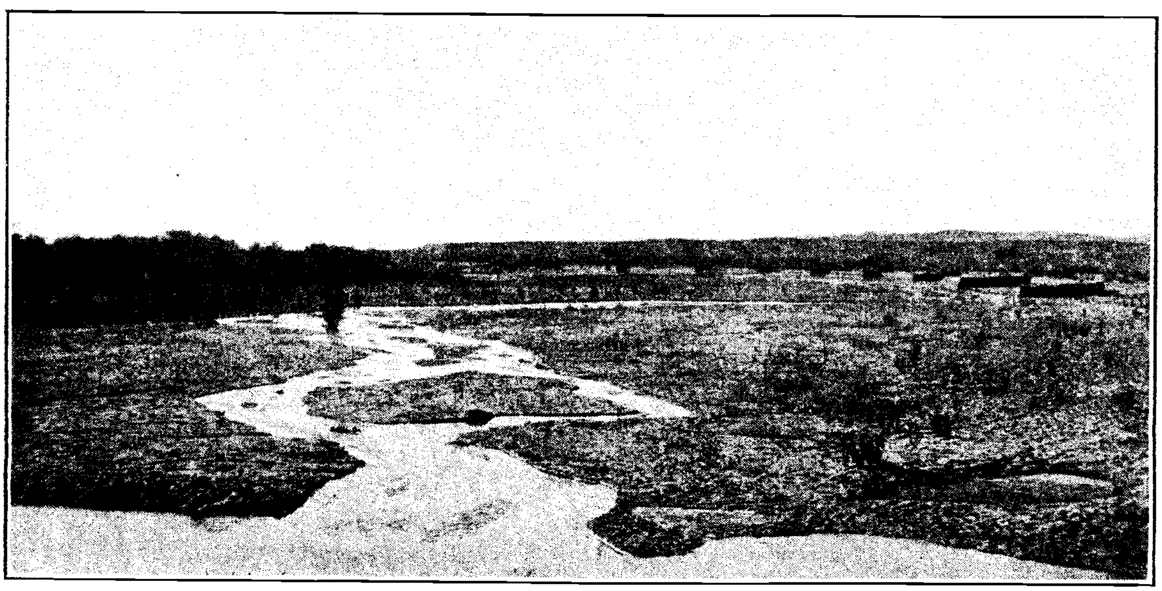
The main transcontinental line of the Atchison, Topeka & Santa Fe Railway follows close to Mohave River from a point within a few miles of its headwaters as far down as Daggett and thence it continues eastward at a greater distance from the river. The San Francisco line of that road goes west from Barstow. The Los Angeles & Salt Lake Railroad uses the tracks of the Santa Fe between San Bernardino and Daggett and thence is close to the river northeastward to its end near Soda Lake. The National Old Trails Road, one of the principal transcontinental automobile roads, is within a few hundred feet to 3 miles of the Santa Fe along its course in the drainage basin. Branch roads from it give easy access to nearly all parts of the drainage basin except the extreme northeastern part, from about Field station, on the Los Angeles & Salt Lake Rail-

[23] McClure, W. F., Sourwine, J. A., and Tait, C. E., op. cit., pp. 84–93.

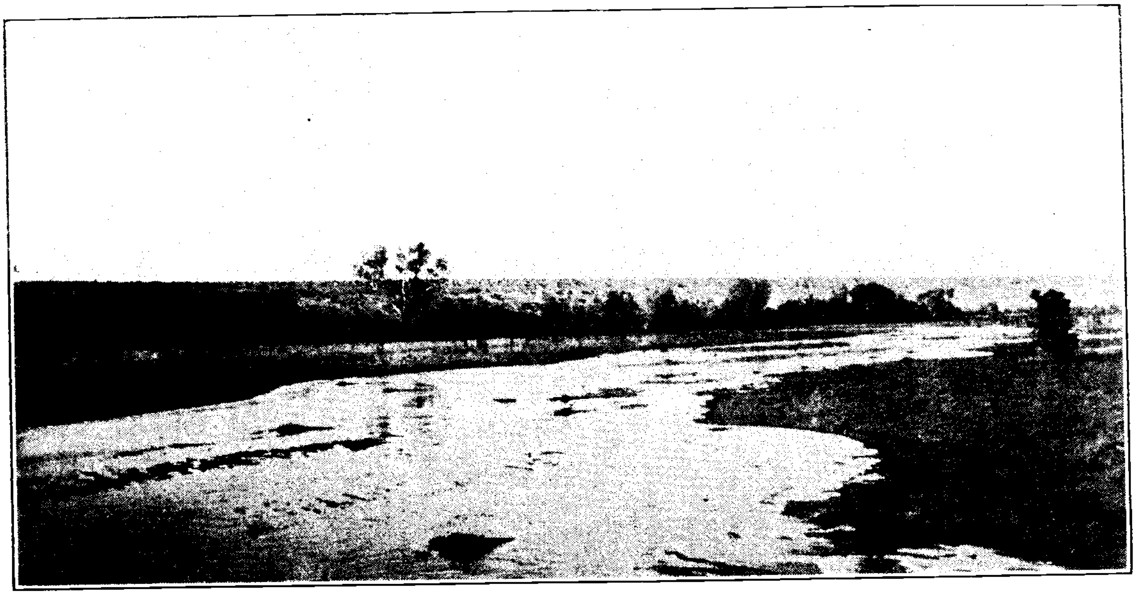


A. MOHAVE RIVER 1,000 FEET ABOVE BARSTOW WAGON BRIDGE, NOVEMBER 30, 1919

Since 6 p. m. of the preceding evening the stream had advanced from a point near where the man is standing



B. MOHAVE RIVER LOOKING UPSTREAM FROM BARSTOW WAGON BRIDGE, JANUARY 23, 1920



A. MOHAVE RIVER ABOUT HALF A MILE BELOW CAMP CADY, NOVEMBER 21, 1919

B. END OF STREAM IN CHANNEL OF MOHAVE RIVER ABOUT HALF A MILE BELOW POINT SHOWN IN *A* road, to the Crucero Valley. Travel in that part of the region is difficult because of sand.

Approximately one-third or one-fourth of the population of the Mohave Desert region live in the Mohave River drainage basin. The relative size of the principal towns is indicated by the statistics on population given on page 24. Although these data include the persons who may live some distance from the towns, the greatest number are inhabitants of the towns listed. The largest town is Barstow, which is a division point and junction of the San Francisco and Los Angeles lines of the Atchison, Topeka & Santa Fe Railway and a general supply point for agricultural and mining activities in a large part of the desert. Victorville, the next largest town, is the center of a large agricultural region and is also the site of a large cement plant. Both these towns have well-equipped stores and garages and afford good hotel accommodations. General supplies are obtainable at Hesperia, Adelanto, Oro Grande (Halleck post office), Hicks, Hinkley, Daggett, Yermo, and Water station (Newberry). The other places along the railroads shown on the map are only headquarters for section men or sidings. Water can be obtained in an emergency from tanks or barrels at practically every siding along the Atchison, Topeka & Santa Fe Railway. On the Los Angeles & Salt Lake Railroad east of Yermo, water is regularly available only at Harvard, Field, Afton, Crucero, King, and Yermo.

INDUSTRIES

A large part of the population of the valley, particularly at Barstow and Yermo, is engaged in the maintenance and operation of the transcontinental railroads that pass through the region. Although there is some agricultural development around each of the principal towns, the areas under cultivation are scattered and small, and the agricultural production so far has probably been relatively small.

The mineral products have been of great value. During the eighties, silver to the amount of about $10,000,000 was produced from the Calico and Grapevine districts, north of Daggett and Barstow respectively, and other metals have been mined in smaller quantities in other localities in the drainage basin. Metal mining has shown little activity in recent years. The production of borax from the borate deposits in the Calico Mountains has amounted to more than $9,000,000. These deposits were practically abandoned several years ago on the discovery of borax deposits in Death Valley, but in recent years production has been continued on a small scale. Two large cement plants, at Victorville and Oro Grande, produce several hundred thousand barrels a year. Talc and kaolin from a deposit in the hills east of Bryman are manufactured into "whiting" for paint filler, sizing paper, and porcelain work. The product is refined in a small mill at Bryman. Strontium-bearing deposits 7 or 8 miles north of Barstow were worked during the war, but little has been done since. Variegated marble occurs about 15 miles northeast of Victorville, and granite for building and for paving blocks has been quarried in the vicinity of Victorville.

PHYSICAL FEATURES

The drainage basin of Mohave River is an irregular-shaped area that extends from the southwestern part of San Bernardino County northeastward to the central part of the county. The boundary of the basin, as determined by a careful study of published and unpublished topographic maps and field observations of the writer, is shown on Plate 7. Because of the low rainfall and the gentle slope of the land, the river probably does not receive any surface drainage from a large part of the basin, but there is doubtless underground drainage to the river from this part. On the other hand, there is at least one place and probably two or three places where there is underground leakage from the drainage basin into adjacent basins. These peculiarities are described in more detail below.

Mohave River is a typical desert river. It rises in the high San Bernardino Mountains, where it is perennial. Within a short distance it emerges on to the desert plain, and much of the water sinks into the porous alluvium, so that it is entirely dry throughout much of its course for many months at a time. The river takes a northerly course from its head to Barstow and thence flows northeastward along the line of the Los Angeles & Salt Lake Railroad. Near Baxter it emerges from a canyon, and, when in flood, the water spreads out in several channels over a large alluvial fan. Some of it runs northeastward to a playa, which in this report is called East Cronise Dry Lake, but the greater part continues eastward to Soda Dry Lake, another playa.

In extreme floods the water has overflowed the two playas mentioned to adjoining playas, the water from East Cronise Lake going westward through a short channel to West Cronise Dry Lake, and the water from Soda Lake going into Silver Lake, a playa a mile or two farther north. In many years no water from the river reaches any of the playas mentioned, but in years of extreme flood the water may be several feet deep and remain for many months. The water that reaches Soda and East Cronise Dry Lakes and the playas beyond them disappears by evaporation and by sinking into the ground, so that Mohave River ends in these depressions. This region has commonly been called "the sink of the Mohave." It has not been generally known, however, that the river divides and empties into two distinct closed basins—that is, that there are really two "sinks" instead of one. (See p. 518.)

The character of the channel of Mohave River differs considerably in different places from its source to its end. In the San Bernardino Mountains the precipitation is great, and the rocks are nearly impervious. Very little of the rainfall percolates into the ground, and most of it is directly concentrated into streams which flow the year round. Below the San Bernardino Mountains the precipitation is small, and for most of its course all or nearly all the flow of the stream is absorbed by the porous alluvial deposits except during the wettest seasons. Consequently, for many months at a time, the river channel is dry for long stretches. Although there is no surface flow at such places there is probably a slow underground movement of the water downstream.

At several places, however, impervious rocks lie so close to the surface that water rises to the surface as it passes over them. Where such conditions exist it is commonly said that a "dike" causes the water to rise to the surface. Wherever the impervious bedrock causes the water to flow at the surface or to rise near the surface a distinctive vegetation is present, of which the predominating types are salt grass, arrow weed, mesquite, poplar or cottonwood, and willow.

Wherever the water is at or close to the surface there is more or less evaporation, not only from the surface streams but also from the ground water supply through direct upward capillary movement and by transpiration from the plants. In some places as summer approaches the evaporation becomes so great that the water is disposed of more rapidly than it reaches the surface, and the stream dwindles and disappears. But even when the stream no longer exists water is generally present a few feet below the surface, except in places where the ground water is not held near the surface by submerged rock "dikes" or dams. As the end of the dry season approaches and evaporation becomes less, more water reaches the surface and the stream becomes wider and deeper and has a greater linear extent. The end of the stream may be seen to advance on cool days and at night and to retreat on warm days. The advance of the stream is shown in Plate 20, *A*, a photograph that was taken on the morning of November 30, 1919, at a point about 1,000 feet upstream from the Barstow wagon bridge. During the interval from 6 o'clock of the preceding evening the stream had advanced from the point where the man stands. As the advance occurred a zone of moisture spread out in the soil in front and to each side of the stream. The moisture may have come partly from a gradual forward movement of the ground water, but it came partly through the advance of the surface stream over the saturated soil. Plate 20, *B*, shows the same locality looking upstream on January 23, 1921, about two months later than the first photograph. It was estimated that less than 1 second-foot was flowing on the surface at this time. The precipitation in the San Bernardino Mountains prior to January 23 had been considerably below the normal, and probably the flow at Barstow had not been augmented by any run-off from the mountains but was due entirely to decreased evaporation.

The decrease in volume of the stream due to absorption by the sand and by evaporation is shown by two photographs. The one shown in Plate 21, *A*, was taken on November 21, 1919, about half or three-quarters of a mile below old Camp Cady, where a rocky point of the Cady Mountains apparently brings the water to the surface. The photograph shown in Plate 21, *B*, was taken a few minutes earlier less than half a mile downstream, where the stream ended. The flow at the upper place was estimated to be possibly as much as 2 second-feet, but it was all absorbed and evaporated within a short distance.

For practically the entire length of the river the width of the drainage basin from divide to divide is approximately the same. The character of the land, however, changes from place to place, so that there is an alternation of wide, nearly level areas favorable for agriculture and hilly or mountainous areas unfavorable for agriculture. The areas best suited for agriculture are the four that are described below in detail. The drainage basin may be divided into several subdivisions, which are described on pages 385–547.

PRECIPITATION

Records of precipitation for six or more years, by months, for Little Bear Valley, the Forks, Hesperia, the Rancho Verde (in the Mohave River bottom several miles south of Victorville), the Dobie ranch (in sec. 2, T. 5 N., R. 5 W. San Bernardino meridian), Victorville, Barstow, Daggett, and Camp Cady are given on pages 77–95. Most of these records, except those for Barstow, are taken from Bulletin 5 of the California State Department of Engineering, and most of them are for short periods.

A comparison of the records with those of stations within a radius of 100 miles where records have been kept for 20 years or more shows that the recorded precipitation at most of the stations is probably a little higher than normal, most of the observations having been made in years slightly wetter than the normal. The difference, however, probably amounts to only a fraction of an inch.

The records show that there is a great range in the average annual precipitation from the headwater region to the lower end of the river. The average annual precipitation at the gatehouse in Little Bear Valley for the period 1893–1920 was practically 32 inches. The station is at an altitude of 5,200 feet. The average precipitation at Bear Valley Dam, on the ocean side of the range, at an altitude of 6,500 feet was approximately 35 inches. A considerable area in the headwater region of Mohave River is above that altitude, and some of it reaches 8,000 feet, so that it is reasonably certain that the average annual precipitation in the highest part of the headwater region is as much as 35 inches. The precipitation decreases with the altitude until at the Forks the average annual precipitation is between 13 and 15 inches. North of the Forks the decrease becomes more gradual, and the average annual precipitation at Hesperia is about 8 or 9 inches, at Victorville about 5 or 6 inches, and at Barstow about 4 inches.

The records mentioned probably give a fairly reliable idea of the average annual precipitation at other places in the basin situated in the same latitude. Differences in altitude and geographic location doubtless cause some differences, but these are probably not great except in the southern part of the basin along the San Bernardino and San Gabriel Mountains. There the precipitation is undoubtedly affected by the easy path afforded to some of the rain-bearing winds through the low Cajon Pass, as contrasted to the great heights on both sides to which the winds must rise. The details of the local variations near Cajon Pass have not been studied, but it is said that here is a noticeable difference in rainfall near the pass and farther from it. Baldy Mesa, west of the pass, is said to get more rain than the alluvial slope farther east.[24]

It is believed that north of the San Bernardino and San Gabriel Mountains only one or two mountains are high enough to affect the precipitation—Ord Mountain and the Calico Mountains, which rise to altitudes of about 5,000 feet above sea level. The areas that reach such high altitudes are not great, however, and these mountains probably do not exert much influence on the precipitation. It is probable that in practically all of the drainage basin north of Hesperia the average annual rainfall is not more than 7 inches. The lower end of the Mohave River basin lies at a low altitude, and Crucero Valley lies at 1,000 to 1,200 feet. The geographic conditions are such that the rainfall in that part of the basin is probably as low as anywhere else in the region, perhaps not more than 2 or 3 inches annually.

In most of the basin except the headwater region and especially in the valley areas the precipitation occurs largely in the form of rain. Snow sometimes falls in the higher interior mountains when none falls in the valleys, but it does not remain long. A large part of the precipitation in the headwater region, however, comes as snow. Records show that the average annual snowfall in Holcomb Valley for seven years was approximately 100 inches and that snow may be expected in all except four months in the year. As a result of the

[24] California Dept. Eng. Bull. 5, p. 35, 1918.

gradual melting of the snow the run-off in the headwater region is equalized more than it otherwise would be if such a large proportion of the precipitation were not snow.

SURFACE WATER

Mohave River is the only stream in this basin in which there is any considerable surface flow. On the north slope of the San Bernardino and San Gabriel Mountains, outside of the area drained by the river along the Forks, there are one or two streams, notably Sheep Creek and Arrastre Creek, in which small streams may flow for several days or weeks after rains. In the mountains in the interior of the basin water flows on the surface only during heavy rains or for a very few hours afterward. Most of the precipitation either sinks into the ground or is evaporated. There are no data as to whether any large quantity of water is carried to the river by the larger arroyos during the occasional heavy rains. Some of the arroyos reach back 10 or 15 miles from the river, but there are no observations to show whether the surface floods run their entire length or whether they extend for only a short distance during any one storm.

Some data are available in regard to the flow of Mohave River, but they are practically all for the flow in the upper stretches. Observations were made by the United States Geological Survey from February, 1899, to November, 1905, at a station at the Upper Narrows at Victorville.[25] The yearly totals, from October 1 to September 30, during that period are given in the accompanying table.

Annual discharge of Mohave River at Victorville, Calif., 1899–1905 [a]

	Discharge in second-feet				Run-off	
	Maximum	Minimum	Mean	Per square mile	Depth in inches on drainage area	Total in acre-feet
1899–1900	80	17	34.5	0.086	1.16	24,900
1900–1901	4,820	29	148	.370	4.84	103,000
1901–2	77	33	55.9	.140	1.94	40,400
1902–3	[b] 13,413	32	148	.370	5.03	107,000
1903–4	68	28	47.7	.119	1.61	34,600
1904–5	5,410	27	135	.338	4.58	97,600
Average for the period						97,900

[a] Compiled from U. S. Geol. Survey Water-Supply Paper 300, pp. 401–402, 1913.
[b] Float measurement.

For more than three years, from January 1, 1902, to February 28, 1905, daily gage readings were not made, and the monthly discharge was determined by averaging discharge measurements made at inter-

[25] McGlashan, H. D., and Dean, H. J., Water resources of California, Part III, Stream measurements in the Great Basin and Pacific Coast river basins: U. S. Geol. Survey Bull. 300, pp. 396–402, 1913.

vals of a few days, so that for those years data for this station are not very reliable. The channel shifts from time to time, and accordingly the discharge may be different at different times although the gage height may be the same.

In addition to the measurements by the United States Geological Survey, measurements have been made at the narrows and at other points by private parties. The Arrowhead Reservoir & Power Co. has measured streams in the upper part of the basin tributary to its reservoir in Little Bear Valley and the East and West Forks at the Forks since 1891, except for a period between 1900 and 1904, and the main river at the Lower Narrows since 1905. The Mohave Water & Power Co. made measurements at the Upper Narrows after the discontinuance of the measurements by the United States Geological Survey until 1914 and also measured the East and West Forks at the Forks from 1906 to 1914. The measurements of these companies were studied and compared carefully by the Mohave River Commission, and the results of the study have been published.[26] It is not necessary here to consider the data in detail, but the essential results of the study of the commission may be given briefly.

Some of the measurements of the United States Geological Survey and the companies disagree. No measurements of the flow of the river at the Forks prior to 1905 are available, but by comparison of later records at that point with records at the Upper Narrows, the Mohave River Commission compiled the following estimate of the discharge of the river at the Forks for the period 1897–1915, inclusive.

Estimated discharge of Mohave River at the Forks, 1897–1915, inclusive.[a]

Year	Discharge (acre-feet)	Year	Discharge (acre-feet)	Year	Discharge (acre-feet)
1897–98	27,040	1904–5	95,016	1911–12	46,964
1898–99	13,878	1905–6	135,220	1912–13	26,360
1899–1900	18,132	1906–7	254,317	1913–14	169,935
1900–1901	96,598	1907–8	60,776	1914–15	122,636
1901–2	33,789	1908–9	69,740		
1902–3	107,315	1909–10	135,705	Average	[b] 88,311
1903–4	28,232	1910–11	147,938		

[a] California Dept. Eng. Bull. 5, p. 72, 1918.
[b] In Bulletin 5 the average is given as 89,416 acre-feet, but this is not the average of the figures given there. There is apparently an error either in the average or in the figure for some year.

The average annual discharge at the Forks for the 18-year period is nearly 90,000 acre-feet. The discharge varies greatly from year to year, and the maximum annual discharge is about 18 times the minimum. The number of years in which the annual discharge was above the average was the same as the number of years in which it was below the average, but about 80 per cent of the total discharge for the period occurred in the years when the discharge was above the average.

[26] California Dept. Eng. Bull. 5, pp. 68–72, 1918.

Data for the discharge according to measurements at both the Forks and the Upper Narrows for eight years from 1905 to 1912 are given in Bulletin 5. These are reproduced in the following table, except that, as explained in Bulletin 5, there seems to be a marked error in the measurements at the Lower Narrows for the year 1905–6, and the record for that year is accordingly omitted.

Discharge of Mohave River at the Forks and the Upper Narrows, 1905–1913.[a]

Year	Mohave River at Forks (acre-feet)	Mohave River at Upper Narrows (acre-feet)	Discharge at Forks in per cent of discharge at Upper Narrows
1906–7	254, 317	259, 906	97.8
1907–8	60, 776	56, 057	108.4
1908–9	89. 740	97, 781	91.8
1909–10	135, 705	118, 084	114.9
1910–11	147, 938	135, 903	108.9
1911–12	46, 964	50, 519	93.0
1912–13	26, 360	35, 297	74.7
Average	108, 828	107, 649	------------

[a] Compiled from California Dept. Eng. Bull. 5, p. 71, 1918.

An inspection of this table shows that in some years the run-off is greater at the Forks than at the Upper Narrows and in other years it is less. In regard to this variation the Mohave River Commission states:[27]

In general, there is a loss from the Forks to the Upper Narrows in years of heavy flood and a gain in years of relatively small flood. This may be explained on the theory that water in this part of the river is lost from the surface flow to the underflow in the heavy floods and returned by the charged gravels to the surface stream above the narrows in seasons of light discharge. It appears from the measurements that practically all of the water which enters the underground basin below the Forks is re-collected above the narrows and flows out through them. The observations on underground water serve to confirm this belief.

It is undoubtedly true that during the flood seasons water is lost from the surface flow and in the dry seasons water moves from the underflow to the surface flow, but it is doubtful whether the variations can be explained by such a simple generalization. In the year of greatest discharge (1906–7) there was actually an increase from the Forks to the narrows, and in 1907–8, when the discharge was only a little more than half of the average, there was a loss. This fact is all the more striking when it is noted that this was the year following the year of greatest discharge. If conditions were as suggested by the commission the gravel should have been heavily charged in 1906–7 and should have been discharging during 1907–8. It is likely that there is some movement of ground water to the river from the east and west mesas, which is supplied from ephemeral streamways. This movement should be taken into consideration in explaining the varia-

[27] California Dept. Eng. Bull. 5, p. 71, 1918.

tions in underflow. Furthermore, the variation between the discharge at the Forks and that at the narrows is doubtless affected by differences in the character of the precipitation and other climatic conditions which influence the run-off. For instance, a heavy storm might result in considerable run-off from the lands between the Forks and the narrows.

Below the Lower Narrows the surface flow of Mohave River gradually decreases, largely because the water is absorbed by the sandy soil along the river. In dry months for long stretches there is no surface flow, but small streams appear where bedrock is close to the surface. During floods a large quantity of water is undoubtedly absorbed by the sand and gravel, but no reliable data are available to show just how much water is absorbed. In many years practically the entire surface flow is absorbed above the end of the river. Almost every year the water flows as far as Barstow. It is said that during the period 1894–1902 the flood water did not reach Daggett, but that after that period it extended beyond Daggett each year until 1917 or 1918. On Plate 20, *B*, is shown a view of the river at Barstow on January 23, 1920. At this time the river was dry at the Daggett bridge. The winter prior to this time had been dry, but more rain fell later on, and the stream may have advanced. On the other hand, in some years great floods come down the river. After heavy rains in January, 1916, so much water flowed down the river that it not only reached Soda Dry Lake but continued across that playa to Silver Lake, which it filled to a depth of about 10 feet. It is said that practically all the water in Silver Lake, when the playa of that name s flooded, comes from Mohave River, particularly the headwater region, and not from the desert land immediately adjacent to the playa.

IRRIGATION PROJECTS

In the last half century a number of projects have been launched which have contemplated using the surface flow of Mohave River or pumping ground water from adjoining lands to irrigate large tracts of land. Although most of these projects were started prior to 1910, none of them are yet on a successful operating basis. A detailed history of these different projects would involve a tedious recital of financial difficulties and litigation over water rights. The areal descriptions give such actual developments as are useful in considering important problems. In order that the reader may have a general understanding of conditions, a brief statement of the projects is given below. The history of the different projects is described in more detail in a publication of the California Department of Engineering,[28] from which part of the data here given are abstracted.

[28] California Dept. Eng. Bull. 5, pp. 16–25, 1918.

A few small ditches derived water from the river prior to 1870, but the first large project was started in 1870, when an organization known as the Thirty-fifth Parallel Association, through Max Stroebel, purchased 30,000 acres from the Government on the upper part of the river, comprising some of the bottom lands and the west mesa. In 1886 the Hesperia Land & Water Co. was organized to supply water to and sell the lands of the Stroebel organization, which it acquired. Among the lands originally owned by this company and later sold was the Upper Narrows dam site. The company acquired some lands at the Forks of the river. It diverted water from Deep Creek (or the East Fork) above the Forks and carried it across Mohave River in an inverted siphon and thence through a pipe line to a reservoir near Hesperia. This supply has been used for irrigation and domestic supply for Hesperia. The inverted siphon across Mohave River has been washed out several times, and for two years prior to 1911 no water was delivered at Hesperia.

In 1911 the Appleton Land, Water & Power Co. was organized and took over the Hesperia Land & Water Co.'s system. It repaired the siphon and in other ways improved the pipe line. The Hesperia Water Co. was organized as a subsidiary public-utility company in 1915 to serve water for domestic and other uses in Hesperia. Although in the early history of the project about 1,000 acres was irrigated, as the supply was repeatedly cut off by the destruction of the siphon across the river the area irrigated decreased, and in recent years it has been very small.

In 1891 the Arrowhead Reservoir Co. was organized.[29] This company proposed to construct a series of reservoirs on the streams tributary to the East Fork or Deep Creek. The largest reservoir, on which some construction work was done, was to be on Little Bear Creek, and the others were to be connected with it by tunnels. It was planned to carry the water through the San Bernardino Mountains in a long tunnel and sell the water for irrigation near San Bernardino. Work on the project was suspended by difficulties in finance and construction, as it was found that the expense would be excessive if the water were used for irrigation alone. The later development of practical means of long-distance transmission of electrical power made the project more feasible, as considerable income could be obtained from the development of electrical energy. In 1909 the Arrowhead Reservoir & Power Co. was organized and took over the property of the Arrowhead Reservoir Co. This company, like its predecessor, proposed to carry the water to the south side of the mountains. In 1909, however, some owners of riparian lands along the river filed suits to prevent the company from diverting

[29] In addition to the information given in California Dept. Eng. Bull. 5, notes on the early development work of the Arrowhead Reservoir Co. are given in U. S. Geol. Survey Nineteenth Ann. Rept., pt. 4, pp. 615–628, 1898.

water from the drainage basin. These cases have been pending for many years. The company began to purchase some riparian lands to dispose of some of the opposition to their proposition, but the procedure was halted as the result of a decision of the State Supreme Court in another case that the flood waters of a stream could not be legally diverted from the natural drainage basin. The plans of the company were necessarily changed to provide for using the water on the north side of the mountains. As the diversion of water from a drainage basin for domestic use is legal, the company offered to sell its water supply to the city of San Diego, but this offer was not accepted.

The Arrowhead Reservoir Co. and its successor have done considerable construction work. In 1920 the dam for the Little Bear Valley Reservoir was about 80 per cent completed. Several thousand feet of the necessary connecting tunnels had also been driven. The Little Bear Valley Reservoir then provided storage for about 35,000 acre-feet, but the Arrowhead Reservoir & Power Co. had so far not utilized the stored waters. In recent years an option on its property and water rights was taken by the Victor Valley Irrigation District, which contemplated the use of the water on the land west of the river.

In 1920 an application was filed with the division of water rights by the city of Pasadena to utilize the headwaters of Mohave River for its municipal supply. This action has further delayed the development of the headwaters of the river, as it would involve the use of the reservoirs built or contemplated by the Arrowhead Reservoir & Power Co. and also would bring about complications in regard to the supply of water users farther down the river. The status in recent years of the projects to develop the headwaters of the river is described further on pages 420–423.

Another project to which considerable attention has been given at one time or another involves the construction of a dam at the Upper Narrows and the formation of a large reservoir above the narrows. This project was first considered by the Columbian Colonization Co., which was organized about 1895. The water was to be used on lands below Victorville. Later certain individuals proposed to construct a long tunnel south from the reservoir through the San Bernardino Mountains. The dam site and some of the lands that would be flooded are now owned by the Mojave Water & Power Co. No construction work has been done, and this project has been dormant for a number of years.

In the early nineties plans were filed in the United States General Land Office for a project to divert the flow of Mohave River in sec. 21, T. 9 N., R. 3 W., and carry it into Harper Valley, north of Hinkley, which would be used as a storage reservoir. The plans submitted are vague. Apparently the water was to be used on lands farther down the river. To distribute the water by gravity an outlet pipe or tunnel buried at a maximum depth of 50 to 100 feet and 14 miles or more in length would be necessary to reach lands lower than Harper Valley, and the nearest large area that could be irrigated is east of Daggett, more than 25 miles from the proposed reservoir. The project was ill advised and was soon dropped.

About 1892 the Southern California Improvement Co. began construction on a submerged dam across Mohave River about 3 miles west of Daggett. The notes on this development are based largely on statement to the writer by Buel Funk, one of the present owners of the ditch. It was planned to convey the water by ditch to a point about a quarter of a mile north of the corner of secs. 28, 29, 32, and 33, T. 9 N., R. 2 E., near Minneola. At that place there was to be a drop of 70 feet to generate power to be used at the mines and mills at Calico. The water was then to be used to irrigate land north and east of Minneola. It was expected that 2,000 miner's inches (40 second-feet) would be developed, and some persons optimistically predicted more. The maximum quantity obtained was actually only about 500 miner's inches (10 second-feet). This water was allowed to run down to Minneola, wasting there without use, until 1901. The tunnel and ditch became clogged until in 1913 only about 70 miner's inches was obtained. In 1913 three or four persons undertook to develop the water for irrigation. The submerged dam and tunnel were repaired, and the water, about 200 miner's inches at a maximum, has been used to irrigate several hundred acres east of Daggett. Further developments, which were made recently to obtain a larger supply of water, are described in detail on pages 505–507.

In 1910 the Mojave River Land & Water Co. was organized to develop several thousand acres northeast of Yermo. The company planned to obtain water from the underflow of the river at a point where there is a small surface stream and from wells on the north side of the river. Several wells were put down and several miles of concrete ditches were built. The company met with financial difficulties and was reorganized in 1916 as the Yermo Mutual Water Co. When the region was visited in 1919 the pumping plants were partly dismantled, and no active development work was being done on the project. The details of this project are given on pages 507–509.

About 1915 the Valley Cultivating Co. was organized to develop water for irrigation in Cronise Valley, though only for the lands of stockholders. It has planned to divert water from Mohave River where it emerges from Caves Canyon and store it in a small reservoir formed by constructing a small dam across a narrow channel between rock hills that is one of the distributary channels. When visited in December, 1919, the dam was partly constructed. The development was not far enough along to demonstrate whether it will prove successful. This project is discussed in greater detail on pages 540–542

LOCAL DETAILS

The following pages contain general descriptions of the physical features and geology and more detailed data on the water resources and agricultural conditions of different parts of the Mohave River drainage basin. The physical features of the basin are such that it is not feasible to draw sharp boundaries between the different parts of the basin, but for convenience in description the drainage basin is separated into five large areas (see pl. 7), including the headwater region, in the San Bernardino Mountains; the Upper Mohave Valley, which extends as far north as the north boundary of T. 7 N. (pl. 22); the Middle Mohave Valley, including the region eastward to Barstow (pl. 17); the Lower Mohave Valley, extending from the vicinity of Daggett eastward to the Cady Mountains (pl. 24); and Crucero and Cronise Valleys (pl. 28). A smaller distinct area is Cave Canyon, between the Lower Mohave Valley and Crucero Valley. Silver and Soda Lake Valleys receive some drainage from Mohave River, but as they also receive drainage from territory not directly tributary to the river they are considered separately. (See pp. 554–572.)

HEADWATER REGION

The headwater region includes not only that part of the San Bernardino Mountains that is directly tributary to the East Fork (Deep Creek) and West Fork of Mohave River but also the territory in the San Bernardino and San Gabriel Mountains that is drained by minor streams which pour their waters onto the alluvial slope and which, if they ever flow as surface streams as far as the river, reach it below the Forks.

East, southeast, and south of the Forks the main mass of the San Bernardino Range rises steeply to altitudes of several thousand feet. Southwest of the Forks the West Fork of Mohave River for about 5 miles flows in a deep, broad valley. On the south of it the mountains rise to great altitudes. North of the river are intricately dissected hills which rise only about 500 feet above the river.

East and southeast of the Forks the main mass of the San Bernardino Range is composed of old intrusive rocks and patches of sedimentary rocks, more or less metamorphosed. The location of the sedimentary areas as shown on the map (pl. 8) have been furnished to the writer by W. C. Mendenhall, of the United States Geological Survey, and J. R. Finlay.

Mr. Finlay has found fossils in Holcomb Valley which have been determined by G. H. Girty to be of Carboniferous age, probably Pennsylvanian. The age of the granite, which forms a large part of the range, has generally been believed to be Mesozoic, the same as the intrusive rocks of the Sierra Nevada, but Finlay, on the basis of studies south of the San Bernardino Mountains, believes it to be Permian.[30]

West and southwest of the Forks, as far as the south side of Horsethief Canyon and westward to Sheep Creek, a large part of the headwater area is underlain by Pleistocene deposits. (See pl. 8.) These deposits not only occur along the stream channels but also form the very intricately dissected hills north of the West Fork and Horsethief Canyon. Farther west they form the divide between the Mohave River basin and Cajon Creek, which drains to the Pacific Ocean. The beds are very well exposed both along the Atchison, Topeka & Santa Fe Railway near Summit station and along the main automobile road near the summit of Cajon Pass. They are apparently a remnant of a former alluvial slope which was built out from the San Gabriel and San Bernardino Mountains and was later uplifted and greatly dissected. The uplifting is probably related to movements in the San Andreas fault zone.

As the main mass of the mountains consists of relatively impervious rocks and has steep slopes most of the rainfall and melted snow is carried directly into the streams. There is, however, some soil and vegetation that temporarily retains a part of the precipitation and hence makes the run-off more evenly distributed through the year. For this reason the principal streams in the area underlain by bedrock are perennial.

In the area of dissected alluvium along the West Fork and Horsethief Canyon a large part of the precipitation is absorbed as it falls and does not reach the streams. It apparently moves northward beneath the alluvial slope and becomes part of the great ground-water body that lies beneath Upper Mohave Valley. The West Fork occupies a rather broad valley filled with more recent alluvium, which absorbs some of the flow of the stream. In the valley of the West Fork there is a little irrigation by water taken from some of the near-by streams before they reach the porous alluvial filling of the valley.

The headwater region forms a collecting area for the water of both the surface flow of Mohave River and a large part of the ground water of different parts of Upper Mohave Valley. The total drainage area of the headwaters of Mohave River above the Forks is about 215 square miles. It is divided into two main parts—that drained by Deep Creek, also called the East Fork, and that drained by the West Fork and its tributaries. The area tributary to Deep Creek is a little more than two-thirds of the total area, and that of the West Fork nearly one-third. The Deep Creek basin reaches altitudes from 2,000 to 3,000 feet higher than the West Fork basin. The

[30] Finlay, J. R., The Permian revolution in North America: Eng. and Min. Jour., vol. 112, No. 27, pp. 1058–1059, 1921, and personal communication to the writer.

average annual discharge for the 10-year period from 1905–6 to 1914–15 was about 72,000 acre-feet from Deep Creek and 47,000 acre-feet from the West Fork (p. 379). This relation suggests that although the West Fork basin does not reach such high altitudes as the Deep Creek basin, the precipitation is greater, perhaps because of topographic conditions, especially the way in which rain-bearing winds blow through Cajon Pass.

Outside of the area tributary to Mohave River above the Forks, there are areas of mountainous territory on each side of the river. The areas are small, and the streams in them are short. The largest stream is Sheep Creek, at the west end of the area included in the Mohave River Basin. This creek has built up below the mountains a large alluvial cone which slopes northeast, north, and northwest. This cone forms the divide between the Mohave River Basin and Antelope Valley on the west. At one time or another, whenever there has been any surface flow, the creek has discharged first into one basin and then into another. The present channels were not traced, and it is not known just where the surface drainage goes. As a matter of fact, any surface flow from the stream is probably absorbed before it gets very far out on the cone. The water thus absorbed probably percolates both northeastward to Upper Mohave Valley (including El Mirage Valley) and northwestward to the drainage basin of Antelope Valley. The drainage area of Sheep Creek is about 13 square miles. For a distance of about 5 miles on the south border of the basin the mountains rise to an altitude of more than 8,000 feet, with precipitous slopes. The presence of large pine trees shows that the precipitation in the upper part of the valley must be considerable. The channel of the creek is cut in bouldery alluvium, and apparently a large part of the run-off is quickly absorbed, even before the alluvial slope is reached. On May 1, 1920, there was no surface flow in the wash as far as about 4 miles above the mouth of the canyon. At a point located approximately in the SE. ¼ sec. 7, T. 3 N., R. 7 W. San Bernardino meridian, there was a small stream estimated to flow about 0.3 second-foot.

The only other noteworthy drainage area in the headwater region is the Arrastre Canyon Basin, east of the Forks, which covers 20 square miles. Most of this basin is less than 5,000 feet above sea level. No data are available in regard to discharge from it, but the discharge is probably less than that of Sheep Creek. Like Sheep Creek the stream has built an alluvial cone in front of the mountains that form the surface divide of the Mohave River Basin.

UPPER MOHAVE VALLEY

In this report the term "Upper Mohave Valley" is applied in a general sense to that portion of the drainage basin of Mohave River shown on Plate 22, except the headwater region in the San Bernardino and San Gabriel Mountains. Locally other names are given to parts of the valley, such as Victor Valley, Sunrise Valley, Apple Valley, Fairview Valley, and El Mirage Valley, but no definite boundaries can be drawn between these valleys.

The writer spent but a very short time in the valley. The discussion of ground-water conditions is based largely on well data collected by C. E. Tait in the investigation by the Mohave River Commission, which he kindly made available to the writer. Some of these data that relate to size and depths of wells, depth to water, altitude of well, yield, and equipment are published in Bulletin 5 of the California Department of Engineering.[31] In addition, the data collected by Mr. Tait but not used in Bulletin 5 include well logs and other valuable information. The information on wells 302 to 333 was collected by G. A. Waring in the fall of 1916 for the United States Geological Survey. For convenience in reference the well data given in Bulletin 5 are republished in the present report. In order to avoid confusion, the same numbers are used as in Bulletin 5, and the additional wells that are not listed in that report are added at the end.

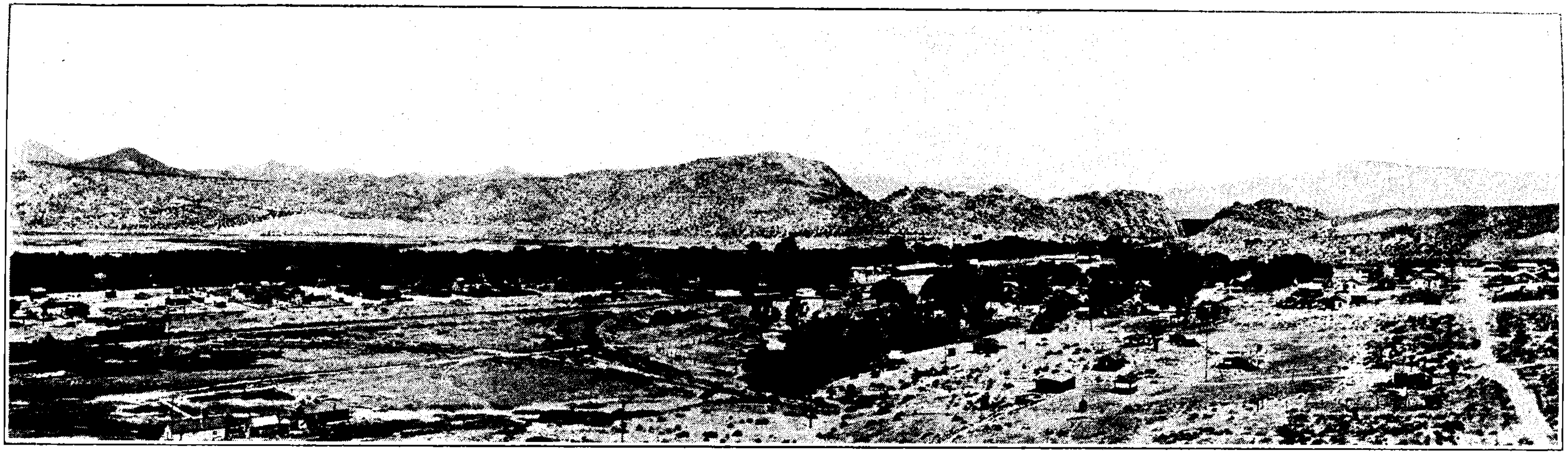
PHYSICAL FEATURES AND GEOLOGY

The Upper Mohave Valley is a great alluvial plain that in general slopes gently northward from the San Bernardino and San Gabriel Mountains. This plain has been formed from disintegrated rock débris washed down from these mountain ranges. The southern border of the plain extends approximately east and west and is nowhere more than 2 or 3 miles north or south of the line between Tps. 3 and 4 N. The northern border of the plain is more irregular. At the extreme eastern edge of the area the plain is only 2 or 3 miles wide where it abuts against mountains on the north. West of Victorville the plain extends northward for a distance of 25 miles or more from the mountains.

The alluvial slope built out from the San Bernardino and San Gabriel Mountains and the continuation of these ranges extends in an approximate west or northwest direction continuously for more than 100 miles. The area that is tributary to Mohave River, however, is only about 30 miles long. It is limited on the east and west by two alluvial fans, which have been built out against mountains on the north by streams that emerged from the San Bernardino and San Gabriel Mountains.

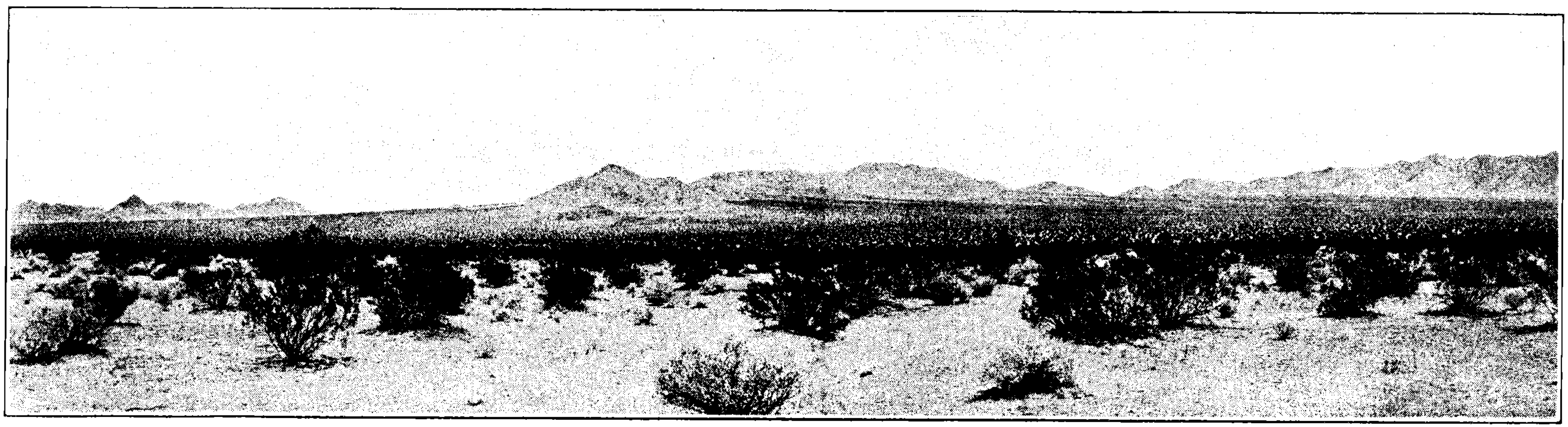
On the east the surface divide is formed by a fan built out from Arrastre Canyon to rock hills near Deadman Point. East of this fan there is a small closed basin several square miles in extent that is cut off from the Mohave drainage basin by a very low divide, and east of that basin there is another small closed basin formed in a similar

[31] California Dept. Eng. Bull. 5, pp. 84–92, 1918.



A. VIEW LOOKING EAST AND SOUTHEAST ACROSS MOHAVE RIVER VALLEY AT VICTORVILLE

Upper Narrows at right and Sidewinder Wash at left. Photograph by G. A. Waring



B. ALLUVIAL SLOPE RISING TO THE GRANITE MOUNTAINS ON THE NORTH SIDE OF BICYCLE VALLEY

Photograph by G. A. Waring

way by fans built out against the hills on the north, one of them near Fifteenmile Point and the other about 2 miles west of the Box 5 ranch. Although there is no surface drainage from these two small basins, apparently there is some movement of ground water from them to the Mohave River Basin, and they are therefore included in the description of the Upper Mohave Valley. No local names are known for these basins, but for convenience in this report the eastern one is called Fifteenmile Valley and the other one Deadman Valley, after the points at their west ends.

On the western part of the alluvial plain the boundary of the basin is formed by a huge fan that appears to have been built largely by the discharge from Sheep Creek. This fan extends northward for 15 miles or more, and where it abuts against the south ends of low hills arranged in a bow, it has caused the complete closing of a small basin, which is known as El Mirage Valley. There is evidence that ground water moves from this basin into the Mohave River basin, and it is therefore described as a part of the Upper Mohave Valley. (See pp. 405–410.)

The northern boundary of the Upper Mohave Valley is irregular. On the west, low hills just mentioned form a definite divide, which bounds El Mirage Valley. The southwest end of these hills, including Gray Mountain, is composed of granite. Farther north the hills are more rounded and from a distance appear to be composed of alluvium. Probably, however, bedrock surrounds El Mirage Valley entirely on the north. East of El Mirage Valley the boundary of the alluvial plain is indefinite. Alluvial beds, apparently of the same series as those that form the alluvial plain of the Upper Mohave Valley, extend northward for many miles, but in the northern part the slope is more eastward from hills on the west toward the river than northward from the mountains. A long wash, which heads near the south end of the Shadow Mountains, at the east side of El Mirage Valley, extends northeastward to Mohave River near Helendale, and this may be considered to mark the north side of the Upper Mohave Valley west of Mohave River.

East of Mohave River rock hills and mountains lie within half a mile to 4 miles of the river from Helendale south to Victorville. The largest of these mountains is Oro Grande or Silver Mountain, which rises to an altitude of more than 4,000 feet. East of Victorville low rock hills extend for about 10 miles, broken at several places by low passes. The southeastern border of the basin is formed by the Granite Mountains, which reach an altitude of more than 5,000 feet.

There are several stream channels that join Mohave River on the alluvial plain and extend back 10 or 15 miles to the mountains. The largest is a wash that reaches the Mohave east of Victorville, between the Upper and Lower Narrows, and drains a large territory to the east and northeast. A small nearly inclosed valley in the southwestern part of T. 7 N., R. 2 W. San Bernardino meridian, apparently drains through a narrow pass westward and thence southwestward into the large wash. For convenience this large wash and the valley in which it lies may be called Sidewinder Wash and Sidewinder Valley, respectively, after a watering place and abandoned mill near the center of the valley. A valley that branches to the southeast from Sidewinder Valley may be called Granite Valley.

The rocks of the mountains east of the river are principally metamorphosed sedimentary rocks and intrusive rocks. The sedimentary series occurs in Silver Mountain, as quartzite and limestone, which have been called the "Oro Grande series" by Hershey.[32] On the basis of lithologic comparison with rocks in other regions Hershey believes these rocks to be Cambrian. Metamorphosed sediments also probably occur in the Granite and other mountains on the eastern border of the basin, but large parts of these mountains are composed of intrusive rocks. Some Tertiary volcanic rocks occur in the northeastern part of the area shown on Plate 22.

The great alluvial plain that forms the Upper Mohave Valley slopes generally northward at the rate of 50 to 100 feet to the mile. The steepest slope is nearest the mountains. Near Mohave River the alluvial slope has a component of slope toward the river, and near the mountains on the east and north sides of the valley for a short distance the land slopes directly from these mountains. The upper part of the alluvial slope is considerably dissected by channels of erosion. Most of these channels reach only a mile or two from the mountains, but in an area southwest of Victorville and west of Hesperia several large drainage channels extend for many miles. The largest of these channels is Oro Grande Wash, which extends from a place near the summit of Cajon Pass northeastward to the river at Victorville, a distance of about 15 miles. The land adjacent to these washes and to the large wash that extends from El Mirage Valley to the river near Helendale is more or less dissected. Most of the great alluvial slope, however, is nearly level and requires very little work to prepare it for agriculture.

The materials that form the alluvial slope are sand, gravel, and clay washed down from the mountains. Near the mountains the materials may be coarse, but throughout most of the valley there is very little coarse gravel or boulders. The beds are well exposed at a number of places along Mohave River, especially near the Forks and also on the west side of the river about opposite Bryman station, where there are nearly vertical cliffs 100 feet or more in height.

[32] Hershey, O. H., Some crystalline rocks of southern California: Am. Geologist, vol. 29, pp. 287–289, 1902. Baker, C. L., Notes on the later Cenozoic history of the Mohave Desert region in southeastern California: California University Dept. Geology Bull., vol. 6, No. 15, pp. 336–337, 1911.

The total thickness of these alluvial deposits is unknown. A number of wells have been drilled in the Upper Mohave Valley to depths of 500 to 900 feet without striking bedrock. The deepest well in the valley (No. 47, pl. 22), in sec. 36, T. 5 N., R. 4 W., is in alluvium for its entire depth of 985 feet. (See log, p. 403.) This well is on the Mohave River bottom. A well in sec. 15, T. 4 N., R. 6 W. San Bernardino meridian (No. 171, pl. 22), is believed to be 909 feet deep, and it is said to have been drilled all the way through material much like that at the surface. Well 182, in the SE. ¼ sec. 16, T. 5 N., R. 4 W., struck bedrock at a depth of 835 feet. (See log, p. 407.) This well is about a mile from the Upper Narrows, where granite hills rise from the valley. Hershey estimates the thickness of the sand and gravel beds where they are exposed in tributaries of Mohave River and Cajon Creek, near the head of Cajon Pass, to be about 2,000 feet. The upper beds, at least, are Quaternary, and doubtless also the lower, although the lowest beds may be Tertiary.

The great alluvial slope of Mohave Valley is divided into two areas, unequal in size, by Mohave River. The smaller area lies east of the river and is commonly known as the east mesa and also as Apple Valley. The much larger area west of the river is called the west mesa. The part of it that extends for 8 or 10 miles from Victorville is also called Sunrise Valley, and the elevated part near Phelan post office is known as Baldy Mesa. The areas designated by these terms have no definite boundaries.

For about 2½ miles north of the Forks the valley of Mohave River is not more than a mile wide. On the east it is bordered by the hard rocks of the San Bernardino Mountains, but on the west it is bordered by dissected hills of alluvium. Farther north, as far as the south edge of Victorville, the land rises gradually on each side. On the west the alluvial slope stretches southwestward from the river to the mountains, a distance of 10 or 12 miles, but on the east the land rises away from the river only a mile or two to the upland or mesa, which has almost no slope.

From the Forks to the south edge of the town of Victorville Mohave River flows over alluvium. As the river emerges from the mountains most of the water is quickly absorbed by the alluvium, and in dry seasons there is often no surface flow for several miles. At the south edge of Victorville the river passes through a steep, narrow canyon, cut in granite, which is known as the Upper Narrows. The rocks at these narrows act as a barrier behind which the ground water is partly impounded, with the result that water is brought close to the surface on the lowlands and there is a perennial stream for several miles above the narrows.

The canyon at the Upper Narrows is only about 1,000 feet long. (See pl. 23, *A*.) The narrowest point at the stream bed is 140 feet, and at a height of 150 feet the canyon walls are only 360 feet apart.[33] Soundings show that the channel is filled with sand and gravel to a depth of about 50 feet, where bedrock is struck. The granite hills extend east of the river for several miles and without doubt form an impervious barrier to the movement of ground water. On the west side of the river, however, the granite is exposed for only a very few hundred feet and then gives way to alluvium. There is no evidence that the granite lies close to the surface for even a quarter of a mile from the river. In well 142 (pl. 22), about a mile south of the Upper Narrows, bedrock was struck at a depth of 835 feet. (See log, p. 407.)

North of the Upper Narrows, for a distance of about 3 miles, the river flows over a broad flood plain composed of aluvium that is about 100 feet below the undissected surface of the alluvial slope. Three miles north of Victorville the river passes through another short canyon cut in granite, known as the Lower Narrows. The Lower Narrows are not as deep as the Upper Narrows, but the conditions are essentially the same as at the Upper Narrows in that the bedrock extends eastward for several miles but westward for only a few hundred feet.

The Upper and Lower Narrows present an interesting geologic feature in that the river has cut its channel in hard rock instead of following what seems to be the easiest course and cutting a channel in the soft alluvial materials a little farther west. This feature, which is uncommon, may be explained by assuming that the present course of the river was determined at an earlier period, when the river valley was filled with alluvium that completely covered the spurs of the mountains on the east in which the narrows are now cut. As the river cut down its channel it encountered the bedrock, but instead of turning westward onto the more easily eroded alluvium, it was able to cut gradually into the granite until the present canyons were formed—that is, the present drainage has been superimposed on the old rock hills.

The rocks at both the Upper and Lower Narrows act as barriers behind which the ground water is partly impounded, with the result that water is brought close to the surface on the lowlands. The river is perennial between the Upper and Lower Narrows and generally for several miles both above and below them. The length of the perennial stream, however, varies from month to month and from season to season according to the precipitation.

Below the Lower Narrows the river flows across alluvium, which absorbs much of the water, and except in times of flood the stream gradually dwindles in size. It usually disappears entirely several

[33] Schuyler, J. D., Reservoirs for irrigation: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, pp. 708–710, 1897.

miles below Oro Grande, but farther down it comes to the surface at other places where rocks are close to the surface.

In the vicinity of Victorville the stream is about 100 feet wide, but normally the water is only a few inches deep. Experiments made by Slichter at the Upper Narrows show that there is some underflow through the gorge, although it is not great.[34] It was estimated that the total underflow through the gorge for 24 hours probably did not exceed 300,000 gallons.

Along most of its course in the Upper Mohave Valley Mohave River is bordered by a flood plain half a mile or more wide. South of the Upper Narrows the land rises more or less gently from the flood plain, but north of that place it is steeper. In some places, particularly on the west side, near Bryman station, there are cliffs of alluvium 100 feet or more in height. The flood plain is nearly everywhere covered by mesquite, cottonwood, or willows, except where the land has been cleared.

SOILS

The United States Bureau of Soils[35] has made a reconnaissance soil survey of the part of the Upper Mohave Valley that lies south of latitude 34° 30′ and the Mohave River Commission[36] studied the alkali content and moisture requirements of the soils at a number of places. Like most soils of the desert region, those of this area are very low in humus except on the flood plain of the river, where the content of humus is slightly higher. Alkali in injurious amounts is absent in most of the region, but it occurs around the borders of the playas or dry lakes in El Mirage Valley, Deadman Valley, and Fifteenmile Valley. The playas can not be cultivated. The soil for some distance around El Mirage Valley is unusually silty and can be pulverized into a fine powder. In some parts of the area the soil is more or less cemented into a calcareous hardpan. In Apple Valley, on the east side of the river, the soil in places appears to contain more clay than the soil on the west mesa. This condition may be due to the fact that part of the valley is almost completely separated from the river by a long alluvial ridge, which reaches northward from the mountains nearly to the rock hills east of Victorville. Possibly at one time the separation was complete, and a playa may have existed east of the ridge.

GROUND-WATER CONDITIONS

For convenience in discussing the occurrence of ground water the Upper Mohave Valley may be divided into several parts, in each of

[34] Slichter, C. S., Field measurements of the rate of movement of underground waters: U. S. Geol. Survey Water-Supply Paper 140, pp. 55–64, 1905.

[35] Dunn, J. E., and others, Reconnaissance soil survey of the central southern area, California: U. S. Dept. Agr. Bur. Soils Field Operations, 1917–1921, advance sheets.

[36] McClure, W. F., and others, Report on the utilization of Mojave River for irrigation in Victor Valley: California Dept. Eng. Bull. 5, pp. 31–34, 1918.

which conditions are more or less different from those in the adjacent parts, although no sharp boundaries may be drawn. These areas are the Mohave River lowlands, the west mesa, El Mirage Valley, the east mesa, Deadman and Fifteenmile Valleys, Sidewinder Valley, and the upland on the east side of the valley north of Oro Grande.

Data have been collected for about 350 wells in the Upper Mohave Valley and these are summarized in the table below. The location of the wells is shown on Plate 22.[37]

[37] California Dept. Eng. Bull. 5 contains a valuable map showing contours of the water table, to which the reader is referred for details of the shape of the water table.

Records of wells in Upper Mohave Valley, Calif. [a]

No. on pl. 22	Location (San Bernardino meridian)			Owner	Altitude of surface above sea level (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth to water (feet)	Date of measurement	Method of lift	Reported yield (gallons a minute)
	Sec.	T. N.	R. W.									
1	7	3	3	Martin McInnis	2,945.8	Dug	22		7.5	Feb. 26, 1917	Cylinder	
2	7	3	3	do		do	30		10.4	do	do	
3	7	3	3	A. Dewitt	2,944.4	do	11		8.3	do	None	
4	6	3	3	—— Vlodek	2,931.4	do	20		2.8	do	do	
5	1	3	4	C. F. Hedrick	2,935.1	Drilled	216	10	11.0	Feb. 16, 1917	6-inch centrifugal	720
6	1	3	4	F. Spencer	2,927.4	do	250	12	11.0	do	7-inch centrifugal	900
7	1	3	4		2,922.9	Dug					Cylinder	
8	6	3	3	M. J. Springer		do			5.7	Feb. 26, 1917	None	
9	36	4	4	Appleton Land, Water & Power Co		Drilled	113	14	3.5	Feb. 17, 1917	do	
10	36	4	4	do		do	202	14		do	do	
11	36	4	4	do	2,927.0	do	280	14	6.2	do	do	
12	31	4	3	I. C. McLaughlin	2,910.0	do	34	14	34.0	Feb. 26, 1917	Cylinder	
13	31	4	3	do	2,913.5	do	52	8	20.9	do	4-inch centrifugal	468
14	30	4	3	A. O'Neil	2,897.7	do	225	12	16.4	do	Centrifugal	1,260
15	30	4	3	A. W. Cole	2,897.7	Dug	36		31.7	Mar. 6, 1917	Cylinder	63
16	30	4	3	do	2,898.0	Drilled	162	12	32.8	do	5-inch centrifugal	720
17	19	4	3	County well	2,899.9	Dug			12.6	do	None	
18	19	4	3	G. W. McLester		Drilled		10		Feb. 26, 1917	do	
19	19	4	3	do		do		12	22.7	do	do	
20	30	4	4	H. A. Jock	2,905.2	do	54	10	18.0		3-inch cylinder	315
21	29	4	3	O. A. Minister	2,896.3	Dug			30.0		do	81
22	29	4	3	do	2,891.2	Drilled	120	12	24.3	Feb. 25, 1917	6-inch centrifugal	1,350
23	20	4	3	Sidney O'Neil	2,882.1	do		12	24.5	Feb. 26, 1917	None	
24	20	4	3	J. M. Allison	2,880.1	do	70	10	30.0		do	
25	20	4	3	do	2,883.4	do	70	10	25.0		do	
26	17	4	3	W. C. Roberts	2,868.5	do	155	12	20.0		6-inch centrifugal	1,125
27	17	4	3	D. W. McPherson	2,862.4	do		7	20.4	Feb. 25, 1917	Cylinder	
28	17	4	3	do	2,866.8	do		12	20.6	do	None	
29	7	4	3	I. K. Miller	2,861.9	do	150	10	19.5	do	8-inch centrifugal	
30	7	4	3	C. G. Lewis	2,854.6	do	146	12	12.0		4-inch ceutrifugal	495
31	7	4	3	H. A. Carden	2,853.7	do	225	10	15.1	Feb. 25, 1917	7-inch centrifugal	
32	6	4	3	Harris Garcelon	2,842.9	do	133	12	16.0		6-inch centrifugal	1,170
33	7	4	3	E. Garcelon	2,848.8	do	166	12	10.0		7-inch centrifugal	1,350
34	6	4	3	A. H. Hohman	2,833.7	Dug	25		11.8	Feb. 24, 1917	3-inch centrifugal	216
35	6	4	3	A. W. Phillips	2,830.5	Drilled	94	12	8.0		6-inch centrifugal	1,944
36	36	5	4	Orr & Pullar	2,825.2	do	110	12	7.0	Feb. 17, 1917	5-inch centrifugal	675
37	23	5	4	Verde ranch	2,751.5	do	260	10	Flows.	Apr. 12, 1917	Flowing	
38	23	5	4	do	2,748.6	do	350	10	Flows.	do	do	297

[a] The data on wells Nos. 1 to 301 were furnished by C. E. Tait, senior irrigation engineer, U. S. Dept. Agr. Bur. Public Roads. The data are essentially as given in Bull. 5, California State Dept. Eng. The numbers are the same as those used in that bulletin.

Records of wells in Upper Mohave Valley, Calif.—Continued

No. on pl. 22	Location (San Bernardino meridian)			Owner	Altitude of surface above sea level (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth to water (feet)	Date of measurement	Method of lift	Reported yield (gallons a minute)
	Sec.	T. N.	R. W.									
39	23	5	4	Verde ranch	2,750.2	Drilled	92	10	Flows.	Apr. 12, 1917	Flowing	
40	15	5	4	do	2,765.0	do		10	Flows.	do	Auxiliary pump	
41	26	5	4	do	2,782.1	do	552	10	Flows.	do	Flowing	
42	26	5	4	do	2,782.1	do		10	Flows.	do	do	
43	26	5	4	do	2,783.3	do	106	10	Flows.	do	do	
44	26	5	4	do	2,798.4	do		10	Flows.	do	do	
45	26	5	4	do		do		10	Flows.	do	do	
46	35	5	4	do	2,800.4	do		10	Flows.	do	do	
47	35	5	4	do	2,799.1	do	895	10	Flows.	do	do	
48	35	5	4	do	2,800.2	do		10	Flows.	do	do	
49	35	5	4	do	2,811.0	do	270	12	4.0	do	Centrifugal	}
50	35	5	4	do	2,811.0	do	270	12	4.0	do	do	} 3,150
51	35	5	4	do	2,811.0	do	270	12	4.0	do	do	}
52	35	5	4	do		do	306	12	4.0	do	8-inch centrifugal	
53	36	5	4	do	2,824.0	do	270	12	12.8	Mar. 5, 1917	12-inch centrifugal	}
54	36	5	4	do	2,824.0	do	270	12	12.8	do	do	} 3,600
55	36	5	4	do	2,824.0	do	270	12	12.8	do	do	}
56	24	5	4	W. and C. H. Shaw	2,815.7	do	72	14	53.0	Feb. 17, 1917	Cylinder	
57	24	5	4	W. and G. Weldon	2,801.7	do	300	12	50.0		Centrifugal	
58	25	5	4	W. A. Foster	2,833.0	do	100	10	48.0		6-inch centrifugal	900
59	19	5	4	M. L. Foster	2,835.0	do	100		48.0		Double deep well	360
60	31	5	3	E. P. Dewey	2,850.0	do	545	8	23.5	Feb. 24, 1917	6-inch centrifugal	1,125
61	30	5	3	Victor Ranch	2,845.8	do	500	12	55.3	do	7-inch centrifugal	1,125
62	30	5	3	W. B. Ames	2,845.8	do		12	47.6	do	do	
63	30	5	3	do	2,848.0	do		12	47.6	do	do	
64	31	5	3	W. C. Smith		do		12			None	
65	31	5	3	S. L. Wheatley	2,863.8	do		12	45.3	Feb. 24, 1917	Centrifugal	
66	31	5	3	L. C. Bailey	2,865.0	do					do	
67	6	4	3	A. W. Phillips	2,866.5	do	100	10	50.0	Feb. 24, 1917	Cylinder	54
68	6	4	3	G. L. Smith	2,878.7	do	100	12	50.0		7-inch centrifugal	
69	5	4	3	W. A. Westphal	2,923.4	do	370	12	80.0		6-inch centrifugal	720
70	5	4	3	Apple Valley School	2,923.8	do	160	7	100.0		Cylinder	
71	8	4	3	Edwin Rhodes	2,904.1	do	164	14	71.0		10-inch turbine	900
72	7	4	3	—— Cozard	2,880.4	Dug	48		46.8	Feb. 25, 1917	Cylinder	
73	8	4	3	—— Keplinger	2,904.3	do			66.0	do	do	
74	8	4	3	C. F. Ten Eyck		Drilled	225	14	132.0		12-inch turbine	405
75	17	4	3	F. E. Harrison		Dug	81		78.2	Feb. 26, 1917	Cylinder	
76	20	4	3	N. F. Marsh	2,969.0	Drilled	180	12	100.0		5-inch screw	288
77	21	4	3	W. O. Wade	3,090.0	do	250	12	242.0	Mar. 1, 1917	Cylinder	
78	8	4	3	W. C. Harris	3,030.9	do	345	14	186.2	do	Single deep well	270

79	9	4	3	A. E. Hull	3,033.9	do	687	14	188.9	do	5-inch centrifugal	495
80	10	4	3	W. M. Hunt, jr.	3,060.4	do	300	14	212.0	do	38-inch double deep well	378
81	10	4	3	W. E. Tussing	3,090.0	do	385	12	238.0		28-inch double deep well	243
82	5	4	3	R. M. Ferguson		do	272		166.0		None	
83	4	4	3	O. L. Morgan		Dug			170.0		Cylinder	
84	4	4	3	H. W. Fitzpatrick	2,992.9	do			155.0		None	
85	3	4	3	J. Billingsley	2,978.9	do			149.0	Mar. 3, 1917	do	
86	3	4	3	C. A. Bonadiman	3,030.8	Drilled	241		190.0		Cylinder	
87	2	4	3	T. E. Dennison	2,997.6	do	180	6	159.0		do	
88	2	4	3	J. F. Olsen	2,995.6	Dug	167		159.0		do	
89	2	4	3	W. J. Fifield	3,053.0	Drilled		10	213.0	Mar. 2, 1917	do	
90	1	4	3	E. D. S. Pope	3,037.0	do	730	12	196.0		Double deep well	90
91	1	4	3	D. D. Spaid		do	250	12	163.0		6-inch screw	270
92	6	4	2	H. E. Walsh	3,125.0	do	340	12	200.0		38-inch double deep well	297
93	6	4	2	A. J. Lintner	3,030.0	do		8	200.0	Mar. 4, 1917	None	
94	26	5	3	B. Peaks	2,946.8	Dug	150		100.0		Cylinder	
95	34	5	3	A. M. Byron	2,967.0	do	148		128.5	Feb. 28, 1917	do	
96	33	5	3	L. H. Clock	2,985.2	Drilled	512	12	155.2		None	
97	5	4	3	C. H. White	3,002.1	do	204	12	166.0		6-inch deep well	72
98	33	5	3	T. J. Anderson	2,987.3	Dug	167		157.4	Feb. 17, 1917	None	
99	32	5	3	W. Paine	2,994.5	do	167		160.0		Cylinder	
100	32	5	3	M. F. Ihmsen	2,994.7	Drilled	300	14	164.0		12-inch turbine	630
101	32	5	3	Theresa Smith	2,986.8	do	269	12	151.8	Feb. 27, 1917	None	
102	28	5	3	A. S. Kibbey	2,975.9	do	400	10	130.0		9⅝-inch turbine	477
103	29	5	3	K. Evans	2,968.0	do	207	12	155.0		Deep well	135
104	27	5	3	A. G. Kent		do	253	12	127.0		None	
105	28	5	3	W. W. Hitchcock	2,951.5	do	492	14	112.0	May 15, 1912	8-inch turbine	450
106	22	5	3	H. C. Decker	2,944.7	do	722	10	107.7	Feb. 28, 1917	Air lift	
107	22	5	3	N. Elmer	,939.0	Dug	119		101.9	Mar. 2, 1917	None	
108	26	5	3	L. L. Lytle	2,939.0	do	101		98.3	do	do	
109	26	5	3	R. D. Sperry	2,938.4	do	111		97.8	do	do	
110	30	5	2	H. Meacham	2,960.0	Drilled		10	109.0	Mar. 3, 1917	do	
111	24	5	3	—— Rau		do	183	12	87.1	Mar. 2, 1917	do	
112	24	5	3	—— Harlan		do	155	12	81.8	Mar. 4, 1917	Cylinder	
113	24	5	3	Verde Ranch		do	300	12	80.0		None	
114	14	5	3	N. A. Graffin	2,916.0	Dug	92		80.0	Mar. 3, 1917	Cylinder	
115	14	5	3	S. Miller	2,926.0	do			87.3	do	do	
116	14	5	3	E. D. S. Pope	2,913.0	Drilled	160	12	78.3	Apr. 4, 1917	None	
117	14	5	3	—— Hatch	2,906.6	Dug			Dry.		do	
118	20	5	3	M. E. Gibson		do	138				Cylinder	
119	20	5	3	M. W. Minor		do	147		Dry.		do	
120	18	5	3	A. E. Dennis	2,929.4	Drilled	184	12	125.8	Feb. 27, 1917	None	
121	18	5	3	—— Cochran	2,933.5	Dug	144		143.0	do	Cylinder	
122	18	5	3	do	2,933.5	do	142		138.0	do	None	
123	18	5	3	J. D. Humiston	2,908.0	Drilled	464	14	97.0	do	2-inch deep well	
124	18	5	3	J. M. Raphael	2,925.0	Dug					None	
125	8	5	3	Robert Cook		do					Cylinder	
126	8	5	3	do	2,918.0	Drilled	170		106.0		None	
127	8	5	3	do	2,925.0	do	125	10	109.2		Cylinder	
128	22	5	3	C. E. Van Horn	2,941.5	do	185	12	107.7	Feb. 28, 1917	do	
129	8	5	3	M. M. White		Dug	90		88.0	Mar. 5, 1917	do	
130	8	5	3	J. J. Hill	2,950.9	do			72.0		None	
131	9	5	3	F. A. Fletcher	2,910.0	Drilled	458		89.1	Mar. 5, 1917	Centrifugal	

Records of wells in Upper Mohave Valley, Calif.—Continued

No. on pl. 22	Location (San Bernardino meridian)			Owner	Altitude of surface above sea level (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth to water (feet)	Date of measurement	Method of lift	Reported yield (gallons a minute)
	Sec.	T. N.	R. W.									
132	9	5	3	F. A. Fletcher	2,905.5	Drilled	213	7	77.4	Feb. 28, 1917	None	18
133	10	5	3	O. S. Overholt	2,905.5	Dug	85		77.5		Deep well	
134	10	5	3	J. W. Kyle	2,903.6	Drilled	218	12	72.0		Screw	135
135	10	5	3	J. F. Fitzsimmons		Dug	80		77.6	Mar. 5, 1917	None	
136	12	5	2	E. D. Mitchell	2,965.9	Drilled			126.0	Mar. 4, 1917	do	
137	18	5	3	W. H. Bronson		Dug			132.0		do	
138	12	5	3	C. M. Abbeys	2,947.3	do	127				do	
139	12	5	3	M. Liebold	2,950.9	do					do	
140	2	5	3	E. H. Keller		do			116.7	Mar. 4, 1917	do	
141	2	5	3	J. S. Nation		Drilled		6	108.0		do	
142	2	5	3	G. Green		Dug	165		157.6	Mar. 4, 1917	Cylinder	
143	4	5	3	G. B. Holbrook		do	97		72.8	Mar. 5, 1917	do	
144	4	5	3	do		Drilled	94	7	80.0		do	
145	34	6	3	E. H. Corwin		Dug	110		101.2	Mar. 4, 1917	do	
146	28	6	3	Byron Buneman		Drilled	193	12	117.0		Single deep well	27
147	28	6	3	do		do	190	12	120.6	Mar. 4, 1917	6-inch screw	
148	7	5	3	G. A. Ground		Dug	133		130.0		None	
149	6	5	3	A. B. Edmonds		do					do	
150	5	4	2	A. B. Sheridan	3,100.0	Drilled	311	12	221.0		do	
151	8	4	2	John McDonald		do	418		255.0		do	
152	5	4	2	A. L. Martin	3,041.0	do	280	12	187.0		7-inch screw	540
153	4	4	2	E. C. Vessey	3,027.0	do	450	12	177.0	Mar. 1, 1917	Air lift	540
154	32	5	2	E. Beasley	3,025.7	do	307	12	170.0	Mar. 3, 1917	None	
155	32	5	2	J. B. Davis	3,011.5	do	200	10	160.7	do	Cylinder	
156	4	4	2	E. R. Wheatley	3,024.9	do	195	7	168.0		do	
157	4	4	2	do	3,036.0	do					None	
158	4	4	2	D. W. Hurlihy	3,075.6	do	500	12	222.9	Mar. 1, 1917	Air lift	360
159	10	4	2	do	3,073.2	do	550	12	220.3	do	do	360
160	10	4	2	J. W. Beasley	3,058.2	do	501	12	183.7	do	do	
161	14	2	4	F. Liebold		Dug	147		144.2	Mar. 2, 1917	Cylinder	
162	12	2	4	W. S. Cherry		Drilled	270	12	63.0		Double deep well	
163	12	2	4	do		do	70	12	62.0		Cylinder	
164	1	2	4	John McPherson		Dug	24		19.0		do	
165	6	1	4	—— Lockhart		do					None	
166	6	1	4	do		do	30		24.3	Mar. 2, 1917	Centrifugal	
167	6	1	4	do		do	30		26.4	do	Cylinder	
168	5	1	4	C. P. Summers		do	26		23.4	do	do	
169	5	1	4	do		do	26		23.4	do	do	
170	35	5	4	F. H. Hunt	3,613.9	Drilled	816	12	750.0		do	
171	15	6	4	S. Zacsek	3,800.0	do	909	12	869.5		do	9
172	22	5	4	L. J. Hampton	3,551.9	do	802	12	650.0		5-inch deep well	45

173	35	6	5	F. W. Lang	3,405.9	do.	598	12	505.3	Apr. 6, 1917	None	
174	5	5	4	Verde Ranch	3,390.0	do.	644	12	510.0	Apr. 11, 1918	do.	
175	22	6	5	F. C. Lang	3,254.5	do.	536	12	330.0		7-inch double deep well	297
176	22	6	5	Julia Lang	3,250.1	do.	475	12	328.5	Apr. 6, 1917	None	
177	12	5	4	Secord & Black	3,351.5	do.	572	12	490.0	Apr. 12, 1918	Cylinder	
178	21	4	5	Appleton Land, Water & Power Co.	3,200.0	do.	753	8	342.0		None	
179	18	5	5	W. W. Yeager	3,142.8	Dug	305		298.6	Apr. 6, 1917	do.	
180	15	5	5	C. R. Smyth	3,090.3	Drilled	323	8	292.5	do.	Cylinder	
181	20	5	5	S. V. Benson	3,165.3	do.	365	7	323.0	Mar. 8, 1917	None	
182	16	4	5	Appleton Land, Water & Power Co.	2,848.3	do.	861	14	29.0	Feb. 24, 1917	Turbine	315
183	22	5	5	W. G. Dobie	3,125.9	do.	340	10	305.0		Double deep well	
184	22	5	5	do.	3,125.9	do.	325	5	300.0		Single deep well	
185	22	5	5	H. T. Woods	3,121.0	do.	340	8	297.5		Double deep well	108
186	12	5	5	P. S. Carl	2,938.3	Dug			143.1	Mar. 8, 1917	None	
187	12	5	5	A. M. Corder		Drilled	80	8	70.0		do.	
188	13	5	5	Atchison, Topeka & Santa Fe Ry.	2,967.1	do.	300	8	70.0		do.	
189	2	5	5	C. H. Smith	2,949.6	Dug	156		153.0		Cylinder	
190	2	5	5	do.	2,902.2	do.			120.9	Mar. 8, 1917	None	
191	8	5	5	E. L. De Bolt	3,050.0	Drilled	285	12	238.6	do.	Deep well	
192	12	6	5	L. W. De Bolt	3,065.0	Dug			211.0	Apr. 6, 1917	Cylinder	
193	6	5	5	J. D. Caldwell		Drilled	650	10	174.6	Mar. 8, 1917	Deep well	225
194	32	5	6	J. Biescar		do.	243	12	112.0		18-inch double deep well	180
195	34	5	6	E. S. Fisk	2,925.0	Dug			150.0	Feb. 13, 1918	Cylinder	27
196	34	5	6	J. M. Scott		Drilled	157		137.0		3-inch cylinder	
197	33	5	6	H. Martin		do.					5-inch cylinder	
198	26	5	6	J. L. Trummond		do.	500	6	153.2	Apr. 5, 1917	None	
199	14	5	6	H. K. Hedges	2,841.1	Dug			119.0	Feb. 13, 1918	5-inch cylinder	
200	14	5	6	do.	2,836.7	do.			120.0	do.	None	
201	16	5	6	E. K. Isaacs	2,838.3	Drilled	158	12	102.0	do.	Cylinder	108
202	28	5	6	E. H. Richardson	2,879.5	do.	595	12	113.0	do.	Air lift	225
[b] 203	28	5	6	do.		do.		14	124.3	Apr. 5, 1917	do.	135
204	20	5	6	do.	2,857.6	do.		12	88.0	Feb. 14, 1928	Cylinder	
205	20	5	6	do.	2,857.0	do.		12	89.0	do.	None	
206	20	5	6	do.		do.					do.	
207	27	5	6	W. S. Lehman		do.	709	7	100.0		do.	
208	8	5	6	—— Campbell		do.	295				do.	
209	5	7	5	A. M. Steele	3,155.1	do.	390	6	232.0		Cylinder	
[b] 210	9	7	5	O. W. Jessup	3,211.1	do.	350	8	280.0		do.	
211	4	5	7	T. O. Ford	3,157.4	do.	300	12	238.3	Apr. 7, 1917	4-inch cylinder	
212	2	5	7	G. S. Pownald	3,157.8	do.	380	6	235.0		Cylinder	
213	12	5	7	De Meville-Rowley		do.	415	12	315.0		None	
214	6	5	6	W. Sly	3,149.3	do.		12	251.0	Feb. 19, 1918	do.	
215	31	6	7	G. W. Phenice		do.	410	12	153.4	Apr. 7, 1917	do.	
216	30	6	7	Paul Showers		do.	295	12	80.0		Deep well	
217	27	6	7	H. M. Engebritson		Dug	150		135.0		do.	9
218	27	6	7	W. Campbell		Drilled	400	12	125.0		3-inch centrifugal	225
219	21	6	7	C. B. Hawks		Dug	97				Deep well	9
220	22	6	7	J. R. Palmer		Drilled	330	12	76.0		None	
221	22	6	7	C. Williams		do.	425	12	73.0	Apr. 6, 1917	Air lift	117
222	24	6	7	D. Anderson	2,922.0	Dug	61		57.0	Feb. 21, 1918	None	
223	24	6	7	H. Braden		Drilled			88.6	Mar. 7, 1917	do.	

[b] For analysis see p. 417.

Records of wells in Upper Mohave Valley, Calif.—Continued

No. on pl. 22	Location (San Bernardino meridian)			Owner	Altitude of surface above sea level (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth to water (feet)	Date of measurement	Method of lift	Reported yield (gallons a minute)
	Sec.	T. N.	R. W.									
224	30	6	6	C. H. Sampson		Drilled	250	12	133.2	Mar. 7, 1917	None	
225	30	6	6	do		do	136	12	133.2	do	do	
226	32	6	6	F. Reinke	3,047.8	do	380	12	131.0	Feb. 20, 1918	do	
227	28	6	6	J. W. Walker	2,948.3	do	136	12	102.0		Cylinder	
228	28	6	6	L. M. Cotton	2,948.9	do	150	12	105.0	Feb. 20, 1928	Deep well	
229	18	6	6	W. B. Phillips		do	76	12	45.0		None	
230	18	6	6	F. P. Williams		do		12	48.9	Apr. 7, 1917	do	
231	18	6	6	do		do	205	12	32.0		Deep well	
232	14	6	7	R. Atz		Dug					Cylinder	
233	15	6	7	Ed. White		Drilled	58	8	49.0		Deep well	
234	20	6	7	W. Huston		Dug	67		65.3	Apr. 7, 1917	None	
235	17	6	7	Etta McKelvey		Drilled	300	12	73.5	do	do	
236	18	6	7	W. J. Shaw	2,920.8	Dug			55.5	Feb. 17, 1918	do	
237	18	6	7	E. Bonino	2,897.8	do			50.0	do	do	
238	18	6	7	W. E. Anderson		do			52.0		do	
239	7	6	7	F. A. Forsyth	2,870.4	Drilled	50	8	37.5	Feb. 16, 1918	do	
240	7	6	7	J. Dobersch		do		12			do	
241	8	6	7	G. B. Flock		do	42	8	37.0		do	
242	9	6	7	I. S. Lindley		do		8			do	
243	10	6	7	E. F. Anger	2,857.1	Dug	140		24.0		Cylinder	
244	11	6	7	J. Seward	2,869.0	do			23.2		Deep well	
245	11	6	7	E. J. Krause	2,849.2	Drilled	210	12	21.0	Feb. 21, 1918	Centrifugal	378
[d] 246	11	6	7	K. McDonald	2,853.9	Dug	25		21.5	do	None	
247	2	6	7	Grace E. Davis	2,841.1	Drilled	226	14	20.5	do	5-inch centrifugal	405
248	3	6	7	W. M. Gray		do	392	12	16.0		None	
249	3	6	7	do		do	367	12	23.1	Mar. 7, 1917	do	
250	4	6	7	T. R. Crowell		do	183	12	27.0		Deep well	135
251	9	6	7	do		Dug	26		26.0		None	
252	5	6	7	Marian B. Charles		Drilled	157	7	25.0		2½-inch centrifugal	162
253	5	6	7	do	2,853.3	Dug	41		36.0	Feb. 16, 1918	Cylinder	36
254	5	6	7	W. H. Anderson		Drilled	58	8	22.0		½-inch centrifugal	135
255	7	6	6	Southern Pacific R. R.	2,838.2	Dug	24		23.0	Feb. 14, 1918	None	
256	35	7	7	L. C. Wheeler	2,859.3	do			42.0	do	Centrifugal	
257	32	7	7	W. C. Brockman	2,843.3	Drilled	80	12	27.0	Feb. 16, 1918	None	
258	28	7	7	L. L. Whitlock	2,848.0	do	93	7	31.0	do	4-inch centrifugal	
259	22	7	7	C. Munsey		do	118	7	78.0		Cylinder	
260	27	7	7	L. Hess	2,862.9	do	125	10	46.0	Feb. 16, 1918	6-inch centrifugal	675
261	8	7	7	J. Young		Dug	100		95.0		None	
262	10	5	4	F. Busch	2,719.6	do			8.0		3-inch centrifugal	

[d] For analysis see p. 417.

263	10	5	4	G. Smith	2,714.0	Drilled	59	14	3.0		6-inch centrifugal	
264	10	5	4	E. Doulch	2,715.8	do	39	14	10.5		None	
265	3	5	4	S. Rogers	2,708.6	do			14.6		Cylinder	
266	34	6	4	C. Bassini	2,696.4	do	75	14			4-inch centrifugal	630
267	34	6	4	do	2,758.4	do	107	12	87.0		Deep well	270
268	34	6	4	—— Hadley		do			56.3	Feb. 16, 1917	None	
269	10	5	4		2,770.9	Dug			48.2		do	
270	5	5	5		2,780.7	do					do	
271	32	6	4		2,737.3	do			3.0		do	
272	32	6	4		2,721.4	do			9.1		do	
273	18	6	4	Victor Cement Co		Drilled	260	12			3-inch centrifugal	
274	18	6	4	do		do	125	16			8-inch centrifugal	1,620
275	18	6	4	do		do	270	16			do	1,620
276	30	7	4	W. Watkins		do	202	12	54.0		8-inch double deep well	135
277	30	7	4	do		do	100	12	15.0		4-inch centrifugal	
278	19	7	4	C. A. Poole		do	225	12	30.6	Apr. 8, 1917	8-inch centrifugal	108
279	26	7	5	A. Edwards	2,737.0	Dug			171.0	Feb. 18, 1918	None	
280	27	7	5	J. M. Peden		do					do	
281	27	7	5	—— Kirkpatrick		do					do	
282	27	7	5	W. Warren	2,718.3	do			81.0	Feb. 18, 1917	do	
283	15	7	5	—— Gwyne		Drilled	235	12			do	
284	31	7	5	Y. M. C. A		do	230	12			do	
285	2	6	5	—— Mallman	2,786.0	do	235	12	208.0	Feb. 18, 1918	do	
286	26	7	5	L. P. Burgmeir	2,724.0	Dug			105.0	do	do	
287	2	6	5		2,780.0	do			204.0	do	Cylinder	
288	10	6	5		2,807.0	do			108.0	do	None	
289	28	6	5	E. H. Richardson	2,878.0	Drilled		12			do	
290	28	6	5	do	2,878.0	do	350	8	133.0	Feb. 14, 1918	do	
291	14	6	5		2,823.0	Dug			113.5	Feb. 18, 1918	do	
292	14	6	6	B. S. Hook	2,833.0	do			42.5	Feb. 20, 1918	Centrifugal	
293	35	7	7	W. J. Jensen	2,853.0	Drilled	203	12	36.0	Feb. 14, 1918	None	
294	26	7	7	B. M. Elsey	2,857.0	Dug	44		42.0	do	do	
295	26	7	7	—— Gilbert	2,891.0	do			74.0	do	do	
296	6	5	7	L. B. Coleman	3,109.0	Drilled		10	199.0	Feb. 17, 1918	do	
297	35	7	7	John Breen	2,837.5	Dug	25		20.0	Feb. 21, 1918	do	
298	2	6	7		2,835.7	do			17.0	do	do	
299	3	6	7	El Mirage School	2,842.8	do			22.0	do	do	
300	12	6	7		2,867.0	do			21.0	do	Cylinder	
301	18	4	5	F. L. Thomas		Drilled	330	7	Dry.		None	
302	6	6	4	W. H. Robinson		Dug	41		35.0		Cylinder	
303	19	7	4	E. B. Rowley		Drilled	270		60.0		Centrifugal	900
304	19	7	4	do		Dug	110		92.0		None	
305	7	7	4	P. Herlick		do	40		34.0		do	
306	18	7	4	F. C. Abbott		Drilled	270		55.0		Centrifugal	945
307	21	6	5	C. A. Garbutt		Dug			170.0		None	
308	26	6	5	A. H. Diamond		do			120.0		do	
309	19	6	5	H. C. Jones		do	87		75.0		do	
310	30	6	5	J. C. White		do			96.0		do	
311	30	6	5	Olive A. Stone		do			100.0		do	
312	20	6	6	W. L. Norris		Drilled		12	130.0		do	
313	27	6	6			do		12	128.0		do	
314	18	6	6	R. R. Jamison		Dug	58		56.0		do	

Records of wells in Upper Mohave Valley, Calif.—Continued

No. on pl. 22	Location (San Bernardino meridian) Sec.	T. N.	R. W.	Owner	Altitude of surface above sea level (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth to water (feet)	Date of measurement	Method of lift	Reported yield (gallons a minute)
315	14	6	6	R. R. Jamison		Dug	50		43.0		None	
316	14	6	6			do	54		40.0		Cylinder	
317	30	6	7	W. W. McKinney		do	159		139.0		None	
318	2	5	6	G. Penaul		do			236.0		do	
319	12	5	6	T. A. De Bolt		do			150.0		do	
320	12	5	6	D. S. Ball		Drilled	423		300.0		do	
321	18	5	5	P. Weile		do	365		313.0		do	
322	34	5	5	S. I. Pickert		do	578		570.0		do	
323	24	5	5			do			240.0		do	
324	1	5	5			Dug			119.0		do	
[e] 325	10	5	4	Atchison, Topeka & Santa Fe Ry		Drilled	200		10.0		Centrifugal	
326	34	3	5	L. Harris		do	344		187.0		None	
327	15	3	4	R. W. Miller		do	195		145.0		do	
328	4	2	4	E. D. Vessey		Dug			160.0		Cylinder	
329	19	2	5	F. H. Nett		do			98.0		None	
330	19	2	5	—— Hitchcock		do			100.0		do	
331	27	3	7	W. C. Marston		do			130.0		Deep well	90
332	28	2	6	A. J. Allen		do			123.0		None	
333	33	2	6	—— Jackson		do			160.0		do	
335	21	3	7						−50.0			
336	[f] 4	3	6	Mrs. E. L. Adams		Dug	75		−64.0			
337	[g] 8	3	6			Drilled			−42.0			
[h] 338	[j] 8	3	6	Sidewinder well		Dug	33	48	[i] 30.4	Feb. 19, 1918 [k]	Hand pump	
339	9	3	6	⅕ mile east of Sidewinder well		do	46		41.0	do. [k]		
340	17	3	6	G. Marietta		do	87		73	Dec. 30, 1917 [k]		35
341	27	4	6	E. C. Mann		do	85		Dry.	Feb. 19, 1918		
342	27	4	6			Drilled	81	12	Dry.	do		
343	4	2	5	H. F. Anders		Dug	175		Dry.			
[h] 344	3	2	5	A. G. Trendell					298.0			
345	10	2	5						4.0			
346	12	2	5						25.0			

[e] For analysis, see p. 417. [f] SW. ¼. [g] NE. ¼. [h] For analysis see p. 417. [j] SE. ¼.
[i] Reference point, top of platform, 8 inches above ground surface. [k] Measured by D. G. Thompson.

MOHAVE RIVER LOWLANDS

The Mohave River lowlands form a narrow belt, in most places not more than a mile wide, which extends along the river from the Forks to the north end of the Upper Mohave Valley. The belt comprises the flood plain of the river. It is separated into three parts by rock barriers at the Upper and Lower Narrows.

In the stretch of the flood plain from the Forks to the Upper Narrows more than 30 wells have been drilled or dug, and the depth to water has generally been found to be less than 25 feet. A number of flowing wells have been obtained on the lands of the Rancho Verde in a narrow belt that extends upstream from the Upper Narrows for a distance of about 3⅓ miles. This belt is apparently not more than half a mile wide. In wells on the east and west mesas the water rose from 5 to 25 feet when struck, but it is not clear whether the formations beneath the river flood plain are the same as those beneath the mesas. Probably part of the flood plain is underlain by river deposits of more recent age than the alluvium of the mesas. It is hardly likely, however, that the river has at any time excavated its channel very deep and refilled it. The accompanying log of a flowing well on the Rancho Verde shows that a strong flow was obtained as deep as 542 feet. This well was originally drilled as a test for oil.

Log of flowing well on Rancho Verde [a]

[Well 47, pl. 22; sec. 36, T. 5 N., R. 4 W. San Bernardino meridian]

	Thickness (feet)	Depth (feet)
Coarse sand and gravel	135	135
Blue clay; flow of 495 gallons a minute at 150 feet	23	158
Coarse sand and gravel; flow of 540 gallons a minute at 180 feet	30	188
Blue clay	13	201
Coarse sand and gravel; flow of 540 gallons a minute at 220 feet	34	235
Blue clay	7	242
Coarse sand and gravel; flow of 540 gallons a minute at 265 feet	26	268
Blue clay	9	277
Shaly rock	15	292
Coarse sand and gravel; flow of 450 gallons a minute at 312 feet	22	314
Blue clay	10	324
Yellow clay; flow of 495 gallons a minute at 357 feet	46	370
Soapstone	7	377
Coarse sand and gravel; flow of 405 gallons a minute at 395 feet	39	416
Soapstone; flow of 495 gallons a minute at 421 feet	5	421
Coarse sand and gravel	24	445
Soapstone	8	453
Coarse sand and gravel; flow of 765 gallons a minute at 461 feet	34	487
Soapstone	9	496
Coarse sand and gravel; flow of 1,440 gallons a minute at 542 feet	78	574
Blue clay, hard; water at 687 feet	150	724
Coarse sand and gravel	11	735
Shaly rock	4	739
Coarse sand and gravel	16	755
Shaly rock	4	759
Coarse sand and gravel; water at 762 feet	16	775
Shaly rock	4	779
Coarse sand and gravel	10	789
Yellow clay	10	799
Shaly rock; 90 gallons a minute of mineral water at 820 feet	39	838
Blue clay	8	846
Shaly rock	55	901
Blue clay	7	908
Yellow clay	38	946
Blue clay	11	957
Shaly rock	28	985

[a] From data collected by C. E. Tait, senior irrigation engineer, U. S. Dept. Agr. Bur. Public Roads.

The first eight flows raised over 45 feet of pipe; the ninth flow (461 feet ?) raised over 55 feet of pipe; the tenth flow (542 feet ?) raised over 74 feet of tower. All water closed off as far as possible; pressure was so great that the water was forced up outside the casing. In 1917 well was flowing from first water-bearing stratum.

The conclusion is that the flows, in part at least, are derived from formations that are continuous with those beneath the mesas and that flowing wells are obtained in a small area along the river flood plain because the surface is below the altitude to which the water will rise and not because the artesian conditions are due to deposition of water-bearing materials by the river.

The rise of the water in well 47 is apparently greater than the rise in any other well in the Upper Mohave Valley, either on the flood plain or on the uplands. Probably this difference is due to the greater depth of the well, but perhaps the partial barrier created by the granite ridge at the Upper Narrows is responsible for some of the artesian pressure on the flood plain above the narrows.

The immediate source of the water obtained from the flowing wells is conjectural beyond the fact that it must enter the alluvium some distance upstream, probably near the Forks. Even if no water is absorbed above the Forks some water percolates into the gravel below that point, as is shown by the fact that the water level in wells close to the river in secs. 30 and 31, T. 4 N., R. 3 W. San Bernardino meridian, changes from 15 to 25 feet between wet and dry seasons. Apparently as a result of the percolation from the river during periods of high run-off, the water table is built up higher than it is a short distance farther away on each side.

Between the Upper and Lower Narrows and north of the Upper Narrows several wells on the flood plain obtain water at slight depths, but there are no flowing wells. This leads to the conclusion that the rocks at the Upper Narrows act in some way to cause the artesian flows south of them. Flowing wells may be absent below the Upper Narrows because the water-bearing beds do not have sufficient slope to produce artesian pressure or perhaps because the rocks of the narrows prevent ready access to any horizons that present the proper conditions.

Practically all the wells along the flood plain of the river have large yields. Three wells (Nos. 53, 54, and 55) on the Rancho Verde are said to have a combined yield of 400 miner's inches (about 3,600 gallons a minute, or 1,200 gallons a minute for each well). Three other wells on the same ranch (Nos. 49, 50, and 51) are reported to have a combined yield of 350 miner's inches (about 3,150 gallons a minute, or more than 1,000 gallons a minute for each well).

The well of A. W. Phillips (No. 35) in the NW. ¼ sec. 6, T. 5 N., R. 3 W., is said to pump 216 miner's inches (nearly 2,000 gallons a minute) on the river bottom and to pump 148 inches (about 1,300 gallons a minute) when the water is raised several feet to the bench above the river. This well is only 98 feet deep. Several other wells on the flood plain above the Upper Narrows yield 100 miner's inches (900 gallons a minute) or more. The only data available for the yield of wells farther downstream relate to two wells (Nos. 274 and 275) of the Golden State Cement Co., at Oro Grande, which have a combined yield of 180 miner's inches (about 1,600 gallons a minute).

Yields of less than 25 miner's inches (225 gallons a minteu) were reported from two or three wells on the river flood plain, but apparently these low yields are due to the fact that the wells are not pumped to capacity and not to poor yield of the water-bearing beds. There seems to be no reason why properly constructed wells on the flood plain should not yield 50 miner's inches (450 gallons a minute) or more, provided they are not too close to the edge of the flood plain, where they may penetrate materials that do not yield as much water as the alluvial filling of the flood plain. Although the strongest flow of the deep well on the Rancho Verde (No. 47, see p. 403) was obtained below a depth of 500 feet it is probably not necessary to go that deep on the flood plain in order to get yields sufficient for irrigation. Doubtless large yields can be obtained at depths not greater than 100 to 200 feet, and deeper drilling simply means added expense.

WEST MESA AND EL MIRAGE VALLEY

The great alluvial slope that lies west of Mohave River really includes El Mirage Valley, which differs from the rest of the slope in that it is hemmed in on the north by low hills in such a way that a closed basin is formed. On this great alluvial plain which slopes generally northward, 100 or more wells have been put down, and these wells give a good idea of ground-water conditions in the area.

The water table slopes in general in the same direction as the land—that is, north and northeast—but there are some local differences. The slope of the water table, however, is much more gentle than that of the surface. Thus, from the SE. ¼ sec. 2, T. 5 N., R. 5 W. (well 189), to the SE. ¼ sec. 5, T. 4 N., R. 5 W. (well 174), a distance of about 6½ miles, the land surface rises about 440 feet, or a little more than 60 feet to the mile, whereas the water table rises only about 85 feet, or a little more than 10 feet to the mile. As a result the depth to water increases away from the river and toward the mountains. In well 189 the depth to water is 153 feet, and it becomes less northward and eastward. In well 174 it is 510 feet, and in several wells from 2 to 4 miles southwest or southeast of that well it is said to be as much as 800 feet.

In the eastern half of the alluvial slope, the water table slopes in a northeasterly direction, toward the river. Farther west it slopes more to the north. The effect is that of a bulge or swell of the water table beneath the western part of the area similar to the bulge formed by the great alluvial fan built out in front of Sheep Creek. The water table follows the same general outline as the surface of the great fan, except that between Victorville and El Mirage Dry Lake it slopes somewhat more directly toward the river than the surface. This slope doubtless is in part due to the effect of the rock hills east of El Mirage Dry Lake, which divert the underground waters eastward toward the river.

The bulge of the water table beneath the fan of Sheep Creek makes the depth to water in wells at a given altitude on the fan considerably less than it is farther east. This condition is undoubtedly due to the fact that a greater quantity of water is poured out on the fan by Sheep Creek and is absorbed and reaches the water table than the quantity farther east, where there is less concentration of run-off. Conditions here are similar, in part at least, to those in Antelope Valley, where the water table is higher and nearer the surface beneath the fan of Little Rock Creek than where no large stream pours out onto the alluvium. (See p. 337 and fig. 13.)

The depth to water is more than 100 feet throughout nearly all the alluvial slope west of the river, except in El Mirage Valley and eastward nearly to Adelanto and in a narrow belt near the river flood plain. On Plate 22 are lines along which the depth to water is 100 and 200 feet. On the west mesa the 100-foot line, north of which the depth to water is less than 100 feet, extends almost due east from El Mirage Valley about 2 miles north of the south side of T. 6 N. nearly to Adelanto and thence bends north. From Adelanto a belt about 2 or 3 miles wide runs northward on the west side of the river in which the depth to water is more than 100 feet. The greater depth to water in this belt may be due to the fact that the water table slopes downward to the river, whereas the surface does not slope very much toward the river. Well data indicate apparent abnormal conditions in this belt, for in two wells (Nos. 285 and 287) the depth to water is more than 200 feet, and the water table appears to be considerably lower than in wells a mile or more to the north or south.

On the upland close to the flood plain of Mohave River, between Victorville and Oro Grande and for a mile or two south of Victorville, the water table stands considerably above the river. In well 182, about a mile south of Victorville, the water struck at a depth of 380 feet stands about 30 feet below the surface. Water struck at higher levels during drilling stood about 60 feet below the surface. The surface altitude of this well is about 100 feet higher than the river bottom about a mile east, and the water table in the upper beds is fully 40 feet higher than the river. The log of this well is given here as typical of conditions on the west mesa:

Log of well 182, SE. ¼ sec. 16, T. 5 N., R. 4 W. San Bernardino meridian

	Thickness (feet)	Depth (feet)
Compact gravelly soil	6	6
Compact bedded dry fine gravel	8	14
Compact medium coarse gravel	11	25
Bedded coarse sand with fine gravel and thin layers of yellow clay	6	31
Very hard light-yellow sandy clay	2	33
Bedded sand	2	35
Compact light-yellow sandy clay	14	49
Sand with little fine gravel	6	55
Compact yellow sandy clay	23	78
Soft sandy clay and layers of water sand	9	87
Compact yellow sandy clay	8	95
Coarse water sand	3	98
Sandy yellow clay	5	103
Sand with layers of hard clay	5	108
Sandy yellow clay and layers of sand	12	120
Hard grayish sandy clay	8	128
Hard rusty yellow clay	39	167
Coarse sand and little fine clay	6	173
Hard yellow sandy clay	35	208
Soft sandy clay	9	217
Soft sandy clay with layers of coarse sand and fine gravel and soft sandstone	16	233
Very hard sandy clay, changing every few feet in color and texture	34	267
Soft sandy clay	7	274
Coarse sand with clay and little gravel	4	278
Hard sandy clay	12	290
Coarse sand with clay and little fine gravel	6	296
Sandy yellow clay	21	317
Sand and fine gravel, dirty	16	333
Sandy gray clay	5	338
Sand and fine gravel	24	362
Hard gray clay	8	370
Very compact shalelike yellow clay	10	380
Sand with very little fine gravel	22	402
Cemented coarse sand	13	415
Hard blue clay	23	438
Blue and brown shale	22	460
Layers of packed sand and sandy shale	70	530
Layers of packed sand and sandy shale mixed with boulders	25	555
Soft sandrock	3	558
Sand, clay, and gravel	22	580
Hard shale	32	612
Hard shale with loose boulders	10	622
Hard shale	18	640
Sand, gravel, and clay	128	768
Fine water sand and gravel	10	778
Sand, gravel, and clay	34	81[illegible]
Gypsum conglomerate	14	826
"Rock"	9	835
Hard granite	26	861

NOTE.—Appleton Land, Water & Power Co., owner. Originally drilled to a depth of 460 feet for the Hesperia Land & Water Co. Drilling stopped in October, 1911. Later the well was drilled to a depth of 861 feet. The log given above is compiled from the two logs that represent the two different periods of drilling. Altitude of surface 2,853 feet.

Water said to stand generally 36 feet from surface, but on February 24, 1917, the depth to water measured 29.0 feet.

The driller's log for the first 460 feet contains the following notes. It is not known whether the well was perforated as recommended.

Water bearing but hazardous to perforate because of fineness of material. Water 60 feet below the surface: 95–98 feet, 103–108 feet, 167–173 feet.

Water bearing; hazardous to perforate because of fineness of material but might be perforated with fine blade. Water 60 feet below surface: 217–233 feet 274–278 feet.

Water bearing; should be perforated with fine blade. Water 57 feet below surface: 290–296 feet, 317–333 feet, 338–362 feet.

Should be perforated with fine blade. Water 36 feet below the surface: 380–402 feet.

A series of springs emerges on the side of the cliffs or steep hillsides that separate the upland from the flood plain. These springs occur at intervals along a stretch of 3 or 4 miles from a point about a mile south of the Upper Narrows to a point about the same distance northwest of the Lower Narrows. The public water supply for Victorville is obtained from several of these springs. At the springs which are used for the town supply the water appears along the steep slope just above a bed of clay that is several feet thick, and this clay bed doubtless causes the springs to emerge at the other places, although evidence of it is lacking. It is not certain whether the springs are caused by an isolated water-bearing bed "perched" above the main ground-water body, with a dry zone between, or whether the beds are saturated below the spring zone. However, as nearly as can be determined from the available data, the water table in wells a mile or two west of the river appears to be about 100 feet above the river and somewhat higher than the springs. This would indicate that the alluvium below the horizon of the springs is saturated and that the immediate valley of Mohave River is cut below the water table in most of the valley.

The part of the area in which the depth to ground water is less than 100 feet is confined almost entirely to lands which lie within 3 or 4 miles north and south of El Mirage Dry Lake and which extend several miles eastward from the dry lake. Close to the playa the depth to water is about 20 to 25 feet, and in well 298, on the south edge of the playa, in February, 1918, it was only 17 feet. It is said that when the Gray well (No. 248), in the NE. ¼ sec. 3, T. 6 N., R. 7 W., was being drilled, water struck at a depth of about 165 feet overflowed at the surface. When the well was drilled deeper the water sank several feet below the casing. This well, 392 feet deep, is the deepest one within several miles of El Mirage Dry Lake. The log is as follows:

Log of well 248, in southwest corner of NE. ¼ sec. 3, T. 6 N., R. 7 W. San Bernardino meridian

	Thickness (feet)	Depth (feet)
Gray clay	10	10
Red clay	10	20
"Cement gravel," hard and soft layers; much "cement"	64	84
"Cement gravel," loose; little "cement"	6	90
"Cement gravel"	61	151
Fine gravel; water overflowed top of casing at 165 feet	24	175
"Cement gravel"	10	185
Red clay	1	186
"Cement gravel"; streaks of sand	17	203
"Cement gravel"	24	227
Fine sand	10	237
Clay	4	241
Fine sand; in test water bailed down to 110 feet	26	267
Coarse gravel; considerable clay mixed in chunks	10	277
"Cement gravel"	8	285
Sand	5	290
Clay, thin streak		290
Sand; a test at 294 feet yielded 15 miner's inches, lowering water to 35 feet from top	10	300
Streaks of clay	7	307
Sand	8	315
Clay	6	321
Good gravel	3	324
Fine sand	3	327
Clay	1	328
Gravel	5	333
Clay	15	348
Gravel; best yet	15	363
Clay	8	371
Clay	21	392

NOTE.—W. M. Gray owner. Drilled May, 1912, by Clampitt & Moss. Log furnished to C. E. Tait by E. J. Krause. This well is perforated in water-bearing beds for a total length of 144 feet.

This log gives an idea as to the alternation of gravel, sand, and clay in the alluvium. The term "cement gravel" probably indicates gravel and fine sand cemented together by calcium carbonate. The "cement" is probably similar to the "honeycomb cement" penetrated by wells in Antelope Valley.

The depth to water increases both north and south of the playa. The few data available in regard to the altitude of the water table in different wells show that the water table slopes northward from the mouth of Sheep Creek as far as the south side of El Mirage Dry Lake, but beneath the playa and for at least half a mile north of its northern border the water table is essentially flat. Data in regard to the altitude of the water table are not available for wells 259 and 261. The depth increases northward from the playa; it is 78 feet in well 259 and 95 feet in well 261. This increase is believed to be due to a rise in the land surface northward.

Apparently there is some movement of ground water from El Mirage Valley eastward past the south end of the hills that lie east of the playa. The playa is of the dry type, although the depth to water is only a few feet greater than the depth where playas of the wet type occur. This fact is believed to indicate that there is underground drainage from beneath the playa. Doubtless the altitude of the water table beneath the playa is limited by the altitude of the water table at the south end of the hills. The hills north of the playa are low, and the rainfall is meager. There is no great contribution to the ground-water supply which would cause the water table to stand very much higher in that part of the valley than in other parts.

The yield of wells on the west mesa and in El Mirage Valley is generally not as great as that of wells on the river flood plain. The largest yield, 675 gallons a minute (75 miner's inches), is reported from a well of L. Hess (No. 260), in sec. 22, T. 7 N., R. 7 W., San Bernardino meridian, on the north side of El Mirage Dry Lake. Two other wells near El Mirage Dry Lake (Nos. 245 and 247) are reported to yield between 350 and 400 gallons a minute. No other wells west of the river flood plain are reported to have yields as much as 350 gallons a minute, and a number of them yield less than 250 gallons a minute. It was not determined whether the low yields are due to poor construction of the wells, to poor pumping equipment, or to the absence of good water-bearing beds. The material beneath the alluvial slope is probably less porous than the river deposits along the flood plain. It is apparently relatively fine, with very little coarse gravel, and in places the pore space is decreased by cement. The use of casing perforated for practically the entire depth of the well, as in Antelope Valley, might result in somewhat larger yields.

No large streams pour water out on to the alluvial slope, and as a consequence the water table is relatively flat. Doubtless this is one reason why the yield of wells is not large, for the water is not under sufficient head to cause the rapid replenishment of the gravel in a given locality as the water is withdrawn.

EAST MESA

The upland east of the Mohave River flood plain, or, as it is called, the east mesa or Apple Valley, is much smaller than the west mesa, and ground-water conditions beneath it apparently are more affected by the proximity of the hills and mountains that border it on the north and east.

The water table slopes in general toward the river, but in contrast to the water table west of the river there is almost no northerly component to the slope, except at the very south side of the mesa, near the San Bernardino Mountains. In the northern two-thirds of the mesa the slope of the water table is almost due west toward the river. This slope indicates that the source of the ground water in this part of the mesa is probably the Granite Mountains, on the east. On the north the water table rises with a steep slope to the rock hills that border the valley, but the rise is more gentle in a pass between the hills 6 miles east of Victorville, which is apparently filled with alluvium.

On no part of the east mesa is the water table as close to the surface as in El Mirage Valley. In only two wells (No. 130, in the SE. ¼ sec. 8, and No. 134, in sec. 10, T. 5 N., R. 3 W.) is the depth to water less than 75 feet, and in these two wells it is 72 feet. The area in which the depth to water is less than 100 feet lies within the closed line in the northeastern part of T. 5 N., R. 3 W., on the map (pl. 22) that indicates a depth to water of that amount. On the other hand, the depth to water on the east mesa is nowhere as great as on the upper part of the alluvial slope west of the river. The greatest reported depth to water is 248 feet, in well 81. Throughout nearly the whole of the east mesa, except within a mile or two of the mountains, the depth to water is less than 200 feet.

On the west mesa, south of the Upper Narrows, there are only one or two wells within 2 or 3 miles of the river flood plain. Apparently the scarcity of wells is due to the fact that the upland west of the river is much dissected by numerous arroyos, leaving very little land suitable for development, and because the land rises so steeply that the depth to water is considerable a short distance from the flood plain. On the east side of the flood plain the upland is much less dissected and there is a "bench" or terrace between the flood plain and the main mesa. The depth to water beneath this bench in most places is less than 100 feet, and a number of wells have been drilled on it.

The area in which the depth to water is less than 100 feet is separated from the shallow-water area along the river by a strip in which the depth to water is more than 100 feet. This condition appears to be due to two causes. A rock ridge that lies in sec. 17, T. 5 N., R. 3 W., apparently acts as a partial barrier, east of which the water is held, for the few data available indicate that the slope of the water table toward the river is slightly greater west of the rock ridge than east of it. Alluvium washed from the north and south toward this ridge has raised a ridge slightly higher than the land farther east. Furthermore, east of the rock ridge the land surface rises eastward more gently than the water table.

Several wells have been drilled close to rock spurs of the Granite Mountains. All these wells, with one exception, seem to have obtained water. Only one well (No. 136), in the NE. ¼ sec. 12, T. 5 N., R. 3 W., is known to have struck rock, which in that well was reached at 190 feet. Detailed data are not available in regard to the other wells. A well owned by H. F. Anders, in sec. 4, T. 5 N., R. 2 W., is reported to have failed to reach water at a depth of 175 feet. This well is in a reentrant valley that extends eastward for some distance into the mountains. Other wells farther east in this valley reached water.

The yield of wells on the east mesa is in general a little greater than that of wells on the west mesa. Several wells on the bench between the river flood plain and the upland are reported to yield between 450 and 900 gallons a minute (50 to 100 miner's inches), and a number of wells on the upland yield between 450 and 650 gallons a minute. There are nevertheless some wells in which the yield is not great—even less than 225 gallons a minute (25 miner's inches).

DEADMAN AND FIFTEENMILE VALLEYS

Deadman and Fifteenmile Valleys are small closed basins that lie east of Deadman and Fifteenmile Points, respectively. Fifteenmile Valley is also locally known as Cobarts Valley. The basins have been formed by alluvium that has been washed northward from the San Bernardino Mountains to spurs of the Granite Mountains, preventing the movement of surface run-off to either the east or the west. Each basin contains a playa, which lies close to the mountains on the north, because the volume of alluvium washed from the south greatly exceeds that from the north.

Several wells have been drilled in each valley. In Deadman Valley the depth to water ranges from about 160 feet in well 155, in the lowest part, near the playa, to 255 feet in well 151, some distance up on the alluvial slope. Bedrock was struck in two wells near the playa; it was reached in well 154, on the north side of the playa, at 307 feet, and in well 157, southeast of the playa, at 200 feet. Both these wells are close to the foot of the mountains. Wells in Deadman Valley are reported to yield 360 to 540 gallons a minute (40 to 60 miner's inches).

The depth to water in wells in Fifteenmile Valley ranges from about 20 feet in wells near the playa to 63 feet in well 162, about a mile west of the playa, on higher ground. So far as is known bedrock was not reached in any of the wells. No information is available in regard to the yield of the wells, as all except one, when visited, were equipped only with windmills. It is said that the water in some of the wells in this valley is so salty that it is not good for drinking.

The playa in Fifteenmile Valley is more than 50 feet and probably nearly 100 feet lower than the playa in Deadman Valley. The water table near the playa in Fifteenmile Valley, however, is higher, probably at least 50 feet higher, than it is near the playa in Deadman Valley. There is no surface evidence of any barrier between the two basins, and ground water probably percolates from Fifteenmile Valley into Deadman Valley.

Similarly the water table, where it is lowest near the playa (in well 155) in Deadman Valley, is at least 20 feet higher than it is in well 93, just west of the boundary of the basin. There is probably underground drainage toward Mohave River.

The playa in Fifteenmile Valley is about 50 to 75 feet above the playa in Lucerne Valley, 2 miles to the northeast, and there is about as much difference in the water table. As the divide between the two basins in part is formed by alluvium there may be some underground drainage from Fifteenmile Valley into Lucerne Valley. This feature is suggested by the presence of Rabbit Springs, about a mile north of the alluvial divide, and by artesian conditions at the Box S ranch. (See pp. 617, 620.)

SIDEWINDER VALLEY

Sidewinder Wash is a tributary to Mohave River that drains an area of about 50 square miles northeast of Victorville. The main wash reaches back in a northeasterly direction for about 5 miles from the river, and for that distance its valley is comparatively narrow and the grade of the wash and the valley slopes are rather steep. About 5 miles from the river the valley broadens out and the slopes are more gentle. Several branch drainage ways extend eastward and northward for 5 miles or more. For the first 3 or 4 miles back from the river flood plain rock crops out at a number of places half a mile or less from the wash, but the upper half of the valley has typical alluvial slopes that rise gradually 2 to 5 miles on each side of the wash to the mountains. The alluvial slope in the upper part of the valley evidently at one time extended at a higher level across the Mohave River lowlands and was continuous with the mesa west of the river, but the continuity of the slope has been broken by the cutting of Mohave River and by dissection in the lower part of Sidewinder Valley. (See pl. 23, *A*.)

Several wells have been put down in Sidewinder Valley, but the data obtained in regard to them are meager. Near the junction of the wash with Mohave River, a little above the flood plain of the river, water was obtained at depths of 56 to 87 feet, in wells 267 and 268. These wells appear to be sunk on a fan built at the lower end of the constricted part of the valley. One of these wells (No. 267) is reported to yield 270 gallons a minute (30 miner's inches) and another well near by (No. 266) 630 gallons a minute (70 miner's inches). About a mile northeast of these wells, in the constricted part of the valley, wells 341 and 342 were dry at 81 and 85 feet, respectively. The dump piles at these wells indicate that probably rock was struck in each.

In the upper part of the valley, where the land is more level, several wells have obtained water at moderate depths. A dug well (No. 340) on the ranch of G. Marietta, in sec. 17, T. 6 N., R. 3 W., which is 88 feet deep, reached water at 73 feet. This well is said to be pumped dry in three hours when yielding 35 gallons a minute (about 4 miner's inches). About 100 feet west of this well another well, in which the depth to water is about 56 feet, is said to have struck granite at a depth of 100 feet. About a mile northeast of this well is Sidewinder Well, a roadside watering place, which is 33 feet deep, with 30 feet to water. When visited, this well was equipped with a hand pump. A well on the Adams ranch, in the SW.¼ sec. 4, T. 6 N., R. 3 W., is 75 feet deep, and the depth to water is reported to be 64 feet. It is said that this well is easily pumped dry. A well in the SE.¼ sec. 27, T. 7 N., R. 3 W., near the head of Sidewinder Valley, is said to reach water at a depth of 130 feet. This well yields about 90 gallons a minute (10 miner's inches).

Apparently water may be obtained throughout most of the broad, gently sloping upper part of Sidewinder Valley at a depth of less than 100 feet. Near the upper borders of the valley the depth may be greater. The yield of the few wells for which any data are available is small, and it is doubtful if any large quantity of water can be obtained. The drainage area is not great, and the rainfall is light, so that the quantity of water added annually to the ground-water supply can hardly be very great. Furthermore, the slope of the valley toward Mohave River is sufficient for a continual percolation in that direction. Indeed, it is surprising that the water table is so close to the surface, unless a rock barrier has raised it somewhat. Although all the wells in the upper part of the valley apparently are dug in alluvium, it may be that bedrock lies at no great depth and that the water encountered is a body only a few feet thick which is held up on the rock and which is moving slowly toward the river. The prospects for ground-water development are not as good in Sidewinder Valley as on the east and west mesas.

UPLAND EAST OF MOHAVE RIVER BETWEEN ORO GRANDE AND HELENDALE

Several wells have been drilled on the upland east of Mohave River between Oro Grande and Helendale. In this area an alluvial slope rises rather steeply from the flood plain to hills and mountains 3 to 5 miles east of the river. There is no sharp boundary between the flood plain and the alluvial slope.

In the lower part of the alluvial slope, near Bryman station, water is obtained at a depth of 15 feet in well 277 and at a depth of 54 feet less than half a mile farther east, in well 276. In the NW. ¼ NE. ¼ sec. 19, T. 7 N., R. 4 W., well 303, on the E. B. Rowley ranch, is 275 feet deep, and the depth to water is reported as 57 feet. This well is reported to yield nearly 900 gallons a minute (100 miner's inches). In well 304, on the east side of this same section, the depth to water is 94 feet. Well 306, in sec. 18, T. 7 N., R. 4 W., is 270 feet deep, with 55 feet to water. This well is said to yield 1,125 gallons a minute (125 miner's inches).

In general it seems probable that wells on the lower part of the alluvial slope will obtain good yields at depths of less than 100 feet. The alluvial slope rises so steeply, however, that the area in which the water table is close enough to the surface for economical pumping does not extend more than 1½ miles east of the river flood plain, and in some places it may be less.

PUBLIC SUPPLIES

Water for public use is distributed at Victorville by the Victorville Domestic Water Co., and at Hesperia by the Hesperia Water Co. Both companies are subsidiaries of the Appleton Land, Water & Power Co.

The Victorville supply is obtained from seven tunnels, from 3 to 7 feet long, driven into the cliffs west of the river about half a mile north of the center of the town. These tunnels penetrate a hard, impervious clay bed, 2 to 7 feet thick, above which the water is found. The location of the clay bed is indicated by a succession of seeps for a considerable distance. The seven tunnels are distributed over a distance of about 200 feet. The horizon of the springs lies about 10 feet above the flat of a low terrace along the river. The water is carried through ditches to a collecting reservoir that has a capacity of 75,000 gallons. Thence it is pumped into a 50,000-gallon distributing reservoir, at the top of the cliffs, 118 feet above the terrace, giving a pressure in the lower part of the town of about 65 pounds. The water is pumped into the distributing reservoir by an electrically operated belt-driven triplex pump which has a capacity of 39 gallons a minute. The water is distributed through 6 and 4 inch mains. The yield of the seven tunnels is about 90 gallons a minute

(10 miner's inches) and is said to be nearly constant from season to season. The seepage along the horizon of the springs is apparently greater in winter, but this is believed to be due to an actual increase in the flow but to decreased evaporation. As shown by analysis in the table on page 417, the water is very good for all purposes, so far as its mineral content is concerned. The situation of the tunnels is such that if reasonable precautions are taken to prevent contamination between the tunnels and the distribution system, the water is safe for human consumption. In December, 1917, the company served about 150 customers, who represented about 90 per cent of the water users of the town. At that time the rate for domestic use in houses was $1.25 a month.

The water for Hesperia is obtained from Deep Creek, a short distance above the Forks of Mohave River. It is carried through 4 miles of ditches and 6½ miles of pipe line to a reservoir on the south edge of the town. The Hesperia Water Co. operates only from the reservoir, the pipe line and ditches above that being owned by the Appleton Land, Water & Power Co. The original capacity of the ditches and pipe line feeding the reservoir was about 10,800 gallons a minute (1,200 miner's inches), but in 1917 it had dropped to about 6,750 gallons a minute (750 miner's inches). The company at that time was restoring the system to its original capacity. Most of the water carried by the Appleton Land, Water & Power Co. is used for irrigation. In 1917 there were only 10 connections for domestic use, and the rate for these was $1.25 a month. The Atchison, Topeka & Santa Fe Railway Co. buys some water from the company.

QUALITY OF WATER

Analyses of samples of water collected at eight different places in the Upper Mohave Valley are given on page 417. Of these samples, six come from wells, one from the springs that furnish the public supply for Victorville, and one from Mohave River at Victorville. The analyses show that the water obtained in wells nearly everywhere is good for domestic use and irrigation and fair or good for boiler use. One sample (analysis 5) from Sidewinder Well (No. 338), is inferior in quality to the other samples. It contains 636 parts per million of total dissolved solids. It is satisfactory for drinking, but only fair for washing on account of the high content of iron. It is bad for boiler use because of the tendency to foam. It is considered only fair for irrigation. The other samples contain less than 400 parts per million of total dissolved solids and are considered good for domestic use and irrigation and fair for boiler use. The samples from the springs that furnish the public supply for Victorville and from Mohave River are exceptionally low in mineral content and are good for all purposes.

The water in the river at Victorville differs from season to season, as it is somewhat more mineralized in dry seasons, on account of evaporation. However, a determination of the total solids in the river water at the Upper Narrows on August 10, 1902, showed only 135 parts per million.[38] The chloride content was 20.1 parts per million. Determinations were also made in the same month of samples from wells in the bed of the river at the narrows, and in none of them were the total solids higher than 150 parts per million. These samples were taken in the dry season, when the mineral content of the water might be expected to be higher than at other times. The low mineral content of the samples from the surface flow and underflow of the river is an indication that the water from wells along the river flood plain above the narrows is good for all purposes.

No samples were collected very close to any of the playas. It is said that the water in several wells near the playa in Fifteenmile Valley is too salty to drink, especially after the wells have not been pumped for some time. So far as is known, the water around the playa in Deadman Valley and around El Mirage Dry Lake is good enough for domestic use and irrigation.

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[38] Slichter, C. S., Field measurements of the rate of movement of underground waters: U. S. Geol. Survey Water-Supply Paper 140, p. 64, 1905.

Analyses of waters in Upper Mohave Valley

[Parts per million]

	1	2	3	4	5
Silica (SiO_2)	22	20	19	[a] 12	47
Iron (Fe)	.30	.90	Trace.		3.3
Calcium (Ca)	24	28	40	18	14
Magnesium (Mg)	2.1	17	3.2	4.9	3.2
Sodium and potassium (Na+K) calculated	70	46	79	31	174
Carbonate radicle (CO_3)	0	0	0	0	0
Bicarbonate radicle (HCO_3)	95	68	88	110	117
Sulphate radicle (SO_4)	129	164	197	21	254
Chloride radicle (Cl)	5.8	8.8	5.9	14	46
Nitrate radicle (NO_3)	Trace.	Trace.	.0	----	1.4
Total dissolved solids at 180° C	292	336	378	[b] 155	636
Total hardness as $CaCO_3$ (calculated)	69	140	113	65	48
Date of collection	(c)	(c)	(c)	(d)	(e)

	6	7	8	9
Silica (SiO_2)	38	24	25	----
Iron (Fe)	Trace.	.07	.20	----
Calcium (Ca)	54	15	15	----
Magnesium (Mg)	8.9	5.1	2.9	----
Sodium and potassium (Na+K) calculated	63	29	15	----
Carbonate radicle (CO_3)	0	0	0	----
Bicarbonate radicle (HCO_3)	193	122	83	----
Sulphate radicle (SO_4)	91	7.4	7.9	----
Chloride radicle (Cl)	37	9.1	6.0	20
Nitrate radicle (NO_3)	4.0	.93	.36	----
Total dissolved solids at 180° C	395	147	117	[f] 135
Total hardness as $CaCO_3$ (calculated)	171	58	49	----
Date of collection	(g)	(h)	(i)	(j)

[a] Includes silica (SiO_2), iron oxide (Fe_2O_3), and aluminum oxide (Al_2O_3).
[b] Calculated.
[c] Aug. 13, 1916.
[d] Nov. 27, 1915.
[e] Dec. 30, 1917.
[f] Determined with the Whitney electrolytic bridge.
[g] Aug. 12, 1912.
[h] Dec. 29, 1917.
[i] Mar. 17, 1908.
[j] Aug. 10, 1902.

Analysts: 1, 2, 3, 6, S. C. Dinsmore; 4. Los Angeles & Salt Lake Railroad; 5, Addie T. Geiger, U. S. Geol. Survey; 7, A. A. Chambers, U. S. Geol. Survey; 8, Walton Van Winkle.

1. Well 203, pl. 22, and table on p. 399; E. H. Richardson, owner. Sample from a well at Adelanto, but from which one of three wells is not known.
2. Well 210, pl. 22, and table on p. 399, O. W. Jessup, owner.
3. Well 246, pl. 22, and table on p. 400, K. McDonald, owner.
4. Well 325, pl. 22, and table on p. 402, Atchison, Topeka & Santa Fe Railway pumping plant at Victorville. Analysis furnished by Los Angeles & Salt Lake Railroad; recalculated from hypothetical combinations in grains per United States gallon. A sample collected on July 22, 1900, and analyzed by the railroad contained 208 parts per million total solids.
5. Well 338, pl. 22, and table on p. 402. Sidewinder Well.
6. Well 344, pl. 22, and table on p. 402. A. G. Trendell, owner.
7. Springs probably in sec. 9, T. 5 N., R. 4 W., San Bernardino meridian. Victorville Domestic Water Co., owner; furnishes public supply for Victorville.
8. Mohave River at Victorville. U. S. Geol. Survey Water-Supply Paper 237, p. 125, 1910.
9. Mohave River at Victorville. U. S. Geol. Survey Water-Supply Paper 140, p. 64, 1905.

AGRICULTURAL DEVELOPMENT

According to statistics presented in the report of the Mohave River Commission the total area in the Upper Mohave Valley suitable for agriculture is about 325,000 acres.[39] The area considered in that report is essentially the same as that shown on Plate 22. Of this area about one-third consists of patented railroad lands, grant lands, unpatented railroad lands, State school lands, or lands controlled by

[39] McClure, W. F., and others, Report on the utilization of Mohave River for irrigation in Victor Valley, Calif.: California Dept. Eng. Bull. 5, p. 26, 1918.

the Appleton Land, Water & Power Co., the Arrowhead Reservoir & Power Co., or the Rancho Verde Co.—that is, it is owned or controlled by a few organizations. The remaining two-thirds is public land, nearly all of which has been applied for under the homestead and desert-land acts and some of which has been patented.

Of the total area of 325,000 acres only about 7,700 acres, or less than 2.5 per cent, was irrigated at the time of the investigation by the commission.[40] About one-third of this area was irrigated from the river and two-thirds from wells. About 72 per cent of the irrigated land was along the river bottom or the bench between the flood plain and the east mesa; 16 per cent was on the west mesa, including El Mirage Valley; and 12 per cent was on the east mesa and in Deadman and Fifteenmile Valleys. By comparing the area of land irrigated in each unit to the area in that unit that is suitable for agriculture, however, it is found that the area irrigated on the river flood plain is about 35 per cent of the available area in that unit, the irrigated area on the west mesa is only about one-half of 1 per cent of the available area, and that on the east mesa is about 2.5 per cent. In brief, the greatest development, both in area and percentage of possible development, has been on the river flood plain and the bench between it and the east mesa; and although the area developed on the west mesa is somewhat larger than that on the east mesa, the percentage of possible development has been somewhat less.

These conditions are more or less directly due to conditions that govern the water supply. Along the river a considerable area is irrigated by water diverted from the river in a number of ditches at different places from the vicinity of the Forks down as far as Bryman.[41] The largest area irrigated in the entire valley is at the Rancho Verde, on the river flood plain south of the Upper Narrows, where about 1,000 acres is under cultivation, of which about 400 acres is irrigated with water from the river and the remainder from wells. About 9,000 gallons a minute (1,000 miner's inches) is diverted from the river, about 8,000 gallons a minute (880 miner's inches) is obtained from seven pumped wells, and about 3,150 gallons a minute (350 miner's inches) is obtained from 12 flowing wells. On account of the relative cheapness of water from the river and from wells in which the lift is low, most of the irrigated land along the river is devoted to alfalfa. The greater part of the area irrigated along the river lies above the Upper Narrows.

The relatively greater percentage of irrigated area with respect to total agricultural land on the east mesa as compared to the west mesa is due in a large part to the fact that the area in which economical pumping is possible is relatively larger on the east mesa, where the

[40] McClure, W. F., and others, op. cit., p. 28.

[41] Data in regard to ditch filings and appropriation of water from Mohave River are given in the report of the Mohave River Commission: California Dept. Eng. Bull. 5, pp. 48–49, 1918.

area in which the depth to water is less than 100 feet covers from one-fourth to one-third of the entire mesa, including Deadman and Fifteenmile Valleys, and the area in which the depth to water is not more than 200 feet covers fully two-thirds of the entire mesa, if not more. On the west mesa the area in which the depth to water is less than 100 feet covers probably not more than one-fourth of the mesa, and the area in which it is less than 200 feet covers probably not over one-half of the mesa. Furthermore, the lands on the east mesa that are most favorably situated with respect to ground-water conditions are much nearer to Victorville. Throughout a large part of the west mesa the depth to water is too great to permit water for irrigation to be profitably pumped. In the areas on the east and west mesas where there has been any irrigation the water is used principally for fruit orchards, as the pumping lift is generally too great for the profitable raising of alfalfa, except on some of the low land around El Mirage Dry Lake.

One drawback to irrigation development on the mesas, especially the west mesa, has been the small yields from many of the wells, few of them yielding as much as 450 gallons a minute and some of them less than half as much. The initial cost of the well and pumping plant is a considerable item. Few individuals can invest enough capital to farm enough land to run a pump to capacity all the time. When a plant is idle a large part of the time the depreciation is relatively high as compared to the return. The cost of the water can be reduced materially if two or three landowners will unite to obtain water from a single well. In this way the cost of additional wells and pumping plants is saved, and the one pumping plant may be used to its fullest efficiency.

An example of a plan to reduce pumping costs by the reduction of pumping equipment is found at Adelanto. At this place the Adelanto Water Co. has been organized to develop water more cheaply than can be done by individual effort. The company is a mutual organization, and stock in it is purchased by landowners according to the acreage irrigated and the quantity of water used. The developments at Adelanto have been largely under the direction of E. H. Richardson, of Ontario, Calif., who has spared no effort to develop a community that will be a model, as regards both economic and social conditions, for other projects to reclaim desert lands. The yield of wells at Adelanto is from 90 to 225 gallons a minute (10 to 25 miner's inches), and it is not possible to obtain enough water from one well for a large acreage. The maximum pumping lift is about 150 feet, and it is necessary to reduce the cost of pumping as much as possible. The original cost of installation and the subsequent cost of labor in pumping are reduced by pumping with compressed air, which is distributed from a centralized compressor station. When visited by the writer in December, 1919, four wells were pumped from this central compressor station (Nos. 202, 203, 205, and 289). The compressor plant is near the center of sec. 28, T. 6 N., R. 5 W. San Bernardino meridian. Two of the wells (Nos. 202 and 203) are within 300 feet of the plant, a third (No. 289) is about a quarter of a mile distant, and the fourth is half a mile north and half a mile west from the plant. It is stated that the loss in air transmission to the farthest well is very little, and the company hopes to be able to carry air 1 or 2 miles, if necessary. The water is distributed through concrete pipe, and in 1919 the company had laid about 1 mile of 10-inch pipe and 2½ miles of 8-inch pipe. The longest run of water through the pipe is about 1¾ miles. The water is distributed by gravity. Two cement reservoirs, each of which has a capacity of 250,000 gallons, are provided near the central plant. These reservoirs are filled during the night, and the water is used during the day. During the irrigating season the compressor plant is run practically all the time. In June, 1921, the system was used to irrigate 100 acres of pears from 2 to 5 years old, 45 acres of apples from 4 to 5 years old, and 60 acres of farm crops. At that time it was planned to add an additional 100 acres and to drill more wells. Some fruit had been sold, but the trees had not all reached bearing age, and it is not possible to give data on the yields. The cost of water in 1921 was $15 to $18 an acre a year, including power, upkeep, and labor of pumping but not the labor of irrigating.

IRRIGATION PROJECTS AND DISTRICTS

Because the depth to water throughout a large part of the east and west mesas is too great for profitable pumping, projects have been under way for some years to divert water from the headwater region of Mohave River for irrigating land on these areas. These projects are briefly described below, chiefly from the report of the Mohave River Commission. Most of the unirrigated patented land on the east and west mesas is being held by the owners in the hope that water for irrigation may be obtained from the river. In August, 1922, the projects were still under consideration, so that the following statement is not indicative of final plans.

As described on pages 381–384 the first development of the headwaters of Mohave River was undertaken in the eighties and early nineties, and more or less work continuing the early development has been done from time to time. The water rights and improvements are now controlled by two companies—the Appleton Land, Water & Power Co. and the Arrowhead Reservoir & Power Co. The holdings of the Appleton Land, Water & Power Co. consist principally of water rights on Deep Creek and of ditches and pipe line leading from Deep Creek to lands owned by the company in the vicinity of Hesperia. The company owns about 20,000 acres of land on the river flood plain and west mesa, but only a very small portion of it has been irrigated. The Arrowhead Reservoir & Power Co. controls the available reservoir sites on the East Fork (Deep Creek) and West Fork and their tributaries. It has partly constructed a dam to create a reservoir in Little Bear Valley, and also partly driven tunnels to connect reservoirs to be created on others of the headwater streams. The company owns or controls about 16,000 acres of land, of which about 12,000 acres is in the mountains. The remainder is composed of riparian lands scattered along the river for some distance below Victorville, which were purchased to quiet opposition from adverse claimants to water rights. Practically no land is irrigated by the company.

The greater part of the east and west mesas is not included in the lands owned by the Appleton Land, Water & Power Co., or the Arrowhead Reservoir &Power Co., and its owners have not been in a position to benefit by the developments on the headwaters of the river. In 1913 many of the landowners and entrymen on both mesas formed the Victor Valley Mutual Water & Power District Association, an unincorporated organization, with voluntary membership. One of the chief objects of this association was to obtain the development of the headwaters of Mohave River as a project of the Federal Government. Such development was not found to be possible.

After the passage in 1916 of the Smith Act, which permitted the inclusion of Government land in irrigation districts organized under State Laws, the Victor Valley association proposed the organization of a district to include 55,000 acres on the east and west mesas. The entrymen on the east mesa demurred, believing that they could get water cheaper from an independent system serving only that area, and undertook the organization of the Mohave River irrigation district. Subsequently the Victor Valley irrigation district was proposed to include only the west mesa. The organization of the two districts was delayed, pending the approval of the county board of supervisors. The organization of the Mohave River irrigation district was eventually completed on April 9, 1917, and that of the Victor Valley irrigation district on October 22, 1917.

The Mohave River irrigation district as organized comprised 27,655 acres, of which 26,874 acres was irrigable. The district originally proposed to purchase the Forks reservoir site from the Arrowhead Reservoir & Power Co. The water was to be carried to the east mesa by 12 miles of tunnel and canal, with a siphon. Water for most of the mesa would be distributed by gravity, but for the high land on the south it would have to be lifted about 100 feet. Later the district endeavored to unite with the Appleton Land, Water & Power Co.

and the landowners on the west mesa to obtain water from Little Bear Reservoir, but the result of this action is not known.

The Victory Valley irrigation district, as organized, included 71,517 acres, of which 65,000 acres was considered to be irrigable. The district does not cover any land of the Appleton Land, Water & Power Co. At the time of its organization the district obtained options to purchase all or parts of the properties of the Arrowhead Reservoir & Power Co. It was proposed to purchase all the properties for $2,500,000.

Two plans were suggested to distribute water to the lands of the district. One plan calls for the completion of the Little Bear Valley Reservoir and inlet works and construction of a conduit from the reservoir across West Fork of Mohave River to the west mesa. The conduit would be 27 miles long and would consist of a tunnel in the upper part, an inverted siphon across West Fork, and concrete pipe in the lower end. A power drop of 810 feet would be developed. Under this plan all the water would be distributed by gravity. Under the second plan the Little Bear Valley Reservoir would be completed, and the water would all be carried to the Forks in a power conduit. The Forks reservoir site would be improved. Water for the higher land of the district would have to be lifted to a high-line canal, and the lowlands would be served by gravity. A combination of the two plans has been suggested whereby sufficient water to serve the higher lands by gravity would be carried direct to them from the Little Bear Valley Reservoir, and the remainder would be diverted to the Forks Reservoir.

As a result of its investigation the Mohave River Commission considered it doubtful whether water from the Arrowhead Reservoir & Power system could be supplied to the Victor Valley irrigation district at a reasonable cost, on account of the length of conduit, expensive nature of construction, small quantity of water available, and comparatively small amount of power to be developed.[42] The commission suggested that some land on the east mesa could be irrigated from the Little Bear Valley Reservoir at less expense than that of carrying the water to the west mesa and that reservoirs on the West Fork could be used to store water for the west mesa. It also suggested that the present ditch and pipe lines of the Appleton Land, Water & Power Co. would be of value for the distribution of water to the east mesa and to lands near the river on the west mesa.

The commission pointed out that the average annual discharge of the headwaters of Mohave River is about 90,000 acre-feet. Of this quantity the commission considered that about one-third is available for storage in Little Bear Valley and one-third for storage

[42] McClure, W. F., and others, Report on the utilization of Mohave River for irrigation in Victor Valley, Calif.: California Dept. Eng. Bull. 5, p. 81, 1918.

in proposed reservoirs on the upper part of West Fork—that is, about 60,000 acre-feet is available for use on the east or west mesas. The commission believed that one-third should be allowed for riparian lands along the river. It is not clear whether this quantity includes water that is now absorbed by the alluvium and replenishes the ground-water supply in parts of the drainage below Victor Valley. (See p. 434.)

The commission considered that the proper duty of water is between 1.25 and 1.50 acre-feet. On this basis sufficient water is available to irrigate about 45,000 acres on the two mesas. If the water is to be most economically used it is necessary that opposing interests in different parts of the valley unite to bring about an equitable distribution of water with the least expense. The commission has suggested the following plan: Water for the west mesa should be stored in reservoirs on the upper part of the West Fork (above the junction with Horsethief Canyon), and the initial unit should have a capacity of 33,000 acre-feet, subsequently to be enlarged to 60,000 acre-feet. The west mesa district, with the initial unit, would include 18,400 acres and eventually would include 29,000 acres. The east mesa would obtain water from the Little Bear Valley Reservoir system, and the irrigation district would include 23,000 acres. The total area of the two districts would be about 52,000 acres, of which about 45,000 acres would be irrigated.

MIDDLE MOHAVE VALLEY

GENERAL FEATURES

In this report the name "Middle Mohave Valley" is applied to an expansion of the lowland along Mohave River between Hicks and Barstow and northward to low hills north of Hinkley. The greatest development is near Hinkley, and the valley is locally called Hinkley Valley. As nearly as can be determined from available data, the town of Hinkley and a considerable area around it is not in the Mohave River drainage basin but in the drainage basin of Harper Dry Lake, on the north. The divide in this locality, however, is indefinite, and that part of the Harper Dry Lake basin is considered here. The part of the Mohave River basin that lies between Helendale and Hicks (see pl. 17) and a few sections east of Barstow are also described.

Barstow, the only large town in the area, is an important railroad junction, and the population largely consists of railroad workers. It has good stores and garage and several hotels. In 1917 Hinkley and Hicks each had a small store, and Hinkley had a post office. Helendale had a post office but no store. Wild and Todd are railway sidings only, with a few houses for section hands, where water can be obtained in an emergency.

Good train service is available along the two lines of the Atchison, Topeka & Santa Fe Railway. The National Old Trails Road parallels the Los Angeles line of the Santa Fe, and a road of less importance which leads westward along the San Francisco line is used for travel to Kramer, Mojave, and San Joaquin Valley and to the Randsburg district and Owens Valley. A road leads southward from Barstow to Stoddard Well and Victorville. The land west of Mohave River is largely isolated from the east side because of the sandy river bottom. Automobiles sometimes cross near Helendale, but a number of them have become stuck. When the river is not passable in order to reach the west side it is necessary to go south to the bridge 2 miles south of Oro Grande or to cross the river at Barstow.

PHYSICAL FEATURES

The divide of the Mohave River drainage basin in Hinkley Valley is shown on Plate 17. This boundary is only approximate, as practically no part of the area is covered by topographic maps. The area extends northeast, and the river crosses it in the same general direction.

From the vicinity of Helendale to Hicks the conditions along the river are much the same as between the Lower Narrows and Hicks, except that the change from the lowland along the river to the upland is not quite so abrupt as farther south. The river is bordered by a flood plain that is from a few hundred yards to a mile wide. In most of this stretch the river is dry for much of the year, but near Hicks and possibly at other places the water flows where bedrock evidently is close to the surface. The water is near the surface and for a large part of the year appears in a small stream where the channel is close to a rock butte at the west end of Barstow.

West of the river the land rises more or less gradually to low hills that are 6 to 10 miles distant. East of the river the land rises somewhat more steeply to hills and mountains that are higher than those west of the river. The lower slopes consist of alluvium washed down from the hills and mountains. In the upper part of the slopes, however, the alluvium is probably not very thick.

A short distance north of Hicks the lowland that borders Mohave River widens out into a large alluvium-filled basin. An almost level plain extends nearly 10 miles northward to low hills north of Hinkley and as far northeast to Barstow, where the lowland again becomes constricted. On the southeast, although the hills are some miles from the river, the lowland does not extend farther than approximately to the Atchison, Topeka & Santa Fe tracks. A large valley that enters southeast of Todd station reaches back 15 miles or more to the base of Ord Mountain and the Granite Mountains. This valley may be called Stoddard Valley, as Stoddard Well is near the head of its southwest arm.

In order to understand the conditions that govern the occurrence of ground water in the lowland east and southeast of Hinkley it is necessary to consider briefly the relations between this area and Harper Valley, which joins it on the north. They are described on pages 428–429. The bottom of Harper Valley is occupied by a playa, known as Harper Dry Lake, which is about 160 feet below Mohave River near Todd station and about 120 feet below the valley at Hinkley. On the west, northwest, and north hills in which bedrock crops out separate the lowland around Hinkley from land that slopes directly to the playa. The hills extend eastward almost continuously to the area beyond Barstow, but they are broken by a low, broad pass into Harper Valley about 2½ miles northeast of Hinkley.

The lowland is so continuously bordered by these hills on the west and north that at first glance they seem to form the divide between Mohave Valley and Harper Valley. A definite drainage line, however, extends from Harper Dry Lake southward through the pass northeast of Hinkley and reaches at least as far as the northeastern part of sec. 24, T. 10 N., R. 3 W. The land for several square miles near Hinkley is so nearly level that it is almost impossible to tell without instruments which way it slopes. In the absence of detailed leveling, as nearly as can be determined from watercourses, an uncompleted topographic map, and railroad profiles, the divide between the Mohave drainage basin and Harper Valley apparently extends northeastward across the southeastern part of T. 10 N., R. 3 W., as shown on Plate 18. Patches of bare, hardened mud near Hinkley indicate that the slope may not be sufficient to carry off the storm water, but if there is any surface drainage in this locality it must go toward Harper Dry Lake. Although the lowland between Mohave River and Hinkley lies partly in two distinct drainage basins, the occurrence of ground water is apparently unaffected by the surface divide. There is reason to believe that ground water moves from Mohave River into Harper Valley.

At Barstow the lowland along Mohave River becomes constricted, and from that place down as far as Daggett it is not more than a mile wide and in some places less. North of the river rise rough mountains of old crystalline and Tertiary eruptive rocks. From these mountains a typical alluvial slope extends toward the river. Northwest of Barstow the slope is broken by a somewhat abrupt descent to the lowland, but farther east it merges into the lowland without any steep descent. In the area northwest of Barstow bedrock is exposed at many places, and the seeming alluvial slope is probably in reality a mountain pediment underlain by bedrock at no great depth over a considerable area. On the south side of the lowland, at the east and west ends of Barstow, stand two large hills of Tertiary eruptive rocks, which rise abruptly close to the river channel. Each hill is about a third of a mile in diameter and between 100 and 200 feet in height. Several knobs of rocks of the same kind rise from the river lowland north and northeast of town. Between the two hills mentioned and for several miles southwest and southeast of them the land rises rather gradually several hundred feet to a high ridge with rounded outlines. This ridge, wherever seen, is composed of unconsolidated alluvium, probably of Quaternary age. In a railroad cut on the south side of the rock hill east of Barstow gravel beds abut against the Tertiary eruptive rocks. Presumably the gravel, which is probably between 25 and 50 feet above the present river bed, was deposited by Mohave River at an earlier time in its history.

The profile of the alluvial slope northwest of Barstow, if projected across the lowland to the rock hill on the west edge of the town, would indicate that prior to the erosion of the present valley the river ran at a somewhat higher level. There is similar evidence at intervals upstream, as far as the San Bernardino Mountains, that the river has trenched its valley to a depth of 25 to 200 feet or more since the late Tertiary or Pleistocene time. If the main features of relief in the valley at the time Mohave River was at a higher level were about as they are to-day it seems probable that the river, for some time at least, may have flowed into Harper Valley and formed a lake. No outstanding lake beaches or cliffs were observed by the writer during a few hours' visit to the valley, but more careful study may reveal evidence of the existence of a lake. It is reported that shells were found at a depth of about 200 feet in a well drilled near Harper Dry Lake.

SOILS

The soil in a considerable area adjacent to Mohave River is very sandy, especially in the area north of Hicks, where the water is below the reach of the water-loving plants and the sand is blown into low hummocks around the plants that do exist. In the lowland between the river and Hinkley there are numerous patches of clay. In several places these patches were observed to produce bad roads in wet weather, and they are poorly drained for farming. On the uplands the soil is generally the typical coarse arkosic sandy soil formed from the weathering of the crystalline and eruptive rocks.

VEGETATION

The slopes of the upland have a typical growth of creosote bush. Along the stretches of the river where the ground water is close to the surface mesquite, willow, poplar, salt grass, and other water-loving forms flourish. Where the depth to water along the river is greater the soil is very sandy, and only the most resistant types occur.

In places on the lowlands between the river and Hinkley, where the soil is clayey, the vegetation is sparse.

PRECIPITATION

The only records of precipitation available are those for Barstow. These records, which are given on pages 85–94, show the average annual precipitation at that place to be about 4¼ inches. The land in the Middle Mohave Valley that is available for agriculture lies at about the same altitude as that at Barstow, and the precipitation is practically the same.

Ord Mountain and the Granite Mountains, at the head of Stoddard Valley, rise to an altitude of 3,000 to 5,000 feet, and the precipitation on them may be a little greater than in the valley. None of the other mountains rise high enough to influence the precipitation greatly.

WATER RESOURCES

GENERAL FEATURES

Mohave River is the only stream in the valley, and there is no other available source of surface water. The flow of the river during the irrigation season is practically zero, and the area that is irrigated with water from the river, if any, is negligible.

In discussing the ground-water conditions the area may be divided into several parts, as follows: The part between Helendale and Hicks, both lowland and upland; the lowland between Hicks, Hinkley, and Barstow, locally known as Hinkley Valley; the river valley from Barstow eastward for 2 or 3 miles; and Stoddard Valley.

The locations of wells for which data are available are shown on Plate 17, which also shows wells in Harper Valley. The essential data in regard to these wells are given in the table on pages 435–436. Wells 51 to 102, except 96, are within the drainage basin of Mohave River.

HELENDALE-HICKS AREA

Practically all the wells in the Helendale-Hicks area are close to the river. The river is generally bordered by a flood plain a few feet above the present river channel. From the outer edge of the flood plain the alluvial slopes rise, in some places steeply, 10 to 50 feet or more, in other places more gradually. The depth to water on the flood plain is generally less than 25 feet, and in some places it is not more than 10 feet. Away from the flood plain the depth to water increases with the altitude of the surface. Few wells have been drilled on the upland, and few data are available as to the depth to water there. In wells 94 and 95, in secs. 14 and 15, T. 7 N., R. 5 W., the depth to water is 143 and 132 feet, respectively. In well 90, in sec. 23, T. 8 N., R. 4 W., the depth to water is 127 feet, and in well 91, in the next section to the east, it is 160 feet. In well 102, in the S. ½ sec. 19, T. 8 N., R. 4 W., the depth to water is 52 feet, and it is about the same in wells 85 and 86, in secs. 7 and 18, T. 8 N., R. 3 W.

The alluvium of the lowland yields much water. Many of the wells are dug, and they obtain large quantities of water without going very deep. For example, the well of J. L. Thompson (No. 101), in the NE. ¼ sec. 30, T. 8 N., R. 4 W., which is 5 feet in diameter and only 30 feet deep, with 10 feet to water, yields 810 gallons a minute (90 miner's inches). The dug well of B. T. Estler (No. 89) in sec. 15, T. 8 N., R. 4 W., in which the depth to water is 20 feet, is reported to yield 1,215 gallons a minute (135 miner's inches). The dug well of L. S. Emerson (No. 79), in the SW. ¼ sec. 34, T. 9 N., R. 3 W., which is 27 feet deep, with about 16 feet to water, yields 900 gallons a minute (100 miner's inches). This well is 6 by 6 feet to a depth of 16 feet. Below that depth it is curbed with boiler plate 54 inches in diameter for 4 feet, and 42 inches in diameter for the remainder. The boiler plate is perforated. The gravel in this well is said to be coarse, from 1 to 2 inches in diameter.

No data are available in regard to the yield of wells on the upland, but they probably do not yield as much water as those on the lowland. The alluvium of the upland consists of relatively fine compacted sand, with little gravel, whereas the alluvium of the lowland, which has been worked over by the river, contains coarse gravel. The alluvium of the lowland is recharged by underflow from Mohave River, but the area which is affected by underflow from the river probably does not extend very far on either side of it.

HICKS-HINKLEY-BARSTOW AREA

The Hicks-Hinkley-Barstow area is a triangular lowland almost completely surrounded by low hills. The depth to water in the lowland is less than 40 feet, and in several wells it is less than 15 feet. On the border of the lowland area, where the land rises gradually to the hills, the depth to water increases. For example, at Hinkley the depth to water is about 11 feet. About 2½ miles southwest of Hinkley, in well 49, the depth to water is 75 feet. In wells 67 and 69, in the eastern part of sec. 3 and sec. 2, T. 9 N., R. 3 W., the depth to water is about 20 feet. In well 68, in the NW. ¼ sec. 3, nearer the hills, it is 71 feet; in the SE. ¼ sec. 4 it is 87 feet; and in wells 70 and 71, in the NE. ¼ SE. ¼ sec. 8, T. 9 N., R. 3 W., it is 108 and 130 feet, respectively.

Depth to water, altitude of surface, and altitude of water table in wells in Hinkley and Harper Valleys

Well No.	Approximate altitude above sea level (feet) [a]	Depth to water (feet)	Approximate altitude of water table above sea level (feet)
69	2,195	18	2,182
50	2,185	17	2,173
51	2,175	14	2,161
44	2,164	11	2,153
39	2,150	26	2,124
37	2,140	32	2,108
36	2,100	35	2,065
29	2,040	Flows.	2,040+

[a] Estimated from uncompleted topographic map by the U. S. Geological Survey, the Searles Lake topographic map, and profile of Atchison, Topeka & Santa Fe Ry.

The estimate of the altitude may be in error by several feet at any of the wells, but a careful study of the topographic map and railroad profiles indicates that the water table at well 44, at Hinkley, is definitely lower than at well 69, in sec. 2, T. 9 N., R. 3 W., and it is considerably lower at well 37, in sec. 15, T. 10 N., R. 3 W., than at Hinkley.

The water table slopes from Mohave River northward to Harper Valley, indicating that ground water moves from Mohave River toward Harper Dry Lake. In Harper Valley flowing wells are found at the Black ranch (No. 96) and the P. E. McDonald ranch (No. 35), and in other wells the water rises under pressure when struck. Vegetation that indicates an abundance of ground water near the surface also occurs some distance southeast of the playa toward the pass to Hinkley. The drainage area tributary to this part of Harper Valley is not great, and unless the ground water comes from Mohave River it is difficult to explain the abundance of water in this part of the valley.

Two or three miles west of Hinkley, in sec. 19, T. 10 N., R. 3 W., there is a low pass that leads to the main part of Harper Valley in which the divide is only about 20 feet above Hinkley. This pass may be filled with alluvium, so that there may be underflow through it northwestward toward Harper Dry Lake. That there may be such movement is suggested by the fact that the water in well 23, in the SW. ¼ sec. 3, T. 10 N., R. 4 W., when struck at a depth of 200 feet, rose to a level 80 feet below the surface. The writer did not have an opportunity to examine this part of Harper Valley, and no definite data are available to shed light on this possibility.

Data in regard to yield are available for only a very few wells in the Hicks-Hinkley area, but the yield of all these wells is good. Only one well (No. 44, p. 272) is reported to yield less than 360 gallons a minute (40 miner's inches), and that one, which is used by the Atchison, Topeka & Santa Fe Railway, is not pumped to its full capacity. Yields as high as 540 and 675 gallons a minute (60 and 75 miner's inches) are reported. Apparently an abundant supply of water can be obtained from properly constructed wells throughout the area except, perhaps, very close to the foot of the hills, where bedrock may possibly be encountered.

BARSTOW AND VICINITY

On the western edge of Barstow the lowland that borders Mohave River becomes much narrower, and from that locality down to Daggett the lowland is generally not more than half a mile to a mile wide. On the lowland in this stretch, as farther upstream, water is obtained at depths of 10 to 35 feet. The yield of wells is generally sufficient for irrigation. Beyond the borders of the lowland the rise of the land is so great that within a short distance the depth to water is beyond the limit of economical pumping. As a result very few wells have been drilled, except on the lowland. For example, in well 98, probably in sec. 5, T. 9 N., R. 1 W., on the lowland a few feet north of the river channel, the depth to water is 13 feet. In well 66, about half a mile from the river channel, it is 98 feet, and in well 99, less than half a mile farther from the river, it is 142 feet.

BARSTOW PUBLIC SUPPLY

The public water supply for Barstow for many years was furnished by the Atchison, Topeka & Santa Fe Railway, as a large part of the population was employed by the railroad. For domestic and general purposes water was obtained from two drilled wells, each 12 inches in diameter and 65 feet deep, at the east end of the town. The depth to water in each well was about 14 feet, the yield of each was about 350 gallons a minute, and the drawdown when pumping was done at that rate was 6 feet. For engines and use in the shops water is pumped from a dug well, 21 feet in diameter and 28 feet deep, which yields about 500 gallons a minute. In certain seasons the supply from these wells was not sufficient, and water was also obtained from a near-by well owned by the Barstow Ice Co. In 1919 the water service was taken over by the Imperial Utilities Corporation, and an additional well was drilled, 12 inches in diameter and 77 feet deep This well and the well of the ice company are now used to serve the town. Together they yield 650 gallons a minute. The wells are pumped by centrifugal pumps operated by electricity.

STODDARD VALLEY

Stoddard Valley is a large upland valley southeast of Todd station. At its junction with the main valley it is somewhat constricted, but about 8 miles southeast of Todd it expands into a large valley with a gently sloping alluvial floor several miles across. Because of the relatively level character of the land the valley might readily appeal to prospective settlers, but, so far as known, no wells have been drilled in this valley. Stoddard Well, in the southwest side of the valley, is at the foot of the Granite Mountains, and the water is obtained from a tunnel in the granite. In December, 1917, the yield was only about a quarter of a gallon a minute. The water, as shown by analysis 7 on page 433, is of fair quality and contains 472 parts per million of total solids. The well is of value only as a roadside watering place. The water is piped to an open wooden tank near the road between Victorville, Barstow, and Daggett by way of Sidewinder Well. Another unnamed spring is reported to emerge in the Granite Mountains at the extreme southeast end of Stoddard Valley, probably in sec. 30, T. 7 N., R. 11 E. San Bernardino meridian, but nothing definite is known about it. It is reached by a road that branches to the southwest from an old road from Stoddard Well to Ord Mountain about 11½ miles from Stoddard Well. Sweetwater Spring and Aztec Spring, at the north end of Ord Mountain, are probably in the drainage area of Stoddard Valley. (See pl. 24.) However, the boundary of the drainage basin in this locality was not accurately determined, and they may be in the drainage basin of Lower Mohave Valley, and are described under that area. (See pp. 499–500.)

It is not believed that water for irrigation can be obtained in Stoddard Valley. The valley has a considerable drainage area and reaches an altitude of probably 4,000 feet, at the summit of the Granite Mountains and Ord Mountain, so that it may receive a slightly greater precipitation than some other parts of the Mohave Valley. The quantity reaching the water table is probably not great. The small drainage channels do not show evidence of carrying much water, and the run-off is doubtless dissipated over the alluvial slopes and mostly evaporated. The freedom of underflow into the main part of Mohave Valley probably causes the water table to stand at a considerable depth throughout the valley.

QUALITY OF WATER

The analyses of seven samples of water from the Middle Mohave Valley are tabulated on page 433. These analyses show that in general the ground water in the area is good or fair for domestic use and irrigation but poor for boiler use.

The best water is that from wells of the Atchison, Topeka & Santa Fe Railway at Helendale and Hicks. These waters contain 313 and 332 parts per million of total solids, respectively. They are both sodium carbonate waters and similar in composition. The waters are good for domestic use and fair for boilers and irrigation. The wells are on the river lowland, close to its outer border, and probably they are fairly representative of the underflow of the river.

Samples from the wells of W. Graham (No. 78; analysis 5, p. 433), and Miss A. L. Waterman (No. 55; analysis 1, p. 433) are somewhat more concentrated, as they have 565 and 457 parts per million of total solids respectively, but No. 78 is fair and No. 55 is good for domestic use. They are not so good for boiler use because the foaming and scale-forming constituents are more abundant. The more concentrated of these two samples comes from a well on the alluvial slope some distance from the edge of the lowland, where the water is probably not derived from the underflow of the river.

One of the poorest samples comes from two wells that were formerly used for the public supply at Barstow. (See analysis 2, p. 433.) This sample contained 1,036 parts per million of total solids, and it was especially high in sodium sulphate. This water could be considered only fair for domestic use and irrigation, and on account of the high scale-forming and foaming constituents it would be very bad for boilers. Another sample taken from a new well (see analysis 3, p. 433) is of considerably better quality, for it contains only about half as much total solids in solution (519 parts per million). It is a sodium carbonate water. It is good for both domestic use and irrigation but poor for boiler use, because the scale-forming and foaming constituents are abundant, although not as great as in the other sample. The second sample is from wells that are deeper than those that supplied the first sample, and they may penetrate better water-bearing beds. The other four waters are carbonate waters and contain much less mineral matter. The similarity in these two waters suggests that they have a common source. The Leak well is on the alluvial slope south of the river, and probably the water comes from the hills south of the river and not from the river underflow. This same condition may exist at Barstow, but the wells there are so close to the river that the lower strata may be supplied from the river.

Water obtained from wells anywhere in the river lowland will probably be of good quality for domestic use and irrigation. Water from wells on the upland may be somewhat more concentrated, because the supply of water that annually reaches the water table beneath the upland is not great, and the underflow is not rapid, so that there is greater opportunity for the solution of mineral matter from the soil. The water from the upland, however, will probably nowhere be so concentrated as to be bad either for domestic use or for irrigation.

The samples from the lowland between Helendale and Barstow are somewhat more concentrated than the samples from the lowland farther upstream, near Victorville. This is to be expected for two reasons. As the underflow of the river moves downstream it is gradually concentrated by evaporation at places where it comes close to the surface. The accessions to the underflow from the uplands on each side of the river are doubtless somewhat more concentrated than the river flow. It is probable that the concentration of the water beneath the lowlands differs from season to season and from year to year, according to the rainfall and consequent strength of the floods which recharge the alluvium.

Analyses of ground waters in Middle Mohave Valley

[Parts per million]

	1	2	3	4	5	6	7
Silica (SiO_2)	49	56	33	[a]32	37	[a]35	59
Iron (Fe)	Trace.	.15	.90		Trace.		.05
Calcium (Ca)	11	88	57	38	70	31	78
Magnesium (Mg)	5.0	19	13	6.4	14	4.9	22
Sodium and potassium (Na+K) (calculated)	133	232	100	70	96	73	40
Carbonate radicle (CO_3)	31	0	0	0	0	0	0
Bicarbonate radicle (HCO_3)	246	277	233	221	194	215	233
Sulphate radicle (SO_4)	42	348	128	40	130	31	68
Chloride radicle (Cl)	28	148	63	37	104	32	72
Nitrate radicle (NO_3)	.0	3.0	.80	--------	.0	--------	10
Total dissolved solids at 180° C	457	1,036	519	[b]332	565	[b]313	472
Total hardness as $CaCO_3$ (calculated)	48	298	196	121	232	98	285
Date of collection	([c])	([d])	([e])	([f])	([g])	([h])	([i])

[a] Includes silica (SiO_2), iron oxide (Fe_2O_3), and aluminum oxide (Al_2O_3).
[b] Calculated.
[c] Aug. 19, 1916.
[d] Sept. 12, 1917.
[e] Nov. 17, 1919.
[f] July 20, 1908.
[g] Aug. 16, 1916.
[h] July 21, 1908.
[i] Dec. 30, 1917.

Analysts: 1, 5, S. C. Dinsmore; 2, A. A. Chambers, U. S. Geol. Survey; 3, Margaret D. Foster, U. S. Geol. Survey; 4 and 6, Los Angeles & Salt Lake Railroad; 7, Addie T. Geiger, U. S. Geol. Survey.
1. Well 55, pl. 17 and table on p. 435; Miss A. L. Waterman, owner.
2. Atchison, Topeka & Santa Fe Ry. Co. pumping plant at Barstow; formerly used for public supply but now replaced by other wells. (See analysis C.)
3. Well 63, pl. 17 and table on p. 435. Imperial Utilities Co.; public supply for Barstow. Sample is composite from two wells.
4. Well 77, pl. 17 and table on p. 435; Atchison, Topeka & Santa Fe Ry. Co. pumping plant at Hicks. Analysis furnished by Los Angeles & Salt Lake R. R. Co.; recalculated from hypothetical combinations in grains per United States gallon.
5. Well 78, pl. 17 and table on p. 435; W. Graham, owner.
6. Well 103, pl. 17 and table on p. 436; Atchison, Topeka & Santa Fe Ry. Co. pumping plant at Helendale. Analysis furnished by Los Angeles & Salt Lake R. R. Co.; recalculated from hypothetical combinations in grains per United States gallon.
7. Well 104, pl. 17 and table on p. 436; Stoddard Well.

IRRIGATION

A few hundred acres is irrigated in the Helendale-Hinkley-Barstow area. Most of the irrigated tracts cover less than 50 acres, but several contain between 50 and 100 acres, and at the Helendale ranch 150 acres is under cultivation. Except at the Helendale ranch the principal crop is alfalfa, which can be raised cheaply on the lowland because of the abundance of water and low lift. The yield of alfalfa is 6 to 8 tons to the acre. A small acreage is devoted to corn and other grains. At the Helendale ranch 150 acres is planted in fruit trees, 4 acres in pears and the rest mostly in apples. At other ranches grapes and melons are cultivated. Most of the produce is sold locally, especially at Barstow. Some alfalfa and fruit are shipped out of the valley.

Practically all the irrigation is on the lowland, where the depth to water is not great. At the Helendale ranch the water is pumped 40 feet to a bench above the lowland, but nearly everywhere at only a short distance from the lowland the lift becomes so great that pumping is not profitable. On the upland the yield of wells is also probably not sufficient for irrigating on a large scale.

No evidence was obtained of any overdraft of the ground-water supply, and there seems to be opportunity for some further development in the area. If the flood discharge of Mohave River is greatly decreased by storage in the headwater region for irrigation in the upper part of the basin, the quantity of ground water available in the Middle Mohave Valley may be considerably decreased. (See pp. 423, 497.)

WELL RECORDS

The following table gives information concerning wells in the Middle Mohave Valley. The numbers in the first column are the numbers by which the locations of the wells or springs are shown on Plate 17. Wells 62, 62A, 66, 97, and 98 are in the Lower Mohave Valley but are shown on Plate 17 for convenience in indicating their relation to wells in Barstow.

Record of wells in Middle Mohave Valley, Calif.[a]

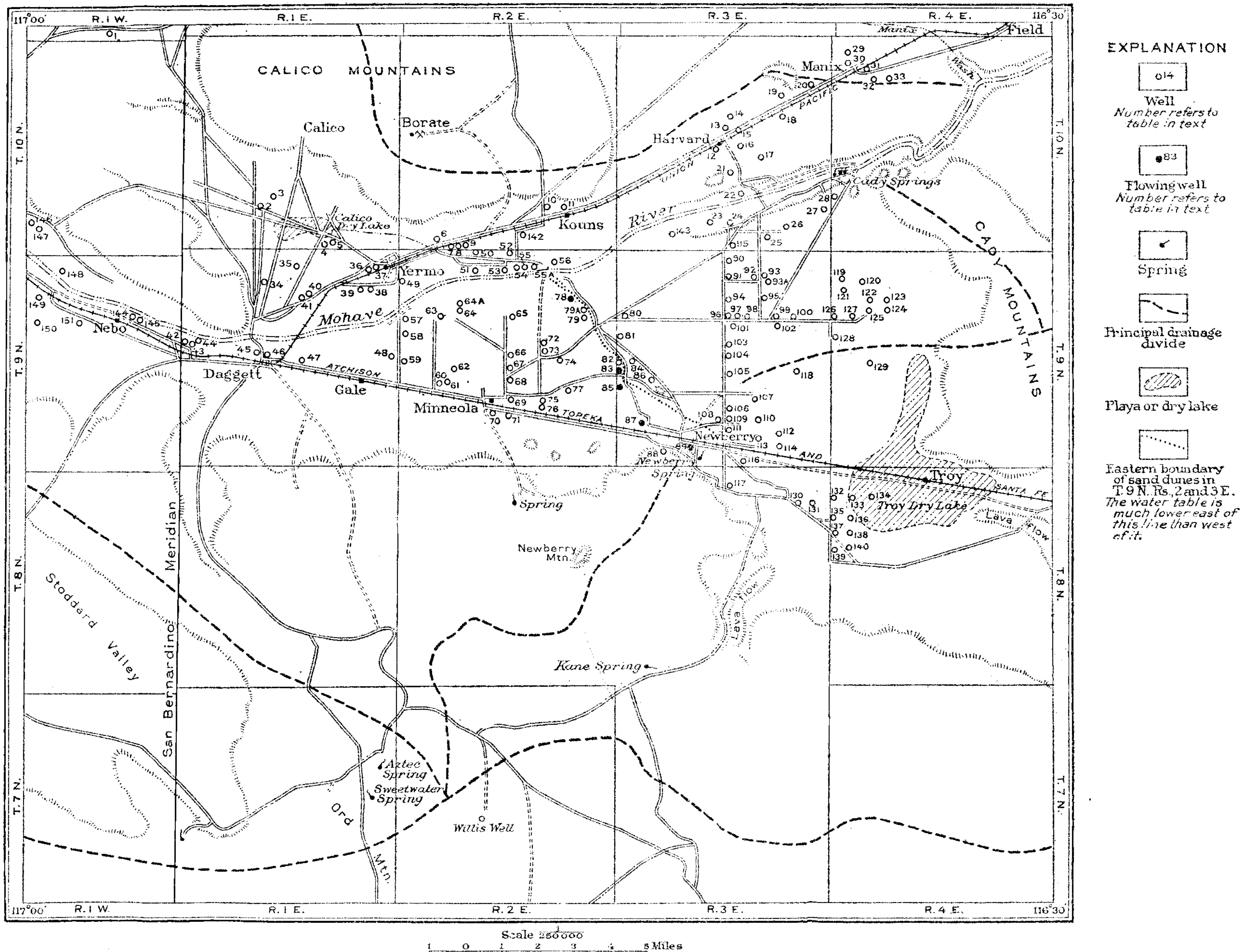
No. on pl. 17	Location				Owner or name	Type of well or spring	Depth of well (feet)	Diameter of well (inches)	Depth to water (feet)	Date of measurement	Yield (gallons a minute)	Remarks
	Quarter	Sec.	T. N.	R. W								
51		30	10	2	J. D. Rich		103		14			
52		32	10	2	A. O. Butler				15			
53		33	10	2		Dug	13		[b] 10.6	Nov. 8, 1919		
54		36	10	2	Mrs. C. Greenburg	Drilled						
55	SW	36	10	2	Miss A. L. Waterman	Dug and drilled.	82	12	[c] 9.3	Oct. 20, 1919	1,000	Drawdown 14 feet. See analysis, p. 433.
56		36	10	2	—— Cook				17			
57		36	10	2	do				10			75 yards south of No. 56.
58		30	10	1	Mary E. Richardson				75			
59		31	10	1	W. D. Rich				27			
60	SE	31	10	1	E. M. Hawes				[d] 11.6	Oct. 20, 1919		A second well near by yields 500 gallons per minute.
61		32	10	1	F. G. Mitchell				23			
62		32	10	1	G. C. Compton				22			
62a		32	10	1	do		14					
63	NE?	6	9	1	Imperial Utilities Corporation	Drilled	77		6		325	Public supply for Barstow. See p. 430; analysis, p. 433.
64		6	9	1	C. E. Williams				110			
65		6	9	1	Mary Dowdy				97			
66	NE	8	9	1	C. A. Leak	Drilled	125		98	Oct. 23, 1919	180?	
67		3	9	3	T. B. Walker		60		20		540	
68	NW	3	9	3			100?		71			
69		2	9	3	F. Walker		60		18		540	
70	NE	8	9	3			152		108			
71	SE	8	9	3			135		130			
72	NW	24	9	3					18			
73		18	9	2	C. Gomes	Dug	65		60			
74	SW	19	9	2			105		95			
75	NW	25	9	3			32				540	1,080 gallons a minute from two wells.
76		27	9	3	H. P. Vordermark		34		8		1,350	
77	NW?	33?	9	3	Atchison, Topeka & Santa Fe Railway.	Dug	16	175	8		450	Drawdown about 3 feet. See analysis, p. 433.
78	NE?	34	9	3	W. Graham				65		315	See analysis, p. 433.
79	SW	34	9	3	L. S. Emerson	Dug	27	72-42	[f] 16.1	Dec. 15, 1919	900	Drawdown 5 feet.
80		8	8	3	P. Cannady				12			

[a] Data on depth of well, depth to water, and yield are those reported by the owner, driller, or other person, except that where a date of measurement is given the depth to water was measured by D. G. Thompson.
[b] Reference point, top of wood casing.
[c] Reference point, bottom of 12 by 12 inch timber about level with ground.
[d] Reference point is 3 notches cut on eastern one of two 12 by 6 inch timbers laid across hole.
[e] Reference point is ground surface.
[f] Reference point, 3 notches in southwest corner top of curb.

Record of wells in Middle Mohave Valley, Calif.—Continued

No. on pl. 17	Location				Owner or name	Type of well or spring	Depth of well (feet)	Diameter of well (inches)	Depth to water (feet)	Date of measurement	Yield (gallons a minute)	Remarks
	Quarter	Sec.	T. N.	R. W.								
81		8	8	3	C. C. Hutchins				32			
82		6	8	3	Mrs. Burns	Dug			16		450	
83		7	8	3	Carrie E. Bennett				10			
84		7	8	3	do				32			
85		7	8	3	G. S. Hodge				57			
86		18	8	3	C. J. Hodge				52			
87		7	8	3	G. S. Hodge				12			
88		14	8	4	W. W. Richardson				9		900	Drawdown 22 feet.
89		15	8	4	B. T. Estler	Dug			20		1,215	
90		23	8	4	—— Duncan		142		127			
91		24	8	4	Lizzie M. Conrad				160			
92		30	8	3	L. C. Frost				160			
93		7	7	4	—— Herlick	Dug	40		34			
94	SW	14	7	5			153		143			
95	SW	15	7	5			138		132			
96		19	11	3			58		5		225	
97	SE	8	9	1	Miles Cook	Drilled	154	12	[a]146.6	Oct. 23, 1919		
98	SW	5	9	1	I. B. Howard				13	Oct. 21, 1919		
99	SE	4	9	3					87			
100	SE?	4	8	3					12			
101	NE	30	8	4	J. L. Thompson	Dug	35	60	10		810	
102	S½	19	8	4					52			
103	SW?	32?	8	4	Atchison, Topeka & Santa Fe Railway.	Dug	30	84	10		115	See analysis, p. 433.
104		9	7	2	Stoddard Well						−¼	Water from tunnel in rock. See description, p. 431, and analysis p .433.

[a] Reference point, top of casing.



MAP OF LOWER MOHAVE VALLEY SHOWING PHYSICAL FEATURES AND LOCATION OF SPRINGS AND WELLS

LOWER MOHAVE VALLEY

GENERAL FEATURES

The Lower Mohave Valley includes in general that portion of the drainage basin of Mohave River that lies between longitude 116° 30′ and 117°. The valley, particularly the part around Yermo, has also been called Yermo Valley or Otis Valley (Otis was the former name of Yermo). A considerable area east of Water post office is separated from Mohave River by a low, indefinite divide, but in the present description it is considered as being a part of the Lower Mohave Valley. The principal features of the region are shown on Plate 24.

The transcontinental line of the Atchison, Topeka & Santa Fe Railway lies along the south side of the valley, and the Los Angeles & Salt Lake Railroad crosses it from northeast to southwest and joins the Santa Fe at Daggett. The National Old Trails Road, a transcontinental automobile road, parallels the Atchison, Topeka & Santa Fe for most of its length in the valley, and nowhere is it more than 3 miles from the railroad. From it a number of minor roads lead to numerous ranches south of Mohave River. The river is crossed by a wagon bridge near Daggett. Local ranchers have established crossings at several other places on the river, but these are generally sandy, and persons not familiar with them should not attempt to use them. From Daggett a road leads northwestward to Superior Valley, Randsburg, and Ballarat and also connects with the road from Barstow to Silver Lake and Death Valley. Several roads lead northward to old mines in the Calico Mountains. The principal route from southern California to Salt Lake City leads northeastward to Yermo and thence along the Los Angeles & Salt Lake Railroad to a point between Manix and Field. Thence it continues northeastward, away from the railroad, through a pass in the Cave Mountains into East Cronise Valley and through another pass in the Soda Lake Mountains to Baker station on the Tonopah & Tidewater Railroad. This road was laid out by San Bernardino County in 1922, after the preparation of Plate 11 for this report, and is not shown on that map but is shown on Plates 7 and 8.

Beyond Field a road formerly continued down Mohave River to Soda Lake. The road led down the river channel and was frequently washed out, and this route to Soda Lake is now practically abandoned. About 3 miles northeast of Yermo a road leads northward to Coyote Valley and thence to the Barstow-Death Valley road near Garlic Spring. (See p. 279.)

Daggett and Yermo are small settlements where general supplies can be obtained. Yermo is a division point on the Los Angeles & Salt Lake Railroad. Food supplies, gasoline, and oil are also obtainable at Newberry station [43] (Newberry Spring), which is an important water-supply point on the Santa Fe Railway. Post offices are located at each of these three places. Water may be obtained in emergencies at Minneola and Hector, on the Atchison, Topeka & Santa Fe Railway, and at Harvard and Field, on the Los Angeles & Salt Lake Railroad. Section crews are stationed at each of these places. The other stations shown on the map are only sidings where neither water nor aid of any sort can be obtained.

MINERAL RESOURCES

Mineral products valued at probably $15,000,000 to $20,000,000, at least, have been obtained from the mountains that border the Lower Mohave Valley, and the greatest production has come from the Calico Mountains.

Early in the eighties rich silver deposits were found in the Calico Mountains, and for several years more than $1,000,000 annually was taken from these deposits. (See tables of production, pp. 27–29.) After the demonetization of silver in 1893, the production decreased to nearly nothing. For many years, however, a few miners have continued to work the patches of highest-grade ore. In recent years the Pittman Act, which guaranteed a price of $1 an ounce for silver, encouraged the working of some of the properties on a small scale. Recently also the tailings of the old mills near Calico were reworked in a small way by the cyanide process to recover silver and gold that were lost in the earlier days.[44]

According to Lindgren, the ores are predominantly chlorides and chlorobromides of silver in a gangue of barite and jasper.[45] The deposits occur principally as fissure veins in liparite, liparitic tufa, and breccia of Tertiary age, but some occur in irregular pockets in the tufa beds. The other rocks of the Calico district include Tertiary sandstone and clay and hornblende andesite. Small quantities of lead and copper are associated with the silver.

At the east end of the Calico Mountains, at Borate, lie deposits from which several million dollars' worth of borax has been obtained.[46] The borax deposits at this place were discovered in 1882. Prior to that time most of the borax produced in California had come from

[43] When this report was written the name of the post office at this place was Water, but according to the 1927 Postal Guide it has been changed to Newberry.

[44] Palmer, L. A., A cyanide plant without frills: Eng. and Min. Jour., vol. 109, No. 23, pp. 1260–1262, 1920.

[45] Lindgren, Waldemar, The silver mines of Calico, Calif.: Am. Soc. Min. Eng. Trans., vol. 15, pp. 717–734, 1887. Storms, W. H., The Calico mining district: California Min. Bur. Eleventh Rept. State Mineralogist, pp. 337–349, 1893; The mines of Calico district, Calif.: Eng. and Min. Jour., vol. 49, No. 14, pp. 382–383, 1890. Palmer, L. A., The Calico district: Min. and Sci. Press, vol. 116, No. 22, pp. 755–758, 1918.

[46] Storms, W. H., The Calico mining district: California Min. Bur. Eleventh Rept. State Mineralogist, pp. 345–348, 1893. Bailey, G. E., The saline deposits of California: California State Min. Bur. Bull. 24, pp. 33–41, 56–59, 1902. Keyes, C. R., Borax deposits of the United States: Am. Inst. Min. Eng. Trans., vol. 40, pp. 693–699, 1910. Campbell, M. R., Reconnaissance of the borax deposits of Death Valley and Mohave Desert: U. S. Geol. Survey Bull. 200, pp. 12–13, 1902.

Searles Lake and similar playas, but the Calico Mountain deposits proved to be so rich that in a few years nearly the whole production from the State came from that district.

In more recent years extensive deposits on the east side of Death Valley were discovered. These deposits are controlled by the same company that controls the Calico deposits, and as the Death Valley deposits were developed the Calico deposits were abandoned. In the last few years, however, some of the richest ore in the Calico Mountains has been mined. It is probable that the Calico deposits have produced nearly $10,000,000 worth of ore, if not more. Two large plants, the ruins of which are still to be seen, were built for refining the borax, one at Daggett and the other about 3 miles northwest of Yermo. The borax at Borate occurs as colemanite ($Ca_2B_6O_{11}.5H_2O$) in a bedded deposit from 5 to 30 feet thick, interstratified with lake beds.

In addition to the valuable deposits of silver and borax in the Calico Mountains mineral deposits occur in the other mountains that border the valley, but at no other place has there ever been any great development. Copper and gold ores are found in the Ord Mountains. Strontium-bearing deposits in commercial quantities occur about 10 miles north of Barstow, at the extreme west end of a large valley that enters the main Lower Mohave Valley north of Daggett.[47] The deposits lie in greenish clay beds of Tertiary age that are doubtless related to the lake beds in which the borax occurs in the Calico Mountains. During the war considerable ore was shipped, but subsequently the production has been very small.

An attempt has been made to find oil in the region, and a well said to be more than 2,000 feet deep has been drilled in sec. 34 or 35, T. 11 N., R. 1 W. San Bernardino meridian.[48] "Showings" of oil were reported, but the well was abandoned. There is little reason to believe that oil in paying quantities will be found anywhere in the region, as the rocks are not of the kind in which oil occurs. (See p. 36.)

PHYSICAL FEATURES AND GEOLOGY

West of Barstow for some miles the valley of Mohave River is wide and nearly level. From Barstow down as far as Daggett it is much narrower, and the land rises to the north and south almost from the river channel. At Daggett the valley broadens out and the river cuts diagonally northeastward across a large, nearly level plain, which is roughly triangular in shape, truncated at its west end, about 20 miles long and 5 to 15 miles wide. It is mostly included in the angle formed by the Los Angeles & Salt Lake Railroad and the Atchison,

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47 Knopf, Adolph, Strontianite deposits near Barstow, Calif.: U. S. Geol. Survey Bull. 660, pp. 257–269, 1918.

48 Pack, R. W., Reconnaissance of the Barstow-Kramer region, Calif.: U. S. Geol. Survey Bull. 541, p. 151, 1914.

Topeka & Santa Fe Railway, which converge at Daggett. Beyond the two railroads rise the mountains, or the alluvial slopes are so steep that they are distinct from the plain. Conditions on the plain are favorable for agriculture, provided water for irrigation can be obtained.

SOUTHERN BORDER OF THE VALLEY

The south side of the Lower Mohave Valley is bordered by a range of mountains that extends continuously from Barstow southeastward for about 50 miles. Near Barstow this range is a low ridge, which rises with rounded outlines only a few hundred feet above Mohave River, but farther east it is higher and much more rugged. Ord Mountain, about 14 miles south of Daggett, reaches an altitude of about 5,000 feet, and for most of its length east of that mountain the range reaches an altitude of about 4,000 feet.

South of Barstow the ridge is composed largely of unconsolidated or partly consolidated alluvium, and these deposits continue eastward nearly to Daggett. About 8 miles southwest of Daggett, on the road to Stoddard Well, beds of gravel, clay, and some limestone of either Quaternary or Tertiary age are exposed. These beds appear to have been deposited under conditions similar to those now existing in the desert. The beds strike nearly due east and dip very gently northward toward the river. About 3 miles south of Daggett, on the road to Ord Mountain, very coarse alluvium that contains boulders 3 feet in diameter is exposed, as well as some limestone. These beds dip gently northward. Farther south on the Ord Mountain road rise knobs of granite and beyond them occur eruptive rocks of Tertiary age. From this vicinity eastward the mountains are composed mostly of a series of Tertiary lavas interbedded with tuffs and probably with sandstone and limestone.

Southeast of Newberry Spring areas of granite are present. Several miles nearly due south of the spring occurs a Quaternary lava flow, which came from a cone high up in the mountains and flowed down a large mountain valley to the main valley. It appears to have been poured out since the beginning of the formation of the present alluvial slope and is undoubtedly of comparatively recent age. Perhaps it is contemporaneous with a lava flow that came from Mount Pisgah, about 12 miles farther east. (See pp. 652–653.)

A notable feature of the range on the south side of the valley is the long alluvial slope that rises from the plain along the river. Between Barstow and Daggett the alluvial slope reaches nearly to the summit of the ridge south of the river. South and southeast of Daggett the grade of the slope is steeper and it reaches far back from the valley plain. Farther east the slope becomes shorter and at Newberry Spring the mountains rise directly from the plain, with nearly no alluvial slope between. Several miles southeast of Newberry Spring the slope is again well developed and rises fully 5 miles from Troy Dry Lake nearly to the summit of the mountains.

Another notable feature is the rather broad washes and valleys that occur near the summit of Ord Mountain. As shown on the relief map (pl. 11), in the center of T. 7 N., R. 1 E., on the northwest side of Ord Mountain, there is a rather gently sloping valley that covers 2 or 3 square miles. It is several hundred feet above Stoddard Valley and only a few hundred feet below the top of Ord Mountain. It is almost completely hemmed in by low hills on the west and north, and whether it drains to Stoddard Valley or directly toward Mohave River near Daggett is uncertain. This valley, although it is strewn with alluvium, is undoubtedly floored with rock at a slight depth. According to recent township plats of the General Land Office, a similar valley lies at the head of Kane Spring Wash, northeast of Ord Mountain, and another valley a little farther south is separated from it by a low divide.

These broad valleys are suggestive of an erosion cycle prior to that of the present, which may have been interrupted by the uplifting of the mountain mass. They are worthy of study in connection with similar elevated valleys in the San Bernardino Mountains and other areas in the southwestern part of the Mohave Desert region.[49]

The range on the south side of the Lower Mohave Valley is continuous with other mountains that extend far to the southeast. South of the range there is a large trough, which extends parallel to it for many miles, although it is separated into several distinct basins by low hills. (See p. 612.) The continuity of the range suggests that it is a great block uplifted by faulting. There are further suggestions of faulting in a series of low ridges that rise above the alluvial slope between the river and the summit of the range south and southwest of Daggett.

NORTHERN BORDER OF VALLEY

The northern border of the valley is more irregular than the southern. Between Barstow and Daggett a ridge of high hills, which is a continuation of mountains north of Barstow, rises almost from the channel of Mohave River. The ridge culminates about a mile northwest of Daggett in a large, nearly flat-topped butte of Tertiary lava. Farther west the ridge consists of a series of Tertiary lavas interbedded with sedimentary rocks.

North of this ridge stretches a broad valley, in which rise several knobs. This valley, which enters the main valley about 3 miles north of Daggett, rises northwestward for more than 10 miles. It

[49] Baker, C. L., Notes on the later Cenozoic history of the Mohave Desert region in southeastern California: California Univ. Dept. Geology Bull., vol. 6, No. 15, pp. 361-371, 1911. Vaughan, F. E., Geology of the San Bernardino Mountains north of San Gorgonio Pass: Idem, vol. 13, No. 9, pp. 321-338, 1922.

is bordered on the west and northwest by low mountains, which contain outcrops of sedimentary and volcanic beds that constitute the Barstow formation, of Miocene age. (See p. 107.) The westernmost of these hills, which are composed of clay, are called the Mud Hills, or Strontium Hills, the latter name being given on account of the deposits of strontium in them. The gentle slope that rises from the plain to the Mud Hills has the appearance of an alluvial slope. It is broken by several knobs, however, and in sec. 26, T. 11 N., R. 1 W. San Bernardino meridian, where it is considerably dissected, steeply dipping Tertiary clay crops out a few feet below the surface. The valley is probably not filled with recent alluvium to any great depth but is more likely an eroded bedrock surface or pediment.

Directly north of Daggett the border of the basin is formed by the Calico Mountains, so called because of the different colors of yellow, red, green, and brown in the rocks. The rocks of the Calico Mountains consist of Tertiary lava and tuff, together with sandstone and clay of the same age. In contrast to the south side of the valley, the alluvial slope at the base of the Calico Mountains is short, and the mountains rise steeply to an altitude of about 5,000 feet and are considerably dissected.

The Calico Mountains extend eastward nearly to the center of T. 10 N., R. 2 E., and east of that place a low ridge continues for several miles, gradually decreasing in height toward the east. In this ridge Tertiary or older rocks crop out at several places. Limestone occurs in a large hill in sec. 11, T. 10 N., R. 3 E., and quartzite crops out along the railroad 1.7 miles northeast of Harvard station. These rocks are probably of Paleozoic age or older. They are probably of about the same age as limestones reported to occur in the Alvord Mountains, about 10 miles to the north,[50] and as a small limestone hill in sec. 30, T. 9 N., R. 4 E., south of Camp Cady.

Near Manix a large wash, known as Manix Wash, extends from the ridge just described southeastward to Mohave River. It is possible that this wash reaches back to Coyote Dry Lake, a playa that lies north of the ridge farther west. The east end of Coyote Valley was not visited by the writer, and statements from local inhabitants in reply to inquiries as to a possible surface outlet of the valley through Manix Wash were conflicting. There is doubtless underground drainage from the valley which reaches Mohave Valley along the valley of Manix Wash. The rock outcrops indicate that the ridge between the two valleys is probably underlain by bedrock nearly as far east as Manix.

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[50] Buwalda, J. P., Pleistocene beds at Manix, in the eastern Mohave Desert region: California Univ. Dept. Geology Bull., vol. 7, No. 24, p. 445, 1914.

EASTERN BORDER OF THE VALLEY

The eastern border of the Lower Mohave Valley is formed by a series of low hills that extend continuously from the vicinity of the Atchison, Topeka & Santa Fe Railway northward to Mohave River. They are the western part of the Cady Mountains, which farther east rise to an altitude of more than 4,000 feet. Where examined, at the extreme northern and southern ends, the hills are composed of Tertiary volcanic rocks, very much sheared. Near Camp Cady an outlier of pre-Tertiary limestone rises from the alluvium. Possibly other pre-Tertiary rocks exist in the main mass of hills.

Southeast of Troy Dry Lake the basin is bordered in part by a lava flow of Quaternary age. This flow originated at a crater in the southwest corner of T. 8 N., R. 6 E. It is described on pages 652–653.

MOHAVE RIVER PLAIN

General features.—Between Barstow and Daggett the flood plain of Mohave River is only a few hundred yards wide. On the north side of the river rock hills rise generally within less than half a mile. In this stretch the river channel is from 3 to 5 feet below the flood plain and 10 to 15 feet below the edge of the alluvial slopes.

From Daggett eastward for 15 to 20 miles the river cuts northeastward across a wide, nearly level plain that slopes gently eastward. Daggett is 2,002 feet above sea level; Manix, in the northeast corner of the plain, 1,765 feet; Newberry Spring, about 1,830 feet. The average grade is between 10 and 15 feet to the mile.

From Newberry Spring the land continues to slope eastward to a playa which may be called Troy Dry Lake, the altitude of which is about 1,780 feet. This playa appears to be lower than the land between it and Mohave River, and there is no surface drainage from it to the river. The difference in altitude is so slight that the divide can not be located except by instrumental leveling. Although the playa occupies a distinct closed basin, physiographically and structurally it is a part of the lower Mohave Valley, and the groundwater conditions in the two basins are intimately related.

North of Daggett the channel of Mohave River is between 15 and 25 feet below the plain. Northeastward the gradient of the river is greater than that of the plain, so that the channel and flood plain are cut lower and below the plain. Near Camp Cady the channel is about 75 feet below the plain. At this place the rise from the flood plain to the level of the upland plain north of the river is an almost vertical cliff, but south of the river the rise is more gentle and is broken by several terraces.

The plain between Daggett and the Cady Mountains is nearly level, but locally there is a relief of 5 to 15 feet. At a number of places occur elongated depressions, which are evidently old channels formed when the river flowed at the level of the plain. Several of these channels are especially noticeable in the northeastern part of T. 9 N., R. 3 E., and a mile or two south of Camp Cady.

An indefinite, scarcely noticeable depression extends from a place about a mile west of Newberry Spring eastward to Troy Dry Lake. The depression continues northward close to the west base of the Cady Mountains, and part of it is occupied by an arm of the playa. A distinct depression also extends southward from the river along the west base of the Cady Mountains, but there does not se^m to be a continuous drainage line from the playa to the river. These depressions suggest an old channel of the river, now separated from the river by wind-blown sand or alluvium washed in from the Cady Mountains.

North of Mohave River the upland plain continues unbroken to Manix Wash, which joins the river about in sec. 11, T. 10 N., R. 4 E. On the south, however, the plain does not extend beyond Camp Cady, below which the river flows close to the northwest end of the Cady Mountains. Two or three miles east of the northwest end of these mountains a long alluvial slope reaches back into an embayment in them. (See pls. 26, *A*, and 27, *B*.) The river has cut its channel 100 feet or more below the upland surface of this alluvial slope. Near Manix Wash at least two terraces were formed during the cutting of the channel. These are especially well developed on the south side of the river. (See pl. 27, *B*.) About 1½ or 2 miles east of Camp Cady the river makes a big bend to the south and then with a sharp curve doubles back upon itself. (See pl. 26, *A*.) A large part of the area in the bow between the river on the two sides of the meander consists of a broad terrace platform about 25 or 30 feet above the present channel. Less prominent terraces are formed at Camp Cady and at other points upstream.

There was no opportunity to determine whether there is any relation between the terraces south of Manix Wash and those in the vicinity of Camp Cady and the other points upstream. The exact origin of the terraces was not determined. It is probable that the terraces near Manix Wash were caused by a stoppage of down cutting by the uncovering of hard rock barriers farther downstream. As explained on pages 111 and 457, this part of Mohave Valley was once covered by a lake. This lake was drained and the present river channel cut when the water overflowed a barrier on the east. As the river cut through this barrier resistant rocks doubtless caused the river to remain at certain levels long enough to cut laterally and develop the terraces. Possibly, however, they may be due to variations in the climate which caused changes in the run-off that affected the eroding power of the stream.

A notable feature of the plain is a belt of sand dunes that stretches from Kouns southeastward across the valley nearly to Newberry sta-

A. STRATIFIED ALLUVIUM ALONG MOHAVE RIVER SOUTH OF YERMO

B. NEAR VIEW OF STRATIFIED ALLUVIUM SHOWN IN *A* tion and thence eastward and northeastward on the northwest side of Troy Dry Lake. The dunes are not especially prominent north of the river. Their greatest development is between the river, on the south side of sec. 3, T. 9 N., R. 2 E., and sec. 30, T. 9 N., R. 3 E. In this stretch at some places the dune belt is a mile or more wide, and some of the dunes rise 15 to 25 feet above the general level of the plain. Directly north of Newberry station the belt is only a few hundred feet wide and the dunes are only a few feet high. The western edge of the dune belt is more or less irregular and indefinite, but the eastern edge is rather sharp within limits of a few hundred feet. East of Newberry station the distribution of the dunes is more irregular. A part of the dune belt in the southeastern part of T. 9 N., R. 3 E., is shown in Plate 26, *B*. The dunes, which cover all but about the left-hand third of the foreground in this view, are marked by the very dark appearance of the vegetation against the white sand. By means of their dark appearance they may be traced in the photograph toward the east end of Newberry Mountain, where they swing eastward toward a prominent black hill rising from the plain.

The dunes are mostly covered with vegetation. Some of the plants are those that live in dry sandy soils, but on all the large dunes grow crawling mesquite, which commonly exists only where its long roots can reach ground water. Between the dunes lie many small closed depressions with bare clay surfaces like playas. In some of these depressions salt grass grows, indicating that ground water is close to the surface.

There is no evidence that the dunes are advancing, the vegetation probably being sufficient to hold them in place. They seem to have a definite relation to ground-water conditions, for they occur only where the water table is near the surface, although they do not necessarily appear in all areas of shallow ground water. The most probable explanation of the presence of the dunes is that because the ground water was so close to the surface water-loving plants, especially the mesquite, grew in abundance, and wind-blown sand gathered around them. Perhaps the ground was so moist that some of the sand was held by moisture, but the growth of the dunes is explained largely by the habit of the mesquite to spread over the ground. As the sand builds around it, the plant grows higher and higher and the sand dunes increase in size, but the roots continue to draw moisture from the water table. The significance of the dune belt in interpreting ground-water conditions is discussed further on pages 478 and 481.

River channel and flood plain.—Conditions along the channel of Mohave River and the bordering flood plain change from one part of the river to another between Barstow and Manix Wash. The different conditions throw some light on the occurrence of ground water in the valley. Normally the river is entirely dry for most of the year except along two stretches described below.

For a mile or two below the buttes of Tertiary lava at the east end of Barstow the channel is almost bare of vegetation, except small plants that can exist in sand. No well data are available for this stretch, but the depth to water is probably 15 feet or more. Farther downstream mesquite and willow trees increase in numbers and size about as far as the center of sec. 18, T. 9 N., R. 1 E., about 2 miles west of Daggett. At this place a low rock hill, not more than 200 feet in diameter, projects above the flood plain just south of the river channel, and hills of the same rock rise a short distance north of the river. Here there is also an abrupt change in the vegetation. The belt of trees ends within 100 yards below the rock outcrop, and for several miles downstream the vegetation is composed of small plants that grow in sand. So far as is known, there is no surface flow from Barstow to a point several miles below Daggett except in the rainy season.

Beginning near the west line of sec. 3, T. 9 N., R. 2 E., and extending downstream for about a mile, there is another stretch where mesquite and poplar grow in abundance along the river channel and on the flood plain. This stretch crosses the dune belt described on page 445. However, although the dunes are well developed on the upland plain and at one or two places reach out onto the higher part of the flood plain, they are entirely lacking near the river. In this stretch there is some surface flow generally throughout the year. When the place was visited by the writer in November, 1919, a small stream of water appeared a short distance west of the line between secs. 3 and 4. It gradually increased in size downstream for several hundred feet but disappeared about a third of a mile below the line between secs. 2 and 3, T. 9 N., R. 2 E., either because it sank into the sand or because it was all evaporated. The stream reached some distance below the stretch in which trees are abundant. In that stretch, about a mile long, there is a channel between 500 and 1,000 feet wide. This channel was swept bare by the last flood, but since then many young mesquite had begun to grow on it. A large part of the sandy floor of this channel was moist in the stretch of the perennial stream.

On each side of the main channel stands a low terrace 3 to 5 feet above it and several hundred feet wide. On these terraces the tree growth is rather abundant, in some places almost impassable. On the terrace on the south side of the river, in the SW. ¼ sec. 3, water emerges at a swampy place in an old channel and flows downstream a few hundred feet to a large pond. This pond at one place is more than 100 feet across and is said to be 10 or 12 feet deep. It is reported to persist throughout the year. At the lower end a small stream flows down the channel for a short distance. On November 11, 1919, the flow was less than a second-foot. It is said that prior to the last large flood the pond had extended farther downstream, but apparently the lower end of the depression was filled with sand.

In the NE. ¼ sec. 3, on the terrace on the north side of the river, there is another marshy area where water comes to the surface. The seepage water is used for irrigation. On November 12, 1919, the flow of the ditches collecting the water from this marshy area was estimated to be 1 to 1½ second-feet.

The total flow of all the streams in sec. 3 observed on November 11 and 12, 1919, did not exceed 3 or 4 second-feet. It was divided into three or four separate streams, and the surface flow disappeared entirely within about 1,500 feet of the lower end of the wooded stretch. During the preceding summer the flow had been considerably less.

Below sec. 3 the river bottom and flood plain bear no trees for 3 or 4 miles. From about the west line of sec. 33 there is a luxurious growth downstream for nearly 6 miles, to a place opposite the northwest end of the Cady Mountains. In this stretch water is close to the surface. A small stream flows most of the time, except perhaps in the driest seasons, and the floor of the channel is moist over a considerable area. At one place on the south side of the river, probably in the SE. ¼ sec. 33, on November 25, 1919, a stream of about 45 gallons a minute was flowing from a pond about 1,000 feet long and 25 feet wide. The water disappeared, either by absorption or by evaporation, a short distance downstream. Pools of water were also observed 2,000 feet downstream from this place, but there was no flow.

On September 6, 1917, water was observed in the channel in the NE. ¼ sec. 25, T. 10 N., R. 3 E., but there was no water a few hundred feet downstream. In this vicinity there are two well-developed terraces, the lower about 5 feet above the river bed and the other about 10 feet higher. In the NW. ¼ sec. 30, T. 10 N., R. 4 W., many springs issue from the short cliff between the lower and upper terraces, and over an area of several acres the floor of the lower terrace is swampy.

Farther downstream the water apparently flows at the surface more persistently. On November 21, 1919, a stream 50 feet wide in places, which was estimated to carry from 2 to 2½ second-feet, was observed opposite the northwest point of the Cady Mountains, in sec. 20, T. 10 N., R. 4 E. Within less than a mile, however, the stream sank into the sand. (See pl. 21.) In this distance the trees, which are so numerous above the point of the mountains, became fewer and fewer. A few clumps of mesquite are scattered at intervals downstream for a short distance, but for several miles below there is little indication that water is near the surface. Just above the junction with Manix Wash a few trees stand along the river and clumps of mesquite grow in the lower part of Manix Wash and on the river bottom. They are not nearly as abundant as the growth in the moist stretches just described, and the indications are that water is not near the surface but that these trees obtain their moisture from flood water.

At the northwest point of the Cady Mountains bedrock crops out a few hundred feet south of the river channel. Although no rock was observed in the river bottom or the flood plain it is probable that the surface flow at this place is due to the fact that the bedrock lies close to the surface.

Playas.—Two playas lie on the plain of the Lower Mohave Valley. A small one, about 2 square miles in extent, is situated about 4 miles north of Daggett. No name is known for it, and the writer suggests that it be called Calico Dry Lake. This playa is separated from Mohave River by a low, almost imperceptible divide, which may have been formed by alluvium that was washed in from the hills to the west. More likely, however, it was formed when Mohave River flowed on the plain before its present channel was intrenched. At that time during floods the river doubtless spread out in all directions and deposited material, either as a cone from the end of the narrow valley at Daggett or as a natural levee. A depression was thus formed between the aggraded bed of the river and the Calico Mountains in which was impounded the run-off from part of the Calico Mountains and the hills to the west. At present the playa is drained by a shallow channel that lies north of Yermo and enters the river about in sec. 5, T. 9 N., R. 2 E.

The surface of the playa is hard and smooth in dry weather. There is no shallow-water vegetation around it nor any noticeable accumulation of alkali. In all respects it is a playa of the dry type, as would be expected, for the depth to water in wells in the western part of the valley is 50 feet or more, and the alluvium is so porous that there is good underground drainage from the playa toward the river.

The second playa, which is considerably larger, is about 3 miles east of Newberry station, in the southeastern part of the valley. It is separated from Mohave River by a low alluvial divide, which apparently has been formed by wash from the low hills that form the west end of the Cady Mountains. A large part of this playa is covered with alkali, and the surface is roughened by "self-rising ground." Mesquite and salt grass grow at some places around the playa, and inkweed grows on the southwest part of the clay flat. The characteristics are those of a playa of the wet type. The depth to water in wells on the west side of the playa is about 7 feet. A long arm of the playa extends northward 3 or 4 miles from the railroad. This part is apparently a little higher than the main part of the playa, for many individuals of some alkali-resistant plant grow on the surface.

Geologic features of the plain.—The plain of Lower Mohave Valley is underlain to an unknown depth by alluvium of Quaternary age. So far as the writer is aware, no bedrock has been struck in any well except No. 19, which is close to a limestone hill. The deepest well (No. 60, pl. 24) is 500 feet deep. Several wells in different parts of the valley reach depths of 300 feet or more without striking bedrock. Well 89, which is only about 1,500 feet north of the foot of Newberry Mountain, did not strike bedrock at a depth of 316 feet.

Surface exposures and well logs show that the character of the alluvium is different in different parts of the valley. The occurrence of ground water in different parts of the valley is affected by variations in the character of the alluvium, and hence the deposits are described below in some detail. On the south side of the Atchison, Topeka & Santa Fe Railway about 2½ miles east of Daggett, in a large cut, the alluvium is well exposed. (See pl. 14, *A*.) The beds are composed of sand and gravel and contain cobbles as large as 3 or 4 inches in diameter. The material is fairly well stratified, but the coarse and fine materials are poorly sorted. The cobbles are mostly angular. The beds are typical of the deposits laid in the lower part of an alluvial fan. Material of this kind is undoubtedly encountered in wells around the borders of the valley wherever there is a well-developed alluvial slope. In two wells (Nos. 60 and 75) boulders of lava rock, as much as 12 inches in diameter, were struck at depths of 300 to 500 feet. These boulders evidently have come from the mountains on the south. Because of the coarseness of the alluvium the yield of wells in such localities is generally large.

In exposures along the south side of Mohave River 1½ miles due south of Yermo the alluvium differs from that just described in that there is a distinct alternation of strata. At the surface is a bed of fine buff clayey sand free of pebbles, which is from 5 to 10 feet thick. Below this sand lie irregularly cross-bedded sand and gravel from 7 to 14 feet thick. At the bottom is another buff bed of clayey sand, slightly coarser than the upper bed, but the coarsest grains are not more than one-sixteenth inch in diameter. The maximum thickness of this bed that is exposed is about 10 feet, but it extends below the river channel. The character of the beds is shown in Plate 25. In Plate 25, *A*, the upper sand member extends down to a hole directly beneath the man. The base of the gravel below it is marked by a hat a little to the right of the center. In Plate 25, *B*, the hat is at the contact between the gravel and the lower clay bed. The gravel bed is exposed continuously downstream for half a mile or more. Farther downstream it is covered by slumped material. It was not possible to determine whether the bed is absent farther downstream because it dips below the river channel or because it pinches out. However, where measurements were made in a stretch of about one-third of a mile, the thickness of the gravel bed decreased from 14 to 7 feet, and apparently it pinches out.

On the north side of the river near Camp Cady, in cliffs 70 feet high, no gravel beds are seen, such as are exposed south of Yermo. The material is mostly buff clay and sand, with only here and there a pebble as large as 1 inch. It is much like the lower sand member of the beds exposed south of Yermo.

About a mile below Camp Cady a gradual change occurs. The color of the beds changes from buff to a light grayish green, and the percentage of clay increases. The green beds extend down the river for 10 miles or more. The graduation from the buff beds to the green beds is in most places almost imperceptible. Fish vertebrae and four species of fresh-water mollusks have been found at several places in the green beds.[51] These fossil remains, together with the evenness of the bedding and the green color, which is due to oxidation beneath water, show that the beds were deposited in a lake. This lake, which Buwalda has named Manix Lake, existed during the Pleistocene epoch, when the climate was presumably more humid than at present. (See p. 111.)

The exact extent of the Manix lake beds is not known. Surface exposures are limited to the cliffs along Mohave River below Camp Cady and along the washes that join the river below that place. Along Manix Wash the beds are exposed as far back from the river as the Los Angeles & Salt Lake Railroad. Beds similar to the Manix lake beds are reported on the west flank of the Alvord Mountains about 10 miles north of the Los Angeles & Salt Lake Railroad.[52] On a map accompanying his report Buwalda shows the Manix lake beds extending several miles northwest of the railroad, as far west as Kouns, and as far southwest as Camp Cady. The writer did not see any beds similar to those south of Manix in this large area, except along the river east of Camp Cady. In sec. 27, T. 10 N., R. 3 E., about 1½ miles south of Harvard, greenish clay lies in a horizontal position, very much like the Manix lake beds, against the east side of a bedrock hill, covering an area about 100 feet in diameter and rising 25 feet above the present plain. These beds are probably at least 50 feet above the river channel less than a mile to the south, where only buff beds are exposed.

Although the green lake beds do not crop out except along the river below Camp Cady and along Manix Wash, they have been struck in several wells on the plain between the Los Angeles & Salt

[51] Buwalda, P., Pleistocene beds at Manix, in the eastern Mohave Desert region: California Univ. Dept. Geology Bull., vol. 7, No. 24, p. 449, 1914.
[52] Bunwalda, J. P., op. cit., p. 448.

Lake Railroad and the Atchison, Topeka & Santa Fe Railway. In well logs, however, the color of the clay is said to be blue instead of green, as the clay is blue when wet.

The dump at well 32, about a quarter of a mile southeast of the road crossing at Manix, showed much green clay. The well is 88 feet deep, but it is not known at what depth the clay was struck.

In well 128, in sec. 18, T. 9 N., R. 4 E., blue clay was struck at a depth of 152 feet, and the bed continued to the bottom at 196 feet. Blue clay was found in well 107. The exact depth to the clay is not known, but it is said to be about 200 feet. Some sand and gravel were reported below the first blue clay, but it was all bluish. Blue clay was probably struck in wells 119 and 126, but definite information could not be obtained. In well 89, of the Atchison, Topeka & Santa Fe Railway at Newberry station, blue clay extended from 27 to 64 feet and from 208 to 247 feet and blue sand from 252 to 260 feet.

Except in well 89, the blue clay was not encountered in wells west and south of Camp Cady above depths of 150 feet. Although blue clay was found at a depth of only 25 feet in well 89, it is not reported so near the surface in other wells near by, and its presence is apparently due to local conditions. Although logs are available for several other wells southwest of Camp Cady, blue clay is not reported in them.

No blue clay is reported in any well west of Newberry station. A very detailed log of well 142, a mile west of Kouns, in which the color of each formation is carefully given, does not show any blue clay. This well reached a depth of 437 feet. According to approximate altitudes determined from railroad profiles, its bottom is nearly 150 feet below the top of the blue clay in the Harvard well (No. 15) and nearly 50 feet below the bottom of the well. Furthermore, although it is not known at what depth the blue clay was struck in well 32, near Manix, the top of the blue clay in the Harvard well is nearly 100 feet below the bottom of well 32, and hence fully that much below the top of the blue clay in that well. The blue clay in wells 107 and 128, south of the river, was apparently struck at altitudes from 25 to 50 feet below the bottom of well 32. In the railroad well at Newberry station (No. 89) the lower blue clay is fully 50 feet below the bottom of well 32.

The approximate altitude of the surface and of the top of the blue clay in these several wells is given in the following table:

Altitude of top of blue clay in wells in Lower Mohave Valley, Calif.

Well No. on pl. 24	Location			Approximate altitude of surface above sea level (feet)	Depth of blue or green clay (feet)	Approximate altitude of blue clay above sea level (feet)
	Sec.	T. N.	R. E.			
32	8?	10	4	[a] 1,760	[b] 88−	[b] 1,672+
15	15	10	3	[a] 1,805	210	1,595
42	34	10	2	[a] 1,875	[c] 437+	[c] 1,438−
128	18	9	4	[d] 1,800	152	1,648
107	26	9	3	[d] 1,820	200?	1,620?
89	33	9	3	[a] 1,829	208	1,621

[a] Well is not far from railroad. Altitude is determined from railroad survey and is probably accurate within 15 feet or less.
[b] Well is 88 feet deep. Dump shows much blue clay, but depth at which it was struck is not known. The altitude of the top of the clay is evidently somewhat more than 1,672 feet above sea level.
[c] Well is 437 feet deep, and no blue clay was struck in it.
[d] Well is several miles from nearest point on railroad where altitude is known. Altitude may be in error as much as 25 feet.

According to the well logs the blue clay pinches out toward the west, but it can not be said just how far west it extends, except that, as shown by the great thickness encountered at Harvard, it must extend some distance west of that place.

No well-developed wave-cut cliffs or beaches which might indicate the maximum extent of Manix Lake have been found, but a large part of the area has not yet been carefully examined for such features. A well-defined pebbly beach is reported to occur west of Cave Mountain, at the northeast end of the area covered by the ancient lake, but no information is available as to the altitude of the beach. Near the southwest end of the Cady Mountains what appears to be a low beach ridge extends northward across an embayment in the hills. It was seen only from a distance, and its true origin is not known. As no lake beds have been reported from wells in this part of the valley at depths of less than 150 feet, except at Newberry station, this ridge is doubtless not related to Manix Lake but has probably been formed when Troy Dry Lake has been flooded.

The character of the beds that underlie different parts of the Lower Mohave Valley is shown by the following well logs:

Log of well 15, sec. 15, T. 10 N., R. 3 E. San Bernardino meridian

[Los Angeles & Salt Lake Railroad Co., owner. Drilled July–August, 1912. Diameter 11⅝ inches. Screw casing, perforated at 75 to 80 feet and 275 to 285 feet. Depth to water at time of drilling, 75 feet]

	Thickness (feet)	Depth (feet)
Sand	65	65
Brown clay	10	75
Gravel; water	5	80
Brown clay	20	100
Sand	60	160
Brown clay	5	165
Sand	5	170
Brown clay	20	190
Sand	20	210
Blue clay	65	275
Gravel; water	10	285
Blue clay	33	318

Log of well 36, sec. 1, T. 9 N., R. 1 E. San Bernardino meridian

[Los Angeles & Salt Lake Railroad, owner. Drilled September–October, 1905. Diameter, 13½ inches. Stovepipe casing, perforated at 100 to 140 feet and 280 to 306 feet. Depth to water at time of drilling, 60 feet. Log furnished by owner]

	Thickness (feet)	Depth (feet)
Gravel	50	50
Brown clay	50	100
Sand	8	108
Gravel	38	146
Sand	32	178
Brown clay	82	260
Sand	26	286
Gravel	20	306

Log of well 37, sec. 1, T. 9 N., R. 1 E. San Bernardino meridian

[Los Angeles & Salt Lake Railroad, owner. Drilled July–September, 1905. Diameter, 13½ inches. Casing, stovepipe, perforated at 70 to 130 feet, and 160 to 270 feet. Depth to water at time of drilling 60 feet. Log furnished by owner]

	Thickness (feet)	Depth (feet)
Sand and gravel	35	35
Sand	49	84
Gravel	96	180
Brown clay	10	190
Gravel	85	275

This well is only a few feet from well 36, but the two logs are considerably different.

Log of well 64, SE. ¼ sec. 8, T. 9 N., R. 2 E. San Bernardino meridian

[A. Elsholz, owner. Drilled by F. A. Canfield, January, 1918]

	Thickness (feet)	Depth (feet)
Surface soil	9	9
Clay	2	11
Sand	7	18
Clay	3	21
Gravel	11	32
Clay	3	35
Gravel	20	55
Clay	27	82
Sand and gravel	14	96
Clay	1	97
Gravel	13	110
Clay	1	111
Gravel	11	122
Clay	2	124
Gravel	20	144
Clay	5	149
Gravel	6	155
Clay	16	171

Perforated at 35 to 55 feet and 82 to 155 feet.

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Log of well 66, SW. ¼ sec. 15, T. 9 N., R. 2 E. San Bernardino meridian

[E. Wooldridge, owner. Drilled August, 1918. Log furnished by owner]

	Thickness (feet)	Depth (feet)
Clay	6	6
Gravel	14	20
Clay	6	26
Not stated	4	30
Fine sand; water	1	31
Clay	10	41
Sand and clay	2	43
Clay	3	46
Sand	1	47
Soft clay	3	50
Sand and clay	10	60
Clay	10	70
Sand and clay	4	74
Gravel; casing perforated	2	76
Clay	1	77
Sand	1	78
Clay	1	79
Coarse sand	3	82
Clay and sand	3	85
Quicksand	5	90
Clay	1	91
Sand and gravel; casing perforated	3	94
Clay	1	95
Gravel; casing perforated	6	101
Clay	1	102
Gravel; casing perforated	1	103
Sand and clay	3	106
Gravel; casing perforated	2	108
Sand and clay	2	110
Clay	3	113
Quicksand	2	115
Clay and sand	5	120
Clay	25	145
Sand	1	146
Clay	23	169
Gravel; casing perforated	1	170
Clay	5	175
Gravel; casing perforated	2	177
Clay	8	185
Sand	2	187
Clay	3	190
Sand	2	192
Gravel; casing perforated	6	198
Clay	3	201
Sandy clay	2	203
Clay	7	210
Gravel; casing perforated	7	217
Clay	5	222
Gravel; casing perforated	12	234
Clay	1	235
Gravel; casing perforated	3	238
Clay and gravel	3	241
Gravel; casing perforated	2	243
Clay and fine sand	8	251
Clay	11	262
Gravel; casing perforated	12	274
Clay	1	275
Gravel; casing perforated	7	282
Clay	2	284
Gravel; casing perforated	8	292
Clay	1½	293½

Log of well 83, southwest corner of SW. ¼ sec. 19, T. 9 N., R. 3 E. San Bernardino meridian

[Mattie J. Edwards, owner]

	Thickness (feet)	Depth (feet)
Drift sand; water at 12 feet	12	12
Quicksand	2	14
Clay	3	17
Sand	2	19
Clay	2	21
Coarse sand	2	23
Clay	5	28
Sandy clay	3	31
Clay	10	41
Coarse sand	4	45
Clay	4	49
Coarse sand	8	57
Clay	3	60
Coarse sand	6	66
Clay	2	68
Coarse sand	6	74
Clay	5	79
Coarse sand	9	88
Clay	5	93
Coarse sand	3	96
Clay	2	98
Coarse sand	4	102
Clay	10	112
Sand and gravel; flowing water	22	134
Clay	5	139
Sand and coarse gravel; water	10	149
Clay	11	160
Coarse sand	2	162
Clay	10	172
Coarse sand	3	175
Clay	4	179
Coarse sand	4	183
Clay	3	186
Coarse sand	10	196
Clay	4	200

This well is in the midst of the sand-dune area, but only about 100 yards west of the eastern boundary of it.

Water originally rose 4 feet above the ground surface, but in 1919 it rose only about 1 foot above the surface. The well then needed to be "sand pumped."

About 100 yards east of this well, on the east side of the dunes, no water was found in a hole that was dug 27 feet; that is, about 15 feet below the depth at which water was struck in the well drilled among the dunes.

Log of well 89, NW. ¼ sec. 33, T. 9 N., R. 3 E. San Bernardino meridian

[Atchison, Topeka & Santa Fe Railway, owner. Drilled September, 1917. Log furnished by the owner]

	Thickness (feet)	Depth (feet)
Clay	8	8
Sand; water	15	23
Coarse sand and gravel; water not flowing	2	25
Sandy blue clay	27	52
Tough blue clay	12	64
Coarse sand; water not flowing	36	100
Tough clay; streaks of gray shale, with imprints of "tule leaves" on lumps of clay	34	134
Coarse sand, gravel; water flowing	6	140
Hard brown clay	4	144
Gravel; water, good flow	3	147
Hard brown clay	37	184
Sandy clay	9	193
Coarse sand, gravel; water, strong flow	6	199
Very hard clay	2	201
Gravel; water, strong flow and pressure	7	208
Hard blue clay	39	247
Sandy brown clay	5	252
Dark-blue sand	8	260
White chalky clay, almost stone	7	267
Gravel; water, large flow, low pressure	5	272
Hard gray clay	14	286
Sand, no water	26	312
Tough clay	2	314

Well originally flowed about 40 gallons a minute and pumped about 160 gallons a minute.

Log of well 97, southeast corner of SW. ¼ sec. 10, T. 9 N., R. 3 E. San Bernardino meridian

[Owned jointly by Harry Burden, J. W. Burden, and R. D. Lippincott]

	Thickness (feet)	Depth (feet)
Clay and streaks of sand	75	75
Coarse sand	28	103
Clay and sand	27	130
Fine gravel	5	135
Clay and sand	20	155
"Fair" gravel	5	160
Clay with chunks of cemented sand	10	170

Depth to water, 30.4 feet.

This well yields about 50 inches, but in 1919 it was practically the only well in the eastern part of the Lower Mohave Valley that yielded more than 20 or 25 inches, except wells southeast of Newberry Springs, where conditions are more favorable.

Log of well 118, NW. ¼ sec. 24, T. 9 N., R. 3 E. San Bernardino meridian

[John J. Cornwall, owner. Originally drilled to a depth of 125 feet, and log to that depth not known. Log furnished by F. A. Canfield, driller]

	Thickness (feet)	Depth (feet)
Not known	125	125
Clay	12	137
Coarse sand	7	144
"Good" gravel	9	153
Clay	3	156
Coarse sand	3	159
Clay	8	167
Sand	5	172
Clay and sandstone, shelly	2	174
"Good" sand	2	176
Clay	2	178
Fine sand	2	180
Clay	1	181
Coarse sand	1	182
Clay	2	184
Coarse sand	2	186
Clay	6	192
Sand	3	195
Clay	6	201
Sand	2	203
Clay	14	217
Gravel	6	223
Clay	2	225
Gravel	3	228
Clay	21	249
Coarse gravel	5	154
Clay	6	260

Yield by pumping not more than 225 gallons a minute.

Log of well 128, SW. ¼ NW. ¼ sec. 18, T. 9 N., R. 4 E. San Bernardino meridian

[H. G. Tienken, owner]

	Thickness (feet)	Depth (feet)
Pit dug to water	24¾	24¾
Clay	10¼	35
Coarse sand	2	37
Clay and sand	30	67
Coarse sand	15	82
Clay	3	85
Fine sand	2	87
Clay and sand	6	93
Clay	15	108
Quicksand	2	110
Sand and clay	38	148
Clay	4	152
Blue clay	39	191
Blue clay and sand	4	195
Clay	1	196

Depth to water, 24.6 feet. Measured by D. G. Thompson Nov. 20, 1919.

The difference in the nature of the alluvium in the different parts of the valley is clearly due to the conditions under which it was deposited. Some of the conditions are not fully known, but there is sufficient evidence to outline the most significant in so far as those affecting the occurrence of ground water are concerned.

It is certain that at one time the floor of the Lower Mohave Valley was much lower than at present—just how much lower we do not know, for no wells have reached the bedrock. It may be fully 1,000 feet or more deep in the middle of the valley, for the absence of rock in wells near the mountains shows that the bedrock of these mountains does not spread out much below the surface.

As a result of some change in the drainage, as yet unknown, a lake was formed. Probably the change in drainage was due to the formation of a barrier by folding or faulting near the northeastern part of the basin, but the appearance of the lake may have been due to other changes somewhere else in the basin. Before this problem can be solved more must be known of the geography of the region during the later part of the Tertiary and the early part of the Quaternary period.

Into the closed basin alluvium was washed from the surrounding mountains, and the coarseness of the material in different parts of the basin was determined by the distance from the mountains. In general the coarse gravel and boulders, if any, were deposited near the mountains, and the finer sand and clay was carried out into the lake. As a result of occasional heavy run-off from time to time, some coarse material was carried farther out from the mountains than usual, so that there is an interfingering of the fine and coarse material. In this manner the valley was gradually filled with sediments.

As the valley was filled up, Mohave River presumably followed in general its present course from the San Bernardino Mountains to Daggett. At Daggett it emerged from a narrow valley into a much broader valley, at the east end of which was Manix Lake. As the river poured into this broad valley, from which there was no outlet, instead of cutting a deep channel it spread out over the plain and deposited the load of sand, gravel, and clay which it carried. The conditions were very similar to those that now exist farther downstream, where the river emerges from Cave Canyon onto a great alluvial slope that reaches Soda Lake. (See pp. 514,518.) This slope has been built up by the deposition of material from the river during floods. From time to time the river has spread out over first one part of the slope and then another.

In this manner a very large part of the valley fill was carried in by Mohave River. Conditions were doubtless much as at present in that at times coarse material was brought in by great floods and at other times only fine clay or sand was deposited. Most of the coarse material was deposited in the western part of the valley, and the gravel beds thinned out toward the east. Because the river moved from place to place none of the gravel beds are of any great lateral extent. The finest materials were deposited in Manix Lake, and material of intermediate fineness would naturally predominate in a zone between the lake beds and the coarser material deposited at the west end of the valley.

Apparently in its later days Manix Lake did not cover as great an area as in its earlier days, for well logs show that as deposition went on the buff sands at successively higher levels reached farther and farther east over the blue clay that was deposited in the lake. It is not known whether this condition was due to a decrease in the average annual precipitation, which caused less water to reach the lake so that it decreased in size, or to the fact that so much material was washed in that the western border of the lake was moved eastward. Doubtless the level of the lake changed considerably from time to time because of the great evaporation, just as such lakes as Owens Lake and Great Salt Lake change to-day. Doubtless also there was a considerable border zone around the lake where conditions were much the same as on some playas. The buff deposits exposed in the cliffs north of Camp Cady are in many respects similar to the surface deposits of some playas.

Eventually a channel was cut through the barrier at the northeast end of Manix Lake, and the lake was drained. Mohave River then flowed across the nearly level surface of the lake plain but did not cut its present channel for some time. It meandered and changed its course, as the gradient of the plain is too small to cause it to follow a very direct course.

SOILS

The soil in most of the Lower Mohave Valley is good for agriculture, although like the soil in other parts of the desert it is lacking in certain valuable constituents. (See p. 60.) It is mostly arkosic sand with some clay and has been derived from the weathered rocks of the adjacent mountains or washed in by Mohave River. There is some fine gravel in spots. The soil is compact, and its sandy nature is not unfavorable to the development of the region except in the belt of sand dunes that stretches northwestward from a place near Newberry station to Mohave River and also along the extreme eastern border of the valley, where sand has accumulated at the base of the Cady Mountains.

In a number of localities the soil contains so much alkali that crops will not thrive. These areas generally occur where the water table is so close to the surface that there is discharge from the water table, and continual evaporation has left considerable alkali in the soil. The principal areas include the belt of sand dunes northwest of Newberry station, the shallow ground-water area around Newberry station and Newberry Spring, and an area of indefinite extent around Troy Dry Lake.

In most places the alkaline character of the soil is shown by a crust of alkali. A sample of soil taken at a depth of 3½ feet from a small clay flat in the sand-dune area in the NW. ¼ sec. 14, T. 9 N., R. 2 E., contained 0.62 per cent of water-soluble salts, mostly sodium carbonate. At this place there was a slight crust of alkali. A sample taken at a depth of 1 foot on the Hunter ranch, in the SW. ¼ sec. 12, T. 9 N., R. 2 E., contained 0.51 per cent of water-soluble salts, and a sample from a depth of 1½ to 2 feet contained 1.24 per cent of water-soluble salts. In the sample from a depth of 1 foot sodium carbonate predominated, but in the other sample sodium sulphate was more abundant. At this place, which is a few hundred feet east of the dune belt, the surface was baked hard but there was no indication of alkali. Four samples of soil were taken from a clay flat among the sand dunes at the Edwards ranch, in the NW. ¼ sec. 19, T. 9 N., R. 3 E., on which an attempt had been made to grow rice. A sample from the upper 6 inches contained 0.51 per cent of water-soluble salts, and a sample from a depth of 4½ to 5½ feet contained 0.47 per cent. There was no crust of alkali at the spot where these two samples were taken, but such a crust was present around the border of the flat. A sample of this crust contained 6.96 per cent of water-soluble salts. A sample at this same place from a depth of 1 to 1½ feet contained 0.93 per cent of water-soluble salts. The soil at this place contains so much alkali that crops probably will not do well.

Alkali is present over an area of several hundred acres around Newberry station and Newberry Spring. Between the railroad and the spring the crust is especially thick. The alkali, however, appears to occur mostly only at the surface. A sample of the crust, as nearly pure as could be obtained, contained 58.33 per cent of salts, in which sodium chloride predominated and sodium sulphate was high. A sample from a depth of 1 foot, however, contained only 0.44 per cent, and a sample from a depth of 2½ feet contained only 0.235 per cent. Although the content of alkali a foot or two below the surface is less than one-half of 1 per cent it is doubtful whether the soil in this locality is suitable for crops. If the land were irrigated the alkali at the surface would doubtless be carried down in the drier seasons and the soil would become more heavily impregnated.

In some places the soil a few inches below the surface is partly cemented into caliche, but in no place was there any indication that the caliche was troublesome in tilling the land. It is not as widespread nor as thick and hard as in some of the other desert valleys. The cement is probably calcium carbonate or calcium sulphate, which are not readily soluble in water. A sample of caliche that was struck at a depth of 2 feet in a well on the Tienken ranch, in sec. 18, T. 9 N., R. 4 E., contained only 0.19 per cent of water-soluble salts.

VEGETATION

The characteristic plant of the greater part of the plain of the Lower Mohave Valley is creosote bush. In some places, notably in the vicinity of Manix station, it is almost the only perennial that is to be seen. (See pl. 4, *A*.) Elsewhere associated with the creosote are *Franseria dumosa*, Mormon tea (*Ephedra californica*), and the cigarette plant (*Eriogonum inflatum*).

At localities along Mohave River where water is close to the surface, as in sec. 3, T. 9 N., R. 2 E., and for several miles west of the northwest end of the Cady Mountains, characteristic water-loving plants are present. These plants include salt grass (*Distichlis spicata*), both the screw-bean mesquite (*Prosopis pubescens* or *odorata*) and the straight-bean mesquite (*Prosopis juliflora*), and species of willow and poplar. A species of mistletoe (*Phoradendron californicum*) is common on the mesquite and other trees in some places. In the western part of sec. 2, T. 9 N., R. 2 E., on the south side of the river, near a large perennial pool of water, *Baccharis emoryi* grows to a height of 7 feet. This plant apparently is an indicator of water. Rabbit brush (*Chrysothamnus mohavensis*) also grows along the river where the water is close to the surface.

Along the stretches of the river where the water table is some feet below the surface the water-indicating types of vegetation are absent and the plants are generally those that exist in the most sandy soil. On the flood-plain directly south of Yermo creosote bush was common. Just west of Daggett bridge, where the depth to water is about 65 feet and the channel is especially sandy, *Dicoria canescens*, a small plant with berries like gooseberries, was abundant. It was not observed elsewhere in the region.

In the belt of sand dunes that stretches northwestward across the valley from an area near Water station several kinds of plants are found, but creosote bush is generally absent. Crawling mesquite bushes, mostly the screw bean, grow on the dunes. Salt grass grows in some of the depressions between the dunes, but in most of the belt the depth of water is a little too great for the grass to grow. Several types of salt bush grow in the dune area, generally on or at the edge of the small clay flats between the dunes, where the soil is somewhat alkaline. These plants include probably *Atriplex parryi* and *A. polycarpa*. Other plants found in the dune area are *Psathyrotes annua*, *Isocoma acradenia*, and *Suaeda suffrutescens* (inkweed).

In the vicinity of Newberry station and Newberry Spring, where the depth to water is only 2 to 5 feet, salt grass covers a large area and a number of mesquite trees are growing, particularly near the spring. Other species include the saltweeds (*Frankenia grandifolia* and *Atriplex torreyi*), yerba mansa (*Anemopsis californica*), wire grass (*Juncus balticus*), and the tule or Indian sugar cane (*Phragmites communis*).

At the west edge of Troy Dry Lake inkweed (*Suaeda suffrutescens*) is abundant. This plant grows where the soil is very alkaline. Other alkali-resistant plants grow around the playa. In contrast to most playas, which are generally entirely devoid of vegetation, the northern arm of this playa supports some plants. Some mesquite grows on sand dunes that are near the playa.

The desert holly (*Atriplex hymenelytra*), which is used for household decoration, is especially abundant on the rocky slopes of Newberry Mountain near Newberry Spring.

Spinose forms are not common in the valley. Species of cholla and other small cactuses grow on the rocky slopes of the mountains but are generally absent on the plain. Yuccas grow at the very west end of the large valley that extends west of the Calico Mountains but are absent in the other parts of the valley.

PRECIPITATION

The only records of precipitation in the Lower Mohave Valley cover one year, from August, 1883, to July, 1884, at Daggett and parts of three years, from March, 1867, to January, 1871, at Camp Cady. The record at Camp Cady is complete for only one year, 1869–70, when the precipitation was 1.28 inches. In 1868–69 the precipitation was 4.74 inches, but the record is lacking for October, 1868, and May and June, 1869—months when the precipitation is generally slight. The long-time records at other stations in California do not extend back far enough to permit any comparison to be made with the records at Camp Cady.

The precipitation for the single year at Daggett was 4.03 inches. The average annual precipitation at Barstow is about 4.25 inches. Probably the average precipitation in the valley is between 3 and 4 inches. The precipitation on the mountains that border the valley on the south may be slightly greater, as they cover a large area and rise to an altitude of 4,000 to 5,000 feet. Although the Calico Mountains rise about as high they do not cover so large an area and doubtless do not affect the precipitation to any great extent.

SURFACE RUN-OFF

Except for Mohave River there are no streams in the area. The flood run-off from the mountains on the south side of the valley is apparently considerable. The drainage areas of several washes in these mountains are large, and the topographic and geologic conditions are conducive to concentration of the run-off. For example, one wash extends nearly from the summit of Ord Mountain north and northwest to Daggett, a distance of 10 miles or more. Recent township plats of the General Land Office show another wash, known as Kane Spring Wash, which leaves the mountains approximately in sec. 22, T. 8 N., R. 3 E. One main branch of this wash extends southwestward to sec. 9, T. 7 N., R. 2 E., a distance of about 10 miles from the mouth, and another branch extends southward about an equal distance to the southeast corner of sec. 26, T. 7 N., R. 3 E. This wash drains nearly 50 square miles of mountainous land. Other washes extend several miles back into the mountains.

Occasionally great floods come down these washes. In September, 1919, after a heavy thunderstorm, a flood came down the Kane Spring Wash and spread over secs. 7 and 18, T. 8 N., R. 4 E. The water is said to have been up to the running boards on automobiles stalled on the road near the Loman ranch. Damage estimated at $3,000 was done at the Loman ranch in washing out alfalfa lands, irrigation ditches, and in the loss of chickens and other stock. At one place a large channel 5 feet deep and 15 feet wide was cut through a large sand dune.

The run-off from the other mountains that border the valley is probably not nearly as great as that from the mountains on the south side of the valley, largely because there are no large areas tributary to any one wash, the mountains being drained by many small canyons and washes which do not reach far back. The Calico Mountains are comparable in height and roughness to the mountains south of the valley, but the alluvial slopes in front of them, even in front of Wall Street Canyon, are much smaller, largely because the drainage area is not so great.

The plain of the valley is so nearly level that there is practically no run-off anywhere on it. During the heaviest storms water may run a few hundred yards to low places. East of Daggett there appears to be no definite drainage channel extending from the mountains on the south to Mohave River, but the flood run-off dissipates itself on the plain before it reaches the river. North of the river a small channel leads eastward from the playa northwest of Yermo, crosses the railroad about a mile east of the town, and thence leads southeastward to the river in sec. 5, T. 9 N., R. 2 E.

GROUND WATER

SOURCE OF DATA

During the present investigation information was obtained in regard to about 150 wells. The location of the wells is shown on Plate 24, and the most significant data are given in the table on pages 464–471. Most of the wells were measured by the writer, and the reference point from which the measurements were made is given in the table for comparison with future measurements. Data in regard to wells along the Atchison, Topeka & Santa Fe Railway and the Los Angeles & Salt Lake Railroad were furnished by officials of these companies. Logs of a number of wells and other data were furnished by Tom Williams, of Yermo, and D. M. Harlow, J. W. Burden, and F. A. Canfield, of Newberry station, who have drilled most of the wells in the valley.

Records of wells in Lower Mohave Valley, Calif.

No. on pl. 24	Location				Name o owner	Type of well or spring	Depth of well (feet)	Diameter of well (inches)	Depth [a] to water (feet)	Date of measurement	Reference point for measurement	Method [b] of lift	Yield [c] when pumped (gallons a minute)	Remarks
	Quarter	Sec.	T.	R.										
1		34?	N. 11	W. 1	Abandoned oil well	Drilled	2,000+		280+					Could not reach water with a 280-foot string.
2	SW	28	N. 10	E. 1	James F. McKinley	Dug	70		65.4	Nov. 4, 1919	3 notches on northeast corner of curb.			
3	NE	28	10	1	Robert M. Campbell.	do	69.6		65.6	do	3 notches on west corner of curb.	Jack pump	Small.	
4	SW	35	10	1	J. A. Fults	Drilled	407		60+			Turbine	630	See p. 501 for analysis.
5	SW	35	10	1	do	Dug	57.6	48	[d] 56.5	Nov. 4, 1919	Top of casing 6 inches above cover.	Windmill		
6		32?	10	2	Mrs. Williams	Drilled		12	44.5	Nov. 11, 1919	Top of casing 1 foot below platform.	Lift		
7	SW	32	10	2	Yermo Mutual Water Co.	do	428	16	(?)			Turbine	1,125	See p. 482.
8	SW	32	10	2	do	do	426	(?)	(?)			None		Pumping plant removed.
9	SW	32	10	2	do	do	413	16	[d] 23.0	Nov. 4, 1919	Top of casing level with surface.	do		See p. 482.
10	SW	26	10	2	J. D. Prosser	do	156	12	[d] 61.4	Nov. 12, 1919	Top of casing		54(?)	Pumping plant removed.
11	SE?	26	10	2		do	57	12	Dry.	do				
12	NE?	21?	10	3	G. F. Getty	do	125	?	83.0	do	Top of 4 by 4 inch timber on top of casing.	Jack pump	27	
13	SW?	15?	10	3		Dug	?		80.8	Nov. 14, 1919	3 notches on east top of curb, 3 feet above surface.	None		
14	NW?	15	10	3		Drilled	145		68 ?			Deep well	360	Could not measure.
15	NE?	15	10	3	Los Angeles & Salt Lake R. R.	do	318	11⅝	75				28	See p. 453 for log and p. 501 for analysis.
16	NE?	22?	10	3		do	91.5	10	74.0	Nov. 14, 1919	Top of casing 3.5 feet above surface.			
17	NW	23	10	3	F. B. Lewis	do	134	10	60			Deep well plunger.	8	Water struck at 70 feet, rose to 60 feet.
18	NE	14	10	3	C. L. Wright	Dug	58	48 by 48	56.1	Nov. 14, 1919	Top of cover	None		
19	SE	11	10	3	William Spencer	do	116.5	72 by 72	114.5	Nov. 12, 1919	Top of curb	Hand		Bedrock struck in this well.

20	NW?..	12	10	3	....	Drilled..	230	12	111.0	Nov. 13, 1919	Top of casing 1 foot above surface.	None......	....	
21	SW...	22	10	3	....	...do.....	127.5	....	87.0	Nov. 14, 1919	...do...............	...do.......	....	
22	SE....	27	10	3	C. L. Wright.......	Dug and drilled.	37	12	9.4	.....do........	Top of T joint of discharge pipe 2 feet above surface.	Horizontal centrifugal.	....	On river flood plain. At rate of about 100 gallons a minute pumps to end of suction in 10 minutes. Another well 20 feet deep, 8 feet to water.
23	NE?..	33?	10	3	....	Drilled..	97	12	5.4	Nov. 25, 1919	Top of casing 8 feet above surface.	None......	....	On river flood plain.
24	NW...	34	10	3	G. E. Bunnell......	Dug.....	21	14	12.0	.....do........	Top of casing........	Windmill.	....	
25	SW...	34	10	3	C. F. Slicton.......	Drilled..	(?)	....	(?)	....	....	Hand pump.	....	Easily pumped dry.
26	NE...	35	10	3	J. T. Carnall........	...do.....	200	12	33.0	Nov. 25, 1919	3 notches, southwest corner top of curb.	Horizontal centrifugal.	90	Sanded up to 171 feet. Drawdown about 25 feet.
27	SE?...	25	10	3	....	Dug and drilled.	108	....	37.1	Nov. 21, 1919	3 notches southeast corner top of curb.	None......	....	
28	NW?..	30	10	4	W. F. Schildt......	Dug.....	21	....	19.5	.....do........	Top of platform.....	...do......	....	
29	NW?..	6	10	4	....	Drilled..	237	12	102.0	Nov. 13, 1919	Top of casing 0.5 foot above surface.	...do......	....	
30	SW?..	6	10	4	....	...do.....	195	10	98.0	.....do........	Top of casing........	...do......	....	
31	SE....	6?	10	4	....	...do.....	56.4	14	Dry.	.....do........	Top of casing 1.7 feet above surface.	...do......	....	
32	NW?..	8?	10	4	....	Dug.....	88	48 by 48	60.4	.....do........	3 notches northwest corner top of curb.	...do......	....	Dug in green clay.
33	NE?..	8?	10	4	....	Drilled..	81	12	77	....	....	...do......	....	
34	SW?..	4?	9	1	....	...do.....	275	12	76.4	Nov. 16, 1919	Top of casing 18 inches above ground.	...do......	....	
35	NW...	3?	9	1	....	...do....	101?	10	73.3	.....do.......	Top of pump base..	Turbine...	....	
36	NW.?.	1	9	1	Los Angeles & Salt Lake R. R.	...do....	306	13½	60	....	....	Compressed air.	220	See p. 453 for log and p. 501 for analysis.
37	NW.?.	1	9	1	.....do..............	...do....	275	13½	60	....	....	...do......	220	Drawdown is 20 feet when each of 2 wells is pumping 220 gallons a minute.
38	....	12?	9	1	W. S. Wilhelm.....	...do....	180	....	30.8	....	Top of curb, 3 notches on east side.	Horizontal centrifugal.	720	Drawdown 3 feet.
39	....	11?	9	1	F. C. Brandt.......	...do....	150?	10	(?)	....	....	....	....	
40	....	10?	9	1	....	Dug....	54	....	Dry.	....	....	....	....	

[a] Where no date of measurement or reference point for measurement is given, the well was not measured by the writer, but the data are those given by the owner, driller, or other person.

[b] In this table by "turbine" is meant a deep-well centrifugal turbine pump; "deep well" is used for single or double plunger or lift pump.

[c] Yield is that reported by the owner or other person unless otherwise stated. Most of the yields have been reported in "miner's inches," which has been transformed to gallons a minute by multiplying by 9.

[d] See p. 490 for one or more additional measurements of depth to water.

Records of wells in Lower Mohave Valley, Calif.—Continued

No. on pl. 24	Location: Quarter	Sec.	T.	R.	Name of owner	Type of well or spring	Depth of well (feet)	Diameter of well (inches)	Depth to water (feet)	Date of measurement	Reference point for measurement	Method of lift	Yield when pumped (gallons a minute)	Remarks
41	----------	10?	9	1	----------	Dug	53	----------	Dry.					
42	SW	18	9	1	R. H. Greer	Drilled	70	12	[d] 24.8	Oct. 23, 1919	Top of pit level with surface.	Horizontal centrifugal.	200	
43	SW	18	9	1	do	Dug	22	----------	15.2	Dec. 31, 1917	Top of curb level with surface.	----------	----------	
44	SW	18	9	1	do	do	23		22?	----------	----------	----------	----------	Within 25 feet from channel of Mohave River. Well was dry on Oct. 23, 1919.
45	SW	16	9	1	Town of Daggett	do	100	84 by 84	[d] 86.0	Oct. 24, 1919	3 notches east side top of curb 3.5 feet above surface.	Lift	60	See p. 501 for analysis.
46	NW	21	9	1	B. La Mantain	do	125	36 by 60	[d] 79.0	Oct. 25, 1919	3 notches on curb 3 feet above surface.	Cylinder	17	Pumps dry in half a day. Tunnel runs 144 feet toward Mohave River at depth of 113 feet.
47	NW	22	9	1	B. A. Funk	Drilled	154	12	75.0	do	Top of casing level with surface.	----------	15	
48	SE	13	9	1	W. W. Clark	do	(?)	8	[d] 51.0	Oct. 24, 1919	Top of casing 0.5 foot above ground.	None	----------	
49	SW	6	9	2	----------	do	157	----------	23.9	Nov. 6, 1919	3 notches southwest corner of pit curb.	Horizontal centrifugal.	----------	
50	NW	4	9	2	Yermo Mutual Water Co.	do	438	16	16.5	Nov. 11, 1919	Top of casing	None	----------	
51	SW	4	9	2	----------	Dug	17	----------	[d] 8.3	Nov. 5, 1919	3 notches southeast corner top of curb.	do	----------	
52	NW	3	9	2	—— Badger	Drilled	420	----------	49.4	Nov. 11, 1919	Top of casing 1 foot below surface.	do	135	Pumping plant removed.
53	SW	3	9	2	Charles E. Johnson	Dug	----------	30	[d] 4.0	Nov. 5, 1919	3 notches southwest corner top of curb.	No. 5 vertical centrifugal.	500	Drawdown 9 feet. A second well dug 9 feet deep, 4 feet to water, yields 270 gallons a minute. See p. 501 for analysis.
54	SE. ?	3	9	2	Jack Fisher	Drilled	53	----------	5	----------	----------	----------	----------	Draw down 2 feet after 4 hours' pumping with No. 3 centrifugal pump; yield probably about 200 gallons a minute.

55	SE ?	3	9	2	Bruce McCormick	do	186		3					Well pumped dry by No. 5 pumps in a minute or two.
55a	SE. ?	3	9	2	do	Dug	17.3		14.2	Nov. 11, 1919	Top of curb 2 feet above surface.	Hand		
56	NW	2	9	2		do	12		Dry.			None		
57	SW	7	9	2		do	54	36	[d] 51.4	Oct. 24, 1919	Top of cover	do		
58	NW	18	9	2	Los Angeles Soap Co.	Drilled	200	12	[d] 53.5	do	Hole in top of pump 0.8 foot below surface.	Turbine	810	A second well 190 feet deep.
59	NW. ?	19	9	2	Chester Swan	do	190		(?)			do	810	
60	SW	20	9	2	E. D. Barry	do	500	16	45			Air lift	1,170	See p. 501 for analysis.
61	SW	20	9	2	do	do	200	24, 8	48.0	Oct. 24, 1919	Surface		45	A third well 60 feet deep.
62	NE	20	9	2	S. W. Odell	do	220	16	40			Turbine	720	
63	SW	8	9	2	Leo Mrkva	do	176		38			None		
64	SE	8	9	2	Annie Elsholz	do	171	12	33			Turbine	810	See p. 501 for analysis.
64a	SE	8	9	2	do	do	60		35.3	Oct. 28, 1919	Top of casing			
65	SE	10	9	2	—— Bowles	do	110	12	20.7	do	3 notches west side top of pit curb.	Vertical centrifugal.		
66	SW	15	9	2	E. Wooldridge	do	293	12	25			Horizontal centrifugal.	900	See log, p. 454.
67	NW	22	9	2		Dug	44	48 by 84	27.5	Oct. 28, 1919	3 notches top of 8 by 10 inch timber 1.3 feet above surface.			
68	SW	22	9	2	V. B. Cooley	Drilled	156		35.0	do	3 notches top 8 by 12 inch timber north side of pit.	Centrifugal.		Originally dug 50 feet. Water stood at 28 feet before drilling.
69	NW	27	9	2	F. H. Webber	do	174	12	24.2	Oct. 25, 1919	3 notches northwest corner top board of curb.	Horizontal centrifugal.	720	Drawdown 7 feet. See p. 501 for analysis.
70	SW?	28	9	2	A. T. Evans	Dug and drilled.	100	54, 12	31.8	do	Top of boiler plate casing.	Vertical centrifugal.	270	Drawdown 30 feet.
71	SW	27?	9	2		Dug	46	36	[d] 29.9	Sept. 1, 1917	Top of casing 1.3 feet above surface.	None		
72	SW	14	9	2	L. N. Skobel	Drilled	173	12	14			Turbine	720	
73	SW	14	9	2	do	do	95.5	12	26.5	Oct. 29, 1919	Top of board cover	Windmill	15	Water poor quality in a third well 150 feet deep.
74	SE?	14	9	2		Dug and drilled.	38.5	36, 12	14.9	do	Top of casing	Vertical centrifugal.		
75	NW?	26	9	2	Tabitha Taylor estate.	Drilled	300	12	20.6	Oct. 30, 1919	3 notches top of 6 by 6 inch timber northeast corner of curb.	Centrifugal.	540	Drawdown 10 feet. See p. 501 for analysis.
76	NW?	26	9	2	do	do	58	22	18.8	do	3 notches top of upright west side of pit 2 inches above surface.	Horizontal centrifugal.	315	See p. 501 for analysis.

[d] See p. 490 for one or more additional measurements of depth of water.

Records of wells in Lower Mohave Valley, Calif.—Continued

No. on pl. 24	Location: Quarter	Location: Sec.	Location: T.	Location: R.	Name of owner	Type of well or spring	Depth of well (feet)	Diameter of well (inches)	Depth to water (feet)	Date of measurement	Reference point for measurement	Method of lift	Yield when pumped (gallons a minute)	Remarks
77	SE?	23?	9	2	----------	Drilled	123	12	13.5	Dec. 10, 1919	Top of casing 8 inches above surface.	None	--------	
78	NE?	11?	9	2	----------	do	(?)	36, 12	Flows.	Oct. 30, 1919	----------	----------	--------	Drilled on sand dune. Flows about ½ gallon a minute. See p. 477.
79	SW?	12	9	2	—— Hunter	do	195	12	6.3	Oct. 29, 1919	Top of well head about 2 feet above sill of well house.	None	--------	
79a	SW?	12	9	2	do	Dug	26.6	(?)	13.2	do	3 notches on railroad tie used as cover.	Windmill.	--------	250 feet north of well 79.
80	SW	7	9	3	S. B. Hampton	Dug and drilled.	195	60 by 72; 12	44.6	do	3 notches west side top of curb.	None	360?	
81	NW?	18	9	3	----------	Dug	45	----------	Dry.	Nov. 26, 1919	----------	do	--------	
82	NW	19	9	3	Mattie J. Edwards	do	----------	----------	8.6	Oct. 29, 1919	Surface	do	--------	Among sand dunes about ¼ mile north of No. 83.
83	NW	19	9	3	do	Drilled	200	12	Flowing.	Oct. 31, 1919	----------	Horizontal centrifugal.	200	Flows about 3 gallons a minute. Temperature, 70.5° F. See pp. 454, 477, for further data, and p. 501 for analysis.
84	NE?	19?	9	3	----------	Dug	25.7	36	Dry.	Nov. 26, 1919	Surface	None	--------	
85	SW	19	9	3	—— Fry	Drilled	151.5	12	Flowing.	Dec. 10, 1919	Top of casing 1.5 feet above surface.	do	--------	Flows 25 gallons a minute. Temperature 70.5° F.
86	SW?	20	9	3	----------	Dug	27.4	60	Dry.	Nov. 25, 1919	Surface	----------	--------	500 feet north of lava knob.
87	SE	30	9	3	L. P. Cutler	Drilled	134	12	Flowing.	Dec. 10, 1919	Casing 8 inches above surface.	Horizontal centrifugal.	--------	Flows 50 gallons a minute or more.
88	SE	32	9	3	L. W. Page	Dug	14	30	1.75	Sept. 2, 1917	3 notches in top of curb level with surface.	do	120	See p. 490 for other measurements of depth to water and p. 501 for analysis.
89	NW	33	9	3	A. T. & S. F. Ry.	Drilled	314	----------	Flows.	----------	----------	----------	--------	Flows about 45 gallons a minute into dug well at altitude of 3 feet below surface. See p. 455 for additional data.

90	NW	3	9	3		do	73	12	42.0	Nov. 25, 1919	Top of casing level with surface.	None		
91	SW	3	9	3		Dug	34	36	32.6	Nov. 19, 1919	Ground surface	do		
92	SE	3	9	3	E. W. Whalen	do	48	60	(?)			Windmill	36	
93	SW	2	9	3	G. L. Willits	Drilled	237	14	35.0	Nov. 25, 1919	Top of casing 2 feet above surface.	None		
93a	SW	2	9	3	do	do	114	14	38.2	do	Top of casing 4 feet above surface.			50 feet east of No. 93.
94	NW	10	9	3		do?	35.0	18 by 18	32.0	Nov. 19, 1919	Top of wood curb	Windmill		A drilled well at this place could not be measured.
95	NW	11	9	3		do	88.4	12	30.8	Nov. 25, 1919	Top of casing 1 foot above surface.	None		
96	SW	10	9	3	E. L. Harlow	do	150	12	32			Horizontal centrifugal.	175	Affected by neighboring well. See p. 484.
97	SW	10	9	3	Burden and Lippincott.	do	170	12	30.4	Nov. 22, 1919	Top of pit curb	Vertical centrifugal.	[a] 485	Drawdown 19 feet. Temperature 71.5° F. See p. 456.
98	SE	10	9	3	J. W. Burden	do	50	12	(?)			Windmill		Poor quality. See analysis p. 501.
99	SE?	11	9	3	W. N. Bozarth	Dug and drilled.	35	48	29.4	Nov. 22, 1919	3 notches west side top of curb.	do		Also a deep well at this place.
100	SW	12?	9	3		Dug	37	60	33.1	do	Top of 6 by 6 inch timber northwest corner of curb.	do		
101	NW	15	9	3		do	34.6		30.2	do	Top of platform over well.	do		
102	NE?	14	9	3	—— Knott	Drilled	200		31.7	do	Top of 6 by 6 inch timber north side of curb.	do		Originally pumped 135 gallons a minute. Yield now much less.
103	SW	15	9	3	N. E. Harlow	Dug	40	48	35.5			Jack	18	Pumps dry in 1 hour. Another well near by.
104	SW	15?	9	3	Schoolhouse	Drilled	75	12	36.6	Sept. 4, 1917	Surface	Windmill		See p. 501 for analysis.
105	NW	22	9	3		do	162	12	[d] 41.9	do	Top of casing 8 inches above surface.	Deep well		
106	NW	27	9	3		Dug	27	72	Dry.	do		None		
107	NW	26	9	3	C. W. Beverstock	Drilled	271	12	32.0	Nov. 22, 1919	Top of casing level with surface.	Air lift		A dug well near by 30.4 feet to water.
108	SE	28	9	3	—— Wagner	do	56?	8	37.7	Sept. 4, 1917	Top of casing 1.7 feet above surface.	Windmill		
109	SW	27	9	3	L. W. Page	Dug	(?)		32.9	Nov. 24, 1919	3 notches top of 6 by 14 inch timber east side of pit.	None		Caved.
110	SW	26	9	3	George W. Archer	Drilled	125		(?)					Also a dug well 26 feet to water.
111	NW	34	9	3	—— Klinkerbeard	Dug and drilled.	36.2		29.1	Nov. 18, 1919	Top of cover 4 inches below manhole.	Centrifugal.		May be drilled deeper.

[a] Measured by D. G. Thompson with Cipoletti weir.

Records of wells in Lower Mohave Valley, Calif.—Continued

No. on pl. 24	Location: Quarter	Location: Sec.	Location: T.	Location: R.	Name of owner	Type of well or spring	Depth of well (feet)	Diameter of well (inches)	Depth to water (feet)	Date of measurement	Reference point for measurement	Method of lift	Yield when pumped (gallons a minute)	Remarks
112	NE	35	9	3	W. E. Thral	Drilled	145	12	22.5	Nov. 26, 1919	Top of casing 1 foot above surface.	None		
113	NW	35	9	3	H. L. Mygatt	do	112	12	25	do	Surface	Horizontal centrifugal.	125	Sanded up to 94 feet.
114	SE?	35	9	3	Miss Irwin	do	94		22.5	do	Top of casing 1 foot above surface.	None		
115	SW	34	10	3	A. C. Tappe	do	140		56					
116	SE	34	9	3	—— Canfield	do	70		20.5					Sanded up.
117	SW	1	8	3		Dug	9?	72 by 72	8.4		Surface			Sticky mud at 8.4 feet. Well may be drilled deeper.
118	NW	24	9	3	John J. Cornwall	Drilled	260	10	(?)				235	See p. 456 for log.
119	SW?	6	9	4	R. L. Riley	do	158		27					
120	SE	6	9	4	W. A. Hopper	Dug	25		24?					
121	NW	7	9	4	E. C. Rochette	do	25		22					
122	NW	8	9	4	J. B. Neumann	Dug and drilled.	35		22					
123	NE	8	9	4	A. E. Erickson	do	21		17					Pumped dry in 15 minutes by No. 2 centrifugal pump.
124	SE	8	9	4	R. W. Holton	Dug	16		15					
125	SW	8	9	4	H. L. Mellon	Dug and drilled.	50	48 by 48; 9	22	Nov. 20, 1919	Bottom of 6 by 6 inch base of derrick, north side.	Windmill	180	Pumping when measured. Water normally is at 20 feet. Temperature 69.5° F. See p. 501 for analysis.
126	SW	7	9	4	E. F. Dodson	Drilled	226		22.6	do	3 notches southwest corner of pit curb.	Centrifugal.		
127	SE	7	9	4	—— Mager?	Dug?	28?		25.3	do	Surface	Windmill		May be drilled deeper.
128	NW	18	9	4	H. G. Tienken	Drilled	196		24.6	do	3 notches top of curb, west side.	Centrifugal.	200	Well sanded up to 74 feet. See p. 457 for log.
129	NW	20	9	4	L. S. Brehaut	do	150							Water struck at 11 feet. One year after drilling was 6 feet from top.
130	NW	12	8	3	I. L. Hannan	Dug and drilled.	133	48 by 60; 10	27.4	Nov. 26, 1919	3 notches northwest corner top of curb.	Horizontal centrifugal.	180	Drawdown 27 feet.

131	NE	12	8	3	do	do	42	48 by 60; 10	14			do	400	
132	NW	6	8	4	R. W. Porter	Drilled	150		11.6	Nov. 26, 1919	Top of 2 by 4 inch timber fastened to discharge pipe about level with surface.	do		
133	SE	6	8	4	R. O. Marquiss	do	110	12	6.2	do	Top of casing 2 feet above surface.	None		Located on playa.
134	(?)	5	8	4	George N. King	Dug	13		7				180	Located on playa. Gravel at 7 feet.
135	NW	7	8	4	George C. Shafer	Drilled	106	12	25.1	Dec. 11, 1919	Top of 36-inch pit casing.	Horizontal centrifugal.	360	
136	NE	7	8	4	do	Dug	18		11					
137	SW	7	8	4	—— Burkhart	Drilled	135		35					
138	SE	7	8	4	C. S. Van Doren	Dug	46		19				235	Drawdown 4 feet.
139	NW	18	8	4	Josephine Van Doren.	Dug and drilled.	184	36, 12	41.6	Dec. 11, 1919	Top of 36-inch iron casing level with surface.	None		Originally 93 feet deep.
140	NE	18	8	4	C. L. Loman	do	204	72 by 72; 12	45.0	do	Top of cement curb level with surface.	Horizontal centrifugal.	575	See p. 501 for analysis.
141	E½	8	8	5	George W. Layman	Drilled	107		Dry.					In clay all the way.
142	SW	34	9	2	Yermo Mutual Water Co. (?)	do	437	12	45					
143	SE	32	10	3	Peter Zeechini	do	97		9					On river flood plain. Casing pulled.
			N.	W.										
144	NE?	11	9	1	B. E. Funk	do	100							One of 5 wells drilled in tunnel above submerged dam. Water overflows top of casing in tunnel 14 feet below top of middle shaft to tunnel. See p. 501 for analysis.
145	NE?	11	9	1		Dug	9		8	Oct. 27, 1919				Old well near bank about 500 feet east of tunnel. Water level 15.8 feet below top of northwest post of corral near by.
146		32	9	1	G. C. Compton		(?)		22					
147		32	9	1	do		14							
148	SW	4	9	1	I. B. Howard		(?)		13	Oct. 22, 1919	Ground surface			
149	NE	8	9	1	C. A. Leak	Drilled	125	8 to 10	98	do	do			See p. 501 for analysis.
150	SE	8	9	1	Miles Cook	do	154		146.6	do	Top of casing			
151	SW?	10?	9	1		do	56?		Dry.	do	Surface			

DEPTH TO WATER AND SHAPE OF WATER TABLE

General features.—The slope of the water table throughout most of the valley is remarkably uniform. Because of this uniformity and the uniform slope of the surface, the depth to water in almost any part of the valley plain can be predicted within a few feet. A distinctive feature, which is of considerable significance in considering the future development of the region, is a sudden drop of 20 to 40 feet about the middle of the valley, along a line that extends from a point near Newberry station northwestward to a point near Kouns siding. A marked drop also occurs about 2 miles west of Daggett. The shape of the water table with relation to certain geologic features is shown by a generalized cross section, Figure 14, and by three more detailed profiles, Figure 15, A, B, and C.

In Figure 15, A, the altitude of the water table between Barstow and Daggett was determined by instrumental leveling to the water level in the river at the Barstow railroad and wagon bridges and to wells as shown on the profile. From Daggett eastward the surface profiles (fig. 15, A and B) on the north and south sides of the valley are based on profiles of the Los Angeles & Salt Lake Railroad and the Atchison, Topeka & Santa Fe Railway, respectively, except that in the northern profile the altitudes of wells 9, 50, 142, and 15 are from data furnished by H. Hawgood, and at these wells the surface profile departs slightly from that of the railroad. The profile of the water table in each diagram is based on wells within half a mile of the railroad. The surface altitude at these wells was determined only approximately by hand leveling, but the relief is so slight that the profile is correct within a few feet.

Figure 14 is more generalized than the other two diagrams. Except near Daggett the surface profile is shown as a uniform slope from Daggett to the base of the Cady Mountains, and the altitude of these end points is determined approximately from the profile of the Atchison, Topeka & Santa Fe Railway. The altitude of the surface at different points may accordingly be a little more in error than it is in the other profiles. In the construction of the section data have been used for wells within a mile of the assumed line of the section, in order to show conditions which seem to be general in certain localities but which are not shown by the available data for the wells along the line of the section. On account of the small scale of the diagram the distribution of the sand, gravel, and clay beds in the section is very much generalized, but the essential features are indicated as shown by several logs.

In the following discussion, unless otherwise indicated, statements in regard to the depth to water refer to the depth as shown by measurements made in the fall of 1919. In most of the wells there is doubtless a fluctuation of a few feet from season to season or from year to year. (See p. 489.)

Water table between Barstow and Daggett.—The profile of the water table between Barstow and the intake of the Van Dyke & Funk ditch, in sec. 11, T. 9 N., R. 1 W., is only indefinitely known. (See fig. 15, A.) In October, 1919, water was at the surface in the river channel at the railroad bridge at Barstow. In an old dug well (No. 145) on the south edge of the river bottom near the center of sec. 11, T. 9 N., R. 1 W., the water was about 8 feet below the surface. In the collecting tunnel for the Van Dyke & Funk ditch, about 500 feet farther upstream, the water was about 5 feet lower. Apparently, as shown in Figure 15, A, in this stretch the water table is not more than 10 or 15 feet below the river bottom, and it has a more or less uniform slope of about 15 feet to the mile. It is possible that at the lava buttes east of Barstow bedrock may be close enough to the surface to cause the water to stand close to the surface and that east of the buttes the water table drops off slightly. The drop can not be great, however, for in well 148, on the river flood plain in sec. 4, T. 9 N., R. 1 E., the depth to water is only 13 feet.

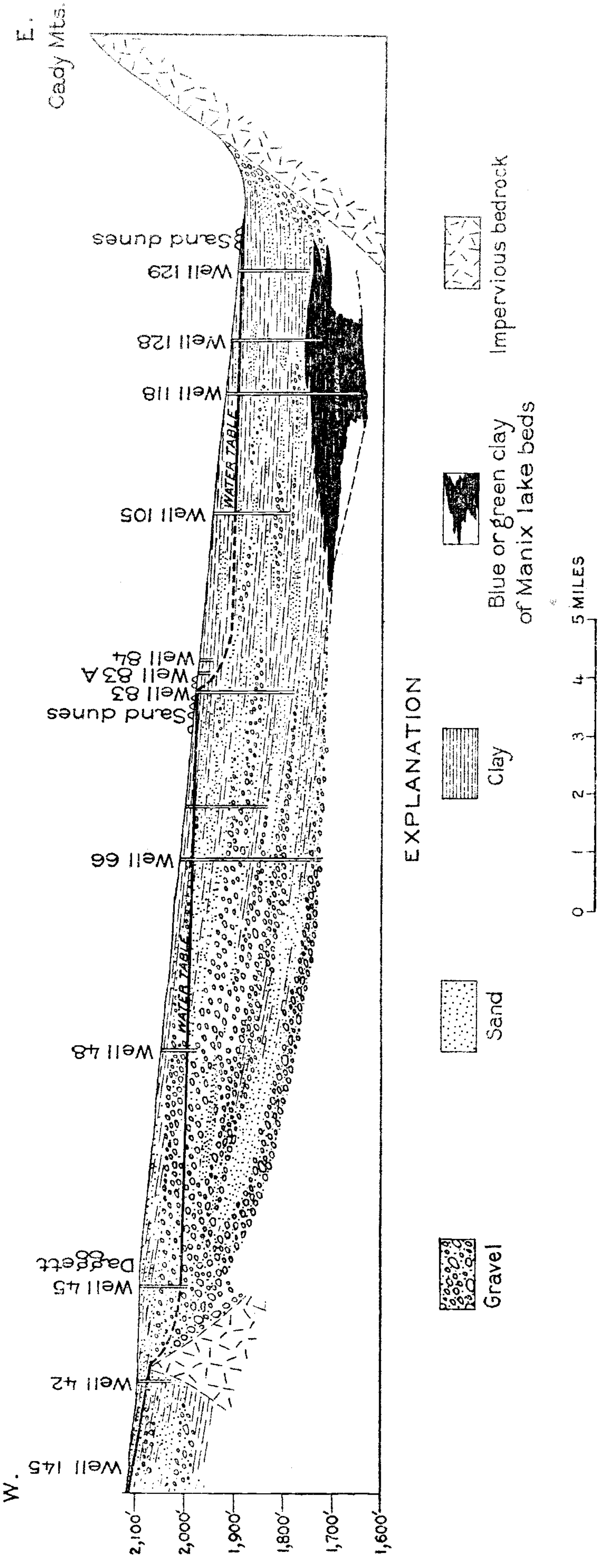


FIGURE 14.—Generalized section of Lower Mohave Valley along an approximate east-west line through Daggett

The nearly uniform slope of the water table continues as far as the Greer ranch, in sec. 18, T. 9 N., R. 1 E. At this place the water level in well 42 is about 23 feet below the surface of a terrace that is about 10 feet above the river bottom. Between the Greer ranch and Daggett the water table drops greatly. In well 45, at the old borax plant on the west edge of Daggett, on October 24, 1919, the depth to water was 86 feet. By instrumental leveling the water level in this well was 66 feet below the river bottom at the Daggett bridge. The water level in well 46, about one-third of a mile farther east, was 6 feet below the level in well 45. The slope of the water table between the Greer well and the well at the borax mill is about 45 feet to the mile, or three times as great as above the Greer well.

The sudden drop in the water level east of the Greer ranch is indicative of a barrier across the river west of which the water is held close to the surface. As previously stated, a few hundred feet northeast of well 42 a small hill composed of rock rises out of the river flood plain. Although west of this hill there are many trees, they do not extend more than 300 yards below it, and except for small plants the river channel is bare for several miles downstream. The drop in the water table evidently begins at this place, and the rock hill is undoubtedly a part of a barrier which extends across the river. The exact shape of the water table between the Greer ranch and Daggett is not known, but, according to conditions at other localities where barriers exist, the slope is probably great near the barrier and becomes less and less farther away.

Although between Barstow and the Greer ranch the depth to water near the river is less than 25 feet, the rise of the surface away from the river is so great that the depth to water is probably 100 feet or more at places not more than a mile or a mile and a half from the river. In well 149, in the NE. ¼ sec. 8, T. 9 N., R. 1 W., the depth to water is 98 feet, and in well 150, less than half a mile farther south, it is 147 feet. Well 151, which is probably in the SW. ¼ sec. 10, T. 9 N., R. 1 W., was dry at 56 feet. This well appeared to be deeper, but the tape would go down no farther.

South side of valley.—The profile of the surface and the water table along the south side of the valley is shown in Figure 15, A. Directly east of Daggett the surface of the land slopes gently eastward with a nearly uniform grade of about 15 feet to the mile except that between Daggett and Minneola there is a slight rise over an alluvial cone built out by wash from the mountains. For a mile or two on each side of Newberry station the grade increases slightly, but farther east it is about the same as along most of the valley. The surface of Troy Dry Lake is nearly horizontal, but the railroad profile shows that it rises 3 or 4 feet from the west border to the east border.

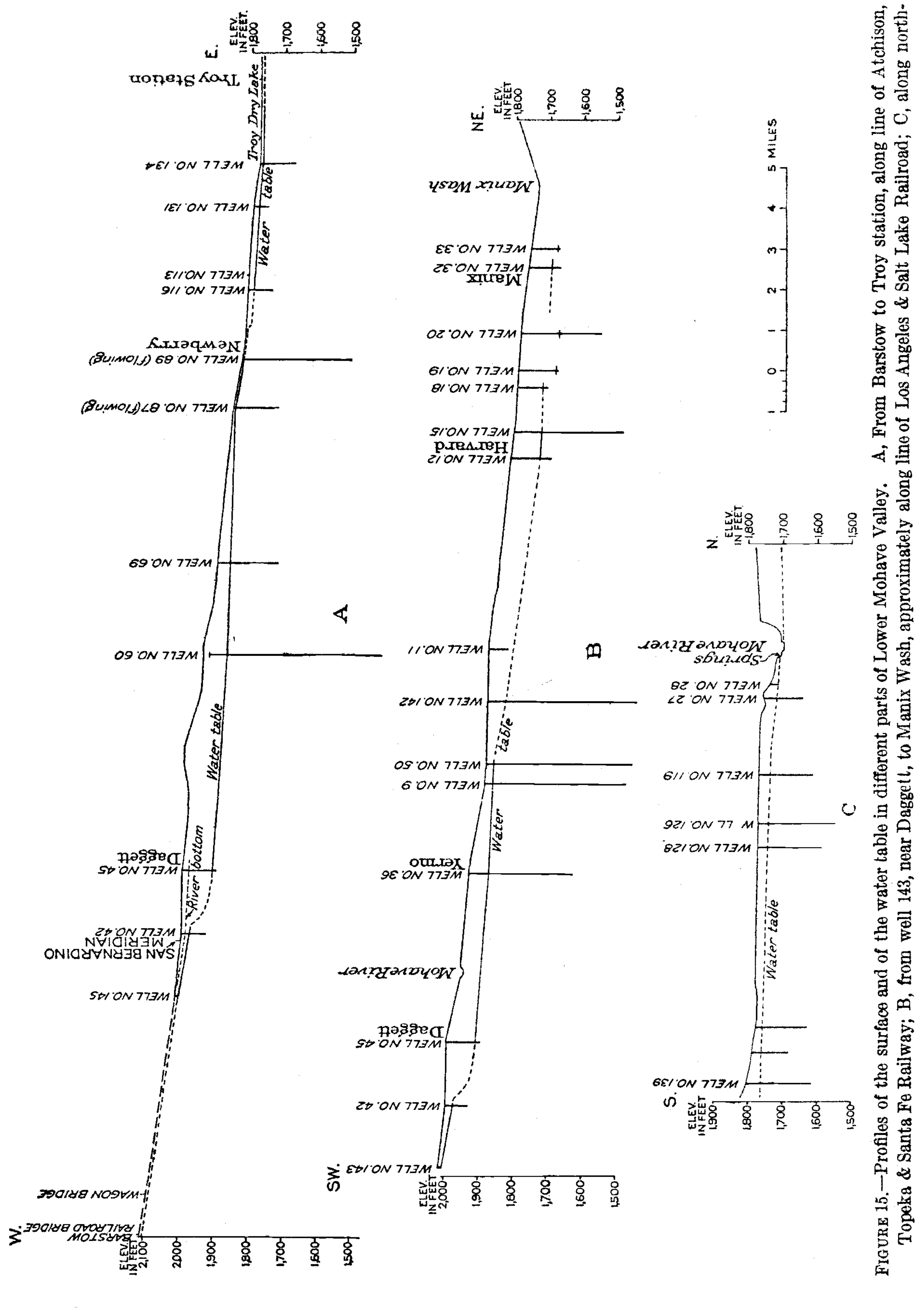


FIGURE 15.—Profiles of the surface and of the water table in different parts of Lower Mohave Valley. A, From Barstow to Troy station, along line of Atchison, Topeka & Santa Fe Railway; B, from well 143, near Daggett, to Manix Wash, approximately along line of Los Angeles & Salt Lake Railroad; C, along north-south line between Rs. 3 and 4 E.

From Daggett the water table slopes gently eastward to about the east line of T. 9 N., R. 2 E., with an average grade of about 5 feet to the mile. Apparently the grade is a little greater near Daggett than farther east. The difference may be due to inaccuracies in the estimate of the altitude of the surface at the wells, but it would not be unnatural for the water table to have a steeper grade in the upper part of the valley than in the lower part.

As the slope of the surface is greater than the slope of the water table, the depth to water becomes less and less toward the east. About in secs. 30 and 31, T. 9 N., R. 3 E., the water table approaches within 5 or 10 feet of the surface, as is shown by the growth of salt grass over a considerable area. In some places, particularly near Newberry Spring, a thick crust of alkali shows the water table to be especially close. The area in which the salt grass grows extends from a point about 1½ or 2 miles west of Newberry station to a point about a mile east of that place, and from a point very near the base of the mountains to a point about half a mile north of the railroad opposite Newberry station. In this area, where the water table is close to the surface, there are two wells—No. 87, in sec. 30, T. 9 N., R. 3 E., and No. 89, at Newberry station.

The depth to water 1½ and 2 miles east of Newberry station, as shown by wells 113 and 116, is between 20 and 25 feet. The grade of the water table between Newberry station and well 116 is at least 15 feet to the mile, and the salt-grass area extends for some distance east of the station, showing that water is close to the surface and that the grade must be even greater. Farther east, at the edge of Troy Dry Lake, the depth to water is only 6 or 7 feet. As shown by the profile in Figure 15, A, the grade of the water table between well 116 and the playa is between 5 and 10 feet to the mile. It is quite obvious that between Newberry station and well 116 a rather abrupt change in the slope of the water table occurs.

As a matter of fact, the abrupt change in gradient east of Newberry station is even more marked when it is considered that well 89 flows. The head on the deeper-lying strata in which the water is under artesian pressure is obviously even higher than is shown in Figure 15, A. The water table as shown there apparently reveals only the level of the so-called surface water. If the water table had been drawn to show the profile of the piezometric surface [53] it would have been above the surface of the ground at well 89, and the abruptness of the change in slope between that well and No. 116 would have been even greater than is shown.

The reason for this change in the slope of the water table is not clear. It may be due to the fact that for part of the distance between

[53] A piezometric surface of an aquifer is an imaginary surface that everywhere coincides with the static level of the water in the aquifer.

Newberry station and Troy Dry Lake the surface slope flattens out and its grade may be less than the grade of the water table between these points. The question arises, however, why the water table comes so close to the surface west of Newberry station instead of having a uniform slope from Daggett to Troy Dry Lake. If the water table did have such a uniform slope it would be from 15 to 30 feet below the surface at Newberry station, instead of nearly at the surface. The conditions suggest strongly that some underground barrier exists which holds the water up on the west side of it. Possibly a buried spur of Newberry Mountain extends far enough out into the valley to hold the water back, but there is absolutely no indication of any such barrier. Some light is thrown on the problem by a study of the water table in the central part of the valley.

Central part of valley.—Conditions in the central part of the valley are illustrated in Figure 14. From Daggett the water table slopes gently eastward, as along the south side of the valley, but as the surface slope is greater the depth to water is gradually less and less toward the east. Along the east side of T. 9 N., R. 2 E., the water table is within 5 or 6 feet of the surface, and in several wells, notably Nos. 78, 83, 85, and 87, the water rises above the ground level.

In about the center of the valley there is an abrupt increase in the depth to water, just as there is along the south side of the valley east of Newberry station. In contrast to conditions near Newberry station, however, the drop in the water table is greater, and it evidently occurs within a short distance. This fact is shown in a number of wells. In well 78, which is probably in the NE. ¼ sec. 11, T. 9 N., R. 2 E., the water overflows from the casing on the side of a dune several feet above the general surface level, and in well 79, about 0.7 mile to the southeast, the water stands only about 6 feet below the surface. In well 80, 195 feet deep, about a mile farther east, the depth to water is 45 feet. Well 81, about a mile south of well 80, when measured, was dry at a depth of 45 feet. In well 82, near the northwest corner of the NW. ¼ sec. 19, T. 9 N., R. 3 E., the water was 8.6 feet below the surface, and salt grass growing near the well showed that the depth to water was not great. Well 83, in the southwest corner of the same quarter section, flows at the surface, yet no water was reached at a depth of 27 feet in a hole dug not more than a quarter of a mile east of this well. Well 85, in the SW. ¼ sec. 19, flows. Two other wells a little farther east and northeast, Nos. 84 and 86, were dry at depths of 26 and 27 feet, respectively. No other wells were found nearer than the center line of T. 9 N., R. 3 E., where the depth to water is from 30 to 40 feet.

The difference in the depth to water in wells 78, 79, 82, and 83 and the wells farther east can not be accounted for by a difference in the altitude of the surface, for, although no careful instrumental leveling was done, observations with a hand level show that the surface continues to slope eastward rather uniformly.

The exact line along which the drop in the water table occurs is not evident, but it can be determined within a few hundred feet. Where the table approaches within about 10 feet of the surface in the eastern part of T. 9 N., R. 2 E., a belt of sand dunes is present. (See p. 445 and pl. 26, *B*.) It is noticeable that the dunes occur only where the depth to water is not more than 10 or 15 feet, and their presence is evidently intimately related to the nearness of the water table to the surface. The western border of the dune belt is irregular, but the eastern border is rather sharp. It apparently marks within a few hundred feet the line along which the abrupt drop in the water level occurs. Well 83, which flows, is in the midst of the dunes, and the hole a quarter of a mile east in which no water was struck is about 25 feet east of the base of the easternmost dune.

The approximate eastern border of the dune belt is shown by dots on Plate 24. The belt extends from Mohave River at about the east line of sec. 3, T. 9 N., R. 2 E., in a southeasterly direction toward Newberry station. At the river the dunes cover the upland plain along the stretch in which water comes to the surface in the river channel in sec. 3, but they do not extend onto the river bottom.

Near the south side of sec. 19, T. 9 N., R. 3 E., the belt bends more in an easterly direction. The belt passes about half a mile north of Newberry station, where it is only a few hundred feet wide. The dunes disappear almost completely in the NE. ¼ sec. 33, T. 9 N., R. 3 E., although low mounds at the railroad crossing about a mile east of Newberry station may be a continuation of the belt. This is about where a change in the water table apparently occurs between Newberry station and well 116, as shown in Figure 15, A. Apparently the nearness of the water table to the surface around Newberry station and its sudden drop farther east are due to the same conditions that cause the more abrupt and greater drop farther northwest.

Other dunes occur in sec. 30, T. 9 N., R. 4 E., and for several miles to the northeast and also along the south side of Troy Dry Lake. The extent of these dunes was not traced out, and it is not certain that they are related to the belt just described. The significance of the dune belt and the cause of the abrupt drop of the water table along its eastern edge are discussed further on pages 481–482.

Beyond the abrupt drop on the east side of the dune belt the water table continues to slope eastward gently with about the same grade as west of the dunes. Along the north-south center line of T. 9 N., R. 3 E., the depth to water is between 30 and 40 feet. In the easternmost wells for which data are available, in the northwestern part of T. 9 N., R. 4 E., the depth to water is between 15 and 20 feet, and in well 129, in sec. 20, of that township, water was struck at 11 feet and several months later had risen to 6 feet below the surface. The presence of alkali on the surface of the arm of Troy Dry Lake that extends northward along the base of the Cady Mountains indicates that the water table is probably less than 10 feet below the playa. North of this arm of the playa, however, the land surface is slightly higher, so that the depth to water is probably a little greater.

North side of valley.—The profile of the water table north of Mohave River is shown in Figure 15, B. From Daggett northeastward to a place about 2 miles east of Yermo the water table has a uniform slope, as south of the river, but the grade is perhaps a little greater. Between wells 50 and 142 there is an abrupt change in the slope of the water table, just as on the south side of the river, but the drop is not quite so great and the water table is not so near the surface. Except on the river bottom there is no salt-grass area nor well-developed dune belt, such as is found south of the river, apparently because the water table is below the depth to which the salt grass or mesquite roots penetrate. As in the area south of the river, the zone in which the water table is closest to the surface is adjacent to the stretch of the river where there is a surface stream.

The depth to water is 75 or 80 feet at Harvard and 60 feet near Manix. The altitude of the water table in several wells, as plotted on Figure 15, B, shows a rather uniform slope between Harvard and Manix, but the slope between Harvard and well 142 is somewhat greater.

North of the river the water level is much lower than south of the river. Thus, at Harvard it is nearly 100 feet lower than at Newberry station, although the surface altitude at Harvard is a few feet lower. In well 19, 2 miles northeast of Harvard, the depth to water on November 12, 1919, was 114.5 feet. The well is dug and reaches a total depth of only 2 feet below the water level. The depth to water in well 20, a mile farther northeast, is 111 feet. This well is drilled to a depth of 230 feet and may have penetrated bedrock. The depth to water in well 32, near Manix siding, on November 13, 1919, was 60 feet. The well is dug to a depth of 88 feet. In well 33, about half a mile farther east, the depth was 77 feet. The surface appears to be not more than 5 or 10 feet lower than at well 32. This well, which is drilled, extends only 4 feet below the water level.

Difference in water level on north and south sides of river.—In the western part of the valley the water table has about the same slope on the north as on the south side, but in the eastern part, beginning about 3 miles east of Yermo, it has a greater slope on the north side. The depth to the water level is about 70 feet greater in well 32, near Manix, than in wells on the west edge of Troy Dry Lake, although the surface is only 10 or 15 feet lower.

On the north side between Harvard and Manix the water table is about at the level of the river or slopes slightly toward the river. On the south side, however, the water table is 10 or 15 feet above the river, for in sec. 30, T. 10 N., R. 4 E., a series of springs issues from the side of the low cliff that rises to the second terrace above the river bottom, and the first terrace below the springs is marshy. The springs continue upstream for a mile or two, but those farther up are not so well developed. Over a considerable area salt grass grows on the second terrace, which is 15 feet or more above the river bottom. There is no such marked spring or salt-grass area along the cliffs on the north side of the river, although mesquite grows on the flood plain, and the water table is doubtless within 10 or 15 feet of the surface.

The water table is apparently about 50 feet lower on the south side of the river at Camp Cady than at a point due south on the Atchison, Topeka & Santa Fe Railway. It is not certain whether the water table descends gradually between the two places or is nearly level to a zone within a short distance of the river and then drops abruptly, but the depth to water in wells 119, 121, 126, and 128, along the west side of T. 9 N., R. 4 E., is between 20 and 27 feet, so that, if allowance is made for slight surface irregularities, the slope of the water table in that locality is not great. In well 27 the depth to water is 37 feet, which represents about the difference in altitude between the surface and the spring outlets along the river terrace. The probable conditions are shown in Figure 15, C.

Borders of the valley.—On the valley plain the maximum depth to water is about 80 feet at the west end of the valley and in the northeastern part around Manix. Beneath most of the plain it is considerably less. Wells 137, 138, 139, and 140, in secs. 7 and 18, T. 8 N., R. 4 W., in the southeastern part of the area, are near the lower part of the alluvial slope. These wells indicate that the water table rises but little if any above Troy Dry Lake, and the depth to water is probably 100 feet within a mile or two south of the dry lake. A hole (No. 141) drilled in the E. ½ sec. 8, T. 8 N., R. 5 E., penetrated only clay and did not reach water at a depth of 107 feet. The surface along the Atchison, Topeka & Santa Fe Railway in this section is not more than about 70 feet above Troy Dry Lake.

So far as is known, no wells have been drilled on the alluvial slopes south of the Atchison, Topeka & Santa Fe Railway between Daggett and Newberry station, nor in the large valley several miles northwest of Daggett. It is very doubtful that water can be obtained at a moderate depth in either of these localities, except in the lowest part of the valley northwest of Daggett. The depth to water in wells 2 and 3, near the lower end of this valley, is only 65 feet. The land for some distance west of these wells rises rather gradually, and although the water table is doubtless nearly flat, it possibly lies within 100 feet of the surface at least as far west as the San Bernardino meridian.

In the northern part of T. 10 N., R. 1 W., and the southern part of T. 11 N., R. 1 W., there is a considerable area of gently sloping land that might seem to be available for agriculture. Water was struck in a deep well drilled for oil in sec. 34 or 35, T. 11 N., R. 1 W., but it is too deep to be available for irrigation. The water was not reached with a 280-foot cord.

Possible underground barrier across valley.—The cause of the abrupt drop in the water table along a northwestward-trending line in about the middle of the valley is not clear. The conditions are similar to those that might be expected if a submerged natural dam extended entirely across the valley. It is not strange that the general explanation has been that a "dike" crosses the valley. This view is further supported by the belt of sand dunes, which forms a distinctive topographic feature and gives the impression of a definite geologic structural feature, such as a fault or a fold.

The dune belt is not in itself evidence of a fault or a fold but is due merely to the nearness of the water to the surface. Because the water table is so near the surface, mesquite has got a foothold and has accumulated wind-blown sand. Dunes have resulted from a similar condition farther east in the valley, near the Cady Mountains, where the water table is near the surface. There are no large dunes north of the river, apparently because the water table is below the depth to which the mesquite can reach.

The writer has not been able to find any definite evidence of a fault anywhere along the dune belt that marks the line of the drop in the water table. In sec. 20, T. 9 N., R. 3 E., 200 or 300 feet north of the dune belt, a hill several hundred feet in diameter rises out of the alluvium. This hill is composed of lava, and there is no indication that it has been faulted up. In wells in the dune belt a mile or two south of the river the water table seems to be several feet above the river bottom, which indicates that the controlling barrier must rise higher than the river channel, but no indication of any fault or fold was found along the river. It hardly seems possible that a fault or fold could extend entirely across the valley without there being some easily visible surface indication of it, at least where it would be cut by the river channel.

The writer has elsewhere suggested that the drop in the water table might be due to a difference in the permeability of the alluvium in the eastern and western parts of the valley.[54] It was suggested that water-bearing gravel extended eastward to about the line where the water

[54] Thompson, D. G., special report on ground-water conditions along Mohave River, San Bernardino County, Calif.; manuscript copies filed in offices of U. S. Geological Survey, Los Angeles, the California Division of Water Rights, San Francisco, and the County Engineer of San Bernardino County, San Bernardino.

table drops, and that there it pinched out. This hypothesis was based on the exposure of a gravel bed along Mohave River south of Yermo, which extended eastward for some distance but gradually pinched out. As a result of the further study of well logs, however, it seems doubtful whether the valley is underlain by definite gravel beds which extend as far east as the dune belt. It is possible, nevertheless, that the drop in the water table may be due to some condition as yet undetermined that arose during the deposition of the alluvium.

YIELD OF WELLS

West of the eastern border of the dune belt that crosses the valley the yield of most wells is 300 gallons a minute or more. East of the belt, with some exceptions, it is much less, and few wells yield as much as 250 gallons a minute.

Wells in western part of valley.—The largest yield reported in the valley is from well 60, on the ranch of E. D. Barry, in the SW. ¼ sec. 20, T. 9 N., R. 2 E., which is 16 inches in diameter and 500 feet deep, the deepest well in the valley. The well is pumped by compressed air. The air pipe is 2½ inches in diameter. The discharge pipe is 8 inches in diameter and extends to a depth of 150 feet. The yield of this well, as measured with a current meter by O. E. Meinzer and the writer on September 1, 1917, was 2.33 second-feet, or fully 1,000 gallons a minute (about 117 miner's inches). In 1919 Mr. Barry stated that the yield had been increased to about 1,170 gallons a minute (130 miner's inches) through the installation of a "spreader" at the bottom of the air pipe, which causes a more efficient mixing of the air and water. The depth to water in this well is about 45 feet, and the drawdown when pumping is only about 10 feet. The well is said to have penetrated sand and gravel from a depth of 45 to 200 feet, and a formation described as "cement" from 200 to 500 feet. Considerable water appears to come from crevices in the cement. Many boulders of lava, some of them 12 inches in diameter, were struck in the cement.

Three wells (Nos. 7, 8, and 9, pl. 24) of the Yermo Mutual Water Co., in the SW. ¼ sec. 32, T. 10 N., R. 2 E., a little more than 400 feet deep, are reported to have yielded in tests about 1,125 gallons a minute each, with drawdowns of about 20 feet. When visited in 1919 two of the pumping plants had been completely dismantled and the third was partly dismantled. The depth to water in the easternmost of the three wells is 23 feet. The logs show that the wells penetrated an alternating series of sand, gravel, and clay. The total thickness of water-bearing gravel ranged from 152 to 179 feet, equivalent to 35 to 43 per cent of the total depth of the holes. It is said that the yield of the wells of the Los Angeles & Salt Lake Railroad at Yermo decreased slightly when the wells of the Yermo Mutual Water Co. were being pumped.

No other wells in the valley are known to yield as much as 1,000 gallons a minute, but several wells in the western half of the valley yield between 500 and 1,000 gallons a minute. These wells include Nos. 4, 38, 53, 58, 59, 62, 64, 66, 69, 72, and 75. As a matter of fact, all wells put down for use in irrigation west of the belt of sand dunes seem to have obtained adequate supplies, if properly drilled and equipped.

The well (No. 45) at the old borax works, which at present is used for the town supply of Daggett, yields only about 60 gallons a minute, but there is practically no drawdown. It is said that when used by the borax company the well yielded 35,000 gallons an hour (about 585 gallons a minute), with a drawdown of only about 2 feet after pumping 24 hours. In the well of B. LaMontain (No. 96), less than half a mile farther east, the ground-water supply is scanty. This well is dug 3 by 5 feet in diameter to a depth of 125 feet. At a depth of 113 feet a tunnel was driven 144 feet northward toward Mohave River. The formation from a depth of 17 feet to the bottom was composed of cemented clay and boulders, much of it so compact that it had to be shot. In the tunnel seepages were struck, but no strong supply. In October the depth to water was 79 feet. When pumped at the rate of 15 gallons a minute the well becomes empty in about half a day, for it takes about that long for the tunnel to be drained of the water stored in it. The well of B. A. Funk (No. 47), about a mile farther east, yields only about 15 gallons a minute. It is 12 inches in diameter, 154 feet deep, and has a depth to water of 75 feet. The well is equipped with a small cylinder pump with which the water level can be lowered to the bottom. The material penetrated by the well was gravel cemented by caliche. The material in other wells elsewhere on the valley plain does not seem to be cemented, and perhaps this cement is the cause of the low yield of the two wells. The low yield is also perhaps in some way related to the situation of the wells on the extreme border of the plain.

Although several flowing wells have been obtained in the shallow-water area in or west of the dune belt near the middle of the valley, from none of them has the flow been very large. Well 83 is reported to have flowed about 25 gallons a minute originally and to have yielded about 450 gallons a minute by pumping. In October, 1919, however, it flowed less than 10 gallons a minute, and a weir measurement by the writer showed the yield by pumping to be only about 200 gallons a minute. The well is 12 inches in diameter and 200 feet deep. In October, 1919, it was sanded up within 152 feet from the top. In the spring of 1919, after the well had been cleaned out, the drawdown was only 12 feet, but as it sanded up again the drawdown increased to 18 feet. As shown by the log on page 455, gravel was struck in the well at only two horizons, from 112 to 134 feet and from 139 to 149 feet, and the rest of the material was either sand or clay. The casing is perforated in each layer of sand below 49 feet, so that there is ample opportunity for sand to enter.

The only other flowing well for which definite information is available is a well of the Atchison, Topeka & Santa Fe Railway at Newberry station (formerly called Water Station). The well is 16 inches in diameter and 314 feet deep. Although gravel was struck at six different horizons, as shown by the log on page 455, none of the layers were thick. The total thickness of the gravel beds is only 29 feet, or less than 10 per cent of the total depth of the hole. In a pumping test this well yielded about 160 gallons a minute. In October, 1919, it was not being pumped but flowed at the rate of 45 gallons a minute into a reservoir at a point about 3 feet below the surface.

Wells in eastern part of valley.—East of the sand-dune belt the yield of wells is generally much less than west of it. Only one well (No. 97) is known to yield as much as 450 gallons a minute. A measurement by the writer on November 24, 1919, using a Cipoletti weir, showed the yield to be about 485 gallons a minute (54 miner's inches). This well is 170 feet deep, but there is a 10-foot sand bucket in the bottom which was lost during drilling. As shown by the log on page 456 only two 5-foot beds of gravel were penetrated, and none of the material was very coarse. The casing is perforated in these beds and also in a bed of coarse sand between 75 and 103 feet. During the pumping test the drawdown could not be measured except by a vacuum gage, which read 21.4. The graduations on the gage were presumably equivalent to inches of mercury, which would make the drawdown 24.3 feet, or more than the practicable suction lift (between 21 and 22 feet) for pumps at the altitude of the region. If the graduations are equivalent to feet, the drawdown is just about at the practicable suction lift. It is said that formerly, when the well sanded up 25 feet, the drawdown was materially affected, and for that reason it is believed that a large part of the water comes from the lower part of the well.

Well 80, in T. 9 N., R. 3 E., is reported to have yielded 360 gallons a minute on a test, but when visited by the writer there was no pump on the well, and the yield of this well is not certain.

The well of E. L. Harlow (No. 96), less than half a mile from well 97, is 150 feet deep and yields only about 175 gallons a minute. A total of 36 feet of gravel was struck at three different horizons. In an attempt to obtain a large yield the well was sunk with an 18-inch shoe followed by 12-inch casing, and the space outside of the casing was filled with gravel. The casing was then perforated for the entire distance. This procedure does not seem to have been entirely successful, for the well had partly sanded up. However, as this well was recently constructed, possibly if it were cleaned out and pumped heavily less sand would enter it. During a pumping test of well 97 the water level in well 96 was slightly lowered. After well 97 had been pumped for two hours the water level in well 96 had dropped 2½ inches, and after about 18 hours of continuous pumping it had dropped 3¾ inches.

The well of H. G. Tienken (No. 128) yields only about 200 gallons a minute with a drawdown of 21 feet. This well is 12 inches in diameter. It was originally drilled to a total depth of 196 feet, but when measured by the writer it had sanded up to 74 feet from the top. The depth to water is 24.6 feet. According to the log (p. 457), no gravel was struck in this well, but coarse sand, which was struck at 35 to 37 feet and 67 to 82 feet, is said to have contained small pebbles that would not go through a ¼-inch mesh sieve. Blue clay, which probably represents the Manix lake beds, was struck at 152 feet. Every other joint of the casing below the water level is perforated with six slits three-eighths of an inch wide and 6 inches long.

The well of J. T. Carnall (No. 26) yields only about 90 gallons a minute. The well is 12 inches in diameter and was originally drilled to a depth of 200 feet, but in November, 1919, it had sanded up 29 feet. The depth to water is 33 feet, and the drawdown when pumped is about 25 feet. Gravel was struck at 87 to 99 feet and 110 to 115 feet, and the casing is perforated only at these beds. None of the gravel was larger than a quarter of an inch in diameter.

The well of H. L. Mellon (No. 125) yields 180 gallons a minute with a drawdown of 14 feet. The well of H. L. Mygatt (No. 113) yields only about 120 gallons a minute.

Wells southwest of Troy Dry Lake yield more water than most of the wells east of the belt of sand dunes. One well on the ranch of I. L. Hannon (No. 131) yields about 400 gallons a minute, although another well in the northwest corner of the same section (No. 130) yields only 180 gallons a minute. In the Hannon well a single bed of gravel was struck between 22 and 29 feet. In well 130 the only bed of gravel was penetrated between 52 and 64 feet. The well of George C. Shafer (No. 135) yields 360 gallons a minute. The well of C. L. Loman (No. 140) is reported to yield about 585 gallons a minute with a drawdown of 18 feet. This is the largest yield in this vicinity. In this well a total of 75 or 80 feet of gravel was struck below the water level, and between 116 and 146 feet the gravel contained cobbles 4 or 5 inches in diameter. The abundance and coarseness of the gravel are evidently due to the location of the well on the alluvial slope that rises southward to the mountains.

On the north side of the river, east of the line of the abrupt descent in the water table, the field of wells is apparently even smaller than south of the river. The only well for which very definite information is available is that of the Los Angeles & Salt Lake Railroad at Harvard. It is pumped at a rate of only 1,700 gallons an hour (about 28 gallons a minute). The pump is operated generally only 20 hours a day, apparently because longer pumping causes too great a draw-down. The well is 11⅝ inches in diameter and 318 feet deep, and when drilled in 1912 the depth to water was 75 feet, but no data are available in regard to the depth in recent years. Water-bearing gravel was struck only between 75 and 80 feet and between 275 and 285 feet, and the casing was perforated only at these beds. From a depth of 210 feet to the bottom the material penetrated was blue clay, except for the 10-foot gravel bed mentioned above. This blue clay is evidently part of the Manix lake beds, which are exposed along Mohave River about 5 miles east of Harvard and which are doubtless very impervious.

A well on the Badger ranch (No. 52) is said to have yielded only about 135 gallons a minute. This well is very close to the supposed line of abrupt descent in the water table.

The well of Bruce McCormack (No. 55) is said to have been pumped empty in a very short time. No information is available, however, as to the size of pump, length of suction pipe, and other details, so that it is not certain whether the well was pumped dry because of improper installation or lack of water. This well is on the flood plain or terrace along the north side of Mohave River, at the east end of the stretch in which water flows at the surface in sec. 3, T. 9 N., R. 2 E. The well is 186 feet deep, and the water stands 3 feet below the surface. It penetrated a total of 53 feet of gravel, but the thickest bed was only 8 feet thick, and most of the beds were only 3 feet thick. The small yield of this well is in marked contrast to that of well 54, on the ranch of Jack Fisher, about a quarter of a mile farther west. In well 54 the water level is said to have been lowered only 2 feet after four or five hours of pumping with a No. 3 centrifugal pump, the yield of which was probably about 200 gallons a minute. This well is only 53 feet deep, but the formation from 13 to 41 feet consisted wholly of gravel.

Only two wells (Nos. 10 and 14) in this part of the valley are reported to yield more than a few gallons a minute. Well 10, on the J. D. Prosser place, is said to have yielded 540 gallons a minute. When visited by the writer in 1918 this plant had been dismantled. The well is 12 inches in diameter and 156 feet deep. On February 26, 1918, the depth to water was 65 feet, but when measured on November 12, 1919, it was 61.4 feet. The well is near low hills that extend eastward from the Calico Mountains. The good yield of the well may be due to this situation, where the alluvium may be coarser than it is farther away from the hills.

Well 14, north of Harvard station, is said to have yielded 360 gallons a minute. No information is available in regard to this well except that it is said to be 145 feet deep, with 68 feet to water.

Cause of low yield of wells in eastern part of valley.—It has been assumed generally that the small yields in the eastern part and on the north side of the valley are due to a fault or fold that extends across the valley. If a barrier did exist across the valley, it would seem that its only effect would be to bring the water close to the surface on the upstream side. If a continual supply of water was added to the ground-water reservoir and the permeability of the alluvium was equal in all parts of the valley, the water would percolate over the barrier and would supply wells below the barrier as freely as above it.

A study of the well logs leads to the belief that the low yields are largely due to a difference in the permeability of the alluvium in the western and eastern parts of the valley. This difference is shown by a comparison of the total thickness of gravel, sand, and clay, penetrated below the water level in several wells in the valley, as given in the accompanying table. In this table the wells are arranged approximately in order from west to east. Nos. 64, 9, 66, 54, and 83 are west of the line of the abrupt drop in the water table and the others are east of it, except No. 55, whose position is uncertain. The logs of several of these wells are given on pages 453–457.

Total thickness and percentage of total depth below water level of gravel, sand, and clay in wells in Lower Mohave Valley, Calif.

Well No.	Owner or entryman	Reported yield (gallons per minute)	Total depth below water level (feet)	Total thickness of gravel below water level		Total thickness of sand below water level		Total thickness of clay below water level	
				Feet	Per cent of total depth below water level	Feet	Per cent of total depth below water level	Feet	Per cent of total depth below water level
64	A. Elsholz	810	131	79	60	0	0	52	40
9	Yermo Mutual Water Co	1,125?	398	198	50	60	15	140	35
66	E. Woodridge	900	259	67	26	32	12	160	62
54	Jack Fisher	200?	48	28	58	7	15	13	27
55	B. McCormick	Small.	183	44	24	49	27	90	49
83	M. J. Edwards	200	182	32	18	65	36	85	46
15	Los Angeles & Salt Lake R. R.	28	243	15	6	85	35	143	59
96	E. L. Harlow	175	118	36	30.5	10	8.5	72	61
97	Burden & Lippincott	485	140	10	7	28	20	102	73
118	J. J. Cornwall	(?)	[a] 135	23	17	27	20	135	63
128	J. G. Tienken	200	161	0	0	25	16	136	84
129	L. S. Brehaut	(?)	138	0	0	54	39	84	61

[a] Total depth below 125 feet. Log from surface to 125 feet not known.

Of the wells given in this table all those in the western half of the valley, except Nos. 55 and 83, penetrated gravel equivalent to 25 per cent or more of the total depth of the well below the water level, and in three of the wells the amount was 50 per cent or greater. On the other hand, in the eastern part of the valley only one well (No. 96), contained more than 20 per cent of gravel, in two the gravel was less than 10 per cent, and in two wells no gravel at all was struck. In these wells the percentage of clay was 59 or more. All those in which a large percentage of the total depth was gravel yield large supplies, except well 96. Well 54 seems to be an exception to this statement, but the fact that the drawdown is only 2 feet probably shows that considerably more water could be obtained with a larger pump. With the exception of well 97 none of the wells that contain little gravel and much clay yield very much water. The owners of well 97 state that the present yield was reached only after repeated sand pumping of the well, which formerly sanded up frequently.

Although the logs of the wells in the eastern part of the valley that are given above show few or no gravel beds other logs of wells in the same locality furnished by well drillers show a number of gravel beds. Statements of the drillers, however, indicate that the so-called gravel has few pebbles as large as a quarter of an inch in diameter. If the valley has had the history outlined on page 457 it would be natural for the alluvium to be finer in the eastern part of the valley as a whole than in the western part, where coarser material would be washed in by Mohave River.

The fact that after considerable work a fairly large yield was obtained from well 97 suggests that other wells in the vicinity may be made to produce fair supplies if careful attention is given to their construction. A study of a number of logs of wells in the eastern part of the valley shows that even where "gravel" beds are reported many of them are only 1, 2, or 3 feet thick. In such wells, unless great care is taken in measuring the depth to the gravel and in perforating the casing, an error of a foot or two may result in placing the perforations in a bed of clay or loose sand.

The failure of the perforator to work properly may result in fewer holes than the driller believes he made, and as the gravel beds form so small a proportion of the alluvium the percolating area of the well may be very small. The writer saw several feet of casing that had been removed from a well in the southern part of the valley in which the perforator had made no holes at a number of places. The perforator by chance had been set on the vertical riveted overlap of the stovepipe and had failed to penetrate the double thickness of metal.

There seems to be more difficulty from sanding up of wells in the eastern part of the valley than in the western part. In the western part of the valley the casing is usually perforated only at the gravel beds, as they are thick and yield much water. In the eastern part of the valley, because the gravel beds are thin or absent and the yield generally small, in many wells the casing is perforated in all sandy layers or even for the entire depth of the well below the water table.

The perforations in several wells for which data were obtained are really slits from 1½ to 6 inches long. In one well the slits were three-eighths of an inch wide, but in two others the width is only three-sixteenths of an inch. In two wells the slits are three-sixteenths of an inch wide and 1½ and 3 inches long. In a third well they were said to be three-eighths of an inch wide and 6 inches long. It would seem that with such large perforations a well would sand up rapidly.

It is suggested that the difficulty from sanding up might be avoided to some extent by the use of casing that is perforated before being put in the well, as in Antelope Valley. (See p. 344.) If this type of casing were used more perforations could be made, but they could also be made smaller. In this way some of the coarsest sand might be excluded from the well and left to form a filter which would prevent the finer material from entering the casing. Before sufficient coarse material has gathered around the casing it may be necessary to sand pump the well several times. If casing is used that is perforated before installation in the well it will probably be necessary to use the rotary hydraulic method of drilling in order to prevent the caving of the hole before the casing is put in the well.

In the eastern part of the valley blue clay that is quite impervious has been encountered in several wells. So far as is known, except in well 89, at Newberry station, no well that struck the blue clay passed completely through it, and in the eastern part of Tps. 9 and 10 N., R. 3 E., and the western part of Tps. 9 and 10 N., R. 4 E., there is no information as to the maximum depth to which it reaches. For this reason it is believed inadvisable to drill very far into the blue clay in the parts of the townships just mentioned. Apparently the blue clay pinches out toward the west, so that in the western part of Tps. 9 and 10 N., R. 3 E., it is probably relatively thin.

FLUCTUATIONS OF THE WATER TABLE

Two measurements were made of the depth to water in several wells in the valley, and additional measurements were made of three other wells. These measurements are given in the table below. All the wells except one (No. 88) are in the western part of the valley. All the wells were measured in the fall of 1919, and wells 9, 42, 45, 46, 48, 49, 51, 53, 57, and 58 were measured again late in January, 1920. Wells 5, 10, 42a, 43, 45, 71, and 88 had been measured in the fall of 1917 or the winter of 1918. The measurements in each well were made from a definite reference point.

Fluctuations of water level in wells in Lower Mohave Valley

No. on pl. 24	Date	Depth to water below reference point (feet)	Reference point	Remarks
5	Sept. 17, 1917 Nov. 4, 1919	51.4 56.5	Top of casing 6 inches above cover	
9	do Jan. 22, 1920	23.0 23.0	Top of casing level with surface	
10	Feb. 26, 1918 Nov. 12, 1919	65.0 61.4	Top of casing about level with floor of house.	
42a	Dec. 31, 1917 Dec. 10, 1919	16.2 24.0	Top of curb	A dug well a few feet from well 42 and at about the same altitude.
42	Oct. 23, 1919 Dec. 10, 1919 Jan. 22, 1920	17.7 17.3 18.0	Top of casing in pit 7.1 feet below surface.	Water level 24.8 feet below surface. Altitude of reference point is 1,990 feet above sea level.
43	Dec. 31, 1917 Oct. 23, 1919	15.2 Dry.	Top of curb level with surface	About 10 feet lower than No. 42. Well dry at 22.2 feet.
45	Sept. 13, 1917 Feb. 16, 1918 Oct. 23, 1919 Dec. 10, 1919 Jan. 22, 1920	[a] 55.2 76.2 86.0 86.5 88.5	3 notches on top of east curb, 3.5 feet above surface.	Altitude of reference point is 1,996 feet above sea level. Water rose within 30 feet of surface after flood in January and February, 1916. Pump running.
46	Oct. 24, 1919 Jan. 22, 1920	79.0 86.5	3 notches on curb 3 feet above surface.	Altitude of reference point is 1,995 feet above sea level.
48	Oct. 24, 1919 Jan. 22, 1920	51.0 58.9	Top of casing 0.5 foot above surface	
49	Nov. 6, 1919 Jan. 22, 1920	23.9 24.6	3 notches on southwest corner of pit curb.	
51	Nov. 5, 1919 Jan. 22, 1920	8.3 8.1	3 notches on southeast corner of curb.	
53	Nov. 5, 1919 Jan. 22, 1920	4.0 3.6	3 notches on southwest corner of curb, level with ground.	
57	Oct. 24, 1919 Jan. 22, 1920	51.4 51.5	3 notches on top of cover	
58	Oct. 24, 1919 Jan. 21, 1920	53.5 53.5	Hole in pump base 8 inches below surface.	Depth to water when drilled about 48 feet.
71	Sept. 1, 1917 Oct. 25, 1919	29.9 31.2	Top of casing 1.3 feet above surface	
88	Sept. 2, 1917 Feb. 16, 1918 Nov. 18, 1919 Dec. 10, 1919	1.8 1.1 1.6 1.5	3 notches on top of curb about level with surface.	
105	Sept. 4, 1917 Nov. 19, 1919	41.9 43.0	Top of casing 8 inches above surface	

[a] The accuracy of this measurement is questionable.

Of the seven wells that were measured in 1917 or 1918 and again in 1919, five had the water level 1 foot to several feet lower in 1919; in one it was at nearly the same level, and in the seventh it was about 3.5 feet higher. Three of the wells—Nos. 42, 42a, and 43—are on the Greer ranch, in sec. 18, T. 9 N., R. 1 E., just west of the place where the water table drops abruptly. Well 42a was nearly 8 feet lower on December 10, 1919, than on December 31, 1917. This well is dug only about 30 feet deep, and as it was abandoned in 1919 and a new well (No. 42) drilled near by, the measurement on December

10, 1919, was made only to connect the measurements in well 42 with the measurement made in 1917. The considerable lowering of the water table in this vicinity is confirmed by well 43, which on October 23, 1919, was dry at a depth of 7 feet lower than the water level on December 31, 1917. These wells are within a few hundred feet of the channel of Mohave River and are doubtless greatly affected by any surface flow or underflow in the river. In years when floods pass down the river the water rises in well 43 nearly to the surface. If there is a rock dam across the valley just below these wells, as there seems to be (see p. 474), in 1917 these wells gave some idea of the depth of the ground water moving over the dam.

The water level in the well at the old borax works at Daggett (No. 45) was about 10 feet lower in the fall of 1919 than on February 16, 1918. According to a measurement on September 13, 1917, the water level was then 21 feet higher than on February 16, 1918. This difference is so great that there is some question as to the accuracy of the first measurement. The well is within a few hundred yards of Mohave River, and the water level is affected considerably by any surface flow in the river. It is said that the water level in this well rose to about 30 feet below the surface in the spring of 1916 after a flood in the river that resulted from heavy rains in the mountains in January and February. So far as is known, however, in 1917 there had been no unusual run-off earlier in the year which might have caused the high level in September.

Of the other wells that were measured in 1917 or 1918 and again in 1919, No. 5 was 5.1 feet lower in 1917 than in September, 1919; No. 10 was 3.6 feet higher in November, 1919, than in February, 1918; and No. 88 was at nearly the same level. Well 5 is in the western part of the valley, and the water level in it doubtless fluctuates in general as in the well at Daggett. Well 10 is east of the line where the water table drops abruptly, and it is very close to the low hills that form the east end of the Calico Mountains. The reason for the rise in the water table in this well when in other wells it fell is not known. Well 88 is in the area of shallow water near Newberry station. Apparently the level of the water table in this well is controlled by some subterranean feature a little farther east, and it is not possible for much variation in the water table to occur in this vicinity. In September, 1917, the depth to water in a well on the place of Ethel Patton, in the SW. ¼ sec. 6, T. 9 N., R. 2 E., was reported to be 18 feet. This well was not visited then, but it is probably the same well as No. 49, which was measured November 6, 1919, when the depth to water was nearly 24 feet.

The measurements show that the water table in the western part of the valley was definitely lowered by several feet between the fall of 1917 and the fall of 1919. The precipitation during the winters of 1917–18 and 1918–19 was below normal, and the flow of Mohave River was low. The lowering of the water level in the wells just described is doubtless due to the fact that the recharge from surface flow in the river was not as great as in the previous year or years.

Of the wells that were measured in October or November, 1919, and again in January, 1920, Nos. 45, 46, 48, and 49 were appreciably lower in January, 1920, than in the preceding fall. The others were at the same level or only an inch or two lower or higher. The greatest differences in level were in wells 46 and 48, in which the water level on January 22, 1920, was 7.5 and 7.9 feet, respectively, lower than on October 24, 1919. Well 45 was 2 feet lower, but as the pump was running when the measurement was made the natural level was doubtless a little higher. The normal drawdown of the well, however, is said to be only 3 or 4 inches. Well 49 was only 0.7 foot lower in January than in the preceding November. Wells 5 and 53 were 0.2 and 0.4 foot higher, respectively.

In well 48 the water table dropped 7.9 feet between October 24, 1919, and January 22, 1920, but in well 58, only a mile to the north, the water level was the same on the two dates. This well and wells 45 and 46 are situated just below the narrow part of the river valley above Daggett and within a few miles of the rock dam in sec. 18, T. 9 N., R. 1 E. They are in a favorable position to feel the greatest effect of any notable recharge of the water table by surface flow in the river or of discharge from the water table at a lower place in the basin. Determination of the altitude of the surface at wells 45 and 46 shows that in October the water level was about 6 feet higher in well 46 than in well 45, but on January 22 the water level in the two wells was just about the same. Between the two measurements the water table was lowered toward the east. Perhaps, as in some other regions, the water moves as a wave, and it had not yet reached well 58, or perhaps some other unknown condition held the water table at the same level in that well.

In general it is probable that at the extreme west end of the valley there is a fluctuation of several feet in the water table, both from year to year, due principally to the occurrence or nonoccurrence of floods in Mohave River, and in different parts of the same year. Farther east, where the water table is much flatter, the fluctuation is probably much less. As most of the recharge of the water table in the valley is probably accomplished by absorption from the surface flow of the river between sec. 18, T. 9 N., R. 1 E., and sec. 3, T. 9 N., R. 2 E., observations on the fluctuation of the water level in wells in this area may make possible the approximate determination of the quantity of water available for irrigation.

There is no indication of much lowering of the water table due to pumping, such as has occurred in some of the ground-water basins in southern California. Although the water table in several wells was several feet lower in 1919 than in 1917 this lowering is believed to be due only to the dryness of the intervening years, and the water table will doubtless rise when there is sufficient rain to cause large floods in Mohave River. (See p. 494.)

There is little evidence of interference of wells in the valley. It is said that when the wells of the Yermo Mutual Water Co. were pumped to capacity the yield of the two wells of the Los Angeles & Salt Lake Railroad at Yermo decreased slightly. On the other hand, Tom Williams states that two wells of the Yermo Mutual Water Co. were pumped at the same time without any apparent decrease in the yield of either.

During a test of the Burden & Lippencott well (No. 97) the water level in well 96, about a quarter of a mile to the west, was lowered 3¾ inches in 18 hours. It is said that when well 97 was being pumped continuously during the irrigating season the maximum drop in well 96 was about 9 inches.

SOURCE OF WATER

As shown in Figures 14 and 15, the water table slopes eastward. There does not seem to be any marked slope of the water table from either the Calico Mountains or the mountains south of the valley, as would be expected if there were any great recharge from run-off from these mountains. The drainage area in the Calico Mountains is not great, and the geographic position of the mountains is such that the rainfall is hardly much more than that at Barstow. The area of the mountains south of the valley is greater than that of the Calico Mountains, and the precipitation may be a little greater. However, as elsewhere in the desert, most of the rain comes in small quantities, and only occasionally is there likely to be much absorption from rainfall in these mountains.

Most of the ground-water supply probably comes from Mohave River. As shown by measurements of wells at Daggett, especially well 45, the water table rises considerably when large floods flow down the river, and then the water table falls slowly as the ground-water supply is depleted by discharge in the form of surface flow and underflow at the northeast end of the valley and by transpiration and evaporation at several localities where the water table is close to the surface. The area in which there can be very much recharge must be confined largely to the stretch of the river between sec. 18, T. 9 N., R. 1 E., and sec. 3, T. 9 N., R. 3 E., for that appears to be the only area in which the water table lies far enough below the river channel to permit much percolation. In the eastern part of the valley, south of the river, as shown by springs near Camp Cady, the water table is higher than the river, so that no recharge takes place there.

RECHARGE OF THE GROUND-WATER RESERVOIR

The run-off of Mohave River at the Forks is about 90,000 acre-feet annually. A part of this water is used for irrigation above the Lower Mohave Valley, a part is lost by evaporation and transpiration where the water table is close to the surface, and a part is carried beyond the valley in times of flood.

About 3,000 acres of land is irrigated from the river, of which about 250 acres is near Daggett and the remainder is farther upstream.[55] In addition about 4,000 acres is irrigated from wells in the river bottom and first bench of the east mesa in the Upper Mohave Valley and on lands in the Middle Mohave Valley, where recharge of the water table probably comes by underflow from Mohave River. The total area above Daggett that is irrigated with water from either the surface flow or the underflow of the river is therefore about 7,000 acres. Most of this area is planted to alfalfa, and water is used freely. If the average duty of water were 4 acre-feet a year, the total quantity used in this area would be about 28,000 acre-feet.

It is estimated that there is some discharge from the water table by evaporation or by transpiration from trees or salt grass or other plants for a total of at least 20 miles along the river. If the average width of the discharge area is a quarter of a mile, the total area is 3,200 acres, and an annual discharge of only 1 acre-foot would equal 3,200 acre-feet from the entire area. It is evident that several thousand acre-feet is lost in this way.

From a thousand to several thousand acre-feet probably percolates (see p. 429) annually from Mohave River into Harper Valley. Thus probably 25,000 to 35,000 acre-feet of the water which passes the Forks does not reach the Lower Mohave Valley.

Under present conditions a large part of the remainder is not available for recharge of the Lower Mohave Valley ground-water basin, for in wet years there is generally more or less stream flow from the headwaters to the end of the river. In some years, as in 1916, great floods rush through the Lower Mohave Valley, and although the greatest recharge of the ground-water supply doubtless takes place at such times, most of the flood water is lost to this part of the valley.

Some idea of the quantity that passes through the valley in the floods may be obtained from the following data. In 1916 Silver Lake was covered to a maximum depth of about 10 feet. East Cronise Dry Lake was covered to about the same depth, and some water ran to West Cronise Dry Lake. Much water also stood in Soda Lake. The water came from floods in Mohave River. The area of Silver Lake is estimated to be about 8,000 acres, and that of

[55] McClure, W. F., and others, Report on the utilization of Mojave River for irrigation in Victor Valley, Calif.: California State Dept. Engineering Bull. 5, pp. 28, 49, 53, 1918.

East Cronise Dry Lake about 1,000 acres. If the average depth was 5 feet the volume covering these two playas was 45,000 acre-feet. In addition several thousand acre-feet was spread over Soda Lake and West Cronise Dry Lake and absorbed by the alluvium in Crucero Valley. Both East Cronise Dry Lake and Silver Lake have been flooded since 1916.

The depth to the underground dam in sec. 18, T. 9 N., R. 1 E., is not known, but measurements in wells 42, 42a, and 43 at the end of two dry seasons indicate that it is probably not more than 30 feet below the surface. The area in which there is much underflow probably does not extend a mile across the valley, for rock hills rise a few hundred yards north of the river. Conditions in wells 46 and 47 suggest that the alluvium of the slopes south of the river is cemented and hence does not offer free movement to the ground water. Slichter [56] estimated that at the Upper Narrows the ground water moves 50 feet a day and the valley fill has a porosity of 33⅓ per cent. If the velocity and porosity were the same at this underground dam, and if the depth of ground water moving over the spillway were 15 feet, about 11,000 acre-feet of ground water would annually move beneath the valley west of Daggett. If the water table were to be lowered in a series of dry seasons, for example 8 feet, as happened in well 42a between December, 1917, and December, 1919, the underflow would be reduced to about 5,000 acre-feet.

As shown on page 490, the water level in several wells in the west end of the valley dropped from 1 to 10 feet in the two years from September, 1917, to October, 1919. During this period the rainfall in the headwater region was considerably below normal, and it is said that no flood waters ran down the river as far as Daggett. The underflow into the basin of the lower valley was not sufficient to replace the water that was removed by underflow out of the basin, by evaporation and transpiration, and by use in irrigation. The area in which there was any marked drop of the water level apparently was not more than 15,000 acres. If the average drop was 5 feet and the average porosity of the alluvium was 33⅓ per cent the volume of water lost in the two years was about 25,000 acre-feet.

DISCHARGE FROM THE GROUND-WATER RESERVOIR

Loss from the ground-water reservoir may occur through pumping of water for irrigation or other purposes, through evaporation and transpiration where the water table is close to the surface, and through discharge from the basin either as surface flow or underflow. On the basis of the reported yields of wells which were used for irrigation in the Lower Mohave Valley in 1919, and the assumption of a pumping period of 12 hours a day for six months, it is estimated

[56] Slichter, C. S., Field measurements of the rate of movement of underground waters: U. S. Geol. Survey Water-Supply Paper 140, p. 63, 1905.

that the quantity of water pumped in that year was about 5,000 acre-feet. Some of this water percolates back to the water table, so that the net loss is considerably less.

Losses from the ground-water reservoir by evaporation and transpiration occur over 1,500 acres in two areas in sec. 3, T. 9 N., R. 2 E., and for 4 or 5 miles west of the northwest end of the Cady Mountains. If the annual rate of evaporation in these areas is 1 foot the total discharge is about 1,500 acre-feet. The rate of evaporation may, however, be greater. In the sand-dune belt that reaches northwest from the vicinity of Newberry station there are many small patches of salt grass and mesquite from which there is ground-water discharge. Near Newberry station salt grass covers an area that is estimated to be about 650 acres. In part of this area the water table is not more than 2 feet below the surface, but in other parts it may be as much as 5 feet below. In wet winters water stands at the surface in several places. The rate of evaporation from this area is probably at least 2 feet a year and the total evaporation 1,300 acre-feet a year. The depth to water at the border of Troy Dry Lake is less than 8 feet, and the surface features indicate that there is some discharge from the playa. In addition, clumps of mesquite along its borders, especially west and northwest of the playa, show that there is also some discharge in that area. From these statements it is evident that several thousand acre-feet of ground water is lost annually by evaporation and transpiration.

On November 21, 1919, the flow near Camp Cady was about 2½ second-feet. This flow represents drainage from the ground-water reservoir, for the river was dry farther upstream. If this rate were maintained the discharge of ground water by seepage would be about 1,800 acre-feet a year. As 1919 was a dry year, the discharge is doubtless larger in some years.

According to the above estimates the average loss from the ground-water reservoir may be between 10,000 and 20,000 acre-feet a year. A considerable part of this water can be recovered through wells for irrigation, for if the water table is lowered by pumping the losses by evaporation, transpiration, and seepage will be reduced.

The data are so inadequate that no prediction can be made as to how much land can be irrigated with ground water in the Lower Mohave Valley, but certainly there is not nearly enough water for all the arable land.

Because wells in the western part of the valley yield larger supplies than those in the eastern part, the development of the western part will be more feasible. It is doubtful whether the eastern part can be irrigated advantageously except by carrying water to it from the western part, which would require canals and these would add to the expense of the project. The area west of the sand-dune belt, which marks the approximate eastern limit of the territory in which large yields are found, is about 30,000 acres. It is therefore probable that if the western part of the valley is chiefly developed most if not all of the available supply can be used west of the dune belt.

EFFECT OF DEVELOPMENT IN OTHER PARTS OF THE VALLEY

The statements made above in regard to available quantity are based on present conditions in the Mohave River basin. Future developments farther upstream may cause a considerable change in conditions in the lower valley. If part of the headwater flow of Mohave River were diverted to the south side of the San Bernardino and San Gabriel Mountains for municipal use, the portion of the flow of Mohave River available for recharge of the ground-water basin would be proportionately decreased, and indeed only in exceptionally wet years, when the reservoirs were filled to overflowing, would there be any discharge down the valley.

If the headwater flow is ever stored in the San Bernardino Mountains and used in the Upper Mohave Valley, conditions would also probably be unfavorable for the lower valley. In the report of the Mohave River Commission it is stated that about two-thirds of the average annual flow of the river is available for storage in the mountains and that one-third should be allowed for riparian lands along the river. Practically all the riparian lands for which water is allowed lie above Daggett, so that the entire flow of the river would be used above that point.

In many regions where irrigation is practiced there is considerable return flow to streams from the water used in irrigation. If the water were used sparingly in the upper valley, however, it is questionable whether very much water would reach the lower valley, either as surface flow or as underflow. If the return flow were considerable, it is possible, on the other hand, that use of water in the upper part of the basin might have a beneficial effect on the ground-water supply in the lower valley; for a large quantity of water that now passes out of the basin in floods would be stored, and the flow would be more regular. The geologic conditions in the basin are so complicated, however, that the results of irrigation on a large scale in the upper part of the valley can not be foretold.

SPRINGS

Springs in the mountains.—An unnamed spring is shown on township plats of the General Land Office in the NW. ¼ sec. 10, T. 8 N., R. 2 E. It is reached by a road from Minneola. Another spring, known as Kane Spring, emerges in the SE. ¼ sec. 31, T. 8 N., R. 3 E. This spring may be reached by a road that branches southward from the National Old Trails road about 2½ miles southeast of Newberry

Spring. It is said that automobiles can not reach it by this road because of the heavy grade, but a passable road leads to it from the north end of Ord Mountain. No definite information is available in regard to either of these springs.

Springs along Mohave River.—Springs rise at several places on the flood plain of Mohave River in sec. 3, T. 9 N., R. 2 E., and also in a stretch that extends for several miles west of the northwest end of the Cady Mountains. In many places the underflow of the river is brought to the surface by underlying impervious beds or by bedrock barriers beneath the channel. However, in sec. 30, T. 10 N., R. 4 E., at Old Camp Cady there are many water seeps from the cliff below the second terrace, at a height about 10 feet above the river channel. The water apparently comes from beds that lie beneath the plain to the south and not directly from the river underflow. As shown by the analysis (p. 501), the water from these springs is of good quality and contains only 274 parts per million of total solids. The water is of the same general character as most of the other samples that were collected in the valley, and only two other samples contained less total solids. The springs are not used.

Newberry Spring.—The most valuable spring in the region is Newberry Spring, in the NW. ¼ sec. 32, T. 9 N., R. 3 E., a few hundred yards south of Newberry station. The spring is owned by the Atchison, Topeka & Santa Fe Railway. It emerges within a few feet of the eastern base of a low hill of Tertiary volcanic rock that forms the extreme northeast point of Newberry Mountain. The spring, however, appears to issue from the alluvium at the edge of an area at the base of Newberry Mountain extending northward for about a mile and east and west for about 2 miles, in which the water table is close to the surface. Salt grass is abundant around the spring, and several large mesquite grow near it. This area apparently is a continuation of a belt extending northwestward across the valley in which the water is near the surface. The reason for the occurrence of water so close to the surface has not yet been determined.

The spring is inclosed by a substantial covered masonry reservoir 32 feet in diameter and 9 feet deep. From the reservoir a pipe line leads to the railroad pumping station. It is estimated that between 300,000 and 500,000 gallons a day (between 280 and 350 gallons a minute) is pumped from the spring. The average daily pumpage at the station during 1919 was about 490,000 gallons, but some of this water was pumped from a well.

As shown by the analysis on page 501, the mineral content of the water is 290 parts per million of total solids. It is good for both domestic use and irrigation, but only fair for boilers because it contains a considerable quantity of scale-forming and foaming constituents. The water is a sodium carbonate water, very similar in character to most of the other samples analyzed from the Lower Mohave Valley. A partial analysis of a sample by the Atchison, Topeka & Santa Fe Railway Co. some years ago gives 324 parts per million of total solids.[57]

The water from the spring is warm, and the temperature is apparently constant, for three determinations at intervals of a year or more differ by only half a degree. On November 28, 1917, the writer determined the temperature as 77° F. and again on November 18, 1919, as 77½°. Waring records the temperature as 77°. This temperature is several degrees above that of water from a number of wells in the valley but is about the same as that in a well (No. 88) half a mile west of the spring. (See p. 130.) This higher temperature may be due to the presence of the Tertiary volcanic rocks, which may not have completely cooled, or the heat may have been derived from Quaternary basalts that lie several miles southeast of the spring. The fact that the temperature is slightly above the normal for wells in the valley suggests that the water may come, in part at least, from a different source than the general ground-water body, perhaps from the Tertiary rocks of Newberry Mountain.

The railroad has been unable to obtain any satisfactory supply between Newberry station and Siam, 84 miles farther east. Water for all railroad use on this stretch, including domestic and locomotive use, is hauled from Newberry station, and a large part of it is obtained from Newberry Spring. From 30 to 40 tank cars, each holding 10,500 gallons, are shipped daily to supply the needs of the railroad. In 1919 a total of more than 128,000,000 gallons was hauled from this station.

Sweetwater Spring.—The Sweetwater Spring is on the north side of Ord Mountain, about 14 miles south of Daggett, probably in sec. 13, T. 7 N., R. 1 E. It is reached by a road that ascends a large wash south of Daggett. About 9 miles south of Daggett the road forks, and the road to the spring is the right-hand branch. At a crossroad about 3 miles beyond it continues due south up a canyon, which contains buildings of a mine camp 0.7 mile from the crossroad. The spring is in a side canyon about 1,000 feet southeast of the camp and about 100 feet above it. It can be found by following a pipe line that leads to it from a water tank near the camp buildings. The spring is really a well dug in rock, about 4 feet square, with a depth of 7 feet to the water. The hole was tightly screened when visited, and the depth could not be measured. The water is apparently siphoned out of the hole by the pipe mentioned above. Water could not be obtained at the spring, but there was water in the pipe at a valve near the tank. A sample of water taken from the pipe proved to be

[57] Waring, G. A., Springs of California: U. S. Geol. Survey Water-Supply Paper 338, p. 317, 1915.

of good quality for domestic use. (See analysis, p. 501.) It is said that the spring can furnish about 5,000 gallons a week.

Aztec Spring and Willis Well.—At the crossroad about 0.7 mile north of the mine camp near Sweetwater Spring, described above, a road leads eastward. Aztec Spring is reported to be south of this road at a point about a mile east of the crossroad, near a mill. It is said to derive its name from hieroglyphics on the rocks near by. About 6 miles southeast of the crossroad there is a well known as Willis Well. No information is available in regard to either of these watering places. It is reported that a road leading to them also leads to Old Woman Spring and Lucerne Valley. On some old maps a spring known as Le Conte Spring is shown near this road on the southeast side of Ord Mountain. Prospectors who are familiar with the region say that they know of no such spring.

QUALITY OF WATER

Samples of water were collected by the writer from 13 wells and 2 springs in the Lower Mohave Valley and analyzed by the United States Geological Survey, and one sample was collected by G. A. Waring and analyzed by S. C. Dinsmore for the Geological Survey. In addition the analyses of water from wells of the Los Angeles & Salt Lake Railroad Co. were furnished by that company, and analyses of water from two wells of the Tabitha Taylor estate were furnished by the owners. These analyses were given in the form of hypothetical combinations and have been recomputed to parts per million. The results of all these analyses are given in the accompanying table.

The total dissolved mineral matter in the samples analyzed ranges from 238 to 2,791 parts per million. However, the mineral content of most of the samples is very moderate, for out of a total of 20 samples 15 contain less than 500 parts per million, and 6 of the 15 contain less than 300 parts per million.

Of the 15 samples that contain less than 500 parts per million of total dissolved solids all but two are sodium carbonate waters. These two samples, from wells 64 and 144, are calcium carbonate waters. However, these two samples are essentially similar to the others, for a small decrease in the sodium would be sufficient to put them into the calcium carbonate class. The 15 samples are all classed as good for domestic use, and several of them are very good. For irrigation five of the samples, from wells 36 and 37, 64, 83, and 144 and Newberry Spring, may be classed as good, and the others are fair. Most of the samples are only fair for boilers, and two of them, from wells 45 and 140, are rated as bad. The relatively poorer quality as regards use in boilers is due to the high content of scale-forming constituents and especially of foaming constituents. The tendency for the waters to corrode boilers is slight.

Analyses of ground waters in Lower Mohave Valley

[Parts per million]

No. on pl. 24 and in table on pages 464-471	Owner or name of well or spring	Date of collection	Total dissolved solids at 180° C.	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K) (calculated)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)
4	J. A. Fults	Sept. 17, 1917	358	57	0.08	31	7.9	76	0	206	52	36	0.25	110
[a] 15	Harvard well of Los Angeles & Salt Lake R. R. Co.	Nov. 27, 1915	[b] 322	[c] 16		16	1.6	100	0	164	56	51		47
[a] 36, 37	Yermo wells, Los Angeles & Salt Lake R. R. Co.	Oct. 22, 1915	[b] 293	[c] 18		40	6.6	58	0	191	28	48		127
45	Town of Daggett	Sept. 13, 1917	450	79	.04	28	9.5	[d] 108	39	132	86	46	1.1	109
53	C. E. Johnson	Nov. 5, 1919	353	32	.72	43	7.4	68	0	246	38	32	Tr.	138
60	E. D. Barry	Sept. 1, 1917	379	94	.05	14	7.5	86	17	153	53	30	.83	66
64	Annie Elsholz	Oct. 28, 1919	238	26	.17	30	7.1	40	0	177	24	14	1.0	104
69	F. H. Webber [e]	Aug. 20, 1916	1,598	47	Tr.	167	9.0	370	0	207	403	453	4.0	454
[f] 75	Tabitha Taylor estate	July 15, 1919	[b] 320	49	Tr.	26	3.9	61	0	161	38	30		81
[f] 76	do	do	[b] 961		Tr.	112	17	177	0	183	220	252		350
83	Mattie J. Edwards	Oct. 30, 1919	240	32	.67	28	3.8	48	0	178	20	16	.45	86
88	L. W. Page	Sept. 2, 1917	359	101	.04	22	6.9	72	26	139	44	26	.22	83
98	J. W. Burden	Nov. 22, 1919	1,928	26	2.9	398	39	[d] 196	0	170	389	728	2.6	1,150
104	Schoolhouse, 3 miles north of Newberry	Sept. 4, 1917	340	50	.54	17	4.4	[d] 95	25	181	34	28	.44	60
125	H. L. Mellon	Nov. 20, 1919	2,791	33	.21	428	27	502	0	160	713	990	.68	1,180
140	C. L. Loman	Nov. 28, 1917	391	56	.03	26	1.1	[d] 96	0	184	76	45	1.5	70
144	B. E. Funk	Oct. 26, 1919	283	29	.08	37	6.8	50	0	187	41	23	1.0	120
149	C. A. Leak	Oct. 23, 1919	1,094	31	.96	28	4.8	303	3.4	158	371	160	1.5	90
([g])	Camp Cady Spring	Sept. 4, 1917	274	60	.09	19	3.7	62	19	117	32	25	.44	63
([g])	Newberry Spring	Nov. 28, 1917	290	54	.05	25	4.9	62	0	163	40	30	.38	83
([h])	Sweetwater Spring	Feb. 23, 1918	360	33	.04	41	21	56	0	172	58	59	6.2	189

[a] Analyses furnished by Los Angeles & Salt Lake R. R. Co.; recalculated from hypothetical combinations in grains per United States gallon.
[b] Calculated.
[c] Includes silica (SiO_2), iron oxide (Fe_2O_3), and aluminum oxide (Al_2O_3).
[d] Determined.
[e] Collected by G. A. Waring.
[f] Analysis furnished by owner; recalculated from hypothetical combinations in grains per United States gallon.
[g] See description, p. 498.
[h] See description, p. 499.

Analysts: 4, C. H. Kidwell; 15, 36, 37, Los Angeles & Salt Lake R. R.; 45, 88, 104, Camp Cady Spring, Addie T. Geiger; 53, 64, 83, 98, 125, 144, 149, Margaret D. Foster; 60, Newberry Spring, A. A. Chambers; 69, S. C. Dinsmore; 75, 76, E. H. Miller; 140, Addie T. Geiger and C. H. Kidwell; Sweetwater Spring, C. H. Kidwell and Margaret D. Foster.

Of the five samples in which the mineral content is high all but one came from wells less than 60 feet deep. These wells are located in parts of the valley where there are other wells that have furnished samples whose analyses indicate that water of better quality can probably be obtained from deeper beds. For example, the sample from a well on the Taylor ranch (No. 76), which is only 55 feet deep, contains 961 parts per million of total solids and is a sodium chloride water, whereas a sample from a 300-foot well (No. 75), a few hundred feet away, contains only 320 parts per million and is a sodium carbonate water.

The sample from the Webber well containes 1,598 parts per million of total solids and is a sodium chloride water. When the sample was taken the well was only 42 feet deep, but it was subsequently deepened to 174 feet. It is not known whether better water was struck, but it is reasonable to suppose that good water could be obtained at a greater depth, as water containing less than 400 parts per million has been obtained from dug wells at the Taylor ranch, only a mile to the east, and at the Barry ranch, about 2 miles to the west.

The sample from the Burden well (No. 98), which is 50 feet deep, contains 1,928 parts per million of total solids and is a calcium chloride water. The sample from the 75-foot well at the schoolhouse (No. 104), about a mile to the southwest, contains only 340 parts per million of total solids and is a sodium carbonate water. The water from a 170-foot well on the Burden ranch is said to be of much better quality than that from the 50-foot well.

The sample from the Mellon well (No. 125) is the most highly mineralized water analyzed from the valley. It contains 2,791 parts of total solids and is a calcium chloride water. The cause for this high mineralization is not known, and it is not certain that water of better quality could be obtained from a deeper well at this place. This well is about 2 miles from the alkali-covered north arm of Troy Dry Lake, and the poor quality may result from conditions related to the accumulation of the playa deposits. There seems to be no reason why there should not be some movement of ground water from the playa toward Mohave River, at Camp Cady. However, the fact that the sample from the springs at Camp Cady contains only 274 parts per million of total solids is believed to show that if there is such movement the water is generally of better quality than that in the Mellon well.

It is said that in several shallow wells in the eastern part of the valley, notably in wells 98 and 125, the quality of the water has become poorer with use. The reason for this condition is not known. It is possible that salts deposited by the evaporation of water at the surface are washed into the wells. This condition might occur, especially where large quantities of water are applied in irrigation. Sufficient analyses are not available from shallow wells in different parts of the valley to show whether the highly mineralized waters are of local extent or whether they occur at shallow depths throughout the valley.

A sample from the well of C. A. Leak (No. 149) contains 1,004 parts per million of total solids. This water is different from any of the other samples analyzed from the Lower Mohave Valley in that it is a sodium sulphate water. It is more nearly like the water from the wells of the Atchison, Topeka & Santa Fe Railway Co. at Barstow. The railroad well and the Leak well are near the foot of hills of alluvium that rise southward. As there are known to be Tertiary or Pleistocene lake or playa beds in these hills, it is possible that the poor quality of the water is due to water moving from the hills and not from the underflow of the river. If such is the case it is not likely that water of better quality could be obtained by drilling deeper.

In summarizing, it may be said that in general water of good quality for domestic use and of fair enough quality for irrigation or for use in boilers can be obtained nearly everywhere in the valley where conditions are suitable for irrigation. Although water of poor quality is obtained in several wells the indications are that water of better quality can be obtained from deeper beds.

The similarity in character of most of the waters analyzed suggests that they have a common origin. The principal source of the ground water is probably the surface flow and underflow of Mohave River. However, the fact that there is no regular change in the character of the water from one part of the valley to another raises a question as to the cause of such differences as are manifest. Thus, the total solids in the sample from the wells at the head of Daggett ditch (No. 144), several miles west of Daggett, is 283 parts per million. This sample came from the underflow of Mohave River, and if the water in the main part of the valley came from the river the samples from other parts of the valley would probably be as highly mineralized. Also, in general, it would be expected that the farther the water moved from its ultimate source the more mineralized it would become, so that samples from wells in the eastern part of the valley might be more highly mineralized. This increase in mineral content, however, does not occur, for three samples, from wells 64 and 82 and Camp Cady Spring, have lower mineral content than the sample from the Daggett ditch. The springs at Camp Cady are farther from the area of ground-water recharge than most of the other places where samples were taken, and it would be expected that the water would be considerably more mineralized. The springs are so high above the river that the water can not have traveled the short distance from the river, nor has it probably come from the near-by Cady Mountains. The most reasonable explanation is that, as has been shown by analyses of the surface flow of the river, the quality of water that enters the gravel changes from time to time and that the water from a given well may also be expected to change as the ground water moves eastward.

TEMPERATURE OF WATER

The temperature of the water from a number of wells and from Newberry Spring was determined by the writer, and the results are given in the table (p. 130). The observed temperature of the water in most of the wells ranged between 69½° and 72½° F. The temperature of the water from two wells and Newberry Spring, however, ranged between 77° and 80°, and in one well it was 74°.

The mean annual temperature at Barstow is about 63.7°, and the mean annual temperature in the Lower Mohave Valley is probably not more than a degree or two higher. The temperature of the water from all the wells observed is thus several degrees higher than the mean annual temperature of the region. The temperature of the water from Newberry Spring and from two wells of L. W. Page, about half a mile west of the spring, is so much higher that apparently they are affected by some local condition.

IRRIGATION

General features.—According to data collected by the writer about 750 acres was irrigated during the summer of 1919. At several ranches in the late fall of that year additional acreage was being prepared, and in 1920 the area irrigated was probably at least 1,000 acres. Of the irrigated land all except about 100 or 150 acres lay in the western part of the valley. About 65 acres of the irrigated area in the eastern part was in sec. 12, T. 8 N., R. 3 E., and secs. 7 and 18, T. 8 N., R. 4 E., where it is not definitely known whether the buried barrier affects the ground-water level. Only about 50 acres was in the area that is definitely known to be affected by the barrier, where the yield of wells is generally much smaller than west of it. All the irrigated crop was alfalfa, except about 50 acres in fruit and a few acres in vegetables or grain. Several ranchers were planning to experiment with cotton, but none had been grown in 1919. D. W. Edwards has experimented in growing rice on some of the small clay flats between the sand dunes in sec. 19, T. 9 N., R. 3 E., but it is doubtful whether conditions are suitable for this crop.

Ranchers report yields of alfalfa ranging between 5 and 9 tons to the acre. F. S. Van Dyke, whose ranch is a mile east of Daggett, reports that in hot years he gets from 7 to 9 tons to the acre and in cool years from 5 to 7 tons to the acre. The crop is cut from four to seven times a season, according to whether it is to be used for feeding horses or for dairy feed.

At all except two or three ranches the water for irrigation is obtained from wells. A very small acreage is irrigated at the McCormick ranch, in sec. 3, T. 9 N., R. 2 E., by the flow from several ponds or sloughs on the flood plain north of the river, where the water comes to the surface. In secs. 14, 22, and 23, on the ranches of T. S. Van Dyke and Buel Funk, about 200 acres is irrigated with water brought by canal from a submerged dam across Mohave River in sec. 11, T. 9 N., R. 1 W. Originally the water was obtained entirely from the seepage collected by a tunnel above the submerged dam, but in the fall of 1919 the supply was augmented by drilling several wells, from which the water flowed into the tunnel. (See p. 506.)

Daggett ditch.—Two projects for the irrigation of large areas have been undertaken in the Lower Mohave Valley, but neither of them has met with the expected success. The older project originated during the period when so many other ill-founded land-colonization schemes were started.

About 1890 it was proposed to carry water from the underflow of Mohave River to the mines and mills of the Calico mining district, but this scheme was not carried very far because of financial difficulties. In 1892 or 1893 the Southern California Improvement Co. was organized to develop water for generating electric power for the Calico mines and mills, and the water was afterward to be used for irrigation.[58] A submerged dam was planned to be constructed across Mohave River about 4 miles west of Daggett, which would allow the recovery of the underflow. Thence the water was to be conducted by canal to a point near the corner of secs. 28, 29, 32, and 33, T. 9 N., R. 2 E., about half a mile southwest of Minneola. At this place power was to be generated by a fall that is said to be 70 to 100 feet. The water was then to be used for irrigation north and east of Minneola. Extravagant claims were made as to the quantity of water that would be developed. At least 2,000 miner's inches (40 second-feet) was expected to be obtained. An advertising prospectus is said to have predicted a flow of 15,000 inches (300 second-feet), and other estimates were as high as 20,000 to 30,000 inches (400 to 600 second-feet). It is also said that on the strength of these absurd statements land was sold for a distance of 10 miles north of the Atchison, Topeka & Santa Fe Railway, even north of Mohave River.

Work on the submerged dam, collecting tunnel, and ditch was carried on for several years. The dam and tunnel were completed only about halfway across the river, but the ditch was completed as far as Minneola, and water ran that far for several years. It is said that the maximum flow from the tunnel was not more than 10 second-feet (500 miner's inches). About 1898 the company went bankrupt,

[58] See Lippincott, J. B., Water supply of San Bernardino Valley: U. S. Geol. Survey Nineteenth Ann. Rept., pt. 4, pp. 629-632, 1898. The facts given here are based also on statements by T. S. Van Dyke and Buel Funk, the present owners of the water rights and canals of the company, and notes in California Dept. Eng. Bull. 5.

probably owing largely to the failure to obtain as much water as was expected. T. S. Van Dyke states that the company spent $200,000 on the project.

In 1901 four persons bought the water rights of the old company and undertook the further development of the water. The canal east of sec. 23 was abandoned, and the water is now used for irrigation in secs. 22, 23, and 14. Most of the water is used on the Daggett ranch, and the ditch is known as the Daggett ditch. At present the rights are held by the owners of two ranches.

After the bankruptcy of the Southern California Improvement Co. the tunnels fell into disrepair, and the yield gradually decreased. The flow in 1913 is said to have been only about 1½ second-feet. In 1914–15 the tunnels were relined, and in 1915–16 a concrete conduit 3½ miles long was substituted for the open ditch. The flood of 1916 caused the tunnel to be silted up so that the yield decreased very greatly. In 1919–20 further improvements were made, as described below. The successors of the Southern California Improvement Co. have spent fully $75,000 on the system. The water has been sufficient to irrigate not more than about 250 acres.

In 1919 the system consisted of 3⅓ miles of concrete conduit, extending from a point about 400 feet south of the quarter corner between secs. 11 and 12, T. 9 N., R. 1 W., to the Daggett ranch; 1,720 feet of tunnel lined with redwood, extending from the head of the cement conduit to the head tunnel; and 587 feet of head tunnel lined with redwood. The 1,720-foot tunnel is 4 by 6 feet in cross section, and the top and sides are lined with heavy redwood planks, but the bottom is open. The head tunnel is 3 feet by 5 feet 3 inches in diameter. It is lined on all sides, but the bottom lining is loose.

The head tunnel extends from a point in the west-central part of the NE. ¼ sec. 11, T. 9 N., R. 1 W., about the middle of the river channel, in a direction approximately S. 35° W., to a point within about 100 feet of the slight cliff that marks the lower end of the alluvial slope. The submerged dam is about 3 feet downstream from the tunnel. It is built of heavy planks fastened together to form a thickness of about 1 foot. The dam reaches from 25 to 36 feet below the top of the tunnel but does not extend above it. The piling of the dam, as originally constructed, did not reach bedrock but was driven only a foot or two into a clay bed, which was assumed to be a residual soil that had resulted from the weathering of the bedrock, and the rock was believed to be only a few feet below.[59] As far as could be learned, this is the condition of the dam at present. The dam, which has a total length of 700 feet, originally reached the 10-foot cliff on the south side of the river channel, but in a subsequent flood the channel was widened about 75 feet beyond

[59] Lippincott, J. B., op. cit., p. 629.

the end of the dam. The dam thus extends only about halfway across the channel and is open at both ends.

In the fall of 1919 six wells were drilled in the head tunnel at intervals of 50 feet for the purpose of increasing the flow, and it was planned to drill two more. The wells range in depth from 66 to 100 feet. During drilling the water stood in the wells about 7 feet from the surface, but the casings were cut off about 14 feet below the surface so that the water flows into the tunnel. All the wells but one were perforated for their entire length. One was perforated only from 60 feet to the bottom at a depth of 100 feet. It is said that the water was under most pressure near the south side of the tunnel, which may be due to a movement of water from the alluvial slope toward the river.

A current-meter measurement of the flow in the tunnel, made by the writer on October 23, 1919, gave 4.06 second-feet (about 600 gallons a minute or 68 miner's inches). As this year was drier than normal and the water table in a number of wells was several feet lower than usual, it is probable that in normal years the flow would be greater.

As the submerged dam extends only part way across the river channel it hardly has more than a slight effect in bringing the underflow closer to the surface. The condition is analogous to that of a board placed partly across a stream or ditch with the water flowing freely around each end. The main advantage of the system is that the tunnel affords a means of collecting the water.

Instrumental leveling on October 26, 1919, showed that the water stood 5 feet lower in the tunnel than the water table in an old dug well about 500 feet downstream. As this well was on the river bottom but within a few feet of the edge of the channel, the dam probably does not hinder the movement of the water downstream. The level of the water table in the tunnel was doubtless lower because the tunnel offers freer passage to the water, and a zone parallel to the tunnel was easily drained.

If the submerged dam were completed entirely across the river channel it would probably raise the water table on the upstream side more than at present and increase the discharge of the tunnel. However, the porous alluvium extends several thousand feet south of the river, and a complete damming of the underflow is hardly practicable. It is very doubtful whether sufficient water could be obtained to irrigate any large area.

Yermo Mutual Water Co.—The second project contemplated the use of the surface flow and underflow of the river where it comes to the surface in sec. 3, T. 9 N., R. 2 E., supplemented by wells on the plain north of the river. The land to be irrigated lies east of sec. 32, T. 10 N., R. 2 E., extending as far as Harvard.

The project was begun in 1910 with the incorporation of the Mojave River Land & Water Co., with a capitalization of $500,000. This company proposed to irrigate from 20,000 to 40,000 acres in Tps. 9, 10, and 11 N., Rs. 2, 3, and 4 E. The company drilled several wells and constructed several miles of concrete canals. The company became involved in financial difficulties. It was reorganized and incorporated in January, 1917, as the Yermo Mutual Water Co., with a capitalization of $160,000. A large number of the stockholders of the new company were creditors of the old company. The new company has reduced greatly the area included within the project and plans to irrigate only about 8,000 acres.

Since its reorganization the company has made slight progress. Apparently very little construction work has been done. At one time or another about 200 acres have been irrigated, but when the writer was in the valley in the fall of 1919 there was no indication that any crops had been irrigated the preceding summer, and all but one of the company's pumping plants had been dismantled.

The failure of the new company to make greater progress was due in part to its inability to meet certain requirements of the United States General Land Office before expenditure for stock in the company can be accepted as annual expenditures required in proof by desert-land entrymen. Because of this difficulty homesteaders have had no incentive to settle on the land with the expectation of obtaining water from the company. It is understood, however, that this difficulty has been overcome by amendment of the articles of incorporation.

In 1917 the works consisted of five drilled wells and several miles of cement canals. The completed distribution system consisted of 3 miles of canal that had an estimated capacity of 26 second-feet (1,300 inches), 3 miles that had a capacity of 66 second-feet (3,300 inches), and 6 miles that had a capacity of 4 second-feet (200 inches). The total cost of the constructed works has been probably at least $50,000 to $75,000. One of the wells is 12 inches in diameter and the others are 16 inches, and they are between 400 and 450 feet deep. (See wells 7, 8, 9, 50, and 142 in table on pp. 464–471.) In wells 7, 8, 9, and 50 the depth to water in the fall of 1919 was between 16 feet, in the easternmost well, and 30 feet. These wells are apparently above the line along which the water table drops abruptly. In well 142 the depth to water is about 45 feet, and this well is probably below the line where the water table drops. Two of the wells in tests have yielded about 2½ second-feet each. The depth to water when this quantity is being pumped is between 50 and 75 feet. So far as the writer knows, the others have not been tested. It is likely that all the wells above the line of drop in the water table may yield at least 2 second-feet if not more, but in view of the results in other wells there is some question whether the yield of well 142 will be large. It is said that two of the wells have been pumped together without appreciable effect on each other. So far as is known, there have been no tests of long duration to show the effect of pumping all the wells at the same time. As three of the wells, in sec. 32, T. 10 N., R. 2 E., are spaced at intervals of less than 600 feet, it seems desirable to make such tests.

The company owns land along Mohave River in sec. 3, T. 9 N., R. 2 E., where water is at or close to the surface throughout the year, and it plans to obtain an additional supply either by diverting the surface flow in the river when feasible or by pumping from wells near or in the river bed. As late as 1919 no work had been done on this part of the project.

The project of the Yermo Mutual Water Co. is commendable in that it contemplates carrying water to land situated where, because of unfavorable geologic conditions, sufficient water can not be obtained for irrigation from wells. However, it is very unlikely that there is enough water to irrigate all the land in the valley, and it seems much more economical to use the water on lands in the western part of the valley, where long distribution canals are not necessary.

CAVE CANYON

GENERAL FEATURES

The Mohave River Valley between Manix Wash and Baxter, in sec. 13, T. 11 N., R. 6 E., has been observed by the writer only from trains of the Los Angeles & Salt Lake Railroad. A wagon road formerly led down the river channel, but since automobiles have come into common use it is little traveled. It is now generally necessary for each traveler to make his own tracks. Automobiles have made the trip, but the route is generally used only occasionally by persons who are taking horses and wagons into Crucero Valley or Cronise Valley. East of Baxter travel in automobiles is difficult if not impossible, because of heavy sand. Water is obtainable at the railroad well at Afton and generally from the section crew at Field and also at Baxter if the limestone quarry at that place is in operation.

The Mohave Valley between Manix and Baxter is uninhabited, except for railroad workers at Field and Afton stations. Iron-ore deposits are reported, but these have not been worked on a commercial scale.[60] In December, 1919, preparations were being made to mine paint ore from deposits on the south side of Mohave River near Afton.

[60] Leith, C. K., Iron ores of the western United States and British Columbia: U. S. Geol. Survey Bull. 285, p. 198 ,1905.

PHYSICAL FEATURES AND GEOLOGY

On the north side of the river east of Manix Wash a long slope rises northeastward somewhat gradually for several miles to a ridge that reaches southward from mountains on the north. South of the river a similar slope rises to the base of the Cady Mountains, but its continuity is broken by tongues of the mountains that reach down toward the river. Mohave River has cut from 50 to 100 feet below the lowest parts of these slopes. For 2 or 3 miles below the entrance of Manix Wash well-developed terraces are seen on the south side of the river, but none were observed on the north side of the river. (See pl. 27, *B*.) Where the ridge that extends from the mountains on the north, mentioned above, approaches the river, the immediate valley narrows. From a distance the narrowing seems to be due to the presence of bedrock, which apparently underlies the ridge, although away from the river the ridge appears to be an alluvial fan. The terraces west of the ridge are probably due to the effect of bedrock in establishing a local base there, perhaps in conjunction with some variation in the flow of the river due to climatic changes. As the river valley immediately below the ridge was not seen, the exact cause of the terraces could not be determined.

Between Camp Cady and the narrows south of Field the greenish Manix lake beds are visible in the cliffs along the river. They do not appear at the surface except in short ravines that are being cut back from the river. However, the lake beds are covered by only a relatively thin layer of later alluvium. A mile or two east of Field the Los Angeles & Salt Lake Railroad descends into the canyon of Mohave River, which is known as Cave Canyon. For several miles the canyon cuts only alluvium. The greenish lake beds continue for some distance but gradually thin out and are overlain by a buff conglomerate or fanglomerate. About a mile east of Dunn and a mile or more south of the railroad about 100 feet of the buff beds overlie the greenish lake beds, which are horizontal and not very thick. South of Afton station greenish beds about 10 or 15 feet thick lie on top of the buff beds. East of Afton the greenish beds are almost entirely lacking, and those present are badly faulted. In place of the greenish beds are red and buff coarse conglomerates. In one place as much as 300 feet of these beds are estimated to be exposed. In some places these beds are exposed in almost vertical cliffs or in high-pinnacled erosion columns. These features with the varicolored aspect of the beds present a striking stretch of scenery.

Near Baxter the lower end of the canyon cuts through badly contorted metamorphic rocks. From the railroad the contortions may be clearly seen in a marble quarry a few hundred yards north of Baxter station. At Baxter the canyon ends and the river passes into a large plain which constitutes Crucero Valley and which is described on pages 512–536.

The lake beds and coarser alluvium through which Cave Canyon is cut for most of its length are all probably of Pleistocene age or younger. The present canyon appears to follow an older valley between the Cady Mountains on the south and the Cave or Afton Mountains on the north. It is not known whether this valley extended to Crucero Valley, so that the ancient Mohave River reached Soda Lake prior to the deposition of the Manix lake beds. If it did, the drainage was dammed in some way and a lake formed in which the Manix lake beds were deposited. The damming may have been the result of folding or faulting either of the older bedrock or of the unconsolidated alluvium, but the great thickness of conglomerate near the east end of the canyon suggests that it may have been accomplished by the building of one or more great alluvial fans across the valley.

Before the cutting of the present canyon and the accompanying great dissection of the Pleistocene alluvium this part of the drainage basins appears to have been a broad valley with gentle slopes, much like the Lower Mohave Valley or the Upper Mohave Valley.

As shown by the following log a well of the Los Angeles & Salt Lake Railroad at Afton penetrated alluvium to a depth of 423 feet:

Log of well of Los Angeles & Salt Lake Railroad Co. at Afton

[Drilled June to August, 1904]

	Thickness (feet)	Depth (feet)
Sand and boulders	63	63
Cemented gravel	305	368
Sand	17	385
Gravel	14	399
Sand	24	423
Rock	6	429

According to altitudes determined by the railroad the bottom of the alluvium in this well is nearly 200 feet below the present level of the river, where it emerges from the canyon at Baxter. It is hardly possible that the great thickness of alluvium in the well represents filling since the drainage of Manix Lake, but it leads further to the belief that a valley of pre-Manix age extended through the region to Crucero Valley. More detailed studies of the canyon undoubtedly will throw much light on the Pleistocene history of the Mohave River Valley.

WATER RESOURCES

On each of three trips along the railroad in September, 1917, and October and December, 1919, the writer has seen small streams of water flowing at several places in Cave Canyon. At no place did the flow appear to be as much as 1 second-foot. Probably there is a small flow at some of these places throughout the year. It is said that in rainy seasons, when floods come down the river, the flow may be from a few hundred to a few thousand second-feet. Small patches of alkali are visible at a number of places.

The only well that is known to exist in Cave Canyon is that of the Los Angeles & Salt Lake Railroad Co. at Afton, the log of which is given on page 511. It is 429 feet deep. The depth to water at the time of completion in August, 1904, was 17 feet. The well is 13½ inches in diameter to a depth of 100 feet, 11⅝ inches from 100 to 316 feet, and 9⅝ inches from 316 feet to the bottom. It is perforated only from 383 to 423 feet. The yield of the well is about 50 gallons a minute. The drawdown is not known.

An analysis of water from this well, furnished by the Los Angeles & Salt Lake Railroad Co. (see p. 532), shows that the water is highly mineralized and contains 880 parts per million of total solids. It is a sodium chloride water, but the carbonate is nearly as great as the chloride. It is fair for domestic use, poor for irrigation, and very bad for use in boilers, because of the large quantity of foaming constituents.

Although no other well data are available, the water table is probably close to the surface of the river channel in most parts of Cave Canyon, for alkali is visible at many places. The land is too rough for agriculture, but if water is required for any mining enterprise it doubtless can be obtained from wells close to the river.

CRUCERO VALLEY

GENERAL FEATURES

Crucero and Cronise Valleys are in the central part of San Bernardino County, at the lower end of the Mohave River drainage basin. The two valleys are in two distinct closed basins, but as Mohave River emerges from Cave Canyon it divides, and in times of flood the water goes into one or the other and sometimes into both valleys. Cronise Valley is described on pages 536–547.

Crucero Valley is really a part of the Soda Lake drainage basin, but for convenience it is described as a separate unit. As here considered it includes all the area that is tributary to the southwestern part of Soda Lake, from Soda station, in sec. 11, T. 12 N., R. 8 E., to the extreme southern part of the playa and westward to the lower end of Cave Canyon, near Baxter. The remainder of Soda Lake basin is described on pages 554–572. The principal physical and geographic features of the parts of Crucero and Cronise Valleys that are susceptible of agricultural development are shown in Plate 28. The relation of the basins to adjoining basins may be best understood by referring to the relief map (pl. 11) and the map showing the divides of drainage basins (pl. 7).

Crucero Valley is crossed from west to east by the Los Angeles & Salt Lake Railroad and from south to north by the Tonopah & Tidewater Railroad. The valley takes its name from the junction station of the two railroads, Crucero, which means "crossing."

Crucero Valley is nearly inaccessible by automobile because of heavy sand, except when the sand has been temporarily packed by rains. A road leads northward from Ludlow. In November, 1917, the writer found this road in good shape as far as a point a mile or two north of Broadwell station, on the Tonopah & Tidewater Railroad, but beyond that place it was in bad condition because of washing. With a little repair work this road would doubtless be passable for automobiles as far as Mesquite Spring, in sec. 25, T. 11 N., R. 7 E., but from the spring to Crucero heavy sand is encountered. The road continues northward from Crucero to Rasor, Soda station, and Silver Lake, but for several miles north of Crucero it can not be traveled by automobile. This road was formerly a much-traveled route to the Death Valley region, but since the building of the Tonopah & Tidewater Railroad and the advent of the automobile it is rarely used, and then only by outfits traveling with horses and wagons.

For many years a road from the west led down the channel of Mohave River in Cave Canyon and across the valley, following approximately the course of the Los Angeles & Salt Lake Railroad. The road in Cave Canyon was frequently washed out, and now travelers seldom attempt to follow it east of Field station. Most of the south end of Soda Lake Valley is covered with sand, and from the east often automobiles can not approach nearer than Kelso. This route along Mohave River and across the south end of Soda Lake Valley was one of the first traveled in the desert. It followed approximately the route along which the Mohave Indians guided Garcés on his trip to the San Gabriel Mission in 1776, the first trip made across the Mohave Desert by a white man. (See p. 10.) It was also followed by the Whipple expedition and by other early exploring parties. It is said that Mormon parties crossed the valley, although the main Salt Lake road was 20 or 25 miles northwest of Crucero. A low pass south of the Crucero Hills, in sec. 20, T. 11 N., R. 8 E., is locally known as Mormon Pass.

A wagon road leads from Crucero northwestward to Cronise Valley and thence to Bitter Springs, where it joins a little-used road from Daggett to Silver Lake. A road also leads from Baxter station northward to this road in Cronise Valley. Automobiles have traveled from Barstow to Baxter by this road, but with difficulty because of the heavy sand in places.

All the roads mentioned are at times obliterated along certain stretches, either by washouts or by wind-blown sand. Although they may be traveled in automobiles under very favorable conditions, it is unwise for anyone not acquainted with the region to attempt to reach it with an automobile. The most satisfactory means of travel, although slow, is with horses and a broad-tired wagon.

Because of its inaccessibility and the unfavorable conditions the region has not been settled to any great extent. Desert or homestead entries have been filed for about 4,000 acres in Cronise Valley and for two to three times that area in Crucero Valley, but the total acreage of patented land is very small. In 1919 a considerable acreage in each valley had been cleared, more than 30 wells had been drilled or dug, and considerable construction work had been done on a project to irrigate part of Cronise Valley with flood water from Mohave River. However, when the writer visited the region in December, 1919, besides the telegraph operators at Crucero, a section crew at King, and quarrymen at Baxter, only one family was living on its homestead near Crucero. There were then no stores in the region nor any accommodations for travelers.[61]

For a number of years a considerable quantity of limestone has been shipped from a quarry in sec. 12, T. 11 N., R. 6 E., about half a mile north of Baxter. Because of its purity the rock is used in refining sugar. Another limestone deposit suitable for sugar refining is said to exist several miles southeast of Crucero. No other valuable mineral deposits are known to exist in the region.

The writer spent six days in December, 1919, with team and wagon in the Crucero-Cronise region, and during that time visited most of the wells in the region. The field work was aided materially by a map of the region furnished by Mr. H. D. Bradley, of Riverside, Calif. This map, which was based largely on surveys by Mr. Bradley, shows the principal features of the region, some of which have not been shown on previous maps. The writer wishes to express his obligation to Mr. Elmo Proctor, who guided him to the principal localities and gave much information.

PHYSICAL FEATURES AND GEOLOGY

From Field station eastward for about 15 miles Mohave River flows in a deep canyon known as Cave Canyon. At Baxter the canyon ends and the river emerges onto a plain that slopes eastward and northeastward. This plain is an alluvial fan built by the river, which lost its carrying power when it passed from the confines of the canyon. From time to time the river has wandered from one side to another of the fan, gradually building up different parts of it. In the last few years at least the flood waters have mostly flowed northeastward across the slope, probably because the southern part of the fan, along the Los Angeles & Salt Lake Railroad, is now a little higher than the northern part. It is not certain whether the present

[61] The 1927 Postal Guide shows that a post office has been established at Crucero.

course is due to the natural slope of the land or to a dike built on the south side of the river northeast of Baxter. Available altitudes, however, show that the slope to the east along the Los Angeles & Salt Lake Railroad is about the same as that to the northeast, and if dikes had not been built to protect the railroad the river might readily change its course more to the south.

The alluvial plain east and northeast of Baxter constitutes the main part of Crucero Valley. It has an average width of about 4 miles and extends almost due east for 10 to 12 miles to Soda Lake. Certain features of the plain and of the hills and mountains that border it deserve brief description. These features may be best understood by reference to Plates 28 and 29. The photograph in Plate 29, *A*, was taken from hills south of Mesquite Spring, in the SW. ¼ sec. 25, T. 11 N., R. 7 E., looking west, north, and northeast. The photograph in Plate 29, *B*, was taken from a ridge on the north side of the valley approximately in the N. ½ SE. ¼ sec. 28, T. 12 N., R. 7 E., looking east, south, and west.

SOUTHERN BORDER OF THE VALLEY

From Baxter the southern border of the plain trends slightly south of east. It is marked by a line of hills that is almost continuous from Baxter to the area near the west line of sec. 22, T. 11 N., R. 7 E. (See pl. 29, *B*.) These hills were seen only from a distance. A prominent hill in sec. 20 or 21 appears to be composed of dark intrusive rocks. The other hills present a partly developed badland type of topography and appear to be composed of Tertiary and Quaternary alluvium. The eastern part of these hills slopes to the north, with an escarpment on the southeast and south. From the base of this escarpment an alluvial slope rises southward for several miles to the Cady Mountains. The hills have the appearance of being a part of the alluvial slope that has been slightly uplifted.

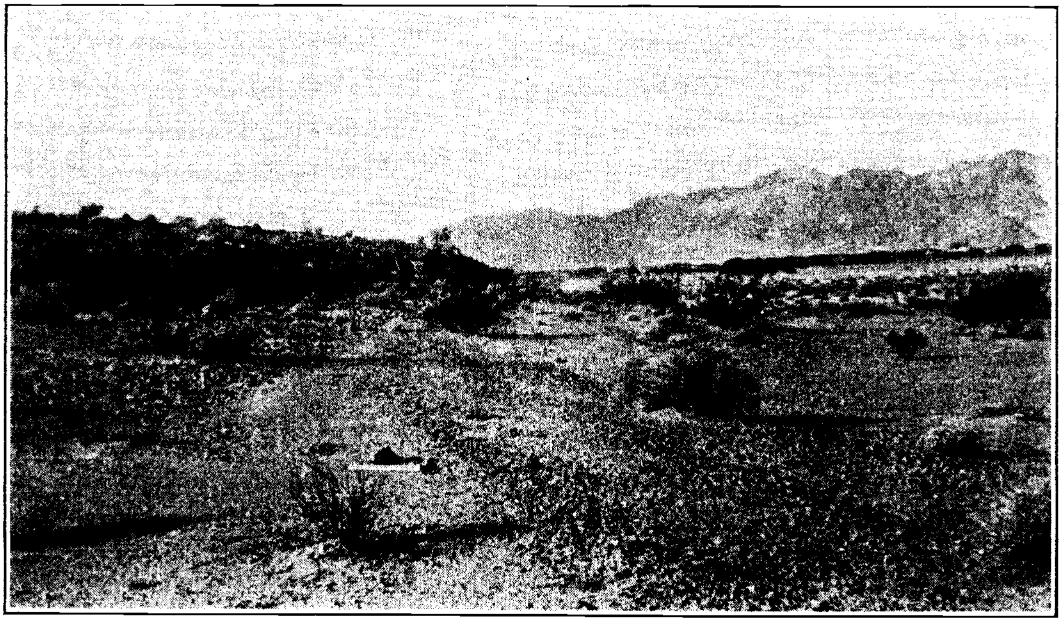
For a distance of a mile or two west of Mesquite Spring there is a break in the hills. The alluvial slope from the Cady Mountains extends with nearly uniform grade to the floor of the valley, but there is a slight northward-facing scarp that is nearly continuous with the higher southward-facing scarp farther west. This scarp extends to low hills that lie a short distance southwest of Mesquite Spring, which appears to have an origin similar to those farther west. (See left foreground of pl. 29, *A*.) Unfortunately on his trip to Mesquite Spring the writer was so pressed for time that he did not have an opportunity to determine the nature of the hills. They are said to consist of unconsolidated alluvium.

From Mesquite Spring a line of hills, known as the Mesquite Hills, extends eastward for about 4 miles. These hills, in contrast to those just described, are composed of granite. A peculiar feature is a more or less continuous bench a few yards north of the base of the Mesquite Hills that has a northward-facing escarpment, in places 25 feet high. The surface of the bench is strewn with semiangular boulders, the largest as much as 6 inches in diameter. Besides the granite of the near-by hills the boulders include vesicular basalt and rhyolite, which must have come from distant hills. In some respects the bench looked like a wave-cut platform. However, the alinement of the scarp in approximate continuation with the scarps farther west suggests that the scarp may be a fault line. Certainly the almost continuous line of hills from Baxter to the east end of the Mesquite Hills is very suggestive of a fault. Unfortunately there was no opportunity to look for criteria that would disprove or confirm the existence of such a fault.

About half a mile southeast of Crucero rise high hills, known as the Crucero Hills, which are composed of the same granite as the Mesquite Hills. The Crucero Hills are connected with the east end of the Mesquite Hills by a low alluvial ridge. This ridge has a gradual slope to the west, but on the east the slope is steeper and the lowland beyond it is considerably lower.

South of the hills described above, which extend from Baxter to the east end of the Mesquite Hills, typical long alluvial slopes rise for several miles to the Cady Mountains and the mountains that lie east of them. The drainage of these slopes flows in a general northerly direction to the south side of the hills described, whence it is deflected along the back of the hills until it reaches a break through which it can enter the lower part of the valley. Thus a large part of it passes through the break west of Mesquite Spring or at the east end of the Mesquite Hills. About a mile east of Mesquite Spring a canyon cuts entirely through the Mesquite Hills. A peculiar feature is the course followed by the drainage that passes through the break in the hills west of Mesquite Spring. Instead of going northeast toward Crucero it goes almost directly east, parallel to the Mesquite Hills, to a clay flat in the N. ½ sec. 30, T. 11 N., R. 8 E., whence it turns north on the west side of the Crucero Hills. The divide that prevents it from going directly to Crucero is imperceptible. The fact that the wash is parallel to the Mesquite Hills suggests that its course may have been determined by faulting if there has been faulting along the hills, but it is more likely that deposition by Mohave River on the south side of its fan has blocked the drainage and gradually pushed it toward the Mesquite Hills.

The Cady Mountains and the mountains east of them rise to altitudes of 4,000 to 5,000 feet and form an almost continuous mountain border on the south side of the drainage basin. However, there is a complete break in them due south of Mesquite Spring, where the Tonopah & Tidewater Railroad goes through a narrow pass to the Broad-



A. WAVE-CUT CLIFF AND STRAND LINES IN THE SW. ¼ SEC. 20, T. 12 N., R. 7 E. SAN BERNARDINO MERIDIAN, EAST CRONISE VALLEY

B. THE MYSTIC MAZE, AN ANCIENT INDIAN CEREMONIAL GROUND 14 MILES SOUTHEAST OF NEEDLES well Basin. (See pl. 29, *B*.) Although the pass is not more than half a mile wide it seems to be filled with alluvium to a depth of more than 100 feet, which forms a low divide between the two basins. (See p. 657.)

The Cady Mountains, where they were observed at the pass southward to Broadwell Valley and also near Baxter, are composed of intrusive or metamorphic rocks. The writer is informed by Elmo Proctor that between 5 and 10 miles southwest of Crucero there is a belt of faulted and folded sedimentary rocks. Still farther southwest he reports a volcanic crater and thick lava flow underlain by old sedimentary rocks. He also reports that limestone occurs several miles southeast of Crucero, but the exact location is not known.

WESTERN AND NORTHERN BORDERS OF THE VALLEY

The west side of Crucero Valley, north and northwest of Baxter, is bordered by the Cave or Afton Mountains, which rise steeply from the valley floor and culminate in Cave Mountain. (See pl. 29, *A*, *B*.) Because of its steepness this mountain appears to be a fault mountain. It has almost no alluvial slope on its east side. At the south end of the range near Baxter occur greatly contorted metamorphic rocks, including the marble quarried at Baxter At the extreme northeast end, in a quarry at a dam in sec. 30, T. 12 N., R. 7 E., the rocks are granite. The mountain appears to be composed wholly of intrusive or metamorphic rocks.

On the north the western part of Crucero Valley is bordered by a long rocky ridge. Farther east, in the southeastern part of T. 12 N., R. 7 E., and the southwestern part of T. 12 N., R. 8 E., stands a low but prominent mountain, known as Red Mountain. (See pl. 29, *A*.) From Red Mountain the valley border bends northeastward and is formed by low hills that reach the Soda Lake Mountains in the northeast part of T. 12 N., R. 8 E.

The ridge west of Red Mountain reaches almost to the northeast end of Cave Mountain, but it is broken at its west end by two passes in the SW. ¼ and SE. ¼ sec. 30, T. 12 N., R. 7 E., separated by a low knob. The alluvial plain that slopes gradually northward from Baxter continues through the passes into Cronise Valley on the north. The ridge is almost broken at a third place, in the SW. ¼ sec. 28, T. 12 N., R. 7 E., but there is nevertheless a distinct divide. The west end of the ridge, in sec. 29, is composed of granitic rocks. Farther east, in sec. 28, it is composed of a series of stratified rocks, probably of Tertiary age, which are mostly of volcanic origin, though some beds may be sedimentary. The beds in the main ridge dip toward the north at low angles, but in low hills south of it they are nearly vertical. The ridge is steep on the south side but more gentle on the north. Its topographic aspect suggests a fault that trends nearly due east.

Red Mountain was not visited, but it appears to be composed of Tertiary volcanic rocks, as do the low hills east and northeast of it. The northeast end of the Soda Lake Mountains is composed largely of volcanic rocks, but south of Soda station, in sec. 11, the volcanic rocks are underlain by granite. A limestone hill several hundred feet in diameter lies between the main mass of the mountains and Soda Dry Lake at Soda station.

CRUCERO PLAIN

The Crucero Plain slopes eastward and northeastward from Baxter to Soda Lake. The grade of the plain from Baxter to Crucero is about 30 feet to the mile, but east of Crucero to the lowest part, about midway between Epsom and Balch sidings, the average grade is only about half as much. From Baxter northeastward to the pass to Cronise Valley, in the SE. ¼ sec. 30, T. 12 N., R. 7 E., the grade is about 25 or 30 feet to the mile. West of Baxter, in Cave Canyon, the grade of the river is somewhat greater and probably averages between 40 and 50 feet to the mile. As a result of the change from the confined channel with a steeper slope to the open plain with a more gentle slope the flood water from the river deposits much of its load. In so doing the river fills its old channels and seeks new ones. Several distributaries lead northeastward from Baxter. These channels are likely to change with each flood, but on Plate 29, *B*, they are shown in a general way as they existed in 1919. Some of the channels lead almost directly northward from Baxter to the two passes into Cronise Valley, and in recent years some of the river floods have gone into that valley. So far as could be ascertained, only a part of the flood waters, however, have gone into Cronise Valley, a large part flowing more northeastward. There is also evidence that at some time in the past the discharge into the valley has been sufficient to produce a lake of considerable size.

Between 1912 and 1919 a dam was erected across the westernmost pass to store some of the flood water for irrigation in Cronise Valley. (See p. 541.) Smaller dams were erected to prevent the floods from reaching Cronise Valley through the eastern pass. At the time of the writer's visit in December, 1919, the distribution of the channels, as shown in Plate 29, *B*, indicated that a large part of the most recent floods had moved northward to the dams and had then been deflected eastward.

From about the SW. ¼ sec. 34, T. 12 N., R. 7 W., as far east as sec. 5, T. 12 N., R. 8 W., the river floods seem to be concentrated in a relatively narrow area near the base of Red Mountain. East of this area, however, the waters spread out, and along the Tonopah &

Tidewater Railroad it has been necessary to construct culverts at several places to take care of the floods.

The alluvium of the Crucero Plain as a whole is fine. Even near Baxter, where Mohave River emerges from Cave Canyon, pebbles larger than 2 or 3 inches in diameter are not common. Farther east the deposits in channels of the river contained only small patches of gravel, and near Crucero there is much silt and sand.

The only reliable well log, for well 30, in the NE. ¼ sec. 18, T. 11 N., R. 8 E., shows that near Crucero at least the fine deposits continue to a depth of 150 feet or more. In this depth only 2 feet of gravel was struck, between 108 and 110 feet. The log is given below. It is notable that below a depth of 58 feet the deposits are mostly blue and that clay is abundant. Blue color in sand and clay generally indicates deposition in a perennial body of water such as a lake. Probably these beds were deposited in the ancient Lake Mohave, which covered the Soda Lake and Silver Lake playas in the Pleistocene epoch. (See pp. 563–568.)

Log of well 30, NE. ¼ sec. 18, T. 11 N., R. 8 E. San Bernardino meridian

[L. B. Joralmon, owner. Log furnished by Elmo Proctor]

	Thickness (feet)	Depth (feet)
Soil; surface water at 6 feet	9	9
Clay	7	16
Sand	9	25
Clay	2	27
Sand	1	28
Clay	4	32
Coarse sand; casing perforated from 33 to 34 feet?	3	35
Quicksand	23	58
Blue clay	5	63
Blue sand	2	65
Blue clay	5	70
Blue sand	1	71
Hard blue clay	6	77
Coarse sand; casing perforated	3	80
Blue clay	3	83
Sand	4	87
Blue clay	8	95
Sand	13	108
Gravel; casing perforated	2	110
Coarse sand; casing perforated	1	111
Blue clay	3	114
Sand	2	116
Coarse sand; casing perforated	2	118
Blue clay	1	119
Coarse sand; casing perforated	6	125
Blue clay	2	127
Sand	7	134
Clay	3	137
Sand	5	142
Clay	2	144
Sand	4	148
Clay	6	154

Well eventually sanded up to 128 feet.

SOILS

The most striking feature of the soil of Crucero Valley is its sandiness. In the lower part of the valley, a little east of the line between Rs. 7 and 8 E., sand dunes are abundant. Farther west in the valley, although dunes are not common, wagon trails are quickly filled with sand, and the surface soil is rather sandy. As a whole, the soil of most of the valley seems more sandy and loose than that in any other valley in the Mohave Desert region in which there has been any earnest attempt to develop the land.

The sandiness of the soil seems to be due largely to the fact that a more or less continual supply of relatively fine material is poured out on the plain by occasional floods from Mohave River. For most of its length below the headwater region Mohave River flows across unconsolidated sediments. At only a very few short stretches are conditions favorable for boulders to be picked up by the stream. Even Cave Canyon, just above Baxter, is cut largely through lake beds and other alluvium in which there is much sand. Whatever coarse material the stream has carried is deposited shortly after it emerges from Cave Canyon onto the Crucero Plain, where the force of the flood is diminished because of diminished gradient and because the stream can spread out. The finer material is deposited farther out on the plain. In dry seasons this fine material is subject to further movement by the winds.

In the northwestern part of the valley, in secs. 32 and 33, T. 12 N., R. 7 E., and the parts of secs. 28 and 29 that lie in Crucero Valley, a special type of soil was observed which was quite distinct from the usual type of desert soil. It was composed largely of very fine sand and silt. A mechanical analysis of a sample from the J. M. Baber ranch, in the SW. ¼ sec. 28, T. 12 N., R. 7 E., showed that a little more than 30 per cent of it was less than 0.05 millimeter in diameter, and 64 per cent of it was between 0.125 and 0.05 millimeter in diameter. The soil contained a large quantity of small flakes of mica and also many small bits of organic matter, which is generally absent in desert soils. This soil seems to have been deposited in a relatively recent flood of Mohave River. The concentration of the greater percentage of the material between definite limits, as just mentioned, is a characteristic feature of soils deposited by streams. This soil was very powdery and created much dust when stirred up, perhaps owing to the abundant particles of mica, which float in the air. This soil undoubtedly would require much water in irrigation. It had a very thin crust on top, but this was easily broken and the soil would probably not bake sufficiently to cause difficulty in tilling crops.

A soil somewhat similar to that at the Baber ranch was found at the Proctor ranch, in the NW. ¼ sec. 7, T. 11 N., R. 8 E. At that place, however, the fine silty soil was overlain by about 2 feet of a coarser sandy soil. It is uncertain whether the fine soil at the Proctor ranch was deposited by the same flood that deposited the fine soil at the Baber ranch or whether it came from an earlier flood.

Chemical analyses were made of the water-soluble materials in the sample of soil at the Baber ranch and of two samples from the Proctor ranch. The water-soluble constituents in the sample from the Baber ranch made up 0.28 per cent of the total sample. A sample of the surface soil at the Proctor ranch contained 0.17 per cent of water-soluble constituents, but another sample, obtained by scraping down the side of a 2-foot hole, contained only 0.04 per cent of water-soluble constituents. The percentages of water-soluble constituents in the soil from the Baber ranch and the surface soil from the Proctor ranch are higher than in samples from similar topographic situations in other parts of the desert. The reason for this difference is not clear, for the soil seems too well drained and the water table is so far below the surface that the soluble material should not be left by evaporation. The quantity of soluble matter in the soil at the Baber ranch may be sufficient to cause trouble with crops, but it is likely that no trouble will be experienced at the Proctor ranch.

VEGETATION

Creosote bush is the characteristic plant of a large part of Crucero Valley. It was observed in the valley in more varied surroundings than in other parts of the desert, where it occupies principally the gravely alluvial slopes in which the water table is so far below the surface that mesquite will not grow. It is most common on the plain between Baxter and Crucero but grows east of Crucero, among patches of mesquite, where the depth to water is only 10 or 12 feet. Large and thrifty individual plants were observed on low sand dunes at the northeast end of the Crucero Hills. Large individual plants were also seen in one of the recent flood channels of Mohave River in sec. 3 or 4, T. 11 N., R. 7 E.

Mesquite is common in the lower part of the valley, where the depth to water is not more than 15 or possibly 20 feet. In general it is not common west of the line between Rs. 7 and 8 E., but on the north side of the valley, near the channel of Mohave River, a few scattered patches were seen as far west as sec. 33, T. 12 N., R. 7 E. The mesquite generally is of the crawling type and grows on dunes, which in some places are 15 or 20 feet high. Its distribution is well shown in the right of Plate 29, *A*, on which the large black patches are mesquite and the much smaller and lighter spots are mostly creosote bush.

The desert willow, *Chilopsis saligna*, grows abundantly in some stretches of the channel of Mohave River between Baxter and Soda Lake. It was more common there than in any other locality that the writer visited in the Mohave Desert region. The desert willow is not a true willow, although closely resembling one. In Crucero Valley it grows where the depth to ground water is not more than 25 or 30 feet, but as it seemed to be confined to river channels the species probably does not depend on the ground water but draws most of its supply from the occasional floods, which are sufficient to moisten the soil to a considerable depth.

Salt grass, *Distichlis spicata,* was observed only in small patches around Mesquite Spring and at two or three places around the border of Soda Lake. Soda Lake was seen close at hand only at Soda station, where the salt grass area is not very wide.

Hilaria rigida, a grass locally known as galleta grass, grows in the lower part of the valley around Crucero. Two other species, not noticed elsewhere in the Mohave Desert region, *Petalonyx thurberi,* locally called honeybush, and *Croton californicum,* locally called dove cover, are common between Crucero and Cronise Valleys.

CLIMATE

No climatic records are available for Crucero Valley. The valley lies from about 925 to 1,225 feet above sea level and is thus lower than most of the Mohave Desert region. The mountains that border it on the west probably do not rise more than 2,000 to 3,000 feet above sea level. There is hardly any barrier between the Lower Mohave Valley and Crucero Valley, so that the rain-bearing winds from the west can descend to lower and lower levels as they pass over Crucero Valley with a resultant lessening tendency toward precipitation. As a result it is probable that the rainfall is even less here than at Daggett or Barstow. The topographic situation is somewhat comparable to that of Bagdad, and very likely the precipitation is no greater than at that place, where it averages about 3 inches annually.

Because of its low altitude and somewhat sheltered position the temperature of the valley is probably a few degrees higher than that in the valleys that lie at higher altitudes. There is much wind-blown sand in most parts of the valley, but it is uncertain whether this is due to stronger winds than in most other parts of the Mohave Desert region or to more favorable features of soil supply.

SURFACE WATER

Mohave River is the only source of surface water in the area. The only large discharge comes when heavy floods descend the river from the headwater region. At such times the discharge is said to reach at least several thousand cubic feet a second and flood waters pour onto Soda Lake playa. (See p. 494.) Mr. Elmo Proctor informed the writer that the river flooded the lower part of Cronise Valley in the spring of 1920. There was another flood in September, 1921, which lasted several days, and the water reached both Soda Dry Lake and East Cronise Dry Lake. About December 23, 1921, a third large flood came, and the flow continued until about May 15, 1922. This flood covered East Cronise, Soda, and Silver Dry Lakes.

No information is available as to whether there is any flow in the river in the drier years. On December 3, 1919, water was standing behind the dam of the Valley Cultivating Co. in the SE. ¼ sec. 30, T. 12 N., R. 7 E., and a small stream was flowing into the partly completed reservoir. The year had been unusually dry, and there had been no flow from the upper part of the drainage basin. The stream apparently came from the underflow from the higher parts of the basin.

GROUND WATER

DEPTH TO WATER

Information was obtained in regard to about 30 wells in Crucero Valley. The location of these wells is shown on Plate 28, and the principal data in regard to them are given in the accompanying table (Nos. 10 to 33 and 41 to 45). At the time of the field investigation there was only one rancher in the valley, and it was impossible to get definite information other than the total depth and depth to water in some of the wells.

In all the wells for which data were obtained the depth to water was less than 45 feet. The greatest depth to water was 41.9 feet, in the Skelton Well (No. 13), in the NW. ¼ sec. 11, T. 11 N., R. 7 E. In wells 14 and 15, near King station, about three-quarters of a mile southeast of well 13, the depth was about 10 feet less. In wells 41 to 45, in secs. 28, 29, 32, and 33, T. 12 N., R. 7 E., the depth to water was 31 to 37 feet. Farther east, around Crucero, the depth to water is considerably less. Within a radius of 1½ miles from Crucero the depth ranges from 3 feet in well 30 to 13.9 feet in well 27. It is less than 10 feet in five wells. At Rasor (well 12) the depth to water is about 12 feet. At Soda station two wells (Nos. 10 and 11) flow at the surface.

Altitudes are available for points along the Los Angeles & Salt Lake Railroad and the Tonopah & Tidewater Railroad and at the dam of the Valley Cultivating Co. in sec. 30, T. 12 N., R. 7 E., and from these altitudes the approximate grade of the water table may be determined. Between Crucero and King stations the grade of the surface is about 30 feet to the mile, but the grade of the water table is only between 15 and 20 feet to the mile. Accordingly the depth to water increases about 10 or 15 feet to the mile from Crucero westward. No well data are available for the area west of King, but if the grade of the water table is the same farther west, the depth to water near Baxter is probably about 100 feet. East of Crucero the grade of the water table is less than 10 feet to the mile, or less than it is farther west. From Crucero northward to Rasor it is about 10 or 12 feet to the mile.

Records of wells in Silver Lake, Soda Lake, Crucero, and Cronise Valleys, Calif.

No. on pl. 28	Location				Owner or name	Type of well	Depth of well (feet) [a]	Diameter of well (inches)	Depth to water (feet) [a]	Date of measurement	Reference point for measurement	Method of lift	Yield (gallons per minute)	Remarks
	Quarter	Sec.	T. N.	R. E.										
1	NE	22	15	8	G. Brauer	Dug	64	48 by 48	61 59.6	Sept. 9, 1917 Jan. 21, 1918	Top of curb, about level with ground.	Windmill		See p. 532 for analysis.
2	NE?	22	15	8	Tonopah & Tidewater R. R.	do	(?)	(?)	(?)				15–20	
3	NW	13	14	8	E. O'Rourke	do	32.8	48 by 48	31.4	Oct. 23, 1917	Ground level	Bucket		
4	NE	14	14	8	A. D. Long	Drilled	289	12	32					Water is of poor quality. A dug well in the same quarter section 40 feet deep and 38 feet to water.
5	(?)	30	14	9?		Dug	44		40.6	Oct. 23, 1917	Top of curb, 2½ feet above surface.	Windmill		
6		36	14	8	R. Y. Williams	do	36.5	48 by 48	34.7	Sept. 9, 1917	Ground level	Jack pump	7	Pumps nearly dry. See p. 532 for analysis.
7	W½	1	13	8	J. D. Heitshusen	Drilled	385							
8		1	14?	9	F. Rickerhouse	do	450		40					Water reported to be of good quality.
9	SE?	1	13	8	O. Pochmeyer	do	400		21					Water is brackish.
10		11	12	8		do	103	6	Flows.	Sept. 9, 1917 and Dec. 7, 1919.				Limestone struck at 15 feet. Flowing water at 25 feet. See p. 532 for analysis.
11		11	12	8		do	39	7	Flows.	Sept. 9, 1917 Dec. 7, 1919				A third well at this place partly clogged.
12	SW	27	12	8	Tonopah & Tidewater R. R.	Dug	14.8		9.6	Dec. 7, 1919	Top of wall at gate into pump house, 3 feet below ground level.	Duplex (?)	100	Well is 24 by 55 feet in area. See p. 532 for analysis.
13	NW	11	11	7	A. Skelton	Drilled	[b] 143.2	8	[b] 41.9	Dec. 27, 1919	Top of casing, 2 feet above ground.			See p. 532 for analysis.
14	SE	11	11	7	E. I. Cook	do	[b] 99	10	[b] 32.4	Dec. 15, 1919	Top of casing, 1.8 feet above ground.			
15	NE	14	11	7	J. J. Berray	do	(?)	8	[b] 32.7	Dec. 15, 1919	Top of casing, 2.3 feet above ground.			
16	NW	14	11	7	—— Massen									
17	NE	14	11	7	B. F. Caldwell	Dug and drilled		88 by 88 and 10	[b] 29.6	Dec. 27, 1919	Top of curb, level with ground.			Dug part way with drive point at bottom.
18	NE	24	11	7	W. T. Tener	Driven	12							Pit dug to 33 feet.
19	SW	6	11	8		Drilled	81		11					
20	NW	7	11	8	Elmo Proctor	do	74	7	11	Dec. 7, 1919	Ground level			Originally 81 feet deep. Not perforated.

21	NW	7	11	8	do	do	23	5	8.9	Dec. 7, 1919	Top of casing, level with ground.	Hand pump	20	Drawdown 1 foot when pumping 20 gallons a minute. See p. 532 for analysis.
22	NE	7	11	8	Mrs. Ora Weishaupt.	do	81	8	10.5	Dec. 7, 1919	Top of casing, 1.5 feet above surface.			
23	SE	7	11	8	L. B. Joralmon	do	150	5	5.3	Dec. 6, 1919	Top board south side of curb, about level with surface.	Horizontal centrifugal.	225	
24	NW	9	11	8	Ida M. Gue	do	74	8	12.4	Dec. 6, 1919	Top of casing, 1.8 feet above surface.			
25	SE	8	11	8	D. L. Young	Dug	13	48 by 48	11.0	Dec. 6, 1919	3 notches cut in northwest top of curb level with ground.			
26	SW	8	11	8	P. B. Sterratt	Drilled	87	7	5.2	Dec. 6, 1919	Top of casing, 1 foot above ground.			
27	SW	9	11	8	—— Craig	do	104	8	13.9	Dec. 6, 1919	Top of casing, 2 feet above ground.			
28	SW	10	11	8	C. C. Klingerman	do	276	7	6			Horizontal centrifugal.	160	See p. 527 for additional information.
29	NE?	17?	11	8	Mohave United Mining & Milling Co.	Dug		48 by 48	10.5	Dec. 6, 1919	3 notches cut in north side top of curb.			150 yards north of rock hills.
30	NE	18	11	8	L. B. Joralmon	Drilled	154	8	3.0	Dec. 7, 1919	Top of casing, level with ground.	Horizontal centrifugal.	180	See pp. 519, 527 for additional information.
30-a	NE?	18	11	8	Mrs. L. B. Brooks	do	80	7	(?)			Horizontal centrifugal.	150	Pumping lift is 30 feet.
31	NE	18?	11	8	A. J. Ingalls	do	91	8	13			Horizontal centrifugal.	100	Pumping lift 30 feet.
32	NW	19	11	8	Laura B. Weichert	Drilled	86	8	12.5	Dec. 2, 1919	Top of casing 0.5 foot above ground.			
33	NE?	29?	11	8	Lousiana Well Mohave United mining & Milling Co.	Dug	12.6	48 by 48	10.1	Dec. 6, 1919	3 notches cut in east side top of curb.			Water slightly salty. Well is 100 yards north of rock hills.
34		17	11	9	Los Angeles & Salt Lake R. R.	Drilled	212	13½	55					See p. 532 for analysis.
35	SW	17	12	7	J. Walton	do	150	12	12?			Deep well turbine.	540?	
36	NE	19	12	7	R. Hendry	do	23	12	15.4	Dec. 4, 1919	Top of casing, 1.5 feet above ground.	Hand pump.		Well is probably deeper than shown by measurement.
37	SE	20	12	7	H. D. Bradley	do	82	9½	20.4	do	Top of casing, 1.5 feet above ground.	Hand pump		

[a] Wells for which a date of measurement and reference point are given were measured by the writer, except as indicated by the following footnote. Where no date or reference point is given, the data were reported by the driller or other person.
[b] Measured by Elmo Proctor.

Records of wells in Silver Lake, Soda Lake, Crucero, and Cronise Valleys, Calif.—Continued

No. on pl. 28	Location				Owner or name	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth to water (feet)	Date of measurement	Reference point for measurement	Method of lift	Yield (gallons per minute)	Remarks
	Quarter	Sec.	T. N.	R. E.										
38	SE	20	12	7	H. D. Bradley	Drilled	85.5	12	21.3	Dec. 5, 1919	3 notches cut in top board north side of curb.	----	225	Originally 100 feet deep.
39	SW	20	12	7	George T. Roberts	do	133.7	12	22.0	do	Top of board cover, about level with ground.	----	300	Originally 142 feet deep. See log, p. 544.
40	NW	30	12	7	L. Holibaugh	do	25	5	14	----	----	----	----	
41	SW	29	12	7	H. Markt	do	44	----	35	----	----	Windmill	----	See p. 545 for analysis.
42	SE?	29	12	7	do	Dug	36	----	34.5	Dec. 3, 1919	3 notches south side of cover, about 3 feet above surface.	----	----	Water salty. Better water in a well 150 feet farther north.
43	NW	32	12	7	do	Drilled	----	8	35.6	do	Top of casing, 1 foot above ground.	----	----	
44	NW	33	12	7	C. B. Baber	do	70	6	37	do	Top of casing, 1 foot above ground.	Hand pump.	----	See p. 532 for analysis.
45	SW	28	12	7	J. M. Baber	do	134	12	31.1	Dec. 5, 1919	Top of well curb	Horizontal centrifugal.	----	Water said to be salty.
46	SE	18	11	6	Afton well, Los Angeles & Salt R. R.	do	429	13½, 11⅝ and 9⅝	17	Aug. 1904 [c]	----	----	50	See p. 511 for log, p. 532 for analysis, and p. 512 for additional data.

[c] Date of drilling of well.

In several wells the water is under a slight head. When the Klingerman well, in the SW. ¼ sec. 10, T. 11 N., R. 8 E., was first drilled the water is said to have flowed a little at the surface, but it later dropped to 6 feet below the surface. In drilling this well the first water was struck at 8 feet. This well is 276 feet deep, the deepest well in the valley. It is cased to a depth of only 146 feet, and the lower part of the well is said to be entirely in clay. The principal water-bearing bed was struck at 119 feet.

In drilling the Joralmon well, in the NE. ¼ sec. 18, T. 11 N., R. 8 E., the first water was struck at 6 feet, but in December, 1919, it was only 3 feet from the surface. In another well in the SE. ¼ sec. 7, the depth to water was only 5 feet, and in the Sterrett well, in the SW. ¼ sec. 8, it was about the same. The water level in these wells is from 5 to 8 feet higher than in other wells, and the differences may be due to surface irregularities.

ARTESIAN CONDITIONS

The geologic conditions appear to be favorable for the occurrence of water under pressure in deep wells around Crucero and farther east. In the Ingalls well (No. 31), in sec. 18, T. 11 N., R. 8 E., blue clay was encountered from a depth of 46 feet to 79 feet, and in the Joralmon well (No. 30), in the same section, blue clay was struck between 58 and 63 feet and at several other horizons below that. These beds doubtless are relatively impervious and act as covers beneath which the water is held under pressure. These clay beds were apparently deposited in a lake which hardly could have extended much west of Crucero. The most favorable area for water under pressure is east and north of that place. The water table west of Crucero rises so gradually, however, that the artesian pressure can not anywhere be very great.

YIELD OF WELLS

The yields of wells in Crucero Valley is not large. A well of L. B. Joralmon (No. 23) is reported to yield 225 gallons a minute (25 miner's inches). No other wells are known to yield as much as 200 gallons a minute, but several are reported to yield between 100 and 200 gallons a minute. The small yield of the wells appears to be due to the general absence of gravel beds. The log of another L. B. Joralmon well (No. 30) shows only 2 feet of gravel in a total depth of 154 feet. This well yielded 180 gallons a minute. In the Ingalls well (No. 31) a mixture of sand, gravel, and clay was penetrated from 26 to 45 feet and water-bearing gravel from 80 to 90 feet. Perhaps the small yields are due in part to the small diameter of the wells, for none in the vicinity of Crucero are more than 8 inches in diameter.

FLUCTUATIONS OF THE WATER TABLE

There is evidence that the water table fluctuates from year to year, owing to variations in the recharge of the ground-water reservoir and discharge from it. On December 7, 1919, the depth to water in the domestic well of Elmo Proctor (No. 21) was 8.9 feet. Mr. Proctor writes that in August, 1921, the depth to water was 10 feet. After heavy floods in the winter and spring of 1922 the water table rose until on December 19, 1922, it was only 6.8 feet below the surface. The rise occurred throughout the valley. In the lower part of the valley it was sufficient to result in the appearance of alkali salts at the surface. In a series of dry years these spots will doubtless disappear, but in wet years some land may be spoiled by them.

There has not been sufficient pumping in the valley to show whether the water table will fluctuate greatly if there is much irrigation. As long as the river floods reach the valley the recharge will doubtless be sufficient to provide for irrigation of the greater part of the valley. If, however, the flood waters are stored in the headwater region and used in the Upper Mohave Valley or diverted from the basin, the supply for recharge will be greatly decreased and may become exhausted.

SPRINGS

Several springs occur on the borders of Crucero Valley. Of these the most notable are Mesquite Spring, Epsom Springs, and springs at Soda station, on the Tonopah & Tidewater Railroad. In addition to these springs, a spring known as Seymour Spring is said to emerge several miles southwest of Mesquite Spring, probably in or near sec. 32, T. 11 N., R. 7 E. Another spring is shown on the original township plat of the General Land Office in the NW. ¼ sec. 35, T. 12 N., R. 8 E. Nothing is known in regard to either of these springs.

Mesquite Spring.—Mesquite Spring is in the SW. ¼ sec. 25, T. 11 N., R. 7 E., about 3¼ miles southwest of Crucero. It emerges at the north base of the granitic hills a few yards west of the Tonopah & Tidewater Railroad. When visited by the writer in 1919 the spring consisted of a boarded pit dug about 6 feet to water, from which a trench led about 25 feet to lower ground. There was no flow from this trench. On one side granite projected about a foot above the water, and the water evidently comes from the rock. A mound of silt surrounds the spring. This mound probably has been formed in part by the deposition of salts from the water and in part by the retention of wind-blown sand and dust by the moisture around the spring. The temperature of the water was 56° F.

As shown by analysis 10 (p. 532), the water is very highly mineralized. It is very bad, if not unfit, for domestic use, and several persons have become ill after drinking it. It should not be used unless absolutely necessary. It is poor for irrigation and unfit for use in boilers because it contains an excessive amount of foaming and scale-forming constituents.

About a third of a mile east of Mesquite Spring is another spring at the north base of the granite hills. The conditions at this spring are similar to those at Mesquite Spring. The water from these springs probably comes from the drainage south of the Mesquite Hills, which act as a barrier to the northward movement of ground water. The highly mineralized character of the water may perhaps be due to the presence of a small playa south of the hills, where salts may be concentrated by evaporation, or it may be that the water comes from Broadwell Valley, about 10 miles farther south, where the ground water is of very poor quality. (See p. 658.)

Epsom Springs.—Epsom Springs are situated southeast of the Crucero Hills, probably in the SW. ¼ sec. 21, T. 11 N., R. 8 E. They emerge at the west end of a long arm of Soda Lake that extends southwest from the main playa. Water comes to the surface at several places, and there is a slight flow toward the east. The water probably comes from the area west of the Crucero Hills and moves beneath an alluvial divide that connects these hills with the Mesquite Hills.

The ground around the springs is more or less covered with white alkali. The water tastes salty but not nearly as salty as might be supposed from the abundance of the alkali on the surface. Analysis 11 (p. 532) shows that this water contains 2,124 parts per million of total solids. It is classed as very bad for domestic use and should not be used except in an emergency. The water is poor for irrigation and unfit for boiler use. It will be noted that magnesium is practically absent, so that the name "Epsom Springs" is not justified. The name perhaps has arisen from the fact that the water contains Glauber's salt, or sodium sulphate, which has the same medicinal effect as Epsom salt.

Springs and wells at Soda station.—Several springs and wells are situated at Soda station, on the Tonopah & Tidewater Railroad, approximately in sec. 11, T. 12 N., R. 8 E. A brief description of the geologic and topographic conditions will help in understanding the springs.

At Soda station the Soda Lake Mountains lie within a few hundred feet of the Soda Lake playa, and they rise very steeply. At the northeastern base of the mountains occur volcanic rocks, probably of Tertiary age, and these rocks probably form a large part of the mountains. Farther south granitic rocks are exposed in the base of the mountain. At Soda station there is a hill of limestone several hundred feet in diameter, which is separated from the main mountain mass by an alluvium-filled area about 100 yards wide. The alluvium probably represents a beach that was formed when a perennial lake covered the area. (See p. 564.)

Two or more springs flow from the east side of the limestone hill. The water appears to seep directly from the rock about 5 feet above the surface of the playa. An abundance of tules and salt grass around the base of the hill shows that the seepage occurs over a larger area than indicated by the few openings that have been cleared out. The largest spring flows into a concrete reservoir about 15 by 30 feet in area and 5 feet deep. When visited in 1917 a small ram pumped water from this reservoir to an elevated tank for domestic use, but it had been removed when visited in 1919. The flow of the spring is between 25 and 50 gallons a minute. In the winter the water flows for some distance out onto the playa. The temperature of the largest spring on December 7, 1919, was 75° F. The temperature of a smaller spring near by on October 22, 1917, was 74°.

Analysis 3 (p. 532) shows the character of a sample of water from the large spring. The water is highly mineralized, and sodium chloride predominates. It has a distinct salty taste, but it can be used for drinking if necessary. It is poor for irrigation and very bad for boilers.

In the alluvium-filled area between the limestone hill and the main mountain two ditches have been dug about 10 feet deep. In 1917 about 20 gallons a minute flowed from these ditches. The water comes entirely from gravel, and there is no evidence of bedrock. The flows appear to originate about 5 feet above the playa surface. The water is of about the same quality as that from the springs described above.

On the south side of the limestone hill there are three drilled flowing wells. The well nearest the hill measured 103 feet deep. The greatest quantity of water comes to the surface about 20 feet southwest of this well. At this place no casing was seen, but a well is said to have been drilled on the spot. The flow of these two wells was estimated to be about 150 gallons a minute. The third well is about 300 feet farther south and is 39 feet deep. The water in this well barely seeps over the top of the casing. On December 7, 1919, the temperature of the water from the second hole was 78½° F. In the well with the least flow it was 73½°. Analysis 4 (p. 532) shows that the water from the strongest well (No. 10) is essentially similar to the water in the big spring on the east side of the limestone hill, although a little less mineralized.

In one of these three wells, probably the 103-foot well, bedrock (limestone) was struck at a depth of 15 feet and artesian water was struck at 25 feet. Thus in both the well and the spring on the east side of the hill the water seems to come directly from the rock. This raises a question as to its source. The water from both the spring and the well is relatively low in calcium or magnesium—that is, it is not a typical limestone water. This fact suggests that the water has not traveled very far through the limestone, perhaps because the limestone does not cover a great area. On the other hand, the water is high in sodium chloride, which is a characteristic of water near playas. Probably the water has its original source in the alluvium. The fact that it flows out of the rock and rises above the surface of the playa may be explained by the clay beds of the playa acting as an impervious cover if the water has access to the fractured limestone from a more porous gravel or sand bed beneath the clay. On the other hand, the temperature of the water from the springs and wells, which ranges from 73½° to 78½°, suggests that the water may come from a deeper source. These temperatures are fully 10° above the probable mean annual temperature of the region.

Other springs.—At times, particularly in the cool months, water comes to the surface at a number of places in Soda Lake playa and stands or flows. The quality of this water changes with the wet and dry seasons. Undoubtedly at best it is fully as highly mineralized as the samples from Epsom Springs or the springs and wells at Soda Lake. In the drier seasons, after there has been much evaporation, it becomes a highly concentrated brine. Samples of brine collected from the playa by H. S. Gale contained 381.49 and 382.47 grams per liter (equivalent to more than 300,000 parts per million) of total solids.[62] A sample of water collected from the playa by Loew[63] contained 2,826 parts per million of total solids. It is possible that Loew's sample was collected from a spring on the border of the playa, as at Soda station, and not on the playa, where it is likely to be more concentrated. The brines collected by Gale contained only about 0.01 gram per liter of potash, which is equivalent to 0.002 per cent of the anhydrous residue. Obviously there is little potash in the brines. The brines contain considerable boron.

QUALITY OF WATER

Samples from several wells and springs were analyzed in the Geological Survey, and the results are given in the table below. These analyses show considerable differences both in the quantity and in the character of the dissolved mineral matter in the water in different parts of the valley. The total dissolved solids range from 371 to 3,129 parts per million. Some of the samples are very bad if not unfit for domestic use.

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[62] Phalen, W. C., Salt resources of the United States: U. S. Geol. Survey Bull. 669, p. 188, 1919.

[63] Loew, Oscar, Report on the alkaline lakes, thermal springs, mineral springs, and brackish waters of southern California and adjacent country: U. S. Geog. Surveys W. 100th Mer. Ann. Rept. for 1876, p. 196, 1876.

Analyses of ground waters in Soda Lake and Silver Lake Valleys, Calif., including Crucero Valley

[Parts per million]

	1	2	3	4	5	6	7
Silica (SiO_2)	61	52	53	70	71	58	12
Iron (Fe)	.15	.32	.06	.13	.05	.16	.36
Calcium (Ca)	6.8	108	16	18	21	29	2.9
Magnesium (Mg)	6.6	88	5.0	6.3	4.4	5.1	1.9
Sodium and potassium (Na+K)	[a] 458	623	[b] 724	[a] 658	[a] 227	[a] 135	[a] 142
Carbonate radicle (CO_3)	35	5.8	0	7.2	1.2	0	33
Bicarbonate radicle (HCO_3)	567	221	264	229	365	270	249
Sulphate radicle (SO_4)	186	153	321	316	108	74	7.2
Chloride radicle (Cl)	223	1,097	736	688	105	63	40
Nitrate radicle (NO_3)	8.6	10	2.2	1.0	.72	Trace.	.28
Borate radicle (BO_3)	------	------	12	------	------	------	------
Total dissolved solids at 180° C	1,269	2,298	2,010	1,929	744	512	371
Total hardness as $CaCO_3$ (calculated)	44	631	60	71	70	93	15
Date of collection	([e])	([e])	([f])	([f])	([f])	([f])	([f])

	8	9	10	11	12	13
Silica (SiO_2)	[c] 16	12	62	111	39	[c] 60
Iron (Fe)		.26	.05	.18	.19	
Calcium	99	16	114	3.8	25	14
Magnesium (Mg)	19	7.2	6.8	1.7	11	4.2
Sodium and potassium (Na+K)	181	[a] 1,145	[a] 1,006	[d] 768	[a] 269	[a] 301
Carbonate radicle (CO_3)	0	0	0	199	0	0
Bicarbonate radicle (HCO_3)	62	1,070	80	512	380	343
Sulphate radicle (SO_4)	43	740	356	270	209	126
Chloride radicle (Cl)	443	643	1,460	454	113	206
Nitrate radicle (NO_3)	------	Trace.	Trace.	.77	3.6	------
Borate radicle (BO_3)	------	------	------	5.9	------	------
Total dissolved solids at 180° C	838	3,129	3,120	2,124	854	[a] 880
Total hardness as $CaCO_3$ (calculated)	325	70	313	16	108	52
Date of collection	([g])	([h])	([i])	([j])	([k])	([l])

[a] Calculated.
[b] Na, 708; K, 16 parts per million.
[c] Includes silica (SiO_2), iron oxide (Fe_2O_3), and aluminum oxide (Al_2O_3).
[d] Na, 757; K, 11 parts per million.
[e] Sept. 9, 1917.
[f] Dec. 7, 1919.
[g] Mar. 1908.
[h] Dec. 3, 1919.
[i] Dec. 2, 1919.
[j] Dec. 6, 1919.
[k] Oct. 29, 1917.
[l] Oct. 28, 1915.

Analysts: 1, 2, Addie T. Geiger, U. S. Geological Survey; 3-7, 9-11, Margaret D. Foster, U. S. Geological Survey; 12, C. H. Kidwell, U. S. Geological Survey; 8, 13, unknown.

1. Well 1, pl. 28 and table on p. 524; G. Brauer, owner.
2. Well 6, pl. 28 and table on p. 524; R. Y. Williams, owner.
3. Soda Lake Spring at Soda station, in sec. 11, T. 12 N., R. 8 E. See p. 529 for description of spring.
4. Well 10, pl. 28 and table on p. 524; at Soda station.
5. Well 12, pl. 28 and table on p. 524; Tonopah & Tidewater Railroad Co.'s pumping plant at Rasor.
6. Well 21, pl. 28 and table on p. 525; Elmo Proctor, owner.
7. Well 13, pl. 28 and table on p. 524; A. Skelton, owner.
8. Well 34, pl. 28 and table on p. 525; Los Angeles & Salt Lake Railroad Co.'s pumping plant at Balch; analysis furnished by the railroad. Recalculated from hypothetical combinations in grains per U. S. gallon.
9. Well 44, pl. 28 and table on p. 526; C. B. Baber, owner.
10. Mesquite Spring, in sec. 25, T. 11 N., R. 7 E. See p. 528.
11. Epsom Spring, in sec. 21, T. 11 N., R. 8 E. See p. 529.
12. Halloran Spring, probably in sec. 14, T. 5 N., R. 10 E. Another sample from this spring collected by G. A. Waring on August 28, 1916, and analyzed by S. C. Dinsmore contained 890 parts per million of total solids. The relative amounts of the different constituents are approximately the same as given in the above analysis.
13. Well 45, pl. 28 and table on p. 526; Los Angeles & Salt Lake Railroad Co.'spumping plant at Afton station; analysis furnished by the railroad; recalculated from hypothetical combinations in grains per U. S. gallon. See p. 512 for description of well.

The best water, that from the Skelton well (No. 13), in the NW. ¼ sec. 11, T. 11 N., R. 7 W., is a sodium carbonate water that contains 371 parts per million of dissolved solids. It is good for domestic use but poor for irrigation. A sample from the domestic well of Elmo Proctor (No. 21), near Crucero, and one from the well of the Tonopah

& Tidewater Railroad at Rasor (No. 12) are of the same general character but somewhat more mineralized. The water from the Proctor well, which contains 512 parts per million of total solids, is good for domestic use but only fair for irrigation. The sample from the Rasor well, which contains 744 parts per million, is only fair for domestic use, and is poor for irrigation. Despite the poor quality of this water for boiler use it is considered relatively good as compared with other supplies used by the engines of the railroad.

The three samples just described come from wells on the alluvial plain of Mohave River and probably indicate the general character of the water that can be obtained in most parts of the plain between Baxter and the Tonopah & Tidewater Railroad. In general the quality of the water appears to be poorer the nearer the wells are to Soda Lake.

An exception was found in a sample from a well of C. B. Baber (No. 44), in the NW. ¼ sec. 33, T. 12 N., R. 7 E., which contained 3,129 parts per million of total solids, being the most highly mineralized sample obtained in the valley. This water is a sodium chloride water but also contains quantities of sulphate and carbonate almost equal to the chloride. It tastes distinctly salty and is very bad, if not unfit, for domestic use. It is unfit for boilers and bad for irrigation. The reason for this great mineralization is not known, for a sample from the Markt well (No. 41), in the SW. ¼ sec. 29, T. 12 N., R. 7 E., about a mile northwest, contained only 537 parts per million of total solids. It is essentially like the samples from the Skelton, Proctor, and Rasor wells and is good for domestic use but poor for irrigation and very bad for boilers. The water from well 43, between the Markt and Baber wells, is also said to be of poor quality. The Baber well is near one of the channels of Mohave River. The conditions seem to be favorable for free movement of the ground water eastward, and it would be expected that any salts in the alluvium would be leached out. The high mineralization of the water indicates some unusual conditions.

In addition to the samples described above, samples were analyzed from Mesquite Spring, Epsom Springs, and a spring and a well at Soda station. These analyses are discussed in the descriptions of these springs on pages 528–531.

TEMPERATURE OF WATER

The temperature of the water in 10 wells and springs in Crucero Valley was determined, and the results are given in the table on pages 130–131. With the exception of the small spring at Soda station, all the determinations were made during the first week in December, 1919. These determinations show a range between 50½° and 78½° F. The lowest temperatures, 50½° and 56°, were found in Mesquite Spring and a similar spring about a third of a mile east of it. These springs have almost no flow and probably fluctuate considerably with seasonal and perhaps daily changes in the temperature of the air.

The temperature in the Joralmon well, the Louisiana well of the Mohave United Mining & Milling Co., and Epsom Springs ranged from 62° to 65° F. The temperature of the water from the Ingalls well, which is situated between these wells, is 72¾°. The reason for this difference is not clear. The temperature of the water from two wells and two springs at Soda station ranges from 73½ to 78½° F.

The mean annual temperature at Barstow is about 63.7° F., and at Bagdad about 72.3°. No data are available in regard to the temperature in Crucero Valley, but from the altitude and topographic conditions and from statements of settlers it seems probable that the mean annual temperature at Crucero is intermediate between that at Barstow and at Bagdad. If so, the temperatures in the Joralmon and Louisiana wells and Epsom Springs are somewhat below the mean annual temperature, and those in the wells and springs at Soda Springs are several degrees above it.

IRRIGATION AND FUTURE DEVELOPMENT

Although the depth to water is not great in a large part of Crucero Valley, in 1919 there had been practically no real development. Several hundred acres of land had been cleared, and about 25 wells had been dug or drilled, of which only four or five were equipped with pumps suitable for irrigation. Most of this development work was done only to meet requirements on homestead entries. Entries have been made on fully 10,000 acres in the valley, most of them as long ago as 1914. In 1922, however, according to records of the General Land Office, only two or three homesteaders had received patents.

At the time of the writer's visit in December, 1919, only one ranch was occupied. So far as is known, up to that time no successful crops had been grown. According to information received in December, 1922, in the three years following the writer's visit the development work had been very slight. One ranch has been irrigated two seasons. This ranch was covered by flood water in the spring of 1920. Subsequently, after May 1, about 4 acres was planted in a variety of experimental crops, including milo maize, Sudan grass, sorghum, watermelons, cantaloupe, Durango cotton, squash, pumpkins, and beans. The land was also irrigated from a well. Two good crops of milo fodder were obtained, but the grain did not set because of the heat. Three good crops of Sudan grass were obtained and two fair crops of cane. No cotton was harvested, but it produced abundantly, and the yield, by count of the open boles, was estimated to be about 4 bales to the acre. Rodents destroyed most of the cantaloupes and beans. By the use of poison they were driven out sufficiently to save the watermelons, which yielded abundantly from August 15 until the first freeze, about November 20. It is said that from a fourth of an acre several wagonloads were sold to section hands, besides many that were given away or fed to chickens and hogs. Many were left in the field unharvested. This land was irrigated again in 1921. The crops of Sudan grass, milo maize, and cane were better than in the preceding year, but rodents destroyed everything else.

Elmo Proctor has experimented with date palms, which were set out about 1918 or 1919. He states that although they have had very little care they have withstood the winters and are in good condition. In December, 1922, they had not yet bloomed.

Conditions are unfavorable for the development of the valley; in fact, in some respects they seem to be more unfavorable than in almost any other part of the Mohave Desert region where any extensive development has been attempted. Probably the most discouraging feature is the fact that the soil is more sandy than in most parts of the desert where agriculture has been tried. The problem of preventing the sand from blowing on cleared land is more difficult than it is in most places. The sandy soil would also require much water for irrigation. An additional disadvantage in some parts of the valley is the possibility of overflow by the flood waters of Mohave River.

The water from wells in different parts of the valley is of only fair or poor quality for irrigation. The water in the western part of the valley is probably better than that in the lower eastern part. Where the depth to the water table is sufficient to allow good drainage probably no difficulty is experienced, but in the lower part of the valley alkali would probably accumulate.

A factor that has doubtless hampered the development of Crucero Valley is its comparative isolation. Although two railroads, one of them a transcontinental line, pass through the valley, the local service is very poor, and transportation charges are high. If enough business were brought into the valley to warrant it, the service would doubtless be improved, but until that time the pioneers in the valley must bear the burden of isolation. The roads into the valley are almost impassable for automobiles, and in the valley itself the trails are so sandy that transportation is very difficult and slow. There are no large towns near by to furnish markets for the products of the valley, which would probably have to be shipped to Los Angeles or more distant points in competition with products from more favorably situated regions.

At present floods from Mohave River cross the valley every two or three years or oftener. At such times there is probably sufficient recharge of the ground-water supply to provide for the irrigation of several thousand acres. If, however, as seems probable, run-off in the headwater region of the Mohave River basin is stored in reservoirs in the San Bernardino Mountains and used in the Upper Mohave Valley or directed to the south side of the mountains, the water that reaches Crucero Valley will be greatly lessened. Even though there might be considerable return seepage from the lands in the upper part of the basin, as some persons contend, the area of available agricultural land above Crucero Valley is so large that the water would probably all be used. Probably only in the wettest years, when the run-off considerably exceeded the storage, would enough water reach Crucero Valley to be of any value in recharging the ground-water reservoir.

CRONISE VALLEY

GENERAL FEATURES

Cronise Valley [64] adjoins Crucero Valley on the northwest. The drainage basin consists of two rather distinct parts, which in this report are called East and West Cronise Valleys, but as they are now or in comparatively recent time have been joined, they are considered together in this section.

Because of the sandy surface of the country surrounding the valley it has been until recently relatively inaccessible. In 1922 a new road was opened by San Bernardino County, which leads from Yermo along the Los Angeles & Salt Lake Railroad to a point near Field and thence through a pass in the Cave Mountains or Cronise Mountains and across the Soda Lake Mountains to Baker station, on the Tonopah & Tidewater Railroad. This road constitutes a part of the Arrowhead Trail. (See p. 143.) A little used and probably sandy road leads southeast to the valley from Bitter Spring. Roads, mostly so sandy that they can be traveled only by horse and wagon, lead southward from East Cronise Valley to different parts of Crucero Valley. The nearest railroad station is Baxter, 4 miles south of East Cronise Valley.

Several ranches have been established in the valley, but when the writer visited it in December, 1919, all of them were deserted. As late as January, 1923, the valley was still practically undeveloped. So far as is known, there has been no mining in the valley.

PHYSICAL FEATURES AND GEOLOGY

The boundaries of Cronise Valley are shown on Plate 7 and the principal features of relief on Plate 11 and in part on Plate 28. The valley is almost completely separated into two parts by the northeast end of the Cronise Mountains, which extend nearly north and south along the line between Rs. 6 and 7 W. Each of the parts contains a playa or "dry lake."

[64] The name of this valley on some maps is spelled Cronese. Information as to its origin is lacking. Possibly it is named after Titus Fey Cronise, a pioneer of California and author of "The natural wealth of California." On this assumption the name is here spelled Cronise.

East Cronise Valley is only about a fifth or a fourth as large as the west valley. On the east and south it is separated from Crucero Valley by low mountains and hills, the most conspicuous of which is Red Mountain, at the southeast, and the Cave Mountains, at the southwest. (See pp. 517–518.) The west side of the valley is bordered by the Cronise Mountains, which form a long, rather narrow ridge that trends mostly in a northeasterly direction, though its northeast end trends almost due north. This ridge is separated from Cave Mountain by a long alluvium-filled valley that rises toward the southwest for 2 or 3 miles. The mountains are steep, a fact which suggests that they have been uplifted by faulting. The rocks at the very north end of the ridge, the only place where they were observed, consist of gneiss and acidic and basic intrusive rocks.

The northern border of East Cronise Valley is formed by the Soda Lake Mountains, which also form the northeastern border of West Cronise Valley. These mountains constitute a large, irregular, and rugged mass that covers nearly three townships. From a distance the mountains appear to consist largely of metamorphic or intrusive rocks.

West Cronise Valley is bordered on the south and southwest by Dunn Mountain and the Alvord Mountains, which form a continuous barrier between it and the Mohave River drainage basin. Buwalda [65] states that the Alvord Mountains consist of a core of granitic rock in which lie patches of limestone, marble, and schist. The mass is cut by pegmatitic, aplitic, and basic dikes, and a series of basic lavas, presumably Tertiary, overlies the granite. He states that Dunn Mountain appears to consist largely of schist.

The western divide of the valley is somewhat indefinite. The extreme western boundary of the basin is formed by low hills along the line between Tps. 12 and 13 N., Rs. 3 and 4 E., which separate the valley from Langford and Coyote Valleys. On the northwest the divide is formed by Tiefort Mountain.

From the playa of the western valley a long slope rises westward but is broken in places by low hills. The most prominent of these hills is one elongated somewhat in a northwesterly direction in the north-central part of T. 13 N., R. 5 E. It is composed of black basaltic lava that is probably of either Pleistocene or late Tertiary age. A smaller ridge farther south appears from a distance to be composed of the same rock. From these hills the sloping plain continues to rise westward and southwestward, but apparently it does not drain directly to West Cronise Lake. Along the road from Langford Valley to Bitter Spring the drainage goes northward along the west side of the large lava hill just mentioned and around the north

[65] Buwalda, J. P., Pleistocene beds at Manix, in the eastern Mohave Desert region: California Univ. Dept. Geology Bull., vol. 7, No. 24, pp. 445-446, 1914.

side of it. On the north side of this hill there is a small alkali flat which apparently for a time was a playa. At present the drainage line continues southeastward, on the east side of the lava hill, past Bitter Spring to West Cronise Lake. The drainage from the north slope of the Alvord Mountains seems also to follow this roundabout course to West Cronise Lake.

The two playas that lie in the lower parts of the east and west valleys are noticeably different in their characteristics. The playa in the eastern valley lies close to the east base of Cronise Mountain. When visited in December, 1919, it presented a hard, black, much cracked surface, with no alkali visible. It was strikingly like the surface of Silver Lake when seen in 1917 and 1918. The water-soluble salt content of samples of soil from the playa ranged from 0.69 to 1.76 per cent of the total sample. (See analyses on p. 67.) The features indicate that the playa is of the dry type. However, the presence of mesquite around its border and well measurements show that the depth to water is probably not more than 15 feet.

The playa known as West Cronise Dry Lake lies at the extreme southeast side of the western basin. Its surface is characterized by "self-rising ground," with some alkali visible. The water-soluble salt content in samples of soil from the playa ranged from 4.20 to 12.73 per cent, which is considerably higher than in the soil from the east playa. (See analyses on p. 67.) Mesquite grows around the borders, particularly on the south and west sides, and the playa is of the wet type.

The playas and their basins were at one time completely separated by a large alluvial fan that was built out from the south side of the Soda Lake Mountains. This fan, where it abuts against the north end of Cronise Mountain, is now cut by a channel from 10 to 25 feet deep and 100 to 200 feet wide. Part of this channel is lined with round boulders as large as a foot in diameter. There is still a divide of a few feet at the northwest end of East Cronise Lake, but the natural conditions here have been disturbed by attempts to run a ditch from the east playa to the west playa. According to data based on instrumental leveling by H. D. Bradley, the west playa is about 5 feet below the east playa.

There is evidence that at some time in the past a lake has existed in the eastern valley, and it probably also extended into the western valley. A faint wave-cut cliff is visible along a low rock mound about a quarter of a mile east of the ranch house of H. D. Bradley, in the SE. ¼ sec. 20, T. 12 N., R. 7 E. Shells of mollusks occur along this cliff, and at the north end there are two or three pebbly strand lines. (See pl. 30, *A*.) The top of the cutting at the base of the cliff is between 10 and 20 feet above the present playa. This altitude is considerably above any divide that may have existed in recent years between the east and west playas, so that the lake must also have covered the west playa. Between the two playas, west of the northern tip of Cronise Mountain, lies a considerable thickness of sand, which may have been deposited in the lake, but the writer did not have an opportunity to study these sand beds sufficiently to determine their origin.

The lake evidently was formed from flood waters of Mohave River. As shown on pages 563–564, a larger lake at one time covered Soda and Silver Lake playas, a few miles farther east. This lake presumably was created and maintained also by the flood waters of Mohave River. Because of the relation of these ancient lakes to Mohave River the names Mohave Lake, for the lake in Soda and Silver Valleys, and Little Mohave Lake, for the lake in Cronise Valley, have been suggested.[66]

When Little Mohave Lake was in existence, Mohave River must have flowed northward, as it does now, from the mouth of Cave Canyon for longer or shorter periods as it built up its alluvial fan. The area of the lake was not very great, and as the wave-cut cliffs are meagerly developed it may not have existed for a very long period, probably not nearly as long as the larger Lake Mohave. (See p. 566.) Doubtless its existence was ended partly because, as the river built up its fan, for periods of varying length the river must have flowed eastward across the fan and avoided the entrance to Cronise Valley. It therefore seems certain that the lake was intermittent, existing for perhaps several years and then disappearing. As the small strand lines cut in alluvium are still preserved they may have been formed within a very few years, perhaps during the flood of 1916. One reason for the small area and depth of the lake is that the pass between Cronise Valley and Crucero Valley is only about 30 feet above East Cronise Dry Lake. The lake could not exceed that altitude, for any excess flood water would go eastward to Soda Lake.

SOILS

The soil in the eastern part of East Cronise Valley is the typical arkosic soil that results from the disintegration of the rocks of the near-by mountains. The soil of the western valley is also of this nature except around the playa. In the eastern valley, south of the playa, the soil contains much sand and silt that was deposited by floods from Mohave River. Much of the sand has been blown into low dunes.

An attempt has been made to grow crops on a small scale in East Cronise Dry Lake. In fact, homestead applications that cover all of the playa have been made. A sample of soil, obtained by scraping

[66] Thompson, D. G., Pleistocene lakes along Mohave River, Calif.: Washington Acad. Sci. Jour., vol. 2, No. 17, p. 424, 1921.

down the side of a 2-foot hole on the playa in the NW. ¼ SW. ¼ sec. 17, T. 12 N., R. 7 E., contained 0.69 per cent of soluble salts (see p. 67), consisting of about equal amounts of sodium carbonate, sodium sulphate, and sodium chloride. Another sample, from a depth of about 4 inches at the northwest end of the playa, contained 1.76 per cent of soluble salts. Evidently the percentage of soluble salts in the playa soil is so high that most plants could not grow. The soil also has a tendency to bake so hard that it is very unfavorable for crops. The very fact that none of the native plants, which would naturally be best adapted to adverse conditions, grow on the playa is evidence in itself that it is useless to attempt the cultivation of this tract of land.

Analyses of soil from the playa in the western valley show from 4.2 to 12.7 per cent of soluble salts. Obviously this playa also can not be cultivated.

VEGETATION

South of East Cronise Dry Lake, in the area of nearly level land between the southern border of the valley and the playa, several types of salt bush are abundant. The abundance of this vegetation evidently depends on the occasional floods from the river. Mesquite abounds in this part of the valley and also grows in more scattered clumps around the border of the entire playa. The desert willow occurs on the south side of the valley. In the eastern part of the valley, approximately east of the line between secs. 20 and 21, T. 12 N., R. 7 E., the vegetation consists typically of creosote bush and its associates.

In the western valley mesquite occurs around the border of the playa but does not extend very far from it. Some salt grass also grows near the playa. Farther away from the playa creosote bush is the dominant plant.

SURFACE WATER

The only surface water available for irrigation in Cronise Valley is the flood water that comes down Mohave River from time to time. Mohave River, where it emerges from Cave Canyon near Baxter, spreads out in a number of distributary channels. Some of these channels continue eastward, but one or more lead northward to two passes into Cronise Valley, in the SE. ¼ sec. 30 and the SW. ¼ sec. 29, T. 12 N., R. 7 E.

No definite data are available in regard to the quantity of water discharged into Cronise Valley through these passes. In some rainy seasons it is doubtless several thousand acre-feet. During the big flood of January and February, 1916, the playa in the eastern valley, as well as land for some distance south of the playa, was covered to a depth of about 10 feet. Some water overflowed into West Cronise Dry Lake through a ditch cut between the two playas. In the winter of 1921–22 the eastern playa was flooded to a depth of about 6 feet. The flow of the stream at times reaches several thousand second-feet for short periods. On the other hand, in dry years there may be no discharge. No reliable measurements have been made of the quantity of water discharged into the valley, and because of the varying conditions it is impossible to make any estimate of the quantity available.

In building up its fan below the mouth of Cave Canyon, Mohave River has frequently changed its channels. The conditions on the fan at the present time are such that it is not improbable that the river may completely change its course and cease to discharge into Cronise Valley.

An attempt has been made to utilize the water that discharges into Cronise Valley by the Valley Cultivating Co., organized about 1912. The company has filed on 3,000 miner's inches (60 second-feet) from Mohave River and 50,000 miner's inches (5,000 second-feet) overflow water, to be diverted near Baxter. Originally it planned to carry the water by ditch to West Cronise Dry Lake, where it was to be stored and pumped back to land in the eastern valley as needed. The pumping lift would probably be not more than 25 or 30 feet. It was discovered that the playa in the western valley, where the water was to be stored, was so saline that it would render the water unfit for irrigation. This plan was accordingly dropped.

Subsequently it was proposed to construct a dam across the larger of the two passes into Cronise Valley, in the SE. ¼ sec. 30, T. 12 N., R. 7 E. This dam would be about 535 feet long, between rock hills, and 26 feet high. A dike would be built southward from the east side of the dam for about a mile. The reservoir thus created would cover about 450 acres and have a capacity of about 5,900 acre-feet. The company expected to irrigate about 2,500 acres. When the writer visited the valley in December, 1919, the main dam had been completed entirely across the pass to a height of about 10 feet. It was about 4 feet wide at the top and 30 feet at the bottom. It is built of rock quarried from the adjoining hills. The dam does not reach bedrock. A gate at the east end provides an outlet and spillway. When the dam was visited by the writer a small volume of water was impounded and a small stream was flowing into the reservoir. There had been no flow in the river from the headwater region, and the water evidently had come from the upper stretches of the river as underflow.

H. D. Bradley states in a letter that the dam successfully withstood floods in the winter of 1921–22, but a temporary dam in sec. 29, east of the main dam, was carried away and the flood waters poured into East Cronise Valley. A new channel was cut around the butte at the east end of the main dam, and the reservoir now holds very little water. The reservoir has silted up about 3 feet.

At the time of the writer's visit the project was not far enough along to determine its feasibility. Certain difficulties, however, must be recognized. In some years the discharge of the river is practically nothing. In other years the flow is very great for short periods, and expensive works may be required in order to control it and prevent damage to the dam and dike. The fact that 3 feet of silt was deposited in the reservoir shows that difficulty is to be expected from this source. The total area that can be irrigated under the project is at most not more than 1,000 to 1,500 acres, so that if difficulties are encountered which require unusual expenditures the cost of irrigation is likely to prove unusually great.

GROUND WATER

DEPTH TO WATER

Only five or six wells have been drilled in East Cronise Valley and, so far as known, none in West Cronise Valley. At the time of the writer's visit no one was living in the valley, and except for measurements on the depth of the wells and the depth to water very few data were obtained. These data are given in the table on pages 525–526 (Nos. 35 to 40).

The depth to water in the wells measured ranged from 15 to 20 feet. In one well (No. 35), which could not be measured, the depth to water is reported to be only 12 feet. In another well (No. 41), it is reported to be 35 feet. This well is situated in the eastern pass from Crucero Valley and only a few feet north of a granite hill, which may shut off direct underflow from the south.

So far as is known, there are no wells east of the line between secs. 20 and 21, T. 12 N., R. 7 E. It is doubtful whether water can be obtained east of this line. Rock is reported to have been struck at a depth of 100 feet in a well of H. D. Bradley at the southwest corner of SE. ¼ sec. 20, T. 12 N., R. 7 E. The well was not drilled deeper, and it is uncertain whether the rock was bedrock or only a boulder, especially in view of the fact that a well less than 100 feet farther west, on the G. T. Roberts ranch, did not strike rock at a depth of 142 feet. Bedrock crops out in the SW. ¼ sec. 21 of the same township. It is probable that the land east of this, although it appears to be an alluvial slope, is underlain by rock at no great depth.

Measurements at several points in the eastern valley show that the water table is nearly level, with only a very slight slope to the north, which probably indicates that the supply of ground water is not great. The granite hills on each side of the pass between Crucero Valley and Cronise Valley suggest that in the pass the bedrock is so close to the surface that the underflow from the fan of Mohave River can not enter the valley. The only important recharge comes from the flood water which actually enters the valley and which is absorbed in the area between the passes and East Cronise Dry Lake. The water that reaches the playa doubtless mostly evaporates, for the clay is so impervious that probably not much of the water percolates to the water table. The conditions as a whole seem unfavorable for much recharge of the ground-water reservoir, especially as in some years there is practically no flood flow into the valley. The water table in East Cronise Valley is only a few feet below the surface of the western playa. The pass between the two valleys is filled with alluvium, and undoubtedly there is some percolation from the eastern to the western valley, where the ground water is discharged by evaporation.

Springs are said to occur around the borders of West Cronise Dry Lake, which is of the moist type, with alkali-covered "self-rising ground." Mesquite on the south and west sides of the playa and some salt grass at its borders show that water is not far from the surface. It can doubtless be obtained at a depth of less than 10 feet near the playa. Away from the playa the depth to water increases in general with the altitude of the surface above the playa. The grade of the alluvial slopes is gentle for some distance away from the playa, especially on the south and west, and very likely the depth to water will be less than 100 feet as far as a mile or more from it. On the northeast side of the playa the slopes rise somewhat more steeply and the depth to water will be greater.

YIELD OF WELLS

Well 35, on the J. Walton ranch, is said to have a yield of 540 gallons a minute (60 miner's inches). This well is 12 inches in diameter. It could not be measured but is reported to be about 150 feet deep, with about 12 feet to water. It is equipped with a Layne & Bowler turbine pump.

The well of H. D. Bradley (No. 38) yielded about 225 gallons a minute (25 miner's inches) after the casing was perforated twice. The G. T. Roberts well, about 75 feet west of the Bradley well, yields 315 gallons a minute (35 miner's inches). The casing of this well was also perforated twice. It is 12 inches in diameter and 142 feet deep, and the depth to water is about 22 feet. So far as could be learned, no other well yielded as much as 225 gallons a minute.

The log of the Roberts well follows.

Log of well 39, southeast corner of SW. ¼ sec. 20, T. 12 N., R. 7 E. San Bernardino meridian

[George T. Roberts, owner. Log furnished by H. D. Bradley. Drilled February, 1914]

	Thickness (feet)	Depth (feet)
Silt and sand	12	12
Silt	6	18
Soft clay	7	25
Sand	4	29
Clay	16	45
Hard sand	5	50
Sand and gravel	2	52
Clay	4	56
Sand	1	57
Clay	2	59
Sand	1	60
Clay and sand	6	66
Sand and gravel	9	75
Gravel; casing perforated	5	80
Fine sand	4	84
Gravel; casing perforated	32	116
Quicksand	2	118
Sand and gravel; casing perforated	8	126
Sandrock	2	128
Sand and gravel; casing perforated	14	142

This log shows that the casing was perforated in 59 feet of gravel, or almost 50 per cent of the total depth of the well below the water level. According to the yield of wells in other parts of the Mohave Desert region, this thickness of gravel should yield water abundantly unless there is some unusual condition. Possibly fine material has clogged the well, but when the writer measured it in December, 1919, more than five years after drilling, the total depth was 134 feet, showing that it had sanded up less than 10 feet. The low yield can hardly be due to poor perforations, for the casing has been perforated twice.

As a whole, the conditions are unfavorable for any great development of ground water in East Cronise Valley. Very likely the ground-water storage area is confined to the land south of the playa, about 1,500 acres, and is practically equal to the area available for irrigation. It is questionable whether the recharge would be sufficient to irrigate even this small area.

No definite statements can be made as to the probable yield of wells in West Cronise Valley. It appears that the geologic conditions in comparatively recent times which resulted in the accumulation of the fine silt and clay in East Cronise Valley did not exist in West Cronise Valley. In the western valley the alluvium is washed from near-by mountains and is probably somewhat coarser than in the eastern valley. However, there is probably no great quantity of water available for recharge.

QUALITY OF WATER

Samples of water were collected from two wells in East Cronise Valley and the results of the analyses are given on page 545.

One sample (2), from the Markt well (No. 41), is moderately mineralized and contains 537 parts per million of total solids. It is good for domestic use but poor for irrigation. This water came from a well in the eastern of the two passes to Crucero Valley. The well is so situated that it receives the first accession from the flood waters that enter the valley and besides there is free drainage northward.

The other sample (1), from the domestic well of H. D. Bradley (No. 37), is somewhat more mineralized, containing 681 parts per million of total solids. It is only fair for domestic use and is poor for irrigation.

The water in other wells is said to be no better than those analyzed, although none apparently is so highly mineralized that it can not be used for a domestic supply. In general it is probable that the water near the playa is somewhat poorer in quality than that farther from it.

Water near the playa in West Cronise Valley is probably more highly mineralized than that in East Cronise Valley, for the soil beneath the western playa is more highly impregnated with salts. The extent to which the water some distance from the playa is mineralized is uncertain, but conditions in other valleys show that the quality probably improves toward the borders of the valley. Whether the water is of sufficiently good quality for irrigation in the territory in which the pumping lift is within the economic limit can be determined only by trial.

Analyses of ground waters in Cronise Valley

[Parts per million]

	1	2	3
Silica (SiO_2)	39	46	81
Iron (Fe)	.11	.23	.20
Calcium (Ca)	5.0	29	14
Magnesium (Mg)	1.0	4.8	7.2
Sodium and potassium (Na+K)	[a] 241	[a] 158	[b] 505
Carbonate radicle (CO_3)	36	0	0
Bicarbonate radicle (HCO_3)	307	367	220
Sulphate radicle (SO_4)	94	64	606
Chloride radicle (Cl)	92	48	246
Nitrate radicle (NO_3)	.24	.36	2.8
Total dissolved solids at 180° C	681	537	1,623
Total hardness as $CaCO_3$ (calculated)	17	92	64
Date of collection	(c)	(d)	(e)

[a] Calculated. [b] Na, 485; K, 20 parts per million. [c] Dec. 4, 1919. [d] Dec. 3, 1919. [e] Feb. 26, 1918.

Analysts: 1, 2, Margaret D. Foster, U. S. Geological Survey; 3, C. H. Kidwell, U. S. Geological Survey.
1. Well 37, pl. 28, and table on p. 525; H. D. Bradley, owner.
2. Well 41, pl. 28, and table on p. 526; H. Markt, owner.
3. Bitter Spring, in sec. 10, T. 13, N., R. 5 E. San Bernardino meridian.

SPRINGS

Cronise Spring.—On several maps a spring known as Cronise Spring is shown at the southeast end of West Cronise Dry Lake. According to Mendenhall,[67] the spring emerges at the southwest base

[67] Mendenhall, W. C., Some desert watering places in southeastern California and southwestern Nevada: U. S. Geol. Survey Water-Supply Paper 224, p. 61, 1909.

of the Soda Lake Mountains. The writer did not see any spring in this locality, and inquiry from several prospectors failed to reveal any definite information as to it. One or more springs are reported to emerge on the northwest side of the playa. The locality was not visited, but mesquite was seen on the west and north sides of the playa, and it is not improbable that seepages or shallow wells may be present there.

When Mohave River pours much flood water into East Cronise Valley the water table possibly rises sufficiently to cause some surface seepage in the channel that leads from the northwest end of East Cronise Dry Lake to West Cronise Dry Lake. During succeeding dry seasons the water table may fall sufficiently to result in the drying up of the spring.

Bitter Spring.—Bitter Spring is in the north-central part of T. 13 N., R. 5 E.,[68] near the head of a long wash that drains southeastward to West Cronise Dry Lake. The drainage in the western part of West Cronise Valley goes northeastward around the west side of a lava butte in T. 13 N., R. 5 E. At the north end of this butte it is joined by drainage from Tiefort Mountain. At this locality there is a clay flat in which the flood waters are now partly ponded. From the clay flat the wash swings to the southeast and passes between the lava butte and a low hill on the east that perhaps formerly formed a complete barrier to the drainage and made a true playa of the clay flat. Where the wash passes between the hills there is much arrow weed, some salt grass, and one or two mesquite trees. At the time of the writer's visit, in February, 1918, there were several small seepages in the wash, which are said to dry up in the summer. Bitter Spring is situated about 100 yards southeast of the uppermost growth of water-indicating plants. The water comes from a pipe that leads from a shallow hole dug in the hillside east of the wash to a watering trough. When seen by the writer the flow was only about 2 gallons a minute. It is said that although the seepages in the wash dry up in summer the flow from the spring continues about the same.

Analysis 3 (p. 545) shows that this water is of poor quality. The high sulphate content gives it the bitter taste from which its name is derived. Nevertheless it can be used in an emergency.

Bitter Spring was for many years a well-known desert watering place, but in recent years it has been less used. It was a regular camping place on the old Salt Lake wagon road, and before that also probably on the old Spanish trail to New Mexico. It seems certain that Bitter Spring was the Agua de Tomaso mentioned by Frémont [69] and other early explorers. On several maps this spring has

[68] The location of the spring is incorrectly shown on the relief map (pl. 11), as in T. 14 N., R. 5 E. According to the General Land Office township plat it is in sec. 10, T. 13 N., R. 5 E. The general location of the spring with respect to roads and topographic features, however, is correct.

[69] Frémont, J. C., Report of the exploring expedition to the Rocky Mountains and to Oregon and California, 1st ed., p. 262, 1845.

been shown in the central or eastern part of T. 14 N., R. 7 E., but no one could be found who knew of any spring in that locality. The latitude and longitude determinations made by Frémont at Agua de Tomaso put it about 2 miles south of the location of Bitter Spring—that is, much nearer to Bitter Spring than to any location in T. 14 N., R. 7 E. Other information in Frémont's journal tends to corroborate the belief that Agua de Tomaso is none other than Bitter Spring, and that the former spring should be eliminated from maps.

IRRIGATION AND FUTURE DEVELOPMENT

Homesteading in East Cronise Valley began about 1912 or 1914. In December, 1919, when the writer visited the valley, there was little evidence of real development. Some land had been cleared and irrigated, but no one was at that time living in the valley. It is reported that there has been some additional development. Some land has been irrigated from the reservoir of the Valley Cultivating Co., but apparently not with much success. There is no evidence that any attempt has been made to irrigate lands in West Cronise Valley.

The conditions in East Cronise Valley do not seem favorable for great development. There is some doubt whether sufficient water will collect in the reservoir in dry years to meet the requirements for irrigation. On the other hand, in years of unusual floods, such as are almost certain to occur, considerable damage may be done either to the reservoir or to the valley lands by flooding. The natural situation of the reservoir is such that the liability to damage can be prevented only by considerable expenditure. The irrigable area is small, and the pro rata expense of protective works might prove burdensome.

If ground water is used for irrigation the conditions are no more favorable. The water table in a large part of the valley is not far below the surface, but the wells for which data are available do not yield large supplies. The ground-water reservoir is not large, and conditions do not seem favorable for recharge. The ground water is of poor quality for irrigation, and the possibilities of drainage are slight. As a result, irrigation, either from wells or from the reservoir, might spoil the land through the accumulation of alkali. If any of the proposed projects for using water of Mohave River in the Upper Mohave Valley or on the south side of the mountains are ever completed the water supply in Cronise Valley will become still smaller. A further disadvantage is the isolation of the valley, though this has been remedied somewhat by the opening of the new road from Yermo to Silver Lake, which passes through the valley. As the irrigable area is relatively small, the farming community can at best not become large.

KELSO VALLEY

GENERAL FEATURES

Kelso Valley, part of the Soda Lake drainage basin, lies a short distance east of the central part of San Bernardino County. (See pl. 7.) The valley is named from Kelso, the only town in the area.

The valley is traversed by the Los Angeles & Salt Lake Railroad. A fair road parallels the railroad from Cima, at the northeast end of the valley, as far as Kelso. Southwest of that point it is so sandy that it is impassable for automobiles, but it could probably be traveled by wagons. A number of secondary roads lead to different parts of the valley (see pl. 12), but the only roads that are satisfactory for automobiles are the road that leads from Cima southward to Cedar Canyon and across the New York Mountains to Lanfair and Fenner and one that leads westward from Cima to Marl Spring. From Marl Spring a road leads northwestward to Silver Lake, but it is said to be so sandy as to be impassable for automobiles.

Kelso is a fuel station for all trains, and there is also a roundhouse for helper engines used on trains ascending the heavy grades to Cima. Groceries can be obtained at a small store. In 1918 Cima, situated on the divide between Kelso Valley and Ivanpah Valley, consisted of only two or three houses, including a small store. Its existence depends largely on mining activity in the near-by mountains. There are post offices at both Kelso and Cima.

Section crews are stationed at Glasgow, Flynn, Hayden, and Elora, and a pumping plant is operated at Sands. Water and help in emergencies can be obtained at these places. In addition water is available at a railroad tank at Chase. Kerens and Ames are only sidings, where neither water nor help is available.

No records of precipitation have been kept in the area. There is evidently a difference of several inches in the average annual precipitation in different parts of the region, which is due to the difference in altitude. In the lowest part of the valley the average annual precipitation is probably not more than 3 or 4 inches. According to short-time records at Lanfair and other points it may be as much as 10 inches in the highest parts on the west slope of the New York and Providence Mountains. Evidence of the greater precipitation in the mountains is found in the presence of piñon on their upper slopes.

The soil of the greater part of the region is the typical desert arkose—a coarse sandy loam that has resulted from the mechanical disintegration of granitic rocks. West and southwest of Kelso the soil is very sandy over a large area. About 5 miles southwest of Kelso a single area 10 or 15 square miles in extent contains immense sand dunes. (See pp. 113, 551.)

The vegetation of the greater part of the area is creosote bush and its associates. The piñon grows on the upper slopes of the New York and Providence Mountains. Near Cima Joshua trees are abundant. (See pl. 4, *B*.) Also in this high altitude a species of grass (probably galleta or grama grass) is abundant and furnishes forage for cattle.

PHYSICAL FEATURES AND GEOLOGY

Kelso Valley constitutes a complete unit of the Soda Lake drainage basin in that the drainage from the entire valley, as shown on Plates 7 and 12, is concentrated into a single wash. This wash passes from the valley to Soda Lake on the west side of T. 11 N., R. 10 E. The valley is primarily a trough that descends southwestward, in which the drainage from the two sides flows through numerous channels to an axial wash. At the southwest end the drainage from a considerable area is concentrated into a single branch wash before it enters the main wash.

The southeast side of Kelso Valley is bounded by the Providence Mountains, which rise to a maximum altitude of 5,800 feet. (See pp. 663–666.) A notable feature of these mountains is the steep northwest face, which is suggestive of a great fault scarp. A number of canyons have cut eastward beyond the crest of the range. This cutting may be due to a renewal of erosional activity that followed uplift of the range. From the railroad a low scarp is visible at the base of the mountains 2 or 3 miles east of Hayden. It has the appearance of a fault scarp that cuts the alluvial slope. However, neither it nor the mountains were studied closely, and definite evidence of faulting was not obtained.

The southern border of the valley is formed by the Granite Mountains and Old Dad Mountains. As suggested by the name, the Granite Mountains consist principally of granitic rocks, and a large part of the other range is probably composed of rocks of the same kind. Township plats of the General Land Office show lava flows in the extreme southwestern part of the valley. A notable feature, which may or may not be significant, is the approximately parallel arrangement of several elongated mountain ranges, including the Old Dad Mountains. The northward trend and parallelism of these ranges are strongly suggestive of regional faulting.

The northern border of the valley is formed by several more or less isolated mountains and knobs. The highest of these is Kelso Peak, which rises 4,746 feet above sea level. The rocks of the low mountains between Cima and Marl Spring are all granite, and it is probable that a large part of the other mountains on the north side of the valley is also composed of granite.

Northwest of Cima the land rises with a rather gentle uniform slope, like an alluvial slope, to a nearly dome-shaped summit, which reaches more than a thousand feet above Kelso Peak. This unusual feature is shown very well on the Ivanpah topographic map. Many outcrops show that this dome is composed of granite and is not an alluvial slope, as it appears to be, but an erosional slope or mountain pediment.

A large part of Kelso Valley consists of smooth valley slopes which rise for 500 feet or more from the axis of the valley to the foot of the mountains. Along the axis of the valley the smooth slopes rise from an altitude of about 1,500 feet at the southwest end to more than 4,000 feet at the northeast end. In fact, west of Cima the smooth slopes rise uniformly to an altitude of more than 5,500 feet, broken only in a few places by a few low hills. In the lower part of the valley, including the axial wash for most of its length, the alluvium is probably present to a considerable depth. For example, well 1 of the Los Angeles & Salt Lake Railroad at Kelso did not strike bedrock at a depth of 882 feet. According to a log of the well furnished by the railroad this well penetrated cemented sand to 465 feet, clay and boulders from 465 to 500 feet, sand and gravel from 500 to 630 feet, sand and boulders from 630 to 740 feet, and sand from 740 to 882 feet. The following log of well 2, which was drilled to a depth of 606 feet at a point less than 100 feet from No. 1 shows many more beds of sand, gravel, and boulders.

Log of well 2 at Kelso, Calif.

[Los Angeles & Salt Lake Railroad, owner]

	Thickness (feet)	Depth (feet)
Sand and gravel	75	75
Sand and boulders	9	84
Boulders	65	149
Sand and gravel	23	172
Clay	14	186
Boulders	10	196
Sand and gravel	12	208
Boulders	23	231
Sand and gravel	15	246
Boulders	54	300
Sand and gravel	35	335
Boulders	14	349
Sand	20	369
Sand and gravel	20	389
Boulders	18	407
Granite (?)	29	436
Boulders	12	448
Sand and boulders	43	491
Granite (?)	19	510
Sand and gravel	55	565
Sand	41	606

The notable difference between this log and the log of the upper 600 feet of well 1 can hardly be due to changes in the alluvium in a short distance but is probably due to the fact that the drillers paid little attention to the nature of the formation in well 1 until water was reached. It is very doubtful whether the formation reported as granite from 407 to 436 feet and from 491 to 510 feet is really granite. It may be arkose, more or less consolidated, similar to that which now forms the surface soil in a large part of the desert. This arkose, which was formed by the mechanical disintegration of granite, looks considerably like drill cuttings of granite.

The alluvium along the axis of the valley is not everywhere as thick as at Kelso. Thus, according to a log furnished by the railroad company, a well at Sands struck the granite bedrock at a depth of only 205 feet and continued in it 41 feet to the bottom of the well. This well is near a constriction between rock hills through which Kelso Wash passes to Soda Lake. The bottom of alluvium in this well doubtless lies at about the lowest altitude to which it extends anywhere in Kelso Valley. On the other hand, at the upper end of the valley, bedrock is near the surface. A dug well at the Gibson ranch at Cima entered granite at a depth of about 25 feet. Farther up the slope, in T. 14 N., R. 13 E., numerous large boulders and small knobs of granite rise above the otherwise gentle slope. It is very evident that the surface in this part of the valley is not an alluvial slope, as it appears to be, but is an erosional surface or mountain pediment beveled across the bedrock. It may have a thin veneer of alluvium on top of it, but at most this is only a few inches or a few feet thick. It is difficult to tell where the alluvial slope ends and the erosional slope begins, for the decayed granite in place is much like the soil of the alluvial slope.

Noteworthy features in Kelso Valley are immense dunes that cover an area of at least 10 or 15 square miles southwest of Kelso. The dunes lie on alluvial slopes north of the Granite Mountains. They are estimated to be fully 500 feet high. The apparent height may be exaggerated by the fact that the dunes lie on the alluvial slope, which may be steeper beneath them than in front of them. This group of dunes is the largest that was observed in the Mohave Desert region. Although they do not cover nearly as large an area as those on the east side of Imperial Valley, it is believed that they are higher. The occurrence of the dunes at this place is undoubtedly greatly influenced by local topographic and geologic conditions. The great fan of Mohave River between Cave Canyon and Soda Lake supplies abundant sand, and the wide expanse of Soda Lake Valley gives opportunity for strong winds to pick up the sand. The sand is blown eastward across the valley. As the air currents approach the high Providence Mountains they must rise more and more. With the increase in the vertical component the wind is less powerful to carry the sand upward and drops it. The dunes are situated at some distance from the Providence Mountains, apparently because the sand is too heavy to be carried farther up the alluvial slope. Their position may be due to a localization of wind eddies caused by topographic features.

In addition to the large dunes southwest of Kelso smaller dunes cover a large area on the lower alluvial slopes, particularly on the westward-facing slope east and northeast of Sands station. This area constitutes part of the Devil's Playground, an area that is covered with sand, which is continually drifting about.

GROUND WATER

WATER IN THE ALLUVIUM

The only wells known to exist in Kelso Valley belong to the Los Angeles & Salt Lake Railroad, three of them at Kelso and one at Sands. The following information in regard to them is furnished by the railroad company.

Wells at Kelso.—The logs of wells 1 and 2 at Kelso are given on page 550. Well 1 is 882 feet deep and ranges in diameter from 13½ to 9⅝ inches. The depth to water is about 450 feet. The casing is perforated from 440 feet to the bottom. Well 2 is 600 feet deep and ranges in diameter from 13½ to 9⅝ inches. The depth to water is about the same as in well 1. The casing is perforated from 460 to 590 feet. No data are available in regard to the third well.

The wells are pumped by deep-well cylinder pumps operated by steam heads. The cylinder in well 1 is set at a depth of 585 feet and in well 2 at 565 feet. The drawdown is 100 feet when each well is pumping 100 gallons a minute.

As shown by analysis 1, below, the water from these wells is moderately mineralized. A sample collected in 1908, which was slightly less mineralized, contained 268 parts per million of total dissolved solids. The water is good for domestic use and for irrigation and fair for boilers.

Analyses of ground waters from Kelso Valley, Calif.

[Analyzed by the Dearborn Drug & Chemical Co. Parts per million.[a]]

	1	2
Silica (SiO_2) } Iron (Fe) }	[b] 9.6	[b] 20
Calcium (Ca)	27	28
Magnesium (Mg)	14	7.8
Sodium and potassium (Na+K) (calculated)	54	73
Bicarbonate radicle (HCO_3)	171	114
Sulphate radicle (SO_4)	42	59
Chloride radicle (Cl)	41	72
Nitrate radicle (NO_3)		4.4
Total dissolved solids (calculated)	272	320
Total hardness as $CaCO_3$ (calculated)	125	102
Date of collection	(c)	(d)

[a] Recalculated from hypothetical combinations in grains per U. S. gallon.
[b] Includes silica (SiO_2), iron oxide (Fe_2O_3), and aluminum oxide (Al_2O_3).
[c] Oct. 22, 1915.
[d] Oct. 28, 1915.

1. Los Angeles & Salt Lake Railroad Co. pumping plant at Kelso, probably in sec. 24, T. 11 N., R. 12 E.; analysis furnished by railroad. See above for description of well.
2. Los Angeles & Salt Lake Railroad Co. pumping plant at Sands station probably in sec. 30, T. 11 N., R. 10 E.; analysis furnished by railroad. See p. 553 for description of well.

Wells at Sands station.—The railroad well at Sands station is 246 feet deep and ranges in diameter from 13½ to 11⅝ inches. The depth to water is 196 feet. The materials penetrated in the well were sand and boulders 105 feet, hard sand from 105 to 117 feet, sand (apparently unconsolidated) from 117 to 195 feet, sand and boulders from 195 to 205 feet, and granite from 205 to 246 feet. The casing is perforated from 190 to 220 feet. The well is pumped with a deep-well cylinder pump, operated by a steam head. The cylinder is set at 217 feet. The capacity of the well is about 125 gallons a minute. The drawdown when it is being pumped at this rate is not known, but it is believed to be not more than 10 feet. Analysis 2 (p. 552) shows the water to be moderately mineralized. Like the water at Kelso, a sample analyzed in 1908, seven years prior to the date of the analysis given in the table, was less highly mineralized. The water from the Sands well is somewhat more mineralized than that from the Kelso wells. Nevertheless, it is good for domestic use and fair for boilers.

General features.—The altitude of the surface at Sands is about 1,235 feet above sea level and of the water table about 1,040 feet. At Kelso the altitude of the surface is about 2,150 feet and of the water table about 1,750 feet. There is thus a difference of about 700 feet between the two places in the altitude of the water table. The distance between the wells along Kelso Wash is about 18 miles, and the grade of the water table is thus about 40 feet to the mile. On this basis the depth to water in other parts of the valley may be estimated. For example, at Ames, 8 miles northeast of Kelso, the water table would be about 320 feet higher than at Kelso. But the surface at Ames is about 900 feet higher than at Kelso, so that the depth to water there would be nearly 600 feet greater, or a total of nearly 1,000 feet. Probably bedrock would be struck before that depth was reached, and very little if any water would be obtained in the rock. It is apparent that drilling at any point very far northeast of Kelso would be an expensive undertaking, with the probability that little or no water would be obtained.

The depth to water in the well at Sands is 196 feet, so great as to preclude its use for irrigation. This well is in the lowest part of the valley. Because of the greater depth to water in other parts of the valley, there is obviously no prospect of any development of irrigation.

SPRINGS

Marl Spring.—Marl Spring is in sec. 36, T. 13 N., R. 12 E. It is reached most easily by a road that leads southwestward from Cima. This road continues westward and northwestward to Silver Lake but is very sandy. Roads lead southward or southwestward from the spring to Kelso, Hayden, and Ames, but in 1917 they were in bad condition. The spring issues at the southeast end of a spur at the northeast end of a low mountain. The water comes from a tunnel or drift that extends for almost 50 feet along the side of the spur. The rock is granite. A pipe line leads from the tunnel to a near-by watering trough. When the writer visited the spring no water was flowing from the pipe line, although there was plenty of water in the tunnel. The tunnel was barricaded to prevent cattle from entering, but water could easily be obtained. No sample was taken, but the water appears to be of good quality.

Cornfield Spring.—Cornfield Spring is in the Providence Mountains, about 6 miles southeast of Kelso. The water is piped to Kelso and used by the railroad, mainly as a reserve when the supply from the wells is insufficient. For this purpose there is about a mile southeast of Kelso a storage reservoir that has a capacity of a little more than a million gallons.

On the Ivanpah topographic map several springs are shown in the Providence Mountains, but none of them were visited and no information was obtained in regard to them. As they are situated in the mountains the water from them is probably of good quality.

SODA LAKE AND SILVER LAKE VALLEYS

GENERAL FEATURES

The unit described in this section as Soda Lake and Silver Lake Valleys lies in the central part of San Bernardino County. It consists of a wide valley elongated in a north-south direction, in the bottom of which are two playas, Soda Lake and Silver Lake. (See map of drainage basins, pl. 7, and relief maps, pls. 11 and 12.) At its southeast end it receives the drainage from Kelso Valley (p. 549) and at its southwest end that from the large Mohave River basin (p. 512). Kelso Valley and the Mohave River basin, however, constitute rather definite physiographic units, distinct from the great depressions that hold the playas, and they are described as such. The unit here described is considered as comprising the area that lies immediately adjacent to the two playas known as Soda Lake and Silver Lake, but the boundaries as shown on Plate 7 are necessarily somewhat arbitrary assumed for purposes of description. The area directly tributary to the two playas is physiographically a single unit, but it may be divided into two smaller units, Soda Lake Valley and Silver Lake Valley, by a line drawn approximately east and west across a former low divide between the playas at Baker station. A large area south and southwest of Soda Lake, although draining directly to that playa, for convenience is described as being part of Crucero Valley, a subdivision of the Mohave River basin. (See pp. 512–536.)

The Tonopah & Tidewater Railroad crosses the two valleys from north to south, and the Los Angeles & Salt Lake Railroad runs along the south side of Soda Lake.

The town of Silver Lake, on the east edge of the playa of the same name, is reached by several roads. The main route from Barstow formerly went by way of Garlic Spring, joining the Randsburg-Silver Lake road about 4½ miles south of Cave Springs. In 1922 a new shorter road which is now part of the route from Los Angeles to Salt Lake City known as the Arrowhead Trail was opened by San Bernardino County. (See p. 143.) A branch from this road leads from Baker to Silver Lake. The new route has the advantage of being near a railroad for most of the distance, whereas on the old route no help is available, except from passing travelers, between Barstow and Silver Lake, a distance of 82 miles. A third route to Silver Lake, seldom used, is by way of Langford Well and Bitter Spring. (See p. 259.) From Silver Lake a road leads westward to Randsburg and other points in the western part of San Bernardino County. This road crosses the playa and ascends an alluvial slope which is so sandy that many automobiles become stalled on it. This sandy stretch may be avoided by turning northward at the west edge of the playa and skirting low hills around the north edge of the alluvial slope. From Silver Lake a road leads northward to Saratoga Springs and points in Death Valley. A few miles west of Saratoga Springs a branch road leads westward to Randsburg by way of Owl Holes and Leach Spring.

From Silver Lake a road leads eastward, and 9 miles east of the town it forks, one branch leading to Goodsprings, Nev., and points in Mesquite and Ivanpah Valleys, and another branch to Valley Wells, Nipton, and Cima. A road leads southward along the west side of Soda Lake to Crucero Valley and Ludlow. However, from Soda station to Broadwell station it is too sandy for automobiles. Roads leading from Silver Lake and Baker to the Whitney mine and Marl Spring, on the east side of the valley, are reported to be too sandy for automobiles.

In 1918 there was at Silver Lake a well-stocked general store, but D. F. Hewett reports that in 1927 the store was no longer in operation and, except for the station agent and section crew of the railroad, the place was virtually uninhabited. According to the 1927 Postal Guide the post office at Silver Lake has been discontinued. A section crew is stationed at Baker, and water can be obtained there in emergency. In December, 1919, no one was living at Soda station, but water of poor quality may be obtained there from springs and flowing wells. (See p. 529.)

The soil of the two valleys is mostly the typical arkose so common in the Mohave Desert region. The slopes on the east side of Soda Lake Valley in many places are covered with wind-blown sand. Some alkali is present around the borders of Soda Lake, but there is none around Silver Lake.

The vegetation of the alluvial slopes of the valley is principally creosote bush, with other species that are commonly associated with it. In the highest part of the Turquoise Mountains and other mountains southeast of them some giant yuccas grow. *Suaeda suffrutescens* (inkweed) and *Sesuvium portulacastrum* were found at the southeast end of Silver Lake after the evaporation of the flood waters that covered the playa in 1916 and 1917. The seeds of these plants, which are indicative of alkaline soils, apparently were washed in by the flood.

No climatic records have been kept in either valley. From a comparison of records at stations within 100 miles of Silver Lake it is believed that annual precipitation is probably not more than 3 to 5 inches. The summer temperatures are rather high, as 120° to 125° F. has been reported at Silver Lake.

There is practically no activity of any sort in either valley. Attempts to farm small areas have not proved successful. Some cattle are grazed on the highland in the eastern part of the valleys. A little mining has been done at the Whitney mine, in the eastern part of T. 13 N., R. 10 E., and also in the western part of T. 15 N., R. 10 E., but there has been no great development. A number of years ago turquoise for gems was mined in the Turquoise Mountains, east of Silver Lake, but there has been no production in recent years.[70] Several years ago a project was started to recover gold from the mud of Soda Lake near Soda station. An elaborate plant was erected, and for a short period as many as 50 men were employed. The promoters of the project claimed that the mud contained large amounts of gold, but it is said that the company spent $30,000 without obtaining any gold. There is little reason to believe that gold would be found in the playa sediments, which are deposited from standing or only slowly moving water. Because of its weight any gold that was carried by flood water moving down the alluvial slopes or mountain sides would be deposited before the water reached the playa.

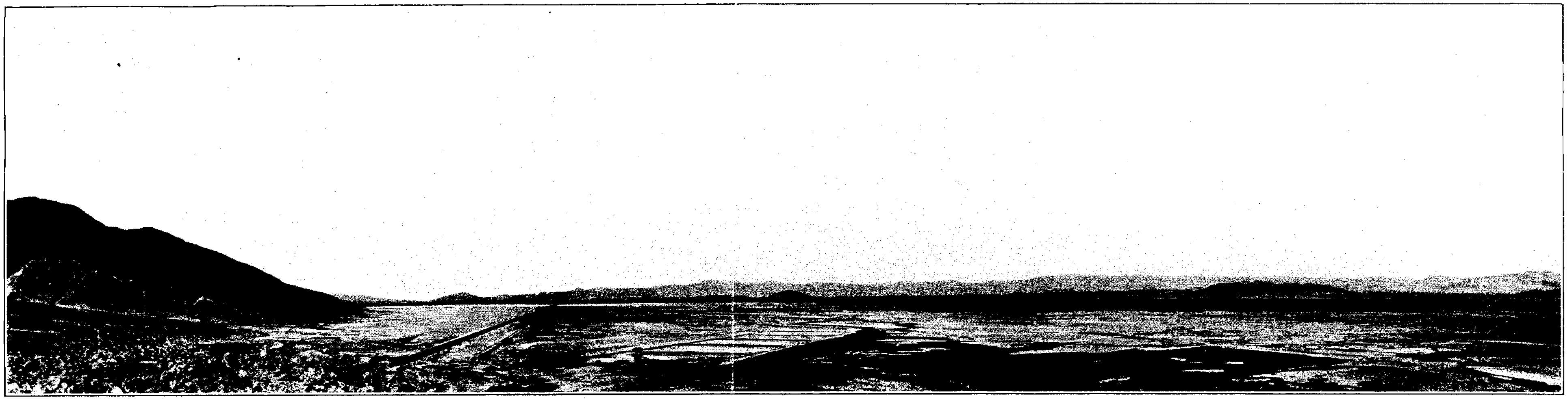
The ruins of large vats on the playa near Soda station testify to an attempt made many years ago to produce salt from the playa deposits at Soda station by solar evaporation. The project doubtless failed because of the greater purity of the salt occurring in other playas where it can be recovered more cheaply.

PHYSICAL FEATURES AND GEOLOGY

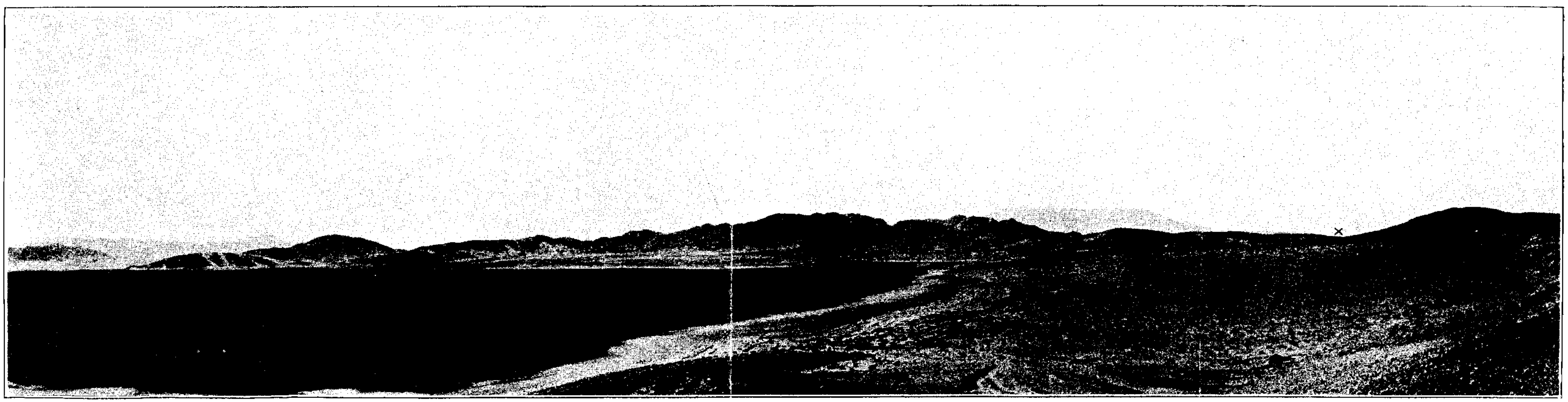
GENERAL FEATURES OF THE VALLEYS

Soda Lake and Silver Lake occupy a part of a great trough that extends from the vicinity of latitude 35° approximately due north-

[70] Cloudman, H. C., and others, Mines and mineral resources of San Bernardino County, pp. 90–94, California State Mining Bur., 1917; in part quoted from Kunz, G. F., Gems, jeweler's materials, and ornamental stones of California: California State Min. Bur. Bull. 37, pp. 107 et seq., 1905.



A. SODA LAKE, LOOKING NORTH AND EAST FROM HILL AT SODA STATION



B. SILVER LAKE, LOOKING SOUTHWEST, WEST, AND NORTH FROM HILL AT NORTHEAST EDGE OF PLAYA

Showing wave-cut cliffs at left, ancient beach, and outlet channel of Lake Mohave (marked ×). The dark smooth surface is not water but hard clay ward for a distance of about 50 miles; thence it bends sharply westward for about 10 miles and continues northwestward as Death Valley for many miles. The trough is cut into three distinct closed basins by low divides. At two other places, and possibly more, there appear to have been divides which have been cut through by erosion. One of these former divides separated Soda Lake from Silver Lake. This divide, no longer continuous, was so low and indefinite that it is not feasible to draw an accurate boundary between the two areas tributary to the playas.

The western border of the part of the great trough that contains the two playas is formed by a continuous range of mountains that extends from the north end of Silver Lake southward as far as Rasor, a distance of about 20 miles. The north end of these mountains is a low ridge, with an eastern arm that extends across the valley just north of Silver Lake. Farther south the mountains are larger, forming the great Soda Lake Mountains. Limestone was found at several places near the base of these mountains, notably at the northeast end of Silver Lake, and at several places on the west border of Silver Lake, about half a mile southwest of Baker station, and in a small hill lying just east of the railroad at Soda station. In the limestone half a mile southwest of Baker station two specimens were obtained which contained fossils. G. H. Girty, who examined the specimens, stated that they were not definitely identifiable, but one specimen was suggestive of a *Syringopora*, and the other contains what appeared to be crinoid stems. He believes them to be of Carboniferous age, possibly Mississippian. It is not unlikely that limestone will be found to cover a considerable area of the mountains on the west side of the trough. In addition to the limestone, granitic rocks form part of the mountains. At Soda station porphyritic volcanic rocks overlie the granite.

The northern border of Silver Lake valley is formed in part by a ridge that extends eastward a mile or two from the north end of the mountains just described and in part by spurs that extend westward from the Turquoise Mountains. Bedrock does not extend continuously across the north end of the basin, but between the mountain spurs on each side the divide is composed of alluvium.

The eastern border of the valley is formed partly by the Turquoise Mountains and farther south by unnamed more or less isolated hills and mountains. The Turquoise Mountains are greatly dissected, and canyons tributary to Silver Lake extend eastward almost entirely through the main mountain mass. The rocks of the Turquoise Mountains are mainly granitic, but at several places there are areas of Tertiary volcanic rock. The most notable of such areas is in the northwest corner of T. 15 N., R. 11 E., where a lava flow overlies the granite and slopes gently southwestward. This is to be seen particularly well from the road between Halloran Spring and Valley Wells. (See pl. 8.) A steep northwestward-facing scarp along the north side of this flow or of a similar flow lying north of it as seen from the road between Silver Lake and Francis Spring suggests a fault scarp.

South of the road between Halloran Spring and Valley Wells for several miles there is no great mountain mass, but a long slope rises more or less continuously from Silver Lake eastward for many miles to a rounded peak in the center of T. 14 N., R. 13 E. This highland area, a sort of plateau with a slight westward slope, is separated from the alluvial slopes in the lowest part of the area by a more abrupt slope in the eastern part of Tps. 13 and 14 N., R. 10 E., and all of Tps. 13 and 14 N., R. 11 E. At the southeast end of the valley the mountains are again more continuous. In the southeastern part of T. 15 N., R. 11 E., and northeastern part of T. 14 N., R. 11 E., there is a nearly flat area, with steep slopes descending on the northwest and west but with more gradual ascent on the east. From the road several miles north of it the flat area appears to be a lava flow similar to the one lying just north of the road.

The physical features of this part of the valley are rather striking. The long gradual slope rising to an altitude of 4,800 feet above the bottom of the valley and 5,700 feet above sea level has the appearance of an alluvial slope, but granite at a depth of only a few feet in mine shafts and small outcrops shows that in many places the alluvium is at best very thin. The slope is probably in large part a mountain pediment or erosional surface beveled across the bedrock.

The southern border of Soda Lake Valley is formed by high mountains, which separate it from Broadwell Valley and which may be called the Broadwell Mountains.

Several more or less isolated mountain ridges lie in the middle of the great trough, near the eastern border of Soda Lake. These have a northerly or slight northwesterly trend and are rather narrow.

Several features suggest that the great trough occupied by Soda Lake and Silver Lake, as well as the part farther north, had its origin in faulting—that it is a great block of the earth's crust that has dropped between blocks on each side. Especially noticeable is the elongated ridgelike character of the mountains west of the playas and of several low mountains on the east side of Soda Lake. One high mountain ridge in the eastern part of T. 12 N., R. 11 E., and the townships adjoining it on the north and south is paralleled by smaller ridges to the west and northwest. The rather abrupt descent at the western edge of the plateau in the eastern part of the trough is also approximately parallel to this ridge. At Soda station a knob of limestone is separated from the main mass of the Soda Lake Mountains, which are composed of granite overlain by lava, in such a way as to suggest faulting.

The alluvium in the valley consists of playa and lake deposits, materials of the alluvial slope, and wind-blown sand. The alluvial slopes have their greatest extent on the east side of Soda Lake and Silver Lake. West of the playas the alluvial slopes are rather narrow—in fact the Silver Lake playa reaches almost to the base of the mountains west of it. East of the playas the slope rises eastward for 10 to 12 miles to the zone of isolated knobs described above.

The alluvial slope east of Soda Lake and to a less extent east of Silver Lake is covered with much wind-blown sand. The sand has also been blown up on to the lower parts of some of the rock ridges that rise above the alluvial slope. The sand is blown about on every windy day. On account of the great accumulations of loose sand, which make travel very difficult, this part of the area has been called the Devil's Playground. The presence of so much sand east of Soda Lake is doubtless due in large measure to its situation with respect to the great alluvial fan at the end of Mohave River, which supplies an abundance of fine sand, together with the topographic conditions, which are favorable to the movement of the wind with high velocity across the broad expanse of Soda Lake. Probably also some of the sand had its origin in the ancient Lake Mohave, which covered the playa at one time. (See p. 563.) The playa and lake deposits are described briefly in a subsequent section.

THE PLAYAS

The two playas, Soda Lake and Silver Lake, present some unusual features. Soda Lake is one of the largest playas in the Mohave Desert region, having an area of about 60 square miles. Silver Lake is much smaller, having an area of only 12 or 13 square miles.[71]

A view of part of Soda Lake is shown in Plate 31, *A*. The playa as a whole is one of the wet or discharging type. At its southwest end the ground water is near the surface and in deep wells is under sufficient pressure to flow. (See p. 529.) When the writer was at Soda station in late October, 1917, and in December, 1919, small streams of water were flowing on the playa surface. The water appeared to come in part from the springs at Soda station but also in part from ground water that reached the surface of the flat. Mesquite, principally of the sprawling, bushy type, is found around the western and southern borders and possibly grows on the east side. In consequence of the discharge of ground water there is more or less alkali on the surface, which is soft and mushy. In dry years wagons and horses can be driven across the flat, but in other years it is too soft. The area covered by visible alkali appears to fluctuate with the amount of water poured into the basin by floods and is greatest

[71] Strangely, large as they are, neither of these playas was shown on the original General Land Office township plats, and as a result they have been omitted from later maps, even some published within the last few years.

in very wet years, when the ground water reservoir is full and the water level is near the surface throughout a larger area. Probably in such years pools of water stand on the surface of the playa.

When the writer visited Soda Lake it was observed that the alkali was most abundant around the borders of the playa, very little being present in the more central part. This may be because the impervious nature of the playa mud prevents much ground water from moving far inward toward the center of the playa. The greatest accession of ground water is from the alluvial slopes, and accordingly the greatest opportunity for deposition of alkali is nearer their borders.

As shown on Plate 31, *A*, alkali is especially abundant on the west side of Soda Lake just north of Soda Lake station. There is no alkali at the extreme northern border of the playa just south of Baker station, for the reason suggested on page 561.

Formerly there was a definite though low divide between Soda Lake and Silver Lake, but in comparatively recent geologic time a channel has been cut across the divide, and during floods water flows from Soda Lake to Silver Lake. A few years ago the Tonopah & Tidewater Railroad cut a second channel between the two playas to protect its tracks. It is certain, however, that a natural channel was cut between the playas before any changes by man, as is shown by the following statement by Williamson,[72] written in 1855, which, so far as the writer is aware, is the first published description of the region.

> On the morning of November 16, at 5 o'clock we started by fine moonlight and traveled to the northern extremity of the salt lake [Soda Lake] and thence to the next one [Silver Lake]. We found the two connected by a ditch, cut by water in the clay soil and about 20 feet wide, with banks 2 feet high. The two lakes were from 3 to 4 miles apart.

The former divide between the two playas was apparently less than 10 feet high. It was formed by the coalescence of alluvial fans built out from the mountains on the east and west sides of the valley. According to profile surveys of the Tonopah & Tidewater Railroad, Silver Lake at Silver Lake station is about 15 feet below the north end of Soda Lake, near Baker station. However, the north end of Silver Lake is possibly a little lower than the south end.

Silver Lake is different from Soda Lake in that all its features are those of a playa of the dry type. Ordinarily the surface is very hard and mud cracked. Alkali is entirely absent. The soil of the playa is unusually dark as compared to that of most of the playas observed. Similar dark soil, however, is found in Soda Lake and East Cronise Lake, and it probably comes from a common source, perhaps from some material washed into the playas by Mohave River. No springs are known to exist around Silver Lake, and as shown below the depth

[72] Williamson, R. S., and others, Report of explorations in California for railroad routes to connect with the routes near the 35th and 32d parallels of latitude: U. S. Pacific R. R. Expl., vol. 5, p. 33, 1855.

to water beneath the playa is from 30 to 60 feet. No mesquite grows anywhere around the playa.

Sesuvium portulacastrum was abundant around the edges of the playa in the fall of 1917, and *Suaeda suffrutescens* (inkweed) grew thickly at its south end. Both these plants grow where the soil is alkaline and generally where the water table is not far from the surface. In this locality, however, they appear not to indicate ground water at a slight depth but to have got a start during a high flood that covered the playa from January, 1916, to July, 1917.

At irregular intervals Silver Lake is covered with water to a depth of as much as 10 feet. (See p. 494.) In view of this fact it is perhaps surprising that there is no more visible evidence of alkali left upon the evaporation of the water. It is reported that after one flood about 1900, the playa surface was white instead of black, as it usually is. The difference between the surface features of Soda Lake and Silver Lake seems to be a permanent condition and not due to seasonal conditions at the time of the writer's visits, for Williamson [73] in 1855 wrote:

> The character of the second lake [Silver Lake] was entirely different from that of the first [Soda Lake]. It was a dry, hard clay bed in which the shoes of the mules scarcely made an impression; while the other was covered with salt and in many places too soft to travel over.

It is believed that these differences in the surface features of the two playas are due almost wholly, if not wholly, to differences in the ground-water conditions. On the west, southwest, and south borders of Soda Lake the water table is close to the surface, and it is on these parts of the playa that the alkali is most abundant. No information is available as to conditions on the east side of the playa. At the north end of Soda Lake and beneath Silver Lake, where alkali is absent, the depth to water below the playa surfaces ranges from about 20 to 50 feet or more. (See pp. 568–569.) The relation of the water table to the playa surfaces is shown in Figure 16, which is based on railroad altitudes and leveling with a telescopic alidade by the writer in the vicinity of Baker and Silver Lake. The significant feature of this profile is that the water table slopes continuously northward and is lowest near the town of Silver Lake. This condition is believed to indicate that there is underground drainage from the basin at some place near the northern part of Silver Lake. Sufficient information in regard to the depth to water at different points is not available to show definitely the point of this outlet. The extreme north end of Silver Lake is surrounded by rock hills, which are without doubt sufficiently impervious to prevent percolation. However, a short distance east of the Tonopah & Tidewater Railroad these hills disappear beneath alluvium, which extends eastward several

[73] Williamson, R. S., and others, op. cit., p. 33.

miles to the foot of the Turquoise Mountains. The alluvium slopes upward to these mountains from the railroad, but the profile of the Silver Lake hills seems to indicate that there is between the hills and the mountains a buried valley of sufficient depth to provide a subsurface outlet of ground water in Silver Lake Valley. If there is any underground percolation from the valley such movement would prevent the accumulation of very much alkali in the soil. Even if the playa were flooded to a considerable depth much of the water would probably percolate into the alluvium and pass northward from the valley, carrying with it most of its alkali content.

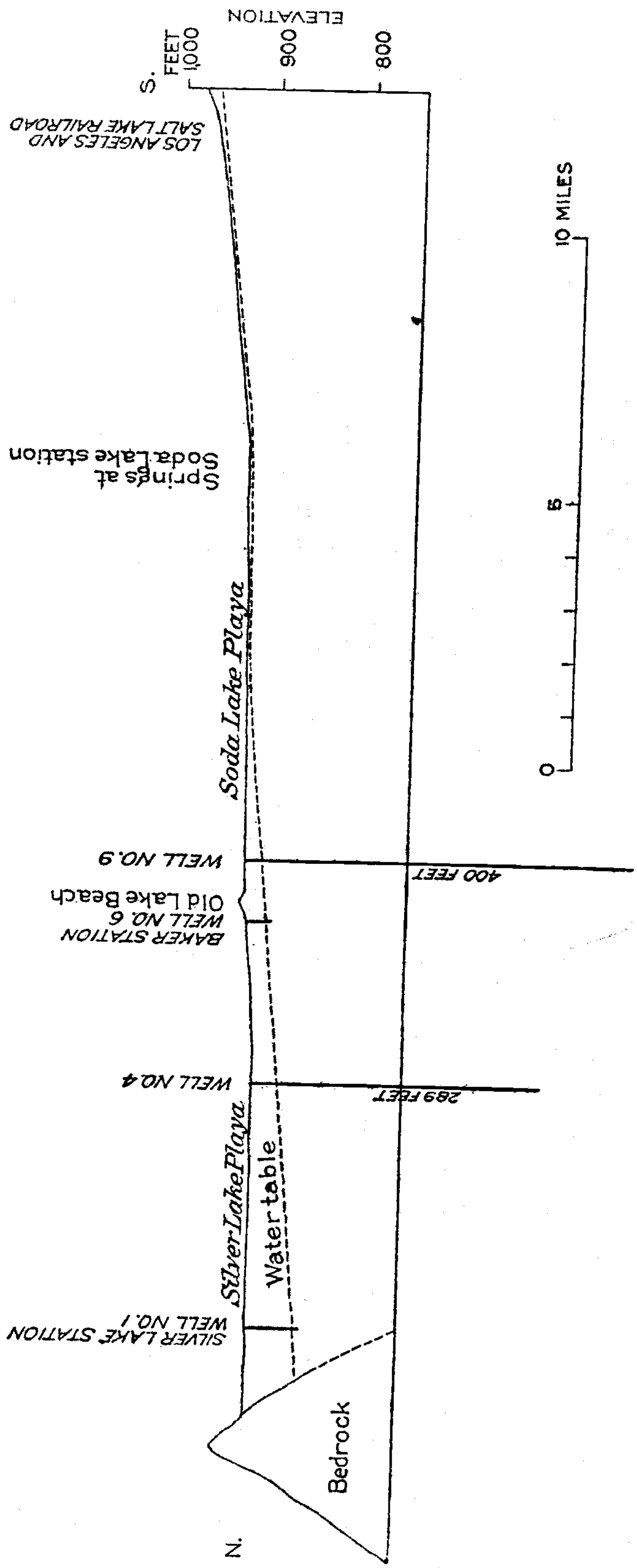


FIGURE 16.—Profile of the surface and of the water table from north to south across Soda Lake and Silver Lake playas

Silver Lake and Soda Lake lie near the west border of the great depression that they occupy. Their present situation seems to have been determined largely by the relative altitudes of the mountains on the east and west. If, as just suggested, there was formerly a connection between Silver Lake Valley and Riggs Valley, to the north, it must have been between the east end of the rock hills at the north end of Silver Lake and spurs of the Turquoise Mountains—that is, the lowest part of the valley must have been slightly farther east than it is now. The mountains on the east cover a much larger area and rise to a much higher altitude than those on the west. These factors would naturally tend to produce larger rainfall and greater run-off from the east, with the result that much more alluvium has been poured out into the valley bottom from the east than from the west. As the great alluvial slopes were built out from the east they cut off the connection to Riggs Valley, and presumably a lake, or at least a playa, was formed just south of the barrier between the valleys. As the alluvial slopes have continued to grow they have crowded the playas to the west side of the valley so that their western edges are practically at the base of the low mountains, from which relatively little alluvium has been carried out into the valley.

LAKE MOHAVE

There is unmistakable evidence that at some time in the past a large lake covered both Soda and Silver Lakes, not only submerging the low divide between them, but also reaching slightly beyond the borders of the present playas. The existence of this ancient lake has been recognized by several writers,[74] but the details of the evidence have not been previously presented. As the ancient lake was for a long period the end of the Mohave River drainage system, and as the discharge from this system was probably the prime factor in its formation, the writer has suggested that it be called Lake Mohave.[75]

The evidences of the existence of Lake Mohave comprise wave-cut cliffs and terraces, beach ridges and other beds deposited in lakes, and an unmistakable outlet channel toward the north. The most manifest evidence consists of wave-cut cliffs and terraces at the edges of rock hills on the west side of Silver Lake, opposite the town of that name and also at the extreme northeast end of the playa. (See pl. 31, *B*.) Beach ridges are also well developed at the north end of Silver Lake. The best, perhaps, is a ridge that reaches from the railroad westward to a limestone hill that extends southward from the main rock hills. This ridge, which rises nearly 40 feet above the playa, apparently was a sand bar, for between it and the rock hills that form the divide of the basin a few hundred feet farther north is a completely closed depression or lagoon, the bottom of which is about 15 feet below the top of the beach. West of the limestone hill the beach ridge is not so evident, for it lies close to the rock hills and the depression north of it is not well developed. About 400 feet south of Baker station the railroad passes through a short cut in a low gravel ridge that rises westward to the foot of the alluvial slope from the mountains. This ridge was probably a bar or spit formed by shore currents or by

[74] Gale, H. S., Notes on the Quaternary lakes of the Great Basin: U. S. Geol. Survey Bull. 540, p. 401, 1914. Free, E. E., The topographic features of the desert basin of the United States with reference to the possible occurrence of potash: U. S. Dept. Agr. Bull. 54, p. 45, 1914; An ancient lake basin on the Mohave River: Carnegie Inst. Washington Yearbook for 1916, pp. 90–91. Huntington, Ellsworth, The curtailment of rivers by desiccation: Carnegie Inst. Washington Yearbook for 1915, p. 96.

[75] Thompson, D. G., Pleistocene lakes along Mohave River, California (abstract): Washington Acad. Sci. Jour., vol. 11, No. 17, p. 424, 1921.

the deposition of alluvium washed in from near-by mountains on the west. At Soda Lake station a low ridge of alluvium lies between the main mountain and a small limestone knob that projects into the playa. Several feet of gravel with clay lenses is exposed in a railroad cut through the ridge. According to railroad surveys the altitude of this gravel is just about the same as the level of the beach ridge at the north end of Silver Lake. It is 15 or 20 feet above the playa. No beach lines were observed east of the town of Silver Lake, but a more careful inspection may show them to exist. It is possible, however, that if any were formed they have been obliterated by alluvial wash from the mountains.

For a time Lake Mohave had an outlet northward in the great valley that reaches to Death Valley. This outlet passed through a low notch cut in the rock hills north of Silver Lake playa, at a point marked X in Plate 31, *B*. From the playa a gradual slope rises for several hundred feet to the barrier beach west of the limestone hill described above. North of this beach the land slopes again toward the rock hills and to the outlet. When the writer saw the outlet in 1917 the conditions were clearly shown, for a short time previously some artificial excavation had been made, apparently as part of an attempt to drain the playa by pumping water over the divide after it was flooded in 1916. The outlet channel was cut slightly into rock but was partly filled again with sand and gravel, which form the divide in the channel. The top of the alluvium in the channel is at about the same level as the top of the beach ridge, but the bedrock in the channel is about 8 feet lower than the top of the beach ridge. The rock channel near the divide is generally less than 20 feet wide and only a few feet deep.

The rather small size of the channel indicates that the discharge of the lake was not great. The lake evidently extended beyond the borders of the present playas of Soda and Silver Lakes. On the north and west the borders of the ancient Lake Mohave were rather definitely determined by rock hills. On the east, south, and southwest, however, alluvium may have been washed in since the lake ceased to exist, pushing the border of the playas some distance inward from the former lake border. There is some evidence of this near Crucero, for blue clay and blue sand, generally believed to indicate deposition in a lake, were found in wells in sec. 18, T. 11 N., R. 8 E., 2 or 3 miles west of the present border of Soda Lake playa. (See p. 519.) The total area of ancient Lake Mohave was probably between 75 and 100 square miles.

The surface of Silver Lake playa is about 900 feet above sea level. Altitudes determined on the beach ridges show that at its maximum the water surface was about 40 feet higher, so that at the north end of the basin the lake was fully that deep. It was, in fact, probably somewhat deeper, having been shallowed in its later stages by the deposition of sediment. If topographic and drainage conditions during the existence of the lake were similar to those at present, the south end of the lake was probably much shallower than the north end, for then, as now, Mohave River doubtless washed in so much alluvium that the playas had a slight northward slope.

The age of Lake Mohave is uncertain. Mollusk shells were found in the beach deposits at Baker, but the species are of little value in determining the age of the beds, except that they are probably Quaternary. On the assumption that during the Pleistocene epoch the precipitation throughout the entire Basin and Range province was somewhat greater than at present the lake is believed to have existed contemporaneously with other lakes now extinct, such as Lake Bonneville, Lake Lahontan, and the Owens-Searles Lake system. (See p. 110.) As described on pages 111, 450, and 538–539, lakes are also believed to have existed at about the same time in Cronise Valley (Little Mohave Lake) and in the Lower Mohave Valley near Manix (Manix Lake). The relation of Lake Mohave to Little Mohave Lake and Manix Lake is uncertain and raises some questions, as pointed out below.

The total area now tributary to the playas that mark the site of Lake Mohave is estimated from planimeter measurements to be about 3,500 square miles. Certain areas now separated from the basin by low alluvial divides but then possibly parts of it may have increased the drainage area by 500 to 1,000 square miles. About half of the present area is tributary to the playas through Mohave River; of the remainder about 670 square miles is tributary through Kelso Wash, and the rest slopes more or less directly to the playas.

It is said by inhabitants of the valley that when Soda and Silver lakes become real lakes, at irregular intervals, the discharge from Mohave River is the only important source of water. Although the mountains east of Soda Lake rise 5,000 to 7,000 feet above sea level, the largest arroyo is only 2 or 3 feet deep and a few yards wide, and apparently most of the water sinks into the alluvium before it reaches the playa. Most of the run-off that causes the flooding of the playas now comes from the very heavy precipitation in an area of little more than 200 square miles in the San Bernardino Mountains, about 125 miles distant. (See p. 386.) In discussing the origin of the Quaternary lakes of the Great Basin, Gale[76] has pointed out that the largest of these lakes were situated in regions that are now drained by perennial streams originating in high mountains where the rainfall is much greater than in the lower portions of the basin. He believes that a slight increase in the precipitation might be sufficient to form lakes in basins fed by these rivers. In the Lake Mohave basin conditions are very similar, though on a smaller scale. Unless the precipitation in the rest of the basin was greatly increased, the head-

[76] Gale, H. S., Quaternary lakes of the Great Basin: U. S. Geol. Survey Bull. 540, pp. 402-403, 1914.

water region of Mohave River must have been the principal factor in producing Lake Mohave.

Assuming, therefore, that the greater part of the water that formed Lake Mohave came from the San Bernardino Mountains, a question arises as to the relative age of Lake Mohave, Little Lake Mohave, and Manix Lake. Did Mohave River reach the site of Lake Mohave before Manix Lake was formed? If so, when the river channel was dammed, in a manner as yet unsolved, and Manix Lake was created, no great supply of water reached the Lake Mohave basin until Manix Lake had overtopped its barrier. Was the Silver Lake basin closed by the inwash of alluvium northeast of Silver Lake prior to the formation of Manix Lake, or during its existence, or even not until sometime after it ceased to exist? Buwalda [77] states that the barrier at the northeast border of Manix Lake is composed of comparatively unconsolidated alluvium, and once the lake overtopped this barrier the water would presumably deepen its channel and drain the lake rather rapidly. It may not have been until this occurred that Lake Mohave came into existence. Under such circumstances, with only one of the two lakes existing at the same time, a much smaller supply of water would have been required than if they had existed contemporaneously. In view of the possible variations in the correlation of the age of these lakes it is believed that further studies of the lake beds in the Mohave River basin may be worth while in order to obtain information for interpreting the climatic conditions under which the lakes existed.

Of more than passing interest is the finding in September, 1917, of the dried remains of many fish along the edge of the Silver Lake playa. Several specimens collected by the writer were submitted to Dr. B. A. Bean, of the United States National Museum, who identified them as the ordinary catfish, *Ameiurus nebulosus*, which presumably had been introduced from other parts of the country, and a species of the chub, *Siphateles mohavensis*. Both of these species are known to live in pools at different places on Mohave River. Apparently they had been washed into Silver Lake by the waters of Mohave River during the flood of 1916, and as the temporary lake dried up they were stranded and dried. They were so numerous, however, that there is some question as to whether all had been washed in or whether only a comparatively few were carried by the floods and most of them had been born and grew during the year or more that the lake existed. The fish must have been carried at least 25 miles by the flood waters and probably a much greater distance from their regular habitat.

The occurrence of these fish remains on a desert playa many miles from their regular habitat emphasizes the fact that the finding of

[77] Buwalda, J. P., Pleistocene beds at Manix, with eastern Mohave Desert region: California Univ. Dept. Geology Bull., vol. 7, p. 455, 1914.

fresh-water remains in deposits in a desert region that show some of the characteristics of lake beds can not be too strictly interpreted to indicate the existence of a perennial fresh-water lake. If these fish remains were buried by later deposits and subsequently exposed, their presence might be considered erroneously to indicate that they had lived in a lake that existed for a period of years. And if, perchance, the wave-cut cliffs and terraces of Lake Mohave were still visible they might be even more erroneously correlated with the lake that cut the cliffs. It is of interest to note that both Orcutt [78] and MacDougal [79] record a similar occurrence of fish remains in Lake Maquata, an ephemeral lake on the delta of Colorado River a few miles south of the Mexican boundary. Fish have been carried into this playa when it is flooded from time to time by the river under conditions similar to those that resulted in the formation of Salton Sea. In addition to the fish remains Orcutt found millions of fresh-water snails and clam shells, although water that was present on part of the playa was very salty.

The writer has endeavored to find criteria that may be used in determining whether deposits in the desert basins like those in the Silver Lake basin have been laid down in perennial lakes or in ephemeral lakes that existed for a year, or two or three years at the most, with intervening periods when the lakes evaporated and playas resulted. However, unless there is physiographic evidence in the form of wave-cut cliffs or beaches the only reasonably reliable criterion appears to be the color of the sediment. The prevailing conception is that a greenish or bluish color of the beds indicates deposition beneath water; but the writer has not been able to find any information as to whether this is an infallible indication of deposition in a lake enduring for only a year or several years, or whether it indicates the existence of the lake for many years.

The presence of *Siphateles mohavensis* in the Mohave drainage system is suggestive in connection with the question of the former extent of that system, as pointed out by Snyder.[80] In describing this species he writes:

> The fishes of the Mohave River belong to a single species, a member of the genus *Siphateles*, a channel and lake minnow which occurs in the Sacramento-San Joaquin, Klamath, Oregon Lake, Columbia, and Lahontan systems and Owens River. The species of this group are very closely related, intergradation of distinctive characters being not unusual. In a measure they resemble geographic races or subspecies of birds and mammals as usually defined, except that, being fluvial and lacustrine forms, the range of each is definitely circumscribed, and no intermingling or interbreeding of individuals of different forms is possible. Species of *Siphateles* are not known from Santa Ana or Colorado Rivers.

78 Orcutt, C. R., A visit to Lake Maquata: Western Am. Scientist, vol. 7, No. 59, pp. 159, 161, 1891.
79 MacDougal, D. T., The desert basins of the Colorado Delta: Am. Geog. Soc. Bull., vol. 39, p. 720, 1907.
80 Snyder, J. O., The fishes of Mohave River, California: U. S. Nat. Mus. Proc., vol. 54, pp. 297-299, 1918.

Snyder states that the Mohave species was originally considered identical with and described as a cotype of a form found in the Sacramento-San Joaquin system (*Siphateles formosus*), but he has considered the Mohave form sufficiently different to constitute a new species. He writes further:

> The large series of specimens from the Mohave reveals a considerable degree of differentiation when comparisons are made with specimens of *S. formosus* and *S. obesus*, the two species which are geographically nearest them. *S. obesus* is indigenous to the Lahontan system and Owens River. The immediate relationship of the Mohave form, which may be known as *Siphateles mohavensis*, can not be determined with certainty from an examination of the fishes, and unless the geology of the region points to some previous connection between the Mohave basin and the Sacramento-San Joaquin or the Lahontan systems, the question may remain only partly answered. There is reason to doubt the possibility that the species reached the Mohave through stream capture near the headwaters, as the species of *Siphateles* appear to be lacustrine and channel forms and are not known to migrate far up into the smaller tributaries. The occurrence of the genus in streams without deep, sloughlike channels or direct connection with a lake is rare, and individuals are not at any time found at a distance from such places.

As described on pages 110–111 a chain of lakes extended from the Owens River basin through Searles Lake to the Panamint Valley. It is believed that there was overflow from Panamint Lake to Death Valley, where the existence of a lake has long been suspected but only recently confirmed.[81] (See p. 186.) Mohave River also at one time reached the south end of Death Valley. It seems quite likely that an ancestral form of *Siphateles obesus*, which now inhabits Owens River, may have traveled through the Owens-Death Valley system and through a permanent or temporary lake in Death Valley and entered the Mohave River basin, where it became modified to the *S. mohavensis* form. If the fish once reached Death Valley, there were no impassable barriers to prevent it ascending the Mohave, providing the water in the valley was not so saline as to kill it. If fish entered Mohave River from Death Valley, it would be reasonable to expect that the same species also entered Amargosa River, which joined the Mohave about 25 miles north of Silver Lake. Perhaps, therefore, *Siphateles* may be found living in the Amargosa River basin.

GROUND WATER

GENERAL CONDITIONS

Meager data were obtained in regard to four wells in the valley of Silver Lake and five wells in the valley of Soda Lake near Baker. These data are given in the table on page 524, and the location of the wells is shown on Plate 28. Ground-water conditions on the

[81] Noble, L. F., Note on a colemanite deposit near Shoshone, Calif., with a sketch of the geology of a part of Amargosa Valley: U. S. Geol. Survey Bull. 785, p. 69, 1926; The San Andreas rift and some other active faults in the desert region of southeastern California: Carnegie Inst. Washington Yearbook 25, p. 426, 1926.

west side of Soda Lake from Soda station southward are discussed under Crucero Valley on pages 523–534.

Five of the nine wells mentioned (Nos. 1, 2, 3, 5, and 6, pl. 28) are dug and reach only a few feet below water level. Well 6, belonging to R. Y. Williams, was dug all the way in material reported as "hard gravel." In the well of G. Brauer (No. 1) the upper 14 feet of material was gravel and sandy clay with small pebbles. For the remaining depth the material was slightly coarser and sandier. No data were obtained in regard to the materials penetrated in any of the other wells. The depth to water in the wells ranges from about 20 to 60 feet. The greatest depth to water is at Silver Lake station, not far from the edge of the playa. A profile of the water table in an approximate north-south direction beneath the two playas is shown in Figure 16. This profile is based principally on altitudes at several points along the railroad. The exact altitude of the wells was not determined accurately, but the error at most of them can not be more than a few feet, so that the profile shows the conditions with reasonable accuracy. The significant features are that the water table is near the surface beneath a large part of Soda Lake, but at the north end of that playa and beneath the whole of Silver Lake it lies at a greater depth; and the water table slopes continuously from the south end of Soda Lake to the north end of Silver Lake. The great depth to water at the north end of Soda Lake in contrast to the shallow depth farther south is seen to be due to the fact that the playa surface at the north end is nearly level, or at least does not have as great a slope as the water table. The northward slope of the water table beneath Silver Lake and its great depth seem to indicate without any doubt that there is percolation from the basin. As indicated on page 562 this probably does not occur through the rock hills at the north end of the playa, but around their east end, where the divide appears to be composed of alluvium to a considerable depth.

So far as the writer is aware there are no wells on the east side of Soda Lake. A single well belonging to the Los Angeles & Salt Lake Railroad has been drilled at Balch station. According to a log of the well furnished by the railroad the materials penetrated were sand and clay to 55 feet, gravel at 55 to 88 feet, sand and gravel at 88 to 160 feet, sand and clay at 160 to 175 feet, sand at 175 to 205 feet, and boulders at 205 to 212 feet. The depth to water was 55 feet. A railroad profile shows that the surface of the well is about 50 or 60 feet above the lowest point where the railroad crosses the south end of Soda Lake, where the presence of alkali shows that the water level is near the surface, and the water level in the well is at about the same altitude as beneath the playa.

The depth to water at different points near the edges of the playas is probably not much greater than is shown in Figure 16. There is no large supply of ground water moving toward the playas, except from Mohave River in Crucero Valley. Therefore the water table on each side of the playas probably does not rise very much toward the mountains. Accordingly at points farther and farther up the alluvial slopes the depth to water will be increasingly great, by an amount about equal to the difference in the surface altitude. In general a depth to water of 100 feet may be expected within 1 or 2 miles of the borders of the playa and of 200 feet within 3 to 5 miles.

No information is available as to the yield of the drilled wells. The yield of the dug wells for which data are available is only a few gallons a minute. This small yield is probably due in part to the fact that the wells are dug only a few feet below the water level, and the water level is quickly lowered to the bottom of the well if the rate of pumping is very great. However, there is also some evidence that the water-bearing capacity of the materials penetrated is not very great. This may be explained by the fact that the wells are near the playas, in a position where the material deposited was naturally rather fine. Indeed, some of the materials may have been deposited in the playa lakes or in Lake Mohave if those lakes at one time covered a larger area than the present playas. It seems reasonable that farther from the playas the alluvium may be somewhat more permeable, and wells drilled a mile or more from the borders of the playas may yield more water than those for which data are available.

QUALITY OF WATER

Analyses have been made of water from two wells, Nos. 1 and 6. (See analyses 1 and 2, p. 532.) Both waters are highly mineralized, containing 1,269 and 2,298 parts per million, respectively. The sample from well 6 is high in sodium chloride, or common salt, but the other is a sodium bicarbonate water. The water from well 1 is only fair for domestic use, and that from well 6 is bad for such use. Both samples are poor for irrigation and very bad for boilers.

The rather high mineralization of the waters is undoubtedly due to their location near the playas. The flood water that occasionally covers the playas becomes concentrated as it evaporates, and such water as enters the alluvium carries with it much of the mineral matter that accumulates during the process of concentration. The ground water at points some distance from the playas may perhaps be of better quality, but this is not certain.

WATERING PLACES

In addition to the wells at Silver Lake and Baker stations there are several places in or near the mountains on the east side of the Soda Lake-Silver Lake basin where water may be obtained under certain circumstances.

Hyten's Well.—Hyten's Well is about 10 miles east of Silver Lake, two-tenths of a mile south of the road from Silver Lake to Valley Wells and Nipton. The well is really an inclined shaft dug in granite, in which the depth to water is about 125 feet. In 1917 the well was equipped with a bucket and windlass. The water has not been analyzed, but it appears to be of good quality. It is reported that water can be obtained from three shallow wells at a stamp mill about 1½ miles south of Hyten's Well. Hyten's Well should not be confused with Hyten's Spring, in the southwestern part of T. 10 N., R. 9 E.

Halloran Spring.—Halloran Spring is 14.5 miles east of Silver Lake by way of the road to Valley Wells. It is near the junction of this road with the new road from Baker to Valley Wells and Roach, which ascends Halloran Wash. (See pls. 7 and 12.) The spring is on the north side of the easterly one of two large branches of the wash, at the west end of low hills that rise toward a large lava flow farther east. The spring issues from granite about 100 feet east of the Silver Lake road. A buried pipe line carries the water to a near-by trough for watering cattle. D. F. Hewett reported that in 1927 the trough was equipped with a ball float, which was housed in such a way that fresh water could not be obtained from the pipe. As shown by analysis 12 (p. 532), the water is moderately mineralized. A sample collected by the writer on October 29, 1917, contained 854 parts per million of total solids, and one collected by G. A. Waring on August 23, 1916, contained about 890 parts per million more of total solids. The water is a sodium carbonate water and is fair for domestic use.

Granite Spring.—Granite Spring is in the north-central part of T. 14 N., R. 11 E. (See pl. 12.) No definite information is available in regard to the spring, but it is believed to be used as a watering place for cattle.

Henry Spring.—Henry Spring is reported to be about 1¾ miles almost due west of Granite Spring, in the northwestern part of T. 14 N., R. 11 E. It is said to flow about a gallon a minute and is used as a watering place for cattle. It can be reached by a road leading from the main road between Valley Wells and Halloran Spring.

Deer Spring.—Deer Spring is shown on the Ivanpah topographic map in sec. 20 or 21, T. 14 N., R. 13 E., about 1½ miles northwest of the high rounded summit that is 6 miles northwest of Cima. It is not near any road, and nothing is known about it.

Indian Creek.—It is stated that water runs throughout the year at the head of Indian Creek, 18 miles almost due west of Cima. A pipe line formerly carried water from this creek to the Whitney mine, but it was torn up in 1917. The road that leads to the west of the creek, from Marl Springs to Silver Lake, is said to be impassable for automobiles because of heavy sand.

Unnamed well.—About 4.5 miles east of Halloran Spring, at a point 500 feet south of the Silver Lake-Nipton road, is an inclined shaft dug in granite, which in 1917 contained water at a depth of about 35 feet. Water for use in emergency probably could be obtained from this well with a rope and bucket.

PROSPECTS FOR IRRIGATION

In 1917 there was no agricultural development in either Soda Lake or Silver Lake Valley. No ranchers were living in the valleys, and there seems to be no prospect of any worth-while development in the future. The meager information available indicates that near the playas the yield of wells is likely to be small and the quality of water poor for irrigation. Higher up on the alluvial slopes, where the water-bearing beds may possibly yield water more freely and the quality of the water may be better, the depth to water is probably so great that water could not be pumped economically for irrigation. The valleys are so far from any market that irrigation could be profitable only under exceptionally favorable conditions, and such necessary conditions do not exist in the region.

AMARGOSA DRAINAGE BASIN

GENERAL FEATURES

The Amargosa drainage basin is one of the largest in the Basin and Range province. It is larger than any other drainage basin in the Mohave Desert region, although the part of it that is wholly in the region is exceeded by the area that is tributary to Soda and Silver Lakes, which include the basin of Mohave River.

The main drainage feature of the basin is Amargosa River which empties into Death Valley. Like Mohave River, the Amargosa is an intermittent stream, with no water flowing in most of its course except in the cool months or in unusually wet years. Besides Amargosa River there is no perennial stream in the region, although in some of the mountain canyons short streams may persist for short periods after heavy rains. The surface features of the part of the drainage basin outside of the area covered by this report are shown on the topographic maps of the Kawich and Furnace Creek quadrangle and the Amargosa region.

What may be termed the headwater region of the Amargosa drainage basin—that is, the part farthest from the lower end of the river—is in a high dissected area known as Pahute Mesa, about 30 miles north of the town of Rhyolite, Nev., and more than 90 miles northwest of the point where the river enters the northern part of the Mohave Desert region as shown on Plate 11. The headwater drainage from a large area of mountainous country is collected in several major drainage lines. Amargosa River is considered as beginning a few miles north of Rhyolite. Near Rhyolite the river emerges from the more or less dissected hilly and mountainous region into a broad valley that slopes southeastward and lies approximately parallel to and just east of the boundary line between Nevada and California.

This valley, which is known as the Amargosa Desert, is 5 to 8 miles wide and practically unbroken by hills for 50 miles. The Tonopah & Tidewater Railroad lies in this valley from Rhyolite to Sperry siding. According to the topographic map the course of Amargosa River for most of this distance is only a sandy wash. The river crosses the California-Nevada boundary line at latitude 36° 30′ and continues in a more southerly direction. Near latitude 36° 15′, about 5 miles south of Death Valley Junction, the valley is somewhat constricted by a low mountain known as Eagle Mountain, which lies practically in the middle of the valley. The drainage apparently is partly ponded behind this barrier, for a playa or somewhat similar clay flat lies just north of it. Flood waters, however, may pass to the west side of the mountain. South of Eagle Mountain the valley here continues for about 25 miles, but its width is only 2 to 5 miles. Near Shoshone, in T. 22 N., R. 7 E. (see pl. 11), the valley is again constricted. South of that point for about 10 miles, although the valley is wide it is much dissected, and the smooth slopes of the portion farther north are lacking. Just south of Tecopa Amargosa River cuts through low mountains for about 10 miles, and between Sperry and Dumont it emerges from them onto an open alluvial slope.

From the point where the river leaves the mountains, near Dumont, it flows southwestward down the alluvial slope for about 10 miles, dropping in that distance an average of about 50 feet to the mile. Near the west-central part of T. 18 N., R. 6 E., the river turns northwestward into the south end of Death Valley and continues in that direction for about 30 miles, to the great salt flat that lies in the bottom of the valley. In this part of its course the grade is only about 15 feet to the mile.

For convenience in description the Amargosa Basin and certain important tributary areas have been divided into several sections—namely, the Upper Amargosa Basin, the Middle Amargosa Basin, the Lower Amargosa Basin, Wingate Valley, Lower Kingston Valley, Upper Kingston Valley, and Riggs Valley. The Upper Amargosa Basin does not lie within the Mohave Desert region and is not described in this report. The boundaries of the other areas are shown on Plate 7. These areas are described in the following pages.

MIDDLE AMARGOSA BASIN

GENERAL FEATURES

In the present report the Middle Amargosa Basin is considered as that part of the basin above the mountains south of Tecopa. Most of the area is not in the Mohave Desert region. The writer did not see any of the Middle Basin, and the following brief statements in regard to the geology and water supplies are based largely on information furnished by G. R. Mansfield and L. F. Noble, of the United States Geological Survey.

The basin is traversed from southeast to northwest by the Tonopah & Tidewater Railroad. From the south it is accessible by automobile only by roundabout routes. A road formerly led up the canyon of Amargosa River through the mountains south of Tecopa, but it has been destroyed by flood waters, and in places the river bed is soft. From the south the approach to the canyon is up a sandy slope which is difficult for automobiles. Although the road is occasionally used by persons familiar with the region, it is dangerous unless the traveler is fully prepared to meet any difficulties that may arise. A road that was formerly much used led from Saratoga Springs northward across mountains to the Ibex mine and thence to Zabriskie. However, sandy stretches on an up grade make this road practically impassable for automobiles going northward from Saratoga Springs. Lightly loaded automobiles might be able to descend this road, but as it is now little used the traveler would be unwise to attempt it. It is understood that a road leading from the Tonopah & Tidewater Railroad near Valjean station in a northerly direction to a point near Rabbit Holes and thence to the Tecopa smelter is also difficult to travel. The most feasible routes to Tecopa, Zabriskie, and Shoshone are either northward in Death Valley to the Confidence mill and thence northeastward by way of Bradbury Well and Salsberry Spring or by way of Silver Lake or Baker to Mesquite and Pahrump Valleys and westward through Emigrant Pass and past Resting Springs to Tecopa. The Death Valley route is much shorter from Barstow and Silver Lake than the route by way of Pahrump Valley, but it has the disadvantage that it passes through entirely uninhabited country for much longer distances than the other route, and sand and long grades are encountered.

Tecopa and Shoshone are railroad telegraph stations with post offices. In 1918 supplies and water could be obtained at both places. At that time Zabriskie was the headquarters for a railroad section crew, but no supplies were available. In the past ranches have been maintained at Resting Springs, Yeoman Hot Springs, and the China ranch (also called the Morrison ranch). There has been some more or less sporadic mining activity in the region. Conditions are not favorable for agriculture.

The distribution of different types of rocks as shown on Plate 8 has been taken from unpublished data kindly furnished by Messrs. Noble and Mansfield. The bedrocks consist chiefly of sedimentary rocks of pre-Tertiary age. In the northwestern part of the region are Tertiary volcanic rocks, and in the vicinity of the China ranch are sedimentary rocks of Tertiary age. The central part of the portion of Middle Amargosa Basin that lies in the Mohave Desert region is underlain by playa and lake beds, presumably of Pleistocene age. These beds contain nitrate and have been explored in an effort to discover deposits of commercial value.[82] The beds in part were deposited in a lake, evidence of which is found particularly as a shore line along the mountain sides.[83] The lake beds have been greatly dissected into badland forms. The conditions are essentially similar to those in the Middle Mohave Valley, where a lake known as Manix Lake once existed and eventually was drained as the lake overtopped the barrier that held it in. After this overtopping of the barrier a river channel was eroded to a considerable depth in the unconsolidated sediment that had been deposited in the lake.

GROUND WATER

Three wells are reported in the northwestern part of a branch of the main basin that is known as Chicago Valley. (See pl. 11.) These are all from 2 to 4 miles north of Yeoman Hot Springs and about 6 miles east of Shoshone, on a road that branches to the northwest from a road that lies in the axis of the valley. Unfortunately no information is available in regard to them. At an old borax works about 1½ miles southwest of Zabriskie are two drilled wells which flow. One of the wells yields sulphur water, but that from the other is of somewhat better quality. There is a dry well in sec. 36, T. 21 N., R. 6 E.

Springs are rather more numerous than in most other parts of the Mohave Desert region. Water is at or near the surface of the wash of Amargosa River at several places, especially in the canyon below the China ranch, but the water is reported generally to be salty. Several more or less permanent springs are found on Willow Creek, about 2 miles east of the China ranch. At that ranch is a spring with a constant flow of fresh water but of small volume. Water for railroad use at Shoshone is obtained from a warm spring a short distance north of the town. Water for Tecopa is obtained from a warm spring just north of the town. About halfway between Tecopa and Zabriskie is a hot spring. The water from the springs at Shoshone and Tecopa is not very good for domestic use. A spring of poor water is reported to be situated in sec. 35, T. 21 N., R. 7 E. A warm or hot spring at the ranch of Alec. Yeoman, about 5 miles southeast of Shoshone, is said to flow 10 miner's inches. It has been used for irrigation. Resting Springs, on a road leading from Tecopa to Pahrump Valley, yields a good supply of water. There is not much definite outflow at Tule Springs, but water for drinking can probably be obtained by digging.

[82] Noble, L. F., Mansfield, G. R., and others, Nitrate deposits in the Amargosa region, southeastern California: U. S. Geol. Survey Bull. 724, 1922.

[83] Idem, p. 60.

LOWER AMARGOSA BASIN (INCLUDING SOUTH DEATH VALLEY)

GENERAL FEATURES

The Lower Amargosa Basin is considered as including the territory directly tributary to Amargosa River below the point where it emerges from a canyon in low mountains near Sperry station on the Tonopah & Tidewater Railroad. Except for the area between Sperry and Saratoga Springs and for certain tributary valleys, this part of the basin of Amargosa River is more commonly known as South Death Valley. Before entering Death Valley the river receives drainage from a large area to the southeast, described on pages 598–606 as Upper Kingston and Lower Kingston Valleys.

There are no permanent habitations in the region. There have been some sporadic attempts at mining both metal and saline deposits in the Owls Head, Avawatz, and other mountains, but up to the time of the writer's visit in 1917–18 there had been no important developments.

Although rather isolated the region has a peculiar fascination for the desert traveler, perhaps in part because of the reputation ascribed to it by the rather awesome name of Death Valley. (See p. 15.) However, regardless of the attraction due to its reputation alone, the region exhibits scenic features that are rather out of the ordinary and make a trip into it well worth while. The region is of special interest to the geologist and geomorphologist, for the little work that has been done shows that its geologic history has been very complicated. For these and other reasons, in spite of the supposed dangers involved, there is considerable travel through the valley.

As a matter of fact, the region may be traversed with comparative safety provided certain precautions are followed, except that because of the great heat the danger is greater in the warm months. The precautions to be observed are essentially only those to be followed in traveling other parts of the desert, but the preparations for meeting emergencies must be doubly sure. Above all, supplies of water, gasoline, and oil must be not merely sufficient for reasonably anticipated needs, but there should be an extra supply for unforeseen emergencies. Heavy sand and long grades will be encountered, and generally more water, gasoline, and oil will be used than in ordinary desert travel. Shovels should be carried for digging out sandy places, and it is not infrequently necessary to rebuild stretches of roads that have been washed out. The traveler's automobile should be in good condition, and minor repair parts should be carried. So far as possible before entering the region the traveler should inquire as to recent changes in road conditions and watering places.

Since the writer worked in the Lower Amargosa Basin in 1917–18, a tourist resort has been established near the Furnace Creek ranch, about 30 miles north of the northern boundary of the area shown on Plate 11. Although a large part of the travel to this resort probably goes by way of the Tonopah & Tidewater Railroad it is understood that a considerable part goes by automobile from southern California. Accordingly road conditions are now probably somewhat better than formerly, and the chance of obtaining help in emergencies is perhaps a little better.

Death Valley may be entered by several routes. One or more roads enter the valley from its extreme north end. An important route is by way of Searles Lake and Trona, or by way of Pilot Knob and Ballarat, to the north end of Panamint Valley, thence across the Panamint Range and down into the valley along Emigrant Wash. A continuation of this road constitutes a route into the valley from Beatty and Rhyolite, Nev., on the east, descending into the valley through Boundary Canyon. This route between Panamint Valley and Beatty by way of Emigrant Wash and Boundary Canyon is used for travel between Los Angeles and Goldfield and points farther northeast. Death Valley may also be entered from the east by way of roads that lead northwest from either Shoshone or Death Valley Junction, on the Tonopah & Tidewater Railroad, into Furnace Creek Wash and thence down that wash into the valley near the Furnace Creek ranch. A third route from the east leads westward from Shoshone and Tecopa by way of Salsberry Spring and Bradbury Well. (See pl. 11.) A little-used route runs from the south end of Panamint Valley through Wingate Pass. (See p. 591.) From the south the valley may be reached by three routes, which unite near its south end. One of these comes from Randsburg and other points to the southwest, by way of Granite Wells and Leach Spring and down Owl Holes Wash. The second comes from Barstow and Daggett by way of Garlic Spring and Cave Springs and down Cave Springs Wash. The third comes from Silver Lake through Riggs Valley. The routes from Barstow and Randsburg are the shortest into the valley for travelers coming from Los Angeles. They are of about equal length, and except for possible bad stretches, which may change from time to time according to weather conditions, there seems to be little choice between them.

Death Valley is a deep trough, the bottom of which is many hundreds of feet below the mountains that almost completely surround it. As a result, in order to get out of the valley it is necessary to climb grades of greater or less steepness. Most of the roads lead through mountain passes that are several thousand feet above the valley bottom, and the grades are steep. For example, the road leading up Emigrant Wash and Canyon for several miles has a grade of 500 to 700 feet to the mile. Although these roads may be descended with ease, the grade, combined in many places with the sandy or gravelly nature of the road bed, makes the ascent difficult and at times impossible for all except the highest-powered automobiles. In contrast to most of the routes, the route from the south end of the valley to Silver Lake has a comparatively gentle grade, ascending only about 700 feet in 30 miles. The road up Owl Holes Wash, at the southwest end of the valley, although having a steeper grade than the Silver Lake road, probably affords the next easiest route out of the valley.

Travel along the axis of South Death Valley goes by way of a road on the west side of the valley to a point about 10 miles northwest of Saratoga Springs, where it crosses to the east side of Amargosa River and continues northward for about 3 miles to the old Confidence mill. In 1918 it was reported that the road was not passable northwest of this place for several miles, and it was necessary to ascend a road leading up Rhodes Wash toward Shoshone for about 6 miles and then turn northwestward again down the so-called Carbonate mine road into the valley.

In 1918 the road from Barstow led down Cave Springs Wash to the base of the alluvial fan in front of the wash and joined the road from Silver Lake about 2 miles south of Saratoga Springs. A mile and a half north of Cave Springs a little-used branch road to the left led to Denning Spring, about 3 miles from the main road. Beyond the spring the road continued through a canyon. A map furnished to the writer by the Automobile Club of Southern California in 1927 showed the road by way of Denning Spring as being more used at that time for travel into Death Valley.

The climate of South Death Valley is probably about the same as at the Greenland ranch (Furnace Creek ranch) on the east side of Death Valley about 65 miles northwest of Saratoga Springs. Data in regard to climatic conditions there are given on pages 69–89. The average annual rainfall is very low, less than 2 inches. The temperatures are high, both in summer and in winter. At the Greenland ranch maximum summer temperatures of 120° have been reported in different years in each month from June to August. Even in the winter midday temperatures of 80° and more are reported. On winter nights, however, the temperature may drop several degrees below freezing. The temperatures in the mountains bordering the valley are, of course, probably several degrees lower than on the valley bottom.

PHYSICAL FEATURES AND GEOLOGY

The principal feature of the Lower Amargosa Basin is the Death Valley trough, which extends in a northwesterly direction for about 130 miles. For less than half of this distance the drainage is tributary to Amargosa River, which ends in a playa in the lowest part of the valley. Within the area shown on Plate 11 the valley is from 3 to 5 miles wide. Along Amargosa River the valley is rather flat for half a mile or more on each side of the river and descends toward the playa with a gentle grade. At Saratoga Springs the altitude is about 215 feet above sea level; at the Confidence mill, about 13 miles to the northwest, it is about 15 feet below sea level, and the grade between the two places is about 18 feet to the mile. The lowest point in Death Valley, which is also the lowest point in the United States, is about 3 miles east of Bennett's Well, about 20 miles northwest of Saratoga Springs, where the surface is 296 feet below sea level.[84]

Near Saratoga Springs Amargosa River hardly deserves the name of a river, for it consists generally only of several dry channels. An uncompleted topographic map made by the United States Geological Survey shows that as the river emerges from its canyon near Sperry it descends an alluvial slope with a grade of 50 to 100 feet to the mile. In this part of its course it divides into two or more distributaries. These, however, are brought together again about 4 miles southeast of Saratoga Springs, where the course of the river is determined by a rock ridge which extends across the valley from the north and through which the river has cut but a single channel. West of this ridge the valley bottom is rather flat, and the stream branches out again into two or more distributaries. In September, 1917, and January, 1918, on the branch road from the Silver Lake-Owl Holes road to Saratoga Springs the course of the river was indicated only by two or three insignificant channels, a foot or two deep and several feet wide. They were dry in September, 1917, and only slightly moist in the following January, but the presence of salt grass and mesquite and of alkali in spots shows that the water is near the surface. It is apparent, however, that in spite of the large drainage area tributary to them there is practically no flow in the channels of Amargosa River near Saratoga Springs except in the wettest seasons.

The flat bottom of Amargosa Valley below Saratoga Springs is interrupted at one or two places by low hills. The most prominent of these are the so-called Confidence Hills, near the old Confidence mill, in T. 20 N., R. 4 E., which are about 10 miles long and 1 mile wide and rise 300 to 400 feet above the bottom of the valley. The hills are composed principally of clay, probably either lake or playa beds, of Tertiary age. The clay contains nitrates, but extensive tests have not shown the deposits to be rich enough to warrant commercial exploitation.[85]

From the relatively level land along Amargosa River alluvial fans rise toward the mountains, their gradients increasing as the mountains are approached. The mountains rise steeply. In the area shown on Plate 11, however, the mountains do not rise as high or as steeply as

[84] U. S. Geol. Survey Bull. 766, p. 267, 1925.

[85] Noble, L. F., Mansfield, G. R., and others, Nitrate deposits in the Amargosa region, southern California: U. S. Geol. Survey Bull. 724, pp. 51-59, 1922.

farther north in the valley. For example, just west of Bennett's well the alluvial slope rises about 1,500 feet in 3 miles, and above that the mountains rise fully 10,000 feet in 8.5 miles to Telescope Peak, in the Panamint Range, and form a veritable wall which constitutes an almost impassable barrier for many miles. The mountains on the east side of the valley are likewise steep but do not rise as high as the Panamint Range. The narrow troughlike character of the valley suggests that it has been formed by faulting, a huge block of the earth's crust being dropped downward between the parts that now constitute the mountains. Faulting of considerable magnitude has been observed on the east side of the valley, but definite evidence of faulting on the west side is still lacking.[85a] The structure is complex, and further work is necessary to determine the true structure.

The rocks of the mountains on both sides of Death Valley north of Saratoga Springs consist principally of pre-Tertiary crystalline and metamorphic rocks—granite and other intrusive rocks, gneiss, schist, and sedimentary rocks that are more or less metamorphosed, including marble, quartzite, and slate.[86] At Saratoga Springs the rocks are limestone, slate, and conglomerate, intruded by gabbro or diabase.[87] The rocks strike approximately north and dip about 50° E.

In T. 18 N., Rs. 4 and 5 E., the southeasterly trend of the great Death Valley trough is interrupted by the Avawatz Mountains, which rise to a height of more than 6,000 feet above sea level and are about that high above the bottom of the valley near Saratoga Springs. However, the valley is not completely closed in, for there is an offset to the east for several miles to Rs. 7 and 8 E., and thence a broad valley extends southward for many miles and includes the Lower Kingston, Riggs, Silver Lake, and Soda Lake Valleys. (See pl. 11.)

The part of the valley that comprises the offset toward the east just mentioned is somewhat constricted but not fully cut off, in two localities, by low hills that extend southward from the main mass of the Amargosa Range. The eastern part of the offset consists of a broad sandy alluvial fan built out from the mouth of Kingston Wash, from which it slopes gently westward. (See p. 604.)

In the eastern part of the valley, below the mouth of the canyon of Amargosa River below Sperry and on the fan of Kingston Wash, there is much wind-blown sand, with some large dunes. Dunes are also to be seen in reentrants in the mountains between Saratoga Springs and the canyon of Amargosa River.

At the southwest end of the valley, opposite Saratoga Springs, is a larger embayment or valley in the mountainous border that is some-

[85a] Noble, L. F., The San Andreas rift and some other active faults in the desert region of southeastern California: Carnegie Inst. Washington Yearbook 25, pp. 425–426, 1926.

[86] Noble, L. F., Mansfield, G. R., and others, op. cit., p. 28.

[87] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California: U. S. Geol. Survey Bull. 208, p. 188, 1903.

what like the offset to the east, just described, except that the land rises more steeply and culminates in a low divide, just west of the Owl Holes, at an altitude about 1,800 feet above Amargosa River near Saratoga Springs. This valley, several miles wide in its lower part, is a large alluvial fan built up principally by the drainage from the Owls Head Mountains. The principal channel of this fan is known as Owl Holes Wash and heads on the south side of the Owls Head Mountains. Near the head of the wash is the Owl Head manganese mine. Mann[88] states that the rocks in the vicinity of the mine consist of granite, which forms the main mass of the mountain, and overlying beds of limestone, jasper, and gypsum. On the south side of the wash are gravel and gravelly clay with some gypsum, which are exposed to a depth of 15 feet. The beds are older than the recent wash and are probably of Pleistocene or Tertiary age. At one place the strike was determined to be S. 85° W. and the dip 27° SE. The beds have apparently been tilted by faulting. On the south side of the wash just west of Owl Holes is a long ridge that extends eastward for several miles as a spur of the Avawatz Mountains. Where crossed by the road southwest of the Owl Holes this ridge is composed of unconsolidated alluvium. Near Denning Springs and in Cave Springs Wash a ridge that is apparently the continuation of that just described contains old sedimentary and igneous rocks, so that bedrock may lie at or near the surface farther west in the ridge. The trend of the ridge is nearly due east, approximately parallel to the strike of the faulted beds of alluvium above Owl Holes Wash. The linear extent of the ridge and its rather steep northern and southern slopes suggest that it has been raised by faulting. The ridge is roughly in line with the eastern end of the great Garlock fault farther west. (See pp. 118, 188, 195.)

The southern and southwestern border of the Lower Amargosa Basin is formed by the Avawatz Mountains. The southeastern part of this range is a high rugged mass, culminating in Avawatz Peak, which reaches an altitude of 6,100 feet above sea level. The range becomes lower toward the northwest.

The geology of the mountain is rather complex. The following notes are based on rather superficial and incomplete observations during the writer's hurried trip between watering places, but they will give some idea as to the complexity of the geology. The west end of the mountains, near Two Springs, is composed principally of granitic rocks. On the south side of the range, about 1½ miles east of Avawatz Dry Lake, talcose schist was observed. Where the Barstow-Death Valley road crosses the mountains in a low pass about 1½ miles south of Cave Springs are beds of more or less weathered white,

[88] Mann, R. L., Owl Head manganese deposit, San Bernardino County, Calif.: Min. and Eng. World vol. 44, pp. 743–744, 1916.

pink, and brownish rocks whose origin was not fully determined. In part they are volcanic, but some of them may be altered sediments. In one place these rocks were observed to strike about due north and to dip almost vertically. Just south of Cave Springs is a red conglomerate which dips north, down the wash in which the springs are situated. The conglomerate is probably of Tertiary or Pleistocene age. On the west side of Cave Springs Wash opposite the springs is a huge block of quartzite about 100 feet wide and 40 feet high, the linear extent of which was undetermined, which apparently has been pushed up through the other rocks by faulting.

Below Cave Springs the wash descends across an alluvial fan for about 3½ miles. A peculiar feature is that the great alluvial fan, the highest part of which lies east of Cave Springs, slopes in a northwesterly direction toward Denning Spring, but Cave Springs Wash cuts diagonally across the fan in a northerly direction—that is, the wash does not follow the original slope of the fan. This unusual drainage feature can be well seen from a rock ridge about 3½ miles below Cave Springs. The traveler is also impressed with it if he leaves Cave Springs Wash 1½ miles below the springs and follows the road to Denning Spring. Below Cave Springs the wash receives the drainage from the alluvial fan that rises southeastward from it. Above the branching of the roads as well as for some distance below it the wash is bordered on both sides by steep banks 5 to 40 feet high cut in alluvium older than the Recent deposits. The bank on the west side of the wash is not as high as that on the east side. Climbing to the top of this bank, the Denning Spring road immediately begins to descend northwestward on a slope that is the continuation of the fan on the east side of the wash. In other words, Cave Springs Wash drains no territory west of the wash. It is apparent that there has been an important change in the drainage—some of the drainage that originally went northwestward toward Denning Spring is now diverted to another course. The conditions are essentially those recognized by geologists as constituting stream piracy, the present Cave Springs Wash having captured the upper part of the large alluvial fan that formerly was tributary to what may be termed Denning Spring Wash. This fan may be termed the Denning Spring fan. A suggested explanation of this change in drainage is as follows. At an earlier period Cave Springs Wash probably did not reach as far south as now but ended on the north side of the rock ridge that crosses its course about 3½ miles north of the springs. Subsequently by headward erosion the wash cut through this ridge and reached the unconsolidated alluvium of the Denning Spring fan, lying back of it. With a steeper grade than that of the fan, perhaps as a result of increased earth movements of which there is much evidence in different parts of the Avawatz Mountains, Cave Springs Wash was able to cut its channel headward and rob Denning Spring Wash of the upper part of its drainage.

About 3½ miles north of Cave Springs the northerly course of Cave Springs Wash is blocked by a rock ridge 75 to 100 feet high that trends about due east. The wash swings abruptly to the east and cuts through the ridge in a canyon, beyond which it swings back to the northwest for a short distance. The main mass of the ridge is composed of limestone, which is cut by veins of a material that is probably siderite. The limestone is shattered. At one place the strike was observed to be due east and the beds were almost vertical. Flanking the limestone on both the north and the south are granitic or dioritic intrusive rocks. At one place on the south side of the ridge the granite overlies the limestone. The ridge continues westward from Cave Springs Wash for several miles. It is cut by a canyon near Denning Spring. The appearance of the ridge and its relation to other rocks strongly suggest that it has reached its present position with relation to the intrusive rocks by faulting, but observations were too meager to prove this to be a fact.

North of the limestone ridge conditions are somewhat similar to those south of it in that there is an alluvial fan whose original slope was northwest, but Cave Springs Wash cuts across it diagonally and has diverted some of the drainage from its original course. Continuing down Cave Springs Wash from the limestone ridge just mentioned, the traveler passes a mass of chloritic granite on the northeast side of the wash, against which lies a red conglomerate that dips 60°–85° NW. The conglomerate extends about 1,000 feet along the wash and gives way to gravel beds of the alluvial fan 25 feet or more in thickness. About a mile north of the limestone ridge these gravel beds, which dip down the wash, lie unconformably on other gravel beds which seem to be of the same nature but which dip southwest. At one place the strike of the underlying beds is N. 10° E. and the dip 20° SE. These gravel beds are faulted. About two-tenths of a mile farther north the wash cuts through brown, gray, and yellow clays which contain salt and gypsum. The beds are crumpled, but the general strike is N. 45° W., and the dip 45°–85° SW. At this place, on the east side of the wash and about 30 feet above it, gravel that dips down the wash overlies the clay beds unconformably. The clay beds are part of a series that form low hills that reach northwestward to the Silver Lake-Owl Holes road about 3 miles west of Saratoga Springs. These hills, which are locally known as the Saratoga Hills, are nitrate-bearing, although extensive testing has not shown the deposits to be of commercial value under present economic conditions.[89] Between Cave Springs Wash and Sheep Creek, farther east,

[89] Noble, L. F., Mansfield, G. R., and others, op. cit., pp. 31–51.

in what is known as Salt Basin, are somewhat similar nitrate beds bearing salt, gypsum, and celestite (a strontium-bearing mineral).[90]

Below the nitrate beds just mentioned cut by Cave Springs Wash are hills of badly weathered granite. The last of these is about 6½ miles north of Cave Springs. North of this point the wash pours out onto a large alluvial fan.

Additional evidence of the complicated structure of the Avawatz Mountains was observed on a trip part way up the wash of Sheep Creek. The wash is reached by a road that turns southwest from the Silver Lake-Owl Holes road about 5½ miles east of the branch road leading to Saratoga Springs. The mouth of the wash is about 4 miles southwest of the main road. On the east side of the wash is coarse alluvium, older than the present wash material, exposed to a depth of 40 feet. At one point near the mouth of the wash this old alluvium, which is probably of Pleistocene age, are a series of old rocks, probably early Paleozoic or pre-Cambrian. The beds strike N. 10° E. and dip about 20° E. On the west side of the wash about 400 feet farther south are somewhat similar rocks, consisting of quartzite, limestone, marble, and slate, but the strike is N. 80° W., or approximately at right angles to that of the beds just mentioned, and the dip is 86° S. This nearly vertical series, a few hundred feet across, is cut on its south side by basaltic rocks. The contact between the igneous and sedimentary rocks is slickensided, indicating that there has been movement along it. The basalt gives way to disintegrated granite. At Sheep Creek Spring, about half a mile up the wash, are ledges of pegmatitic granite. On the east side of the wash as far south as Sheep Creek Spring rises a large mass to much greater heights than on the west. The lower part of this mass is overlain by the older alluvium. From a distance it appears to be largely granite.

South of Sheep Creek Spring the canyon or wash broadens and the main canyon bends to the southeast. Directly south of the spring is a large very much dissected alluvial fan that rises 200 feet or more above the present wash. A number of small canyons only a few feet wide but with straight-walled sides 30 to 50 feet high cut this fan. In some of these canyons coarse fanglomerate, probably of Pleistocene age, is exposed for the full depth. Near the west side of the fan the fanglomerate is underlain by older beds of gypsum. At one place there is about 100 feet of red conglomerate in which was seen an overturned fold whose axis leans about 45° toward the north. This conglomerate rests against gypsum beds, which are also much folded. The gypsum beds are doubtless related to those found in Salt Basin, a mile or two to the northwest. In some of the canyons the fanglom-

[90] Phalen, W. C., Celestite deposits in California and Arizona: U. S. Geol. Survey Bull. 540, pp. 526-531, 1914.

erate rests on a badly weathered granite. At its upper end the fan abuts against a purple rhyolite porphyry, which cuts in a northwest direction across the granite that underlies the fan. The several different types of rocks exposed in the canyon of the alluvial fan exhibit a variety of colors—white, red, delicate pink, and purple. The colors, the variety of rocks, and the dissection of the fan by vertical-walled canyons present a striking scenic feature.

The writer did not go farther up Sheep Creek Wash than the fan just described. A variety of boulders in the bed of the recent wash, including granite and marble, suggest that the geology of the upper part is as complicated as in the short stretch just described.

The recent alluvium on fans in front of the Owls Head and especially on the north front of the Avawatz Mountains is much coarser than that observed in most other parts of the Mohave Desert region. In many of the other valleys the alluvium is largely a coarse sand or fine gravel with little material larger than an inch or two in diameter. In contrast, along the Silver Lake-Death Valley road between Salt Spring and the branch roads to Saratoga Springs, although at a distance of 3 or 4 miles from the base of the mountains, there is much very coarse débris in which are numerous boulders from 1 to 2 feet in diameter. The débris is also much furrowed by small channels from recent rain wash. These conditions suggest that comparatively recent uplift may have produced conditions conducive to unusual erosional activity.

The observations of the writer indicate that the geology of the Avawatz Range, at least of its north side, is as complicated as that of almost any other area of similar size in the Mohave Desert region. In a stretch of less than a mile along Sheep Creek Wash may be seen sedimentary rocks of probable Paleozoic or pre-Cambrian age, pre-Tertiary intrusive rocks of probably two and perhaps three different ages, both igneous and sedimentary rocks presumably of Tertiary age, and alluvial deposits older than the recent deposits. All are rather well exposed, because uplift in comparatively recent geologic time has resulted in marked erosion and consequent dissection of the mountain slopes. In Sheep Creek Wash and Cave Springs Wash there are indications of faulting in at least three different directions. One series of faults shown by the vertical sedimentary series near the mouth of Sheep Creek Wash and the prominent ridge of limestone 3½ miles north of Cave Springs trends almost due east and is doubtless related to the great Garlock fault, which extends from Fremont Valley northeastward across the south end of Searles Lake Valley and eastward through Leach Valley. A second series of faults trends northwest, as seen in the Saratoga nitrate beds. The direction of this fault zone is approximately parallel to the Death Valley trough. A third probable fault line is suggested by the northward-striking beds of old rocks on the east side of Sheep Creek Wash. The strike of these beds is approximately similar to that of beds north of Amargosa River near Saratoga Springs. The Avawatz Mountains seem to be the meeting point of three or more fault systems of considerable magnitude, and detailed geologic study of the locality should yield much valuable information in regard to the history of not only this particular region but adjoining regions.

GROUND WATER

Amargosa River.—The channels of Amargosa River are dry for most of the time. Near Saratoga Springs and for about 10 miles southeast, and probably also for most of its course northwest of the springs ground water is evidently near the surface, as is shown by the presence of patches of salt grass and mesquite, and of alkali on the surface, which in other parts of the Mohave Desert region generally indicate that the depth of the water table is less than 10 feet. It is believed that an abundance of water could be obtained from dug or drilled wells on the flat land along the channels of Amargosa River, but there is little question that the water is of poor quality. The water that is found in places in the river canyon above Sperry is reported to be salty. Water from a salt spring in or near sec. 30, T. 18 N., R. 7 E., in a tributary channel to the river from the southeast, is highly mineralized, containing 5,385 parts per million of total solids, most of which was ordinary salt. (See analysis 5, p. 588.) The water elsewhere along the river is probably about as highly mineralized, if not more so.

It is not surprising that the water of the river bottom has a rather high mineral content. At several places in the long course of Amargosa River in its upper valley there is more or less evaporation of ground water with concentration of the salts contained in the water. These salts may later be carried farther down the drainage basin by flood waters. Furthermore, there are in the drainage basin several areas of Pleistocene or older rocks that contain salt and gypsum beds, such as the lake beds in the vicinity of Tecopa and Zabriskie, the Saratoga niter hills, the beds of Salt Basin, on the north side of the Avawatz Mountains, and the Confidence Hills, from all of which more or less saline material is carried into the surface water or ground water that moves toward Death Valley.

Because of the poor quality of the ground water near Amargosa River travelers are almost wholly dependent on springs for potable water.

Saratoga Springs.—Saratoga Springs are among the largest springs in the Mohave Desert region. They have long been a noted camping place for desert travelers. Picture writings on the south face of a rock hill a few hundred feet to the southeast show that the springs were important in the life of the desert Indian prior to the coming of the white man.

The springs, four in number, are in the NW. ¼ sec. 2, T. 18 N., R. 5 E., on the northwest side of a low rock hill that forms the south end of a ridge that extends southward from the Ibex Mountains (also called Black Mountain). A road formerly led past the springs up the east side of Death Valley for a short distance and thence across the Ibex Mountains to Zabriskie. The road north of the springs is generally impassable for automobiles, and they are now reached only by a branch road that turns off from the Silver Lake-Owl Holes road about 2 miles south of the springs. The road to the springs skirts the south side of the rock hill. Near the west end of the hill tules, or "Indian sugar cane," and salt grass on the south side of the road suggest that water is near the surface, but the presence of the springs is not suspected until a northward turn in the road around the hill brings the main spring into sight. An old road leads directly west across the valley flat to the Silver Lake-Owl Holes road and the road up the west side of Death Valley near the Saratoga niter hills. This road is likely to be treacherous in places, and although it saves several miles it should be avoided.

The principal spring forms a large pool about 30 feet in diameter and 4 feet deep. The bottom is covered with sand, which is agitated by water bubbling up through it. An overflow of at least some tens of gallons a minute escapes through a channel to a pond several hundred feet to the north. Farther north are two or three other ponds that cover an aggregate area of several hundred square feet. The other three springs are much smaller than the one just described. One is a few feet east of the main spring. Another is 150 feet or more east of the main spring, close to the base of the rock hill. The fourth spring, which was not seen by the writer but is shown on a sketch map of the area around the springs which was made by Hoyt S. Gale, is near the base of the hills about 700 feet northeast of the main spring. This spring is said to be poisonous and when visited by Mr. Gale in May, 1918, was walled up.

The water from the springs has a peculiar, unsatisfying taste that is neither especially bitter nor salty. This taste is probably due to a fortuitous combination of certain proportions of sodium sulphate and sodium chloride in such a way as to disguise the characteristic tastes of those substances. The water from the large spring has a stronger taste than that from the two small springs, and water for drinking is generally obtained from the smaller springs. An analysis (2 in accompanying table) of a sample from the first spring east of the main spring shows that the water is highly mineralized and contains 3,098 parts per million of total solids. It is high in sodium sulphate and rather high in chloride. The water is of poor quality for domestic use, but members of the Geological Survey have camped at the springs for several weeks and have used it regularly for drinking without serious effects.

The water from all the springs is warm. The temperature of the large spring appears to be rather uniform within about 1°, for several observations by the writer and others reported to him by Hoyt S. Gale showed readings between 82° and 83° F. The temperature of the water in the small pools that have little or no outflow may be subject to more variation. The large spring with its abundant supply of warm water makes an inviting bathing pool at all seasons.

The presence of salt grass and tules shows that ground water is near the surface over a large area on the valley flat near the springs. Whether the water that emerges in the springs is derived from this body of ground water, which may be considered underflow of Amargosa River, or whether it comes from some independent source is uncertain. The situation of the springs, especially the three smaller ones, in relation to the near-by rock hills, which have been faulted, and the warmness of the water suggest that the water may rise along fractures in the rock.

Analyses of water from springs in the Lower Amargosa Valley, Calif.

[Parts per million]

	1	2	3	4	5
Silica (SiO_2)	90	70	52	74	48
Iron (Fe)	.38	.17	.29	.05	.19
Calcium (Ca)	41	31	96	71	256
Magnesium (Mg)	9.0	36	16	56	120
Sodium and potassium (Na+K)	545	[a] 994	55	[a] 90	1,559
Carbonate radicle (CO_3)	22	22	30	5.8	0
Bicarbonate radicle (HCO_3)	175	410	155	186	313
Sulphate radicle (SO_4)	675	1,039	137	393	901
Chloride radicle (Cl)	261	657	61	23	2,295
Nitrate radicle (NO_3)	29	1.7	5.7	.23	1.8
Total dissolved solids at 180° C	1,804	3,098	535	860	5,385
Total hardness as $CaCO_3$ (calculated)	139	225	306	407	1,130
Date of collection	([b])	([c])	([d])	([e])	([f])

[a] Calculated. [b] Oct. 15, 1917. [c] Sept. 8, 1917. [d] Sept. 7, 1917. [e] Oct. 16, 1917. [f] Jan. 14, 1918.

Analysts: 1, 5, Margaret D. Foster and C. H. Kidwell, U. S. Geological Survey; 2, A. A. Chambers, U. S. Geological Survey; 3, Addie T. Geiger, U. S. Geological Survey; 4, Addie T. Geiger and C. H. Kidwell, U. S. Geological Survey.

1. Owl Holes, a spring or dug well, probably in sec. 23, T. 18 N., R. 3 E. San Bernardino meridian. See below for description.
2. Saratoga Springs, SW. ¼ sec. 2, T. 18 N., R. 5 E. Sample taken from small spring at base of rocks a few feet east of the big spring. See p. 586 for description.
3. Cave Springs, near center of T. 17 N., R. 5 E. (unsurveyed), from southerly of two caves. See p. 589 for description.
4. Sheep Creek Spring, approximately in sec. 5, T. 17 N., R. 6 E. (unsurveyed). See p. 589 for description.
5. Salt Spring, in bed of south branch of Amargosa River, approximately in sec. 30, T. 18 N., R. 7 E. See p. 605 for description.

Owl Holes.—Owl Holes are in sec. 23, T. 18 N., R. 3 E., on the north side of Owl Holes Wash where it emerges from the Owls Head Mountains. When visited by the writer in October, 1917, they consisted of two pits about 2 feet apart. The upper pit was 6 by 18 feet and 2 feet deep; the other was 7 by 14 feet and 3 feet deep. The bottom of the lower pit was mucky and the water dirty, but the water in the upper pit was clear. A small stream of water trickled from the lower pit. Apparently from time to time the holes are filled with alluvium washed in by floods, but water can doubtless be obtained by digging anywhere within 200 or 300 feet of the location of the holes described. The water has a slight salty or bitter taste, but is palatable. As shown by analysis 1 the water is rather highly mineralized, containing 1,804 parts per million of total solids. It is poor for domestic use.

Cave Springs.—Cave Springs are near the center of T. 17 N., R. 5 E. (unsurveyed), on the road from Barstow to South Death Valley. They are about 65 miles northeast of Barstow by the road by way of Paradise Springs and Garlic Springs, and 9 miles almost due south of Saratoga Springs (11½ miles by road). The springs are on the east side of the wash 2 miles north of the point where the road crosses the divide of the Avawatz Mountains. They consist of two caves or short tunnels, about 40 feet apart, dug about 10 feet into the low wall of the canyon. Apparently there is seldom, if ever, any overflow from the springs. The water is clear and cool. As shown by analysis 3, the water is only moderately mineralized. Although the water would be rated as only fair for domestic use as compared to waters in many other parts of the Mohave Desert region it is of better quality than samples collected by the writer from other watering places in the Lower Amargosa Basin.

A number of mesquite growing in the wash near the spring indicate that water is probably near the surface in the vicinity of the springs. A huge block of quartzite crops out on the west side of the wash, and probably a rock barrier lies near the surface in the wash, behind which some water is impounded.

Sheep Creek Spring.—Sheep Creek Spring is approximately in sec. 5, T. 17 W., R. 6 E. (unsurveyed), about half a mile above the mouth of the canyon of Sheep Creek Wash. The location of the spring is marked by an abundant growth of mesquite. Water comes to the surface in the gravel wash near a low ledge of rock on the west side of the canyon and flows for about 200 feet. At this point the wash is only about 200 feet wide, with granite cliffs on both sides. In October, 1918, the water was collected in a pipe about 100 feet long, from which it flowed at a rate of about 3 gallons a minute.

The water is rather highly mineralized, containing 860 parts per million of total solids. (See analysis 4, p. 588.) It is fair for domestic use. The temperature of the water at the time of the writer's visit was 71½° F., but it doubtless varies with the season.

Denning Spring.—Denning Spring is on the north slope of the Avawatz Mountains about 3½ miles northwest of Cave Springs (about 5½ miles by road). The spring is reached by a road that turns northwest out of Cave Springs Wash about 1½ miles below Cave Springs and leads down an alluvial slope. About 2 miles from Cave Springs Wash the road approaches a low rock ridge and parallels it for about half a mile, to a point where the road bends rather sharply toward the north down a canyon that cuts through the ridge. At this point the road strikes a wash draining from the southwest. In 1918 an old shack stood in a small gulch south of the road a short distance southeast of this wash, though it was so hidden that it was not seen until the traveler was almost directly opposite it. A short distance up this gulch was an old well or spring in which the water was not in good condition. A better well was found a short distance up the wash leading from the southwest. It is dug, 5 by 6 feet in cross section, and about 10 feet deep. The depth to water was 4 feet. The sides of the well had partly caved in. No sample was collected, but the water appeared to be all right for drinking. The temperature of the water was 65° F. From Denning Spring a road continues northward through the canyon just mentioned and along the west side of the Saratoga Hills to the Death Valley road.

Rhodes Spring, Bradbury Well, and Salsberry Spring.—Rhodes Spring, Bradbury Well, and Salsberry Spring are on the road between the Confidence mill and Shoshone. The following information is based on data furnished by L. F. Noble, of the United States Geological Survey, in 1918. Rhodes Spring is about 8 miles northeast of the Confidence mill. It is reached by a branch road that turns northeast from the main road near a prominent rock point 6½ miles from the mill. The spring is 1½ miles from the main road. The road toward Shoshone continues up grade for 7 miles beyond the branch road, and water for automobile radiators should be taken at Rhodes Spring or Bradbury Well, which is near the road a mile farther east. In going toward Barstow these two watering places are the last until Saratoga Springs or Denning Spring are reached, a distance of about 25 miles, some of which is through heavy sand. Good water is generally available at Bradbury Well, so that the traveler need not make the long side trip to Rhodes Spring.

Bradbury Well is 7.6 miles by road from the Confidence mill and 18.1 miles from Shoshone. The well is in a wash on the south side of the road and about 500 feet from it. A path leads up a small open wash about two-tenths of a mile east of a point of rocks to some mesquite bushes, surrounded with camp litter, and then about 200 feet west to another small wash in which the well is situated. The well is dug in disintegrated granite, and the water apparently is of good quality.

Salsberry Spring is about 13.8 miles by road from the Confidence mill and 11.9 miles from Shoshone. It is reached by a trail that leads about half a mile east from the road. It is reported that the yield of the spring is small and not always reliable.

WINGATE VALLEY

GENERAL FEATURES

The name Wingate Valley is suggested by the writer to designate a small valley that lies between the south end of Panamint Valley and Death Valley. (See pl. 7.) The name is derived from Wingate Wash, by which the valley is drained to Death Valley.

When the writer was in the valley in October, 1917, and January, 1918, it was uninhabited except for a temporary camp of miners exploring deposits of Epsom salt in hills on the south side of the valley. It is understood that these deposits have been developed in recent years. To ship the recovered material a monorail system has been built leading from the Trona Railroad near Westend in a direct line across Searles Lake and over the Slate Range to the epsomite deposits. Conditions in the valley are unfavorable for agriculture.

In 1918 the valley was reached by a road leading eastward from Panamint Valley about 9 miles north of its south end and 5½ miles north of Lone Willow Spring. The road climbs out of Panamint Valley with a rather steep grade. About 7½ miles east of the Panamint Valley road is a road fork. One road continues eastward down Wingate Wash to Death Valley, reaching the floor of the valley 10 miles or more northeast. This road was not traveled by the writer. It is said to have a rather steep grade, and although automobiles can probably descend it, travel in the opposite direction may be difficult. The other road leads southeastward to low hills known as the Crystal Hills and up a wash through these hills to an open slope beyond. In the hills, about 4 miles from the road fork, are deposits of Epsom salt and other salts. South of the hills the road ascends a rather gentle alluvial slope for several miles to Hidden Spring. (See p. 593.) A short distance south of the Crystal Hills a road comes in from the northeast which is a short cut to the Wingate Wash road to Death Valley. South of Hidden Spring the road continues in a southeasterly direction up a wash to the divide of the Quail Mountains and down another wash to the road from Randsburg and Granite Wells to Leach Spring and South Death Valley, which is reached 7½ miles from the spring.

Hidden Spring is the only watering place in the valley. Distances to other springs outside of the valley are considerable, and the traveler should be well supplied with water if he does not intend to visit Hidden Spring.

Wingate Valley is essentially a break, though an incomplete break, in the great mass of mountains that forms the west wall of Death Valley. The part of this great mass north of Wingate Valley constitutes the Panamint Range, and the part south of the valley constitutes Brown Mountain at its west end and the Quail Mountains farther east. (See pls. 10 and 11.) The valley is almost wholly shut off from Panamint Valley, but at one point there is a break in the mountains, and from a low divide one looks down to the bottom of the south end of Panamint Valley, which is 300 feet lower. From this divide, near a point marked "BM 1977" on Plate 10, the bottom of Wingate Valley, which is occupied by Wingate Wash, slopes eastward and northeastward. Gentle slopes rise northward for a mile or two to the Panamint Range and southward to the Quail Mountains. The lower part of the slope on the south side of the wash is broken by the low Crystal Hills, mentioned above. Although the general depression of which the valley is a part continues eastward to Death Valley, spurs from the Quail Mountains and Panamint Range nearly prevent the drainage from reaching Death Valley and form the eastern border of Wingate Valley. The grade of Wingate Wash in this area is rather gentle—in fact, for some distance it is so gentle there is no single well-defined channel, but there are many small clay-bottomed depressions 5 to 30 feet long in which water appears to have stood. Farther east the grade toward Death Valley increases.

Waring [91] has mapped the rocks of that part of the Panamint Range immediately north of Wingate Valley as metamorphic rocks—limestone, slate, and quartzite. The rocks of Brown Mountain and the Quail Mountains, where seen close at hand by the writer, are principally Tertiary volcanic rocks, but pebbles of granite and other intrusive rocks found in the washes indicate that such rocks are present.

The Crystal Hills are about half a mile south of Wingate Wash and approximately parallel to it, in such a position as almost completely to prevent the waters from the south side of the valley from reaching the wash, but they are cut through at one point by a wash that may be termed Crystal Hills Wash. The hills are not over 50 to 100 feet high and are much dissected. A variety of rocks are exposed—volcanic rocks of probable Tertiary age, clay, beds of gypsum, and other beds reported to be rather pure deposits of aluminum and magnesium sulphates. No distinct bedding of the clay, gypsum, and associated deposits was observed. The volcanic rocks are relatively hard and form the principal hills. The other deposits are in general softer and have been much eroded into a sort of badland topography. Débris resulting from disintegration of both the hard and soft rocks mantles the hills in many places, and it was not possible from a very hasty examination to determine the true nature or origin of the deposits. At the time of the writer's visit several men were engaged in exploration of one of the richest deposits of Epsom salt. The process consisted principally of scraping off a caliche-like crust, which was sacked for shipping. Earlier in the year a similar crust had been taken from the deposit. During a period of several months,

[91] Waring, C. A., Geologic map of Inyo County, Calif., California State Min. Bur., 1917.

when no work was done, and in which there was some rain a second crust had formed. The deposit had been penetrated to a maximum depth of only 8 feet, so that its full extent was not known.

A large lake at one time occupied Panamint Valley and was fed in part by the overflow from a system of lakes in Searles, Indian Wells, and Owens Valleys. Gale[92] has pointed out the possibility that Panamint Lake rose to the altitude of Wingate Pass and discharged into Death Valley. Evidence found by the writer tends to confirm this suggestion, although it is still somewhat indefinite. (See p. 186.)

GROUND WATER

The only known source of water supply in Wingate Valley is Hidden Spring. This spring has had a reputation, suggested by its name, of being difficult to find and known only to prospectors. Perhaps this reputation is really due to the fact that comparatively few travelers have reason to enter the valley. The spring is about 9 miles south of the Wingate Wash road by way of the road through the Crystal Hills and about 4¾ miles south of those hills. From the hills a well-defined road leads along the east side of the valley, almost in a straight line for about 3½ miles, and then bends rather sharply southeastward and ascends the slope for 0.6 mile to a road fork near the base of the rock spurs of the Quail Mountains. The right-hand fork swings southwestward and then southward up a wash and leads across the mountain. The left-hand fork continues for only about 1,000 feet and ends in a short canyon. Hidden Spring is found by following a foot trail that leads to the left up a second short canyon about 200 yards from the end of the road. It is on a hillside and is marked by a large willow tree.

The spring is a hole about 4 feet in diameter and of the same depth, dug into a hard but much jointed reddish porphyritic rock. It is noteworthy that the water emerges not in the bottom of the canyon but about 15 feet up on the east side. This suggests that the water reaches the surface along certain fractures and does not permeate the entire rock mass. A short tunnel had been driven into the canyon wall below the spring, apparently in an attempt to strike the water, but no water was in it. When visited a small stream was trickling from the spring. Men at the epsomite mine in the Crystal Hills reported that the spring yielded several barrels of water a day.

The water is clear and cool and except for a slight taste of vegetation is quite wholesome. The accompanying analysis shows that it is only moderately mineralized, containing 446 parts per million of total solids. The water is good for domestic use but poor for boilers.

[92] Gale, H. S., Salines in the Owens, Searles, and Panamint Basins, southeastern California: U. S. Geol. Survey Bull. 580, pp. 312-317, 1915.

Analysis of water from Hidden Spring, Calif.

[Analyzed by Margaret D. Foster and C. H. Kidwell. Parts per million]

Silica (SiO_2)	74
Iron (Fe)	.21
Calcium (Ca)	50
Magnesium (Mg)	21
Sodium and potassium (Na+K) (calculated)	36
Bicarbonate radicle (HCO_3)	183
Sulphate radicle (SO_4)	55
Chloride radicle (Cl)	52
Nitrate radicle (NO_3)	12
Total dissolved solids at 180° C	446
Total hardness as $CaCO_3$ (calculated)	211

Date of collection, Jan. 12, 1918.

Water from Hidden Spring was hauled for the use of the miners at the epsomite deposits in the Crystal Hills. A nearer source of water would be desirable, but the conditions are not favorable for the development of a large supply. The most likely place is on the south side of the Crystal Hills, where the drainage from several square miles enters the wash that passes through the hills. It seems possible that alluvium extends to some depth below the surface south of the hills, and unless the alluvium of the wash through the hills extends deep enough to provide drainage there is probably some water stored in the underground reservoir thus created behind the hills. However, if the hills have acted as a barrier to the northward movement of water the conditions have been favorable for the prevention of circulation of water, with the result that water contained in the alluvium may be rather highly mineralized. The presence of gypsum, Epsom salt, and similar minerals in the hills is also conducive to the mineralization of the water. The drainage area is not great, and the average annual rainfall is low, probably not more than 5 inches, so that a large quantity of water can not be developed. Nevertheless, if the geologic conditions are such as to produce a reservoir, the water to be obtained would doubtless be ample for mining operations. In spite of the possible but unknown adverse conditions, it is believed that if the need of water for mining purposes is great enough to warrant the expense, it would be worth while to put down one or more test wells south of the hills. They should be preferably about a quarter of a mile from the base of the hills, in order not to strike bedrock too near the surface, but should be close enough to the hills to strike the deepest part of the underground reservoir if there is one there.

RIGGS VALLEY

GENERAL FEATURES

Riggs Valley lies in the north-central part of San Bernardino County. (See pl. 7.) The Tonopah & Tidewater Railroad traverses the east side of the valley. The principal road in the valley is that leading from Silver Lake to South Death Valley. About 7 miles north of Silver Lake this road is joined by a road from the southwest. (See pl. 11.) This branch road leads up a broad southwestward extension of Riggs Valley to Red Pass and thence to Bitter Springs and the Barstow-Death Valley road near Langford Well. About 5 miles west of Silver Lake this road is crossed by the road between Silver Lake and Randsburg. About 13 miles north of Silver Lake the Silver Lake-Death Valley road is joined by a road from Riggs station, 5½ miles to the southeast. A road leads along the railroad from Silver Lake to Riggs and thence northward for several miles and northeastward across the east side of Lower Kingston Valley. From Riggs a road leads eastward to the Riggs mine, on the south side of the Silurian Mountains, and up Riggs Wash. The roads on the east side of the valley are reported to be rather sandy and difficult to travel by automobile.

In 1918 the valley was uninhabited except for railroad employees at Riggs station, on the Tonopah & Tidewater Railroad. At that time water was available at the station, but no other supplies could be obtained. There has been some mining on a small scale in the Avawatz, Silurian, and Turquoise Mountains. Conditions in the valley are not favorable for agricultural development.

Riggs Valley is a part of a large trough that extends southward from the southeast end of Death Valley for about 50 miles. In this trough, to the south of Riggs Valley and separated from it by low rock hills, is Silver Lake Valley, and beyond that is Soda Lake Valley. North of Riggs Valley is the Lower Kingston Valley, separated by an almost imperceptible divide.

At its southwestern border an arm of the valley basin bends southwestward and parallels Silver Lake Valley. (See pl. 11.) Although the trend of the valley proper is north and south, tributary washes extend far back into the mountains on the east and west, with the result that the drainage basin as a whole does not exhibit a linear outline but rather one somewhat similar to an inverted L. A large wash known as Riggs Wash heads in the Turquoise Mountains more than 10 miles southeast of Riggs station, and another large wash heads on the southwest side of the Avawatz Mountains, in or near sec. 1, T. 15 N., R. 6 E., about 10 miles west of the north end of Silver Lake.

The western border of Riggs Valley for a large part of its length is formed by the high Avawatz Mountains, which rise to an altitude of about 6,100 feet above sea level or nearly 5,500 feet above the lowest part of the valley, which is about 675 feet above sea level. The part of the Avawatz Mountains tributary to Riggs Valley was not observed close at hand. Where seen in Cave Springs and Sheep Creek Washes there is a considerable variety of rocks—granite, metamorphic rocks, volcanic rocks, hard sedimentary rocks, and unconsolidated sediments—ranging in age from probable pre-Cambrian or Cambrian through Tertiary and Pleistocene to Recent. (See pp. 581–586.) The rocks in that part of the mountains were much faulted. It is therefore inferred that in the part of the Avawatz Mountains lying in Riggs Basin the geology is rather complicated. A single possibly significant feature was noted in the form of a low scarp cutting across the front of an alluvial fan at the base of the mountains several miles west of the Silver Lake-Death Valley road near the north end of Riggs Dry Lake. The scarp is suggestive of faulting, and if faulting has occurred it is doubtless related to faulting farther northwest.

South of the Avawatz Mountains a large wash leads westward and is followed by the Randsburg-Silver Lake road. In the upper part of the wash alluvium older than the recent deposits, probably Pleistocene, is exposed to a depth of 20 feet or more. A mountain that lies south of the wash, along the line between T. 15 N., R. 6 E., and T. 15 N., R. 7 E., is composed largely of granite. Along the Silver Lake-Randsburg road, about 0.6 mile east of the head of the canyon and about 11½ miles west of Silver Lake station, are hills of almost pure magnetite with some hematite. The mineral body is about 500 feet wide and strikes about due north. These iron deposits are presumably a part of the so-called Iron Mountain group, which is reported to contain 12,000,000 tons of good iron ore.[93] The geologic relations of the ore body were not determined.

The extreme south end of Riggs Valley is bordered by the Soda Lake Mountains. Part of this range also separates the valley from Silver Lake. (See pl. 11.) At the north end of Silver Lake the two valleys are separated by a low, narrow ridge of mountains. Where this ridge is crossed by the Silver Lake-Randsburg road there is a gradual ascent from Silver Lake but a very steep drop into Riggs Valley on the west. Along this road Riggs Valley appears to lie somewhat lower than Silver Lake. The western edge of the ridge is rather straight, and this fact, with the steep west slope, suggests that the ridge has been faulted up.

The eastern border of Riggs Valley north of the Silver Lake Basin is formed by the Silurian and Turquoise Mountains. Along the road from Silver Lake to Goodsprings through the Turquoise Mountains and at the head of Riggs Wash granite cut by basic intrusive rocks is exposed.

Riggs Valley is separated from the north end of Silver Lake Valley in part by low rock hills and east of the Tonopah & Tidewater Railroad by alluvium. The rock hills rise only 50 to 100 feet above Silver Lake, but on the north side they descend 100 feet or more below the level of the playa. There was formerly some overflow from the Silver Lake basin. Prior to the formation of the lake that

[93] Cloudman, H. C., and others, Mines and mineral resources of San Bernardino County, p. 46, 1917.

occupied that basin, which has been called Lake Mohave, it is not unlikely that there was no divide between the two valleys. Thus the drainage of Silver and Soda Lake Valleys at one time emptied into Riggs Valley, as did indeed that of the entire Mohave River basin if the river then reached Soda Lake and the flow of the river did not evaporate or percolate into the alluvium before reaching the valley. As shown on page 564 there is reason to believe that there may now be some underflow from Silver Lake Valley into Riggs Valley.

On its north side Riggs Valley is separated from Lower Kingston Valley by an almost imperceptible divide of alluvium. In fact, it is possible that after heavy rains there may be some drainage into Lower Kingston Valley. At present there is opportunity for underflow into the northern valley, and there is little doubt that in the past there has been a surface connection with the valley. Thus at some time Mohave River flowed through Riggs and Lower Kingston Valleys and joined Amargosa River, unless the connections between the several valleys were not entirely contemporaneous.

The lowest part of Riggs Valley is occupied by a playa, now generally called Riggs Dry Lake but formerly known as Silurian Dry Lake. The playa is of the dry type, with a hard, smooth surface and no alkali or vegetation on its borders that would indicate water near the surface. This is to be expected, for undoubtedly ground water in Riggs Valley percolates northward to Lower Kingston Valley, and available information indicates that near the boundary between the two valleys the depth to water is probably 100 feet or more.

GROUND WATER

So far as the writer could learn the only available water supplies in the drainage basin are derived from springs or wells in the mountains bordering the valley. Mendenhall[94] reported a well at the edge of Riggs Dry Lake, along the Silver Lake-Death Valley road, but the writer could not find any well near the playa. It seems likely that water could be obtained by drilling near the playa, but the depth to it would probably be great. In Lower Kingston Valley water emerges in a stream channel in the southwestern part of T. 18 N., R. 7 E., at a locality known as Salt Spring. (See p. 605.) It is probable that the water level beneath the Riggs playa is not much higher than at the spring unless between them bedrock lies nearer the surface than at the spring. As the difference in altitude between the two points is 100 to 150 feet or more, the depth to water beneath the playa is probably at least 100 feet. It is believed that the quantity of water available from the alluvium of the valley is not great,

[94] Mendenhall, W. C., Some desert watering places in southeastern California and southwestern Nevada: U. S. Geol. Survey Bull. 224, p. 55, 1909.

for the quantity of water emerging at the surface in the vicinity of Salt Spring is small. Presumably all the water that moves from Riggs Valley to Amargosa Valley, as well as most of that moving from Lower Kingston Valley, either rises to the surface or moves a short distance below the surface where the rock hills just west of the spring form a submerged dam. Nevertheless, although the supply is more or less limited, wells drilled in favorable situations would doubtless yield sufficient water for domestic use or mining, for a considerable quantity of water is doubtless stored in the alluvium.

The only watering place in the valley of which the writer obtained definite information is a well near the head of Riggs Wash on the north side of the Turquoise Mountains, in T. 16 N., R. 10 E. (unsurveyed). (See pl. 12.) It is most easily reached from the road between Silver Lake and Goodsprings. On this road 13.3 miles from Silver Lake a little-used road branches to the left (northwest) and descends Riggs Wash. The well is 1½ miles down the wash. The well is really a tunnel excavated in granitic rocks. When visited by the writer in October, 1917, the tunnel was barricaded. A pipe line led about 100 yards down the wash to a trough used for watering cattle. The outlet of the pipe was equipped with a ball valve so arranged as to maintain a certain depth of water in the trough but to prevent waste when water was not being used. The valve was tightly boxed in to prevent tampering, and the only way to obtain water was by dipping it from the trough.

A well known as Riggs Well is reported to be situated on the south side of Silurian Mountains, about 3 miles east of Riggs station on the Tonopah & Tidewater Railroad. In July, 1919, the well was reported to contain a good supply of water.

Two springs, known as Harpers Spring and Harpers Willow Spring, are reported to exist at Harper's mining camp, now abandoned, in the southeast end of the Avawatz Mountains, 10 miles or more northwest of Silver Lake. No definite information could be obtained either as to the springs or as to the route leading to them.

A dug well, dry at a depth of 50 feet, was found in the wash along the Silver Lake-Randsburg road, 9½ miles west of Silver Lake. The well was dug near several willow trees (perhaps the desert willow, *Chilopsis saligna*, rather than the true willow), which did not prove to be an infallible indication of water.

UPPER KINGSTON VALLEY

GENERAL FEATURES

Upper Kingston Valley lies in the northeastern part of San Bernardino County and is separated from the State of Nevada only by part of the Mesquite and Ivanpah Valleys. Apparently this valley has previously had no definite name. The name used in this report is derived from the Kingston Range, which borders the valley on the northwest, and from Kingston Wash, through which the drainage of the valley passes to the Amargosa Valley. Human activities in the valley center around Valley Wells, formerly called Rosalie, in T. 16 N., R. 12 E., where there is a cattle camp. A copper smelter at this place has been worked spasmodically.

A number of mines, most of them on the west slopes of Clark and Ivanpah Mountains, have been worked at intermittent periods. The metals produced include copper, lead, silver, gold, and tungsten.

One of the principal mines is the Copper World, in the northwestern part of T. 16 N., R. 13 E. Many years ago copper ore was mined there and smelted at the Valley Wells smelter. The mine was closed for several years, but it was reopened in 1917 by the Ivanpah Copper Co. Some high-grade ore was hauled to Cima and shipped to Garfield, Utah, for smelting. The smelter was rebuilt and was put into operation in the fall of 1917 to smelt the low-grade ore. The capacity of the smelter was about 150 tons a day. The ore is so low in grade that it probably could not be smelted at a profit. However, it was expected that sufficient copper could be recovered from the slag of the old smelter to warrant the operation of the new smelter. The mine and smelter were reported to have been closed a few months later.

In 1917 about 100 cars of lead and silver ore was produced from the Mohawk mine, on the south side of Mohawk Hill, in T. 16 N., R. 13 E. The lead occurs mostly as cerusite. The ore was hauled about 25 miles to Roach for shipment.

Tungsten has been mined at one or more places in Clark Mountain, but the production has been small. The deposits do not seem to be rich enough to compete with those in the Atolia district. Tungsten is also reported in the Shadow Mountains on the northwest side of the basin.

No land is farmed in the valley. One cattle company runs several hundred cattle in it.

Roads cross the valley in several directions. The road from Silver Lake to Mesquite Valley, Goodsprings, and other places in Nevada passes along its northwest side. A road from Silver Lake to Nipton and Searchlight crosses the center of the valley, and at Valley Wells a branch road leads from it southeastward to Cima. The other roads are less traveled and may not be passable for automobiles.

PHYSICAL FEATURES AND GEOLOGY

The principal topographic feature of Upper Kingston Valley is the mountain barrier that forms the eastern and northern border of the basin. The mountains extend almost continuously from the Ivanpah

Mountains on the south northwestward to the Kingston Range, although there are passes at several places. A considerable part of these mountains is more than 5,000 feet above sea level, and Kingston Peak and Clark Mountain rise to a height of more than 7,000 feet. A large part of these mountains is composed of Paleozoic rocks.[95] Spurr states that the Kingston Range consists of a central core of granite, which on the north and northeast is overlain by beds of Cambrian age. Along the Silver Lake-Goodsprings road, where it descends a canyon in about sec. 33, T. 19 N., R. 12 E., the rock is a blue limestone which strikes a little west of north and dips about 15°–25° NE. The mountain southeast of that place is apparently composed principally of limestone, but in the lower part of the pass, in the southwestern part of T. 18 N., R. 13 E., cross-bedded red sandstone is exposed. The age relations of these rocks have not been established, but they are presumably Paleozoic. The northwestern slope of Clark Mountain, on the road up to the Green mine, is composed of limestone, but southeast of the mine the rocks are granite.

On the Silver Lake-Nipton road the eastern part of the Ivanpah Mountains about as far west as Mexican Well is composed of gneiss and garnetiferous schist cut by granite. Farther west stands Mohawk Hill, which is composed of sedimentary rocks.

Sou'hwest of the Ivanpah Range the divide is formed by a large rounded mountain. The slopes of this mountain are so gentle and so uniform that from a distance of a few miles it appears to be formed of typical alluvial slopes that rise to the summit. As the summit is approached, however, numerous knobs of weathered granite are seen. It is quite evident that the slopes within a radius of 5 miles of the summit are not depositional alluvial slopes but consist of a smoothly eroded rock surface. Probably the granite actually lies within a few feet of the surface over even a much larger area than is shown on the geologic map (pl. 8).

The western border of the valley is formed mostly by granite hills and mountains. However, lava flows, probably of Tertiary age, occur in the northeastern part of T. 14 N., R. 11 E., and southeastern part of T. 15 N., R. 11 E., extending into the adjoining townships on the east. Limestone covers a small area in the vicinity of Francis Spring (T. 16 N., R. 11 E. unsurveyed) and may occur elsewhere in the Turquoise and Shadow Mountains.

A peculiar topographic feature is Shadow Mountain, in T. 17 N., R. 11 E. (unsurveyed). This mountain doubtless receives its name from the fact that the mountain culminates in two peaks that have about the same outline, one of them light colored, and the other dark, as if it were the shadow of the lighter peak. The "shadow" is especially noticeable from the southwest.

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[95] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California: U. S. Geol. Survey Bull. 208, pp. 195–200, 1903.

There is a distinct contrast between the east and west borders of the valley. The western divide, as seen from the valley, is composed of a relatively low and narrow ridge, in many places eroded into numerous more or less isolated knobs, which form the summit of an intricately dissected area of pre-Tertiary rocks that descends toward the west. (See pp. 557–558.) The eastern border of the valley is formed by an almost continuous mountain mass that rises from a few hundred to 3,000 or 4,000 feet above the highest points on the western border.

In many of the desert basins in the Great Basin, where one mountain border rises much above the opposite mountain border, so much more alluvium is carried into the valley from the higher mountains that the lowest part of the valley lies nearer the lower mountains. This condition does not exist in Kingston Valley, but the longest valley slope in general is on the west side. Apparently comparatively little alluvium has been washed in from the mountains on the east side of the valley. Furthermore, the small rock hills that rise from the valley floor at many places suggest that in the entire valley the alluvium is relatively thin. Apparently in this valley erosion has predominated, even in its lowest part.

Upper Kingston Valley is not a closed basin, but it drains through Kingston Wash, at its northwest corner, into Lower Kingston Valley, which is part of the Amargosa drainage basin. An apparently continuous wash extends northward from a place several miles south of Valley Wells to the head of Kingston Wash. However, about 5 miles north of Valley Wells there is a clay flat that may have a low divide at its north end. This flat was not visited, but if it is a true playa it is undoubtedly of the dry type, for the water table is known to be far below the surface.

The central part of Upper Kingston Valley is from 500 to 1,000 feet above the bottom of Mesquite Valley and Ivanpah Valley, which lie east of it. The eastern border of the mountains that separate Upper Kingston Valley from these valleys is much more sharply outlined than the western border, and the slopes are generally steeper. The features suggest that the mountain mass is bordered on the east by a great fault.

VEGETATION

All of Upper Kingston Valley is more than 3,000 feet above sea level. In consequence giant yuccas are more or less abundant throughout the valley. There is also some cholla present, but it is not abundant. Creosote bush is rare. Clark Mountain and Kingston Peak rise more than 7,000 feet above sea level, and on the highest parts of these mountains grow pine and piñon. On the higher slopes of the Mescal and Ivanpah Mountains and Teutonia Peak juniper is found.

SOILS

At a number of places in the valley, particularly in the vicinity of Valley Wells, considerable caliche is exposed in the washes. It appears to be more abundant than in most parts of the Mohave Desert region. The reason for its abundance is not clear, unless perhaps it is due in some way to the presence of so much limestone in the adjoining mountains, which would supply the cementing material for the caliche. In the southern part of the valley, where the rocks are granite, the soil is the typical arkose that is so widespread in the Mohave Desert region.

PRECIPITATION

No records of precipitation have been kept in the valley. The character of the vegetation is evidence that the precipitation in most of the valley is greater than that in a large part of the Mohave Desert region. This heavier precipitation is due to the high altitude of the valley and to the high mountains on its east side, which act as a barrier to the rain-producing winds. The average annual precipitation on the valley slopes probably is between 5 and 10 inches, and in the higher parts of the Kingston, Clark, and Ivanpah Mountains it may exceed 10 inches. Because of the high altitude a large percentage of the precipitation in the mountains comes in the form of snow.

WATER RESOURCES

WELLS

No perennial streams are known in the valley. The high mountains may contain seepages of water for several days after rains. The water supply for travelers is obtained from a few shallow wells and springs.

At Valley Wells water is obtained from dug wells. One well, owned by Sam E. Yates, is situated on the east side of the main wash a short distance north of the Silver Lake-Nipton road. This well is about 13 feet deep, and the depth to water in October, 1917, was 11 feet. The well was equipped with a force pump. A pipe line to a trough a few hundred feet away is arranged to carry water without the necessity of pumping. The water is used for domestic supplies and for watering cattle.

At the Valley Wells smelter of the Ivanpah Copper Co., there are five dug wells, which range in depth from 15 to 30 feet and are all connected by tunnels. The wells are dug in gravel, and a material described as limerock, which is probably caliche, lies at the bottom. The depth of the water in the sump is only 6 feet. When the wells are pumped at the rate of 50 gallons a minute there is practically no drawdown, but when the rate of pumping is increased to 100 gallons a minute the wells can be pumped dry.

The analysis of a sample from the Yates well (analysis 2, p. below indicates that the water in this locality is not very good. The sample contained 904 parts per million of total solids, and calcium sulphate predominates. The water is only fair for domestic use and bad for boilers because of the large quantity of scale-forming constituents. It is good for irrigation.

Analyses of ground water from Upper Kingston Valley, Calif., collected Oct. 24–27, 1917

[C. H. Kidwell, analyst. Parts per million]

	1	2
Silica (SiO_2)	55	37
Iron (Fe)	.42	2.1
Calcium (Ca)	27	151
Magnesium (Mg)	32	53
Sodium and potassium (Na+K) (calculated)	123	30
Carbonate radicle (CO_3)	0	0
Bicarbonate radicle (HCO_3)	395	208
Sulphate radicle (SO_4)	83	438
Chloride radicle (Cl)	39	23
Nitrate radicle (NO_3)	.72	.62
Total dissolved solids at 180° C	536	904
Total hardness as $CaCO_3$ (calculated)	199	595

1. Francis Spring, approximately in sec. 5 or 8, T. 16 N., R. 11 E. San Bernardino meridian. See below for description.
2. Valley Wells, in sec. 22, T. 16 N., R. 12 E. San Bernardino meridian. Sam Yates, owner. See p. 602 for description.

The only other well that is known in the valley is one dug by Mr. Yates about 2 miles south of Valley Wells and half a mile west of the road to Cima. The total depth is about 63 feet and the depth to water about 45 feet. This well yields 6 gallons a minute. It is used for watering cattle.

Mr. Yates states that he dug a well to a depth of 154 feet at the north end of the clay flat several miles north of Valley Wells but found no water. It would seem likely that water might occur close to the surface at places in Kingston Wash, where it cuts between the Shadow Mountains and the Kingston Range. This locality was not visited, however, and the wash may be filled with alluvium to so great a depth that water does not occur close to the surface.

So little information is available that it is impossible to make any prediction as to the occurrence of ground water in the valley. The conditions that cause the water to lie so near the surface at Valley Wells and so deep several miles farther north are unknown. Low hills west and north of Valley Wells suggest that a rock dam may extend across the valley at that place and bring the water close to the surface. On the other hand, the so-called limerock or caliche may act as an impervious bed above which the water is perched.

SPRINGS

Francis Spring.—Francis Spring is on the Silver Lake-Goodsprings road in about sec. 7 or 8, T. 16 N., R. 11 E. (unsurveyed). The spring is on the north side of the road along a wash about 0.7 mile west of the place where the road passes between low hills onto a long slope. The spring, when visited in 1917, was covered level with the ground and might easily be overlooked. However, an iron water trough about 100 yards down the wash called the traveler's attention to the nearness of water. The spring is really a well dug in gravel to a depth of 10 feet and partly walled. The depth to water is about 7 feet, so that a short rope and bucket were necessary to reach it. The trough near by was full of water, apparently fed by a pipe from the spring. The spring is used by travelers and as a watering place for cattle.

The water is moderately mineralized and contains 536 parts per million of total solids, in which sodium bicarbonate predominates. It is good for domestic use and fair for irrigation. (See analysis 1, p. 603.)

On the Ivanpah topographic map several springs are shown in the Clark and Ivanpah Mountains, but with one exception they occur on the east side of the mountains. Pachalka Spring is at the west base of Clark Mountain, about 5 miles northeast of Valley Wells, from which a secondary road leads to the spring. It is used only by prospectors and cattlemen, and no information is available in regard to it. This is probably the same as Pachanca Springs, which are mentioned in Water-Supply Paper 224 as situated above the northwest base of Clark Mountain.

POSSIBILITIES FOR FARMING

Conditions in Kingston Valley are unfavorable for other branches of agriculture than cattle raising. In a large part of the valley the depth of water is too great for economical pumping. Where water is closer to the surface the supply seems to be small.

Although the precipitation in the valley is slightly greater than in most of the Mohave Desert region, it is hardly sufficient for dry farming. It is sufficient, however, to provide some forage for cattle. Summer grazing is found in the high mountains that border the valley. Nevertheless the number of cattle that the valley will support is rather small, and it is probably already grazed to capacity.

LOWER KINGSTON VALLEY

Lower Kingston Valley lies west of the northern part of Upper Kingston Valley. (See pls. 7; 11, and 12.) It is separated from the upper valley by the Shadow Mountains and the Kingston Range but is connected with it by a pass through which Kingston Wash carries drainage from the upper to the lower valley. The lower valley consists almost wholly of a great alluvial slope that descends in a westerly direction from the base of the Shadow Mountains, the Kingston Range, and unnamed low mountains farther northwest. A small part of the basin consists of the alluvial slope on the northeast side of the Avawatz Mountains. The drainage from these alluvial slopes is concentrated into a channel that passes westward from the valley between low rock hills in the western part of T. 18 N., R. 7 E., and a short distance farther west joins Amargosa River. Thus the drainage of both the Upper and Lower Kingston Valleys is tributary to the Amargosa Basin. A large alluvial fan has been built out by Kingston Wash west of the Kingston Range and the Shadow Mountains. This wash, as well as other parts of the alluvial slope, is very sandy. Probably any surface flow that may be carried into the wash is absorbed on the alluvial slope, except perhaps after unusually heavy rains, so that surface run-off from either valley seldom reaches Amargosa River.

So far as the writer is aware, the valley is uninhabited. Some prospecting has been done in the mountains bordering the valley. The Tonopah & Tidewater Railroad lies along the east side of the valley. The only important road is that leading from Silver Lake to South Death Valley and to Randsburg by way of Owl Holes, which lies along the west side of the valley. Roads lead from the railroad, at Valjean and between that place and Riggs, northeastward to the west side of the Shadow Mountains and up Kingston Wash into the northern part of Upper Kingston Valley, where they connect with roads to Ivanpah and Mesquite Valley. A road also leads in a northerly direction to Rabbit Holes, and thence to Tecopa by way of the Tecopa smelter. It is reported that these roads are sandy and difficult to travel, and they are seldom used. In order to avoid these bad roads, persons going to Tecopa, Zabriskie, and Shoshone generally follow much more roundabout routes, either by way of Saratoga Spring and the old Confidence mill in Death Valley, or by way of Mesquite and Ivanpah Valleys. (See pp. 574, 577–578.)

The watering places in the valley known to the writer are the so-called Rabbit Holes, in the southwestern part of T. 19 N., R. 9 E. (unsurveyed), and springs in the southwestern part of T. 18 N., R. 7 E. (See pl. 11.) The Rabbit Holes are reported to consist of a small seepage. The supply is not reliable, and the water is usually contaminated by animals. The holes are reached by a branch from the road from Riggs to the Tecopa smelter, which is seldom traveled.

In January, 1918, water was flowing in a channel of the so-called South Branch of Amargosa River, about two-tenths of a mile east of low rock hills about 12 miles southeast of Saratoga Springs and 20 miles northwest of Silver Lake. This place is sometimes called Salt Spring. The spring is about 250 yards north of the Silver Lake-Owl Holes road and is marked by tules and other vegetation that indicate the presence of water near the surface. The water appears as a very small stream coming from clay and fine gravel. As shown by analysis 5 (p. 588), the water is highly mineralized, containing 5,385 parts per million of total solids, principally sodium chloride. It is very bad for domestic use. Other springs of better quality are reported to exist in low rock hills less than half a mile north of the springs just described.[96] The occurrence of springs in this locality is doubtless due to the extension of bedrock almost continuously across the valley in such a way as to hinder the westward movement of ground water and cause the water to rise near to the surface where it passes over the rock.

No water was found in a well drilled to a depth of 425 feet at Valjean, on the Tonopah & Tidewater Railroad. The material penetrated was all cemented gravel. It is probable that beneath most of the alluvial slope the water table does not rise much above the water level at Salt Spring. An uncompleted topographic map, made by the United States Geological Survey, shows that the spring lies a little more than 500 feet above sea level and that Valjean is a little more than 1,000 feet above sea level. Perhaps water would have been found if the well had been drilled 100 feet deeper. Doubtless water can be reached in other parts of the valley by drilling to a depth below the altitude of Salt Spring. In the lower part of the valley the water may be expected to be salty, but it is possible, although not certain, that water of better quality may be obtained from wells on the upper part of the alluvial slopes. It is believed that no large supply for continuous use, as for irrigation, can be obtained, for there is ample opportunity for the ground water to drain into the lower Amargosa Valley. In fact, the flow of water at Salt Spring may represent almost the entire quantity that is added continuously to the ground-water reservoir. However, a large quantity of water is doubtless stored in the alluvium, and enough water for mining could be obtained if occasion for such use ever arises.

PAHRUMP, MESQUITE, IVANPAH, AND ROACH VALLEYS

Pahrump, Mesquite, Ivanpah, and Roach Valleys lie in the extreme northeastern part of the Mohave Desert region. (See pls. 7 and 12.) Roach Valley lies wholly in Nevada, but the other three lie partly in Nevada and partly in California. The geology and water resources of these valleys have been described briefly by Waring.[97] The geology of most of the region has been studied in some detail by Hewett.[98] A few essential data are given below, and the reader is referred to reports of these men for more details.

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[96] Mendenhall, W. C., Some desert watering places in southeastern California and southwestern Nevada: U. S. Geol. Survey Water-Supply Paper 224, pp. 48–49, 1909.

[97] Waring, G. A., Ground water in Pahrump, Mesquite, and Ivanpah Valleys, Nev. and Calif.: U. S. Geol. Survey Water-Supply Paper 450, pp. 51–81, 1921.

[98] Hewett, D. F., Structure of the Spring Mountain range, southern Nevada (abstract): Geol. Soc. America Bull., vol. 34, No. 1, pp. 89–90, 1923; Two Tertiary epochs of thrust faulting in the Mojave Desert, Calif. (abstract): Geol. Soc. America Bull., vol. 39, p. 178, 1928; report for U. S. Geol. Survey on the geology of the Ivanpah quadrangle, in preparation.

PAHRUMP VALLEY

Only a small part of Pahrump Valley is included in the area covered by this report. The valley is a closed basin bordered by the high Spring Mountains on the northeast and lower mountains on the southwest. On the northwest it is bordered by small mountain masses through which there are several passes only a few hundred feet above the bottom of the valley. The great trough of which Pahrump Valley is a part continues southeastward, where it constitutes Mesquite Valley. The two valleys are separated by a rather low and gentle divide which appears to be underlain largely by alluvium.

Several large springs with recorded discharges during some months of a few to 35 cubic feet a second [99] rise in the Spring Mountains and in the valley, but none of them are within the area covered by this report. A dozen or more wells have been drilled or dug in the valley. The wells range in depth from a few feet to 535 feet and yield from a few to 560 gallons a minute. At two localities flowing wells have been obtained. A few hundred acres has been irrigated.

MESQUITE VALLEY

Mesquite Valley lies in the same large trough as Pahrump Valley, to the northwest, and is separated from it only by a low divide. On the other three sides it is surrounded by mountains that rise 2,000 feet or more above the bottom of the valley. The valley slopes southeastward to Mesquite Dry Lake, a playa that lies near the mountains that form the southeastern border of the valley. The playa is of the wet type and in places has a salt crust.

More than 25 wells have been drilled or dug in the valley. Near the playa the depth to water is less than 10 feet, but it increases in all directions away from the playa. At the old Sandy mill, in sec. 5, T. 25 S., R. 57 E. Mount Diablo meridian, the depth to water is about 50 feet. In sec. 30, T. 20 N., R. 12 E. San Bernardino meridian, the depth to water is at least 90 feet. Little definite information is available in regard to the yield of wells. No large yields have been reported, but this may be because the wells have not been fully tested. The water near the playa is rather mineralized, but that farther away is of better quality.

Some irrigation has been attempted in the valley, but when the writer visited it in 1917 the indications were that no great success had been attained. Near the playa the soil is alkaline, and in other parts of the valley where the depth to water is not excessive for economical pumping the soil is probably too clayey to permit successful cultivation. Some irrigation may be practicable in areas some

[99] Waring, G. A., op. cit., pp. 61–62.

distance from the playa if water can be obtained at a reasonable depth.

There has been considerable mining in the mountains around the valley, but it has been more or less sporadic. In 1914 a town named Platina was established in T. 25 S., R. 57 E., but in the fall of 1917 it was abandoned except for a few persons. Water for travelers was obtainable from a dug well at the Sandy mill, mentioned above, or from a well at the town site of Platina, a short distance south of the mill.

IVANPAH AND ROACH VALLEYS

Ivanpah and Roach Valleys occupy a large trough that trends north. The trough is almost entirely surrounded by mountains—the Spring Mountains, Clark Mountain, the Ivanpah Mountains, the New York Mountains, the McCullough Range, and other mountains that are unnamed—but there are rather broad passes at several points at altitudes of several hundred feet above the bottom of the valleys. The lowest parts of the valleys are occupied by playas, which may be designated Ivanpah and Roach Dry Lakes. Roach Dry Lake is only 10 or 15 feet higher than Ivanpah Dry Lake and is separated from it only by a low divide about a mile wide. This divide is formed by a large alluvial fan that has been built out from mountains on the east side of the trough. It seems likely that the two playas were parts of the same drainage basin until comparatively recent geologic time. The playas are of the dry type, with hard, smooth surfaces. In consistence with this type of surface the water table, as shown by the well data given below, lies at a depth of 75 feet or more. This fact is believed to indicate that water finds an underground outlet to some one of the adjoining basins. Apparently the only direction in which seepage could take place is northward into Mesquite Valley, where the water table is at about the same altitude as in Ivanpah Valley, or northeastward into Las Vegas Valley, where the water table is much lower. The divide between Mesquite and Ivanpah Valleys is composed of bedrock, but D. F. Hewett [1] states that the rocks are much faulted, and conceivably water might move along the fractures. Hewett states that the divide between Roach Valley and Las Vegas Valley is formed of Tertiary volcanic rocks, which may be underlain by older alluvium. These rocks might allow percolation of water into the lower valley.

Food supplies, gasoline, etc., may be obtained at several places, including Goodsprings, Jean, Roach, Nipton, Ivanpah, and Cima. The Los Angeles & Salt Lake Railroad crosses the center of Roach Valley and follows around the eastern and southeastern border of Ivanpah Valley. Numerous roads lead to all parts of the valleys.

[1] Personal communication.

The new Arrowhead Trail between Los Angeles and Salt Lake City (see p. 143) enters Ivanpah Valley through a pass in the Ivanpah Mountains and turns northward along the west side of Ivanpah Dry Lake. It goes northerly through Roach Valley to Jean and thence continues close to the Los Angeles & Salt Lake Railroad to Las Vegas. From the Arrowhead Trail near Valley Wells a road leads southeastward to Cima. From that place roads lead northeastward to Ivanpah and Ivanpah Dry Lake and to the Arrowhead Trail on the east side of the Ivanpah Mountains. Where the Arrowhead Trail leaves the mountains a road continues eastward across the valley to Nipton and thence to Searchlight.

Several wells have been drilled in Ivanpah Valley and at least two in Roach Valley. In the lowest part of Ivanpah Valley, near the playa, the depth to water is 75 feet or more. The water table rises but slightly toward the mountains, whereas the alluvial slopes rise with gradients of 50 to 100 feet to the mile or more. As a result at points higher and higher on the alluvial slope the depth to water becomes increasingly great. At the Murphy well, in sec. 3, T. 15½ N., R. 15 E. San Bernardino meridian (see pl. 12), the depth to water in October, 1917, was 100 feet. In a well of the Los Angeles & Salt Lake Railroad in sec. 13, T. 15 N., R. 15 E., about 3½ miles north of Ivanpah, about 300 feet higher, the depth to water is about 370 feet. In another well of the railroad at Lyons station the depth to water is 275 feet. In Roach Valley the depth to water in a well at Roach is about 90 feet and in a railroad well at Borax siding it is 200 feet. Available data indicate that the yield of the wells is not great. In January, 1918, the Murphy well could be pumped dry in about four hours at a rate of about 20 gallons a minute. This amount of water was derived from a 12-foot tunnel at the bottom of the well, which is in adobe or clay.

The quality of water in the lower part of the valleys is very bad. A sample from one well in sec. 8, T. 27 S., R. 59 E. Mount Diablo meridian, between the two playas, contained 27,501 parts per million of total solids, and a sample from the Murphy well contained 7,702 parts per million. In other wells farther from the playas the mineral content is much less, and the water is good for domestic use.

Some attempts have been made to irrigate land in Ivanpah Valley, but when the writer visited the valley in October, 1917, these had apparently all been abandoned. The depth to water is so great that water could be pumped for irrigation only under the most favorable circumstances. The soil in the lowest part of the valley, where the pumping lift is least, is too clayey to raise good crops, and the water is likely to be of poor quality. Farther from the playas, where the soil is more suitable for crops, the depth to water is excessive, and water could not be pumped economically. A few hundred head of cattle were being grazed in the valley in 1918. The number of cattle that can be raised, however, is dependent upon the supply of wild grass, for the soil and water conditions will not permit the cultivation of grazing crops.

A number of springs and wells are situated in the mountains that surround the two valleys. Many of them are not near any roads and are known only to prospectors. Those most important to travelers are Mexican Well, Roseberry Spring, Wheatstone Spring, Kessler Spring, Cut Spring, and White Rock Spring, in the Ivanpah Mountains; Slaughterhouse Spring, in the New York Mountains; and Crescent Wells, at the south end of the McCullough Range. (See pl. 12.) All of these are believed to be reliable watering places.

LAS VEGAS AND SUTOR VALLEYS

In the extreme northeast corner of the region covered on Plate 7 a small area is shown as being in Las Vegas Valley, and a small basin, to which the name Sutor Valley may be given, lies between it and Roach Valley. The writer did not see either of these valleys and therefore no information is given here in regard to them. The water resources of Las Vegas Valley have been described by Carpenter.[2]

LUCERNE VALLEY

GENERAL FEATURES

Lucerne Valley lies in the southwestern part of San Bernardino County, about 20 miles east of Victorville. The name has been given to the valley in recent years because of its supposed suitability for growing alfalfa, for which the European name is lucerne.

The nearest railroad town is Victorville, about 20 miles distant, which is reached by a good desert road. Just before it enters the valley the road forks. The left branch leads to Lucerne Valley post office and ranches in the central part of the valley. The right branch leads a little farther south to the Box S ranch. At this ranch the main road leads southeastward to Baldwin Lake and Bear Valley by way of the Cushenbury ranch and Cactus Flat. This road is used by many travelers in going to resorts along Bear Lake. On this road water can be obtained at a number of ranches. From the Box S ranch a road continues eastward to Old Woman Springs and points farther east. In the days of wagon transportation this was a much traveled route to prospects in the eastern part of the long trough that reaches eastward to Dale. However, east of Lucerne Valley there are several sandy stretches, which in 1918 were impassable for automobiles a few miles beyond Old Woman Springs.[2a] (See p. 625.)

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[2] Carpenter, Everett, Ground water in southeastern Nevada: U. S. Geol. Survey Water-Supply Paper 365, 1915.

[2a] In 1928 Allen S. Baker, of Lucerne Valley, reported that this road was passable.

Lucerne Valley may be reached from Barstow and Daggett by following the road that leads to Victorville by way of Stoddard Well and by turning southeast from that road 2 miles south of the well. This road is used by persons who are going from the northern part of the county to Bear Valley. The distance from Barstow to the Box S ranch is about 41 miles and from Daggett about 2 miles farther. The valley also probably can be reached from Daggett by a road that leads southward across Ord Mountain. The writer traveled this road only as far as Sweetwater Spring. The route beyond that spring, as shown on Plate 11, was taken from township plats of the General Land Office. It is reported that there is another road east of Ord Mountain. No definite information could be obtained in regard to either of these roads, and possibly they are no longer passable. In addition to the principal roads mentioned numerous roads lead to ranches and to mine prospects in the mountains that border the valley.

In 1928 there were two stores in the valley. Mail is received at Lucerne Valley post office. The principal activity in the valley is agriculture. Although there are a number of mine prospects in the bordering mountains, in recent years there has been no active mining.

No climatic records are available for the valley. At the Bear Valley Dam, in the San Bernardino Mountains just beyond the southern border of the valley, the average annual precipitation is about 35 inches. However, the precipitation is less and less at points progressively northward from the summit of the mountains and at lower altitudes. A comparison of the topographic conditions in Lucerne Valley with those in the upper Mohave and Antelope Valleys where records are available indicates that the annual rainfall in the irrigable part of Lucerne Valley is probably not more than 6 or 7 inches, and it may be less. Much of the winter precipitation in the San Bernardino Mountains falls in the form of snow.

The temperature in the lower part of the valley is probably comparable with that at such places as Victorville and Palmdale. Doubtless in summer such high extremes are not reached as those that occur in some of the desert valleys at lower altitudes. Because of the great altitude on the slopes of the bordering San Bernardino Mountains the temperature reaches rather low marks in winter.

The vegetation is dominantly the creosote bush and the species commonly associated with it. A few small yuccas are scattered on the higher slopes. The sides of the San Bernardino Mountains are covered with large pine trees, but there are no trees on the other mountains. At the Cushenbury ranch there are about 20 large poplars, some of them 2½ feet in diameter. Salt grass covers an area of several acres at Rabbit Springs and at Box S Springs, but elsewhere in the lower part of the valley salt grass or other vegetation that draws moisture from the ground water is generally absent. In the lowest part of the valley the water table is apparently below the depth to which these plants reach.

The soils of the southern half of Lucerne Valley have been described in a reconnaissance report of the United States Bureau of Soils.[3] The soil of the alluvial slopes is an arkose similar to that in most of the desert region. On the upper part of the slopes that descend from the San Bernardino Mountains large boulders are more abundant than in most of the other valleys of the region. The soil in the lowest part of the valley is finer and clayey. This area of clayey soil extends for some distance away from the playa in the bottom of the valley. There is some alkali in the soil around the playa, but it is not sufficiently abundant to appear on the surface.

PHYSICAL FEATURES AND GEOLOGY

Lucerne Valley is part of a great trough that extends in a southeasterly direction from the west end of this valley to the east end of Dale Valley, a distance of about 75 miles. (See p. 120 and pls. 11 and 12.) This trough is separated into several valleys by low rock hills and alluvial divides. The southern border of the valley is formed by the San Bernardino Mountains, which, in the part tributary to Lucerne Valley, reach an altitude of 8,300 feet. The northern border of the valley is formed by Ord Mountain, which reaches an altitude of about 5,000 feet, and a lower ridge that extends westward from it for about 10 miles. Practically continuous with this ridge rise the Granite Mountains, which extend southward for about 15 miles and form most of the western border of the valley. The south end of these mountains is separated from the San Bernardino Mountains by an alluvium-filled valley from 2 to 5 miles wide that connects Lucerne Valley with the Upper Mohave Valley. An alluvial fan built out from the San Bernardino Mountains to the southeast end of the Granite Mountains has formed a low divide that separates Lucerne Valley from Fifteenmile Valley on the west. The eastern border of the valley is formed by a number of rock hills separated by areas of alluvium. Although at several places the divide is formed of alluvium the rock hills extend along so much of the border that bedrock doubtless lies at no great depth beneath the alluvium-covered portions of the divide.

The geology of the southern half of Lucerne Valley has been mapped in considerable detail by Vaughan.[4] The west end of the area that is tributary to the valley is underlain by granitic rocks of undeter-

[3] Dunn, J. E., and others, Reconnaissance soil survey of the central southern California area: U. S. Dept. Agr., Bur. Soils Field Operations, 1917, advance sheets (with map), 1921.

[4] Vaughan, F. E., Geology of the San Bernardino Mountains north of San Gorgonio Pass: California Univ. Dept. Geology Bull., vol. 13, No. 9, pp. 319–411, 1922.

mined age. Farther east occur sedimentary rocks of Paleozoic age cut by a granite (to which Vaughan has applied the name Cactus granite), regarded as probably of late Jurassic age, on the assumption that it is of the same age as granites in the Sierra Nevada, which he believes to be Jurassic. The sedimentary rocks include mostly limestone of Upper Cambrian and Ordovician age, but there is one large area of Silurian or Devonian quartzite. No fossils were found in any of these rocks, and the age determinations are based on lithologic resemblances to rocks in other regions and their relation to the intrusive rocks. In the mountains and on their northern slope Vaughan has distinguished alluvial deposits (fanglomerate and other types) of two ages in addition to the recent deposits.

The Granite Mountains, Ord Mountain, and hills on the east side of the valley have not been studied in detail. At several places where they were observed close at hand by the writer, they are composed of granitic rocks, and parts seen from a distance appear to consist largely of these rocks. Patches of limestone or other rocks are reported to occur in several places.

The recent alluvium that fills a large part of the valley consists of alternating layers of gravel, sand, and clay. According to well logs, gravel and boulders seem to be more abundant in this valley than in many of the other desert valleys, notably the lower part of Antelope Valley and a large part of the Mohave Valley. This abundance of gravel is doubtless due to the proximity of the high San Bernardino Mountains, which have a great precipitation and thus offer good opportunity for coarse material to be washed into the valley. The character of the alluvium is shown by the log of the well of Thomas F. Porter,[4a] given on page 614. This well is the deepest well in the valley for which data were obtained. In this well granite, believed to be bedrock and not merely a boulder, was struck at a depth of 776 feet. Although a total of 167 feet of gravel was penetrated, nearly all of the first 200 feet and the last 100 feet was clay or clay and sand. The logs of several other wells in the lower part of the valley show that the alluvium to depths of 100 feet or more is composed principally of clay.

The lowest part of the valley is occupied by a playa known as Lucerne Dry Lake. It was not visited by the writer, and the true relations between the playa deposits and ground-water conditions were not ascertained. The water table in several wells is within at least 10 or 15 feet of the surface. Alkali was not noticeable from a distance of a few miles in December, 1917, and February, 1918, but a soil map of the area shows that the area occupied by the playa con-

[4a] In 1928 reported to be owned by Julian S. Gobar.

5631—29——40

tains some alkali.[5] There is no salt grass or mesquite around the borders of the playa. Apparently the playa is one of the dry type, but near the border line between the dry and wet types, with the water table just far enough below the surface to prevent the formation of the features that characterize playas of the wet type. The outline of the playa as shown in Plate 11 was taken from a recent township plat of the United States General Land Office, and it is much larger than that shown on the San Gorgonio topographic map. The outline on the township plat agrees approximately with the area in which alkali exists, as shown on the soil map of the area. However, the fact that a number of wells have been drilled on the playa suggests that true playa conditions do not exist in the entire area outlined.

Log of well of Thomas F. Porter (No. 6, fig. 17), in SE. ¼ NE. ¼ sec. 2, T. 4 N., R. 1 W. San Bernardino meridian

[Furnished to G. A. Waring by Julian S. Gobar]

	Thickness (feet)	Depth (feet)
White clay	65	65
White clay with hard cement layers	22	87
White clay with gravel	12	99
Hard clay	21	120
Hard clay and packed sand	12	132
Cemented sand	17	149
Hard clay	8	157
Brown sticky clay with a little gravel	73	230
Clay	22	252
Gravel, sand, and clay	26	278
Sand and clay	16	294
Gravel	8	302
Sand and clay	16	318
Gravel (stones 3 inches in diameter at 344 feet)	60	378
Sand and gravel	54	432
Gravel and boulders	19	451
Clay	4	455
Gravel	12	467
Clay	5	472
Gravel	23	495
Cement	11	506
Cemented clay, gravel, and sand	46	552
Gravel	5	557
Clay	16	573
Gravel and boulders	17	590
Cement	10	600
Hard clay	12	612
Boulders	4	616
Gravel in clay	11	627
Clay	13	640
Gravel	8	648
Clay	3	651
Sand and gravel	11	662
Clay	10	672
Sand and clay	13	685
Clay	20	705
Sand	7	712
Clay	15	727
Red hard clay	43	770
Cemented sand	6	776
Granite, probably bedrock	1¾	777¾

About 9 miles east of Box S Springs, near the eastern border of the valley, lies a small unnamed playa. The surface drainage from this

[5] Dunn, J. E., and others, Reconnaissance soil survey of the central southern California area: U. S. Dept. Agr. Bur. Soils Field Operations, 1917, California advance sheets, 1921.

playa is prevented from reaching Lucerne Dry Lake by a low divide formed by an alluvial deposit that has been built out from the San Bernardino Mountains. Actually the playa occupies a small separate closed basin, but as the water table beneath it is undoubtedly continuous with that in Lucerne Valley proper the area is considered a part of the large valley.

GROUND WATER

No perennial streams are known to exist in any of the mountains that border Lucerne Valley. In several short canyons on the north slope of the San Bernardino Mountains streams probably persist for several days after heavy rains. In the other mountains the run-off persists for only a few hours at the most, after heavy rains.

There are several springs in the valley, and 40 to 50 wells have been drilled. Data in regard to the wells are given in the table on page 619 and their location is shown on Figure 17. Most of the data on the wells were collected by G. A. Waring, of the United States Geological Survey, in the fall of 1916. The writer obtained information in regard to a few additional wells in December, 1917.

WELLS

Most of the wells for which definite data were obtained are more than 100 feet deep, and many of them are from 200 to 500 feet deep. One well is 531 feet deep and one is 778 feet deep. The few logs obtained indicate that it is necessary to drill to a depth of more than 100 feet and in some places more than 200 feet in order to strike water-bearing gravel. This condition is shown by the well of Thomas F. Porter, the log of which is given on page 614. In other wells the first gravel encountered does not lie at so great a depth.

The depth at which water is struck ranges from 7 feet to more than 200 feet in the wells for which data were obtained. In general the depth to water is least in wells near Lucerne Dry Lake and is increasingly greater in wells farther and farther from the playa. The depth to water differs approximately as the altitude of the different wells above the playa. This relation is not everywhere maintained, however, for in wells near the Box S ranch certain local conditions cause the water to stand higher than in wells on lower land between the ranch and the playa. These conditions are discussed below.

The depth to water beneath the playa is about 10 feet, as shown by well 12. Over a considerable area, including approximately the southeast quarter of T. 5 N., R. 1 W., and secs. 19, 20, 29, 30, and 31, T. 5 N., R. 1 E., the depth is not more than 25 or 30 feet. In this area the land slopes rather gently. Beyond it the land rises more rapidly toward the mountains and the depth to water increases more

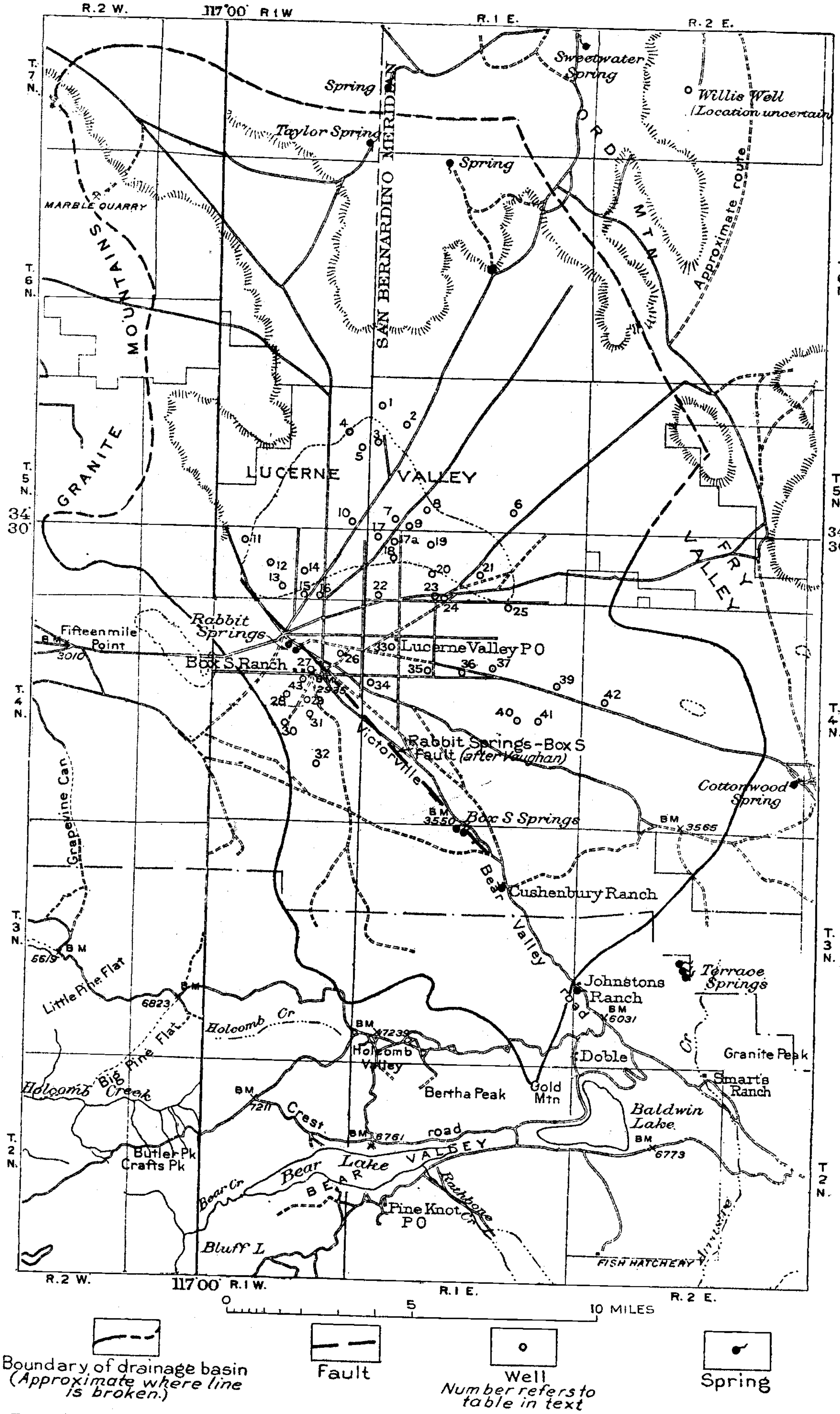

FIGURE 17.—Map of Lucerne Valley, Calif., showing boundary of drainage basin and location of wells

in short distances. Thus in well 33, in the NE. ¼ sec. 7, T. 4 N., R. 1 E., the depth to water is 50 feet, and in well 34, a little more than a mile southwest of No. 33, it is 104 feet. As nearly as can be determined by estimating the altitude of the surface from the topographic map the water table rises from the playa with a very low grade, probably not more than 10 feet to the mile. The difference in the depth to water is therefore due largely to the rise of the alluvial slopes toward the mountains. The alluvial slopes at the base of the San Bernardino Mountains rise more steeply than those on the north side of the valley, and accordingly the increase in the depth to water away from the playa is doubtless somewhat greater on the south side of the valley. The maximum depth reported on the north side of the valley is 72 feet in well 1. This well is about 5 miles northeast of well 10, in which the depth to water is less than in any other well on or near the playa. In well 32, about an equal distance south of well 12, the depth to water is 215 feet.

In the vicinity of the Box S ranch the water table stands abnormally high as compared to the condition farther east and north. At the ranch there are several flowing wells, and in well 28, about a mile farther southwest, the depth to water is only 7 feet. In wells 29 and 31, south of the Box S ranch, the depth to water is 30 and 60 feet, respectively. In contrast to these wells the depth to water in well 26, about half a mile north of the Box S ranch, is 70 feet and in well 34, a little more than a mile east of the ranch, it is 104 feet. Obviously there is some underground condition that holds the water near the surface in the neighborhood of the Box S ranch.

The zone in which the water table is close to the surface has been shown by wells to lie southwest of a line that passes eastward from Rabbit Springs to the Box S ranch. Residents of the valley have advanced the theory that a buried rock ridge cuts across the valley in this direction and holds back of it the ground water that was moving beneath the alluvial slope from the San Bernardino Mountains. An elongated hill between the Box S ranch and Box S Spring tends to confirm this theory. However, so far as the writer is aware, bedrock has not been struck in any wells near the Box S ranch. It does not seem that a rock barrier could hold back the water unless it reached close enough to the surface either to crop out or to be struck in shallow wells.

Vaughan [6] on his geologic map of the region shows a fault that extends from Box S Spring northwestward through Box S ranch and Rabbit Spring. The fault has affected the Quaternary alluvium. The position of this fault is shown in Figure 17. At several places

[6] Vaughan, F. E., Geology of San Bernardino Mountains north of San Gorgonio Pass: California Univ. Dept. Geology Bull., vol. 13, No. 9, p. 397 and geologic map, 1922.

along this line, notably at Rabbit Spring and Box S Spring, there is a slight rise on the southwest side of this line. According to Vaughan's statement, the actual fault is nowhere to be seen, but the topography and the location of the springs mentioned and the flowing wells at the Box S ranch afford evidence in favor of a fault. A fault that has a downthrow on the northeast might very easily bring the clay beds in the lower part of the valley against water-bearing beds on the upper side and form so effective a dam that the water would stand higher on the southwest or upthrown side. All the conditions are more indicative of a fault than of a buried rock barrier.

The artesian conditions that result from this fault are apparently confined to a small zone at the Box S ranch. At this ranch flowing water has been obtained in several wells at depths of 130 to 140 feet. Water under no appreciable pressure was struck at 20 feet and 80 feet. In a well 533 feet deep no greatly increased supply was obtained below the main artesian bed at about 140 feet. The flowing water was encountered in a "honeycomb cement," which is probably a slightly cemented sand.

There seems to be no prospect of obtaining artesian flows from wells in the other parts of the valley, except perhaps in a narrow zone on the southwest side of the fault between the Box S ranch and the southeast end of the Granite Mountains. In this area the surface altitude is about the same as at the Box S ranch or lower. On the upthrown side of the fault, between the Box S ranch and Box S Spring, the surface is so much higher than at the ranch that the depth to water stands some distance below the surface. Enough deep wells have been drilled in different parts of the area northeast of the fault—that is, in the greater part of the valley—to prove that artesian flows will not be obtained there.

Definite information was obtained in regard to the yield of only two wells. One of these wells produced about 450 gallons a minute, and the other between 180 and 270 gallons a minute.[6a] It is probable that properly constructed wells will yield at least 250 to 450 gallons a minute. A study of well logs shows that in order to obtain such yields it is advisable to drill wells to a depth of at least 200 or 300 feet in order to penetrate good water-bearing beds.

[6a] In November, 1928, while this report was in press, information was received that there were in the valley 11 wells with yields said to range from 360 to 1,150 gallons a minute, all but two of them more than 800 gallons a minute. These wells are all in the lower part of the valley, within 2 or 3 miles of Lucerne Dry Lake.

Records of wells in Lucerne Valley, Calif.

No. on fig. 17	Location				Name of owner or entryman	Depth of well (feet)	Depth to water (feet)	Remarks
	Quarter	Sec.	T. N.	R.				
1	SW	6	4	1 W	W. R. Collom	150	72	
2	NE	7	5	1 E			45	
3	SW	7	5	1 E	A. R. Scott	100	30	
4	NW	12	5	1 W	F. Taylor	150	42	
5	SE	12	5	1 W	L. E. Hookes	75	31	Yields 180 to 270 gallons a minute.
[a]6	NE	2	4	1 W	Thomas F. Porter	778	20	See p. 614 for log.
7	SE	19	5	1 E	W. F. Lee		17	Dug.
8		20	5	1 E	P. W. Petheram	282	25	See p. 623 for analysis.
9		20	5	1 E	F. H. Fewell		17	Dug. See p. 623 for analysis.
10		24	5	1 W	B. Pocker	300	36	Reported to yield 1,485 gallons a minute.
11		28	5	1 W	Carrie E. Gribben	185	20	
12	SW	27	5	1 W			10	
13		34	5	1 W	V. A. Porter		16	
14		35	5	1 W			14	
15		35	5	1 W	Georgia R. Hodges	[b]220+	16	
16		35	5	1 W			25	
17	NW	30	5	1 E	W. A. White		20	
17a	NE	30	5	1 E	F. H. Lee		17	Dug.
18	SE	30	5	1 E	H. J. Clubb	262	34	
19		29	5	1 E	H. W. Priester		30	
20	NE?	32	5	1 E			25	
21	NW	34	5	1 E		242	42	Yields 450 gallons a minute.
22	SW	31	5	1 E	J. M. Ross		24	Dug.
23	SE	32	5	1 E	J. Holmes	457	42	
24	SW	33	5	1 E	J. A. Wilferth		60	
25		3	4	1 E	—— Keyes	531	70	
26	NW	12	4	1 W	J. S. Miller	491	70	
27	SE	11	4	1 W	J. E. Goulding	300+	Flows.	See p. 617 for data in regard to several wells at this place, and p. 623 for analysis.
28	NE	15	4	1 W	C. A. Thatcher	205	7	See p. 617 for additional information.
29		14	4	1 W	J. O. Morris		30	
30		22	4	1 W	August Oberlin	(?)	100	
31	SW	14	4	1 W	Alexander Lynd		60	
32		26	4	1 W	P. P. Painter		215	
33	NE	7	4	1 E	John Koehly		50	See p. 623 for analysis.
34	NW	18	4	1 E	A. C. Stevens		104	
35	SE	8	4	1 E		[c]117	[c]109.8	
36			4	1 E	C. Johnson		110	
37	SE	10	4	1 E	C. H. Von Breton	([b])	136	
39		13	4	1 E	P. E. Weigle		120	
40		14	4	1 E	Mary J. Miller		150	
41		14	4	1 E	Eliza A. Puterbaugh		175	
42		18	4	2 E	Enoch Hayes		180	
43	NW	14	4	1 W	W. M. Mulholland	250	(?)	Considerable blue clay struck below a depth of 30 feet.

[a] The location of well 6, in 1928 owned by Julian S. Gobar, was erroneously given to the writer as in the NE. ¼ SE. ¼ sec. 22, T. 5 N., R. 1 E., and it is incorrectly shown in that location on Figure 17.
[b] Drilling not completed when data were obtained.
[c] Measured by D. G. Thompson Dec. 6, 1917.

POSSIBLE MOVEMENT OF GROUND WATER BETWEEN ADJACENT VALLEYS

Part of the divide at both the east and west ends of Lucerne Valley is underlain by alluvium, and the question arises whether there is movement of ground water into or out of the valley at these places. In the eastern part of Old Woman Springs Valley or Johnson Valley, which lies east of Lucerne Valley, the altitude of the water table is between 2,750 and 2,775 feet, as determined from the topographic map. (See p. 628.) In the lowest part of Lucerne Valley the altitude of the water table is about 2,840 feet. Although apparently it is a little higher there than in Old Woman Springs Valley, the gradient is not great. There may be some movement from the western valley. However, the divide between the valleys at several places is formed by rock hills, and it appears probable that these may form a continuous buried barrier above the water table, even where the surface is covered with alluvium.

In Fifteenmile Valley, which adjoins Lucerne Valley on the west, as nearly as can be determined from the topographic map, the altitude of the water table is about 2,890 feet. At the Box S ranch it may be a few feet higher, possibly as much as 2,910 feet. In the absence of accurate leveling to determine the altitude of the wells the difference is so little that it is impossible to assert that there is movement in one direction or the other. Even if there is movement from the vicinity of the Box S ranch westward to Fifteenmile Valley this movement affects only the zone southwest of the Rabbit Springs-Box S fault, for the water table northeast of the fault lies at an altitude of about 2,850 feet—that is, considerably lower than in Fifteenmile Valley.

SPRINGS

Cushenbury Springs.—The largest springs in Lucerne Valley are Cushenbury Springs, in the NE. ¼ sec. 10, T. 3 N., R. 1 E. Several springs rise in a small ciénaga or swampy area on the upper part of the alluvial slope, near the base of the San Bernardino Mountains. There are one or two distinct streams, but much of the water seeps out over an area of about 3 acres. The total minimum flow is estimated to be about 200 to 300 gallons a minute. In the winter and spring this is increased somewhat. The water comes from gravel, and it is said that there is no bedrock near the surface. The exact cause of the seepage over a considerable area, so high on the alluvial slope, is not clear. The springs are situated almost in line with Box S Spring, the Box S ranch, and Rabbit Springs, and the explanation is immediately suggested that the fault which causes shallow water at those places also produces Cushenbury Springs. However, Vaughan does not continue the fault line as far southeast as Cushenbury Springs, and the surface features at the springs do not give evidence of faulting. There is some evidence of a fault along an east-west line on the alluvial slope, although not very near the springs. Possibly this fault has in some way produced conditions that cause the springs, or perhaps bedrock is nearer to the surface than is believed.

Analysis 9 (p. 623) shows the water from the springs to be moderately mineralized, containing 400 parts per million of total dissolved solids. The predominant mineral matter is calcium bicarbonate. The water is similar in composition to that from well 33, and except for concentration is like that from well 27. (See analyses 6 and 3, p. 623.) It is good for both domestic use and irrigation. The temperature of water from one of the main springs was 66.5° F. when measured on December 8, 1917.

The Cushenbury ranch is a favorite stopping place for travelers between Victorville and Bear Valley. The ranch house is surrounded by about 20 large poplar trees, some of them 2½ feet in diameter, whose shade is very inviting after the 30-mile drive across the desert from Victorville. About 30 to 40 acres of pasture and a few acres of fruit trees are irrigated from the springs.

Box S Springs.—The Box S Springs are in sec. 4, T. 3 N., R. 1 E., about a hundred feet south of the Victorville-Bear Valley road. They issue from the side of a steep northeastward-facing slope 25 feet or more high that rises to a gentler terrace-like slope. The main spring is at the base of the slope, and most of the water seeps from the roof and sides of a short tunnel, but some water seeps out within a few feet of the top of the slope. No bedrock is visible either in the tunnel or on the side slope. The terrace is composed of a powdery soil that is evidently in part a deposit formed by the evaporation of the spring water. White alkali covers part of the terrace, and salt grass is abundant on it. Although no bedrock is exposed at the springs, granite occurs a short distance to the northwest. The scarp at the springs continues northwestward for 2 or 3 miles. This scarp undoubtedly marks a fault that continues northwestward through the Box S ranch and Rabbit Springs, where water stands close to the surface. There is little doubt that the Box S Springs are also the result of the faulting, perhaps merely through the exposure of a water-bearing bed. However, as the springs are located rather far up on the alluvial slope, where the water table normally would be expected to lie far below the surface, it seems likely that the faulting must have produced a damming effect to raise the water to the surface. This effect may be due either to the formation of an impervious gouge along the fault or to the displacement of the water-bearing beds.

The water from the main spring is piped to a trough by the roadside for the use of travelers. Analysis 8 (p. 623) shows that the water, except for its hardness, is good for domestic use. It is also good for irrigation. The water is in general similar to that from Cushenbury Springs and wells 27 and 33, except that it is a little more highly mineralized. The temperature of the water on a cold December afternoon was 55° F.

Rabbit Springs.—Rabbit Springs are in the northeast corner of sec. 10 and the northwest corner of sec. 11, T. 4 N., R. 1 W. The water issues as seepages near the top of a low terrace that is about 5 feet above the nearly level land to the east. The terrace rises gradually westward to the southeast end of the Granite Mountains. The short, steep slope at the eastern edge of the terrace continues in a southeasterly direction toward the Box S ranch for about a quarter of a mile, but on the northwest it continues only a few hundred feet. The soil of the terrace is rather silty but contains small pebbles. Some of this soil has probably resulted from the deposition of calcium carbonate and other salts on the evaporation of the spring water. Crusts of both white and black alkali are present around the spring. Salt grass covers an area of several acres on the terrace, showing that the water table lies within a few feet of the surface. East of the base of the steep slope, however, there is no salt grass, and the records of the nearest wells to the northeast, more than a mile distant, indicate that the depth to water is probably at least between 25 and 50 feet and may be more.

The springs are on a line that passes southeastward through the Box S ranch and Box S Springs, on the upper or southwest side of which the water table is near the surface. It is believed that this line marks a fault. No bedrock crops out at Rabbit Springs, and the only evidence of faulting is the slight escarpment.

Analysis 7 (p. 623) shows that the water is a calcium bicarbonate water of moderate mineral content, suitable for all ordinary uses. For many years Rabbit Springs was a much used watering place on the road from Victorville to Old Woman Springs and mines to the east as far as Dale. However, with the development of ranches in Lucerne Valley and between that valley and Victorville, it is less utilized.

Other springs.—On township plats of the General Land Office two springs are shown in canyons on the south slope of the granite ridge that forms the northern border of Lucerne Valley. One of these springs, called Taylor Spring, is in sec. 36, T. 7 N., R. 1 W., and the other is about 2½ miles farther east, in sec. 4 or 5, T. 7 N., R. 1 W. Taylor Spring is reached by roads that branch from the road between Stoddard Well and Lucerne Valley. The other spring is reached by a branch of a road that leads from Lucerne Valley to Ord Mountain. No information was obtained in regard to either of these springs.

QUALITY OF WATER

The results of the analyses of nine samples of water from wells and springs in Lucerne Valley are given in the table on page 623. The mineral content of all these samples is moderate except two (from wells 8 and 9), which show 5,510 and 2,898 parts per million, respectively. The mineral matter in the two highly mineralized waters consists largely of sodium chloride, but the water from well 9 also contains a considerable proportion of calcium and magnesium. These two waters are bad, if not unfit, for nearly all purposes, although doubtless they could be used in an emergency. The water from wells 27 and 33 is good for domestic use and irrigation, but only fair for boiler use because it contains a considerable quantity of scale-forming constituents.

The two wells in which the water is so highly mineralized lie within the area of alkali soil in the lowest part of the valley. The higher mineral content is thus doubtless due to the evaporation of rain water that collected in the basin or to ground water that is carried to the surface by capillary action. Well 9 is only 20 feet deep, but the depth of the other well is not known. It is uncertain whether water from deep wells would be of better quality. Water of bad quality has been struck in other wells near the two mentioned, but in most of the valley water of good or fair quality may be obtained.

Analyses of ground waters from Lucerne Valley, Calif.

[Parts per million]

	1	2	3	4	5
Silica (SiO_2)	43	24	32	36	30
Iron (Fe)	.10	.30	Trace.	.34	Trace.
Calcium (Ca)	267	241	41	65	48
Magnesium (Mg)	31	113	19	41	24
Sodium and potassium (Na+K) (calculated)	1,663	545	24	57	42
Bicarbonate radicle (HCO_3)	139	105	222	288	210
Sulphate radicle (SO_4)	862	396	34	153	104
Chloride radicle (Cl)	2,405	1,236	6.9	33	20
Nitrate radicle (NO_3)	0	10	5.0		Trace.
Total dissolved solids	5,510	2,898	269	537	367
Total hardness as $CaCO_3$ (calculated)	795	1,070	180	331	218
Date of collection	(a)	(b)	(c)	(d)	(e)

	6	7	8	9
Silica (SiO_2)	27	30	60	32
Iron (Fe)	.33	.25	.10	.08
Calcium (Ca)	36	20	76	56
Magnesium (Mg)	24	22	35	17
Sodium and potassium (Na+K) (calculated)	33	55	72	47
Bicarbonate radicle (HCO_3)	222	222	289	176
Sulphate radicle (SO_4)	40	44	198	135
Chloride radicle (Cl)	7.4	6.5	33	19
Nitrate radicle (NO_3)			Trace.	1.2
Total dissolved solids	250	262	624	400
Total hardness as $CaCO_3$ (calculated)	188	140	334	210
Date of collection	(f)	(g)	(h)	(i)

[a] Aug. 14, 1916. [b] Aug. 14, 1916. [c] Aug. 12, 1916. [d] Jan 12, 1909. [e] Aug. 12, 1916.
[f] Jan. 13, 1909. [g] Jan. 12, 1909. [h] Dec. 8, 1917. [i] Dec. 7, 1917.

Analysts: 1, 2, 3, 5, S. C. Dinsmore; 4, 6, 7, Walton Van Winkle; 8, 9, Addie T. Geiger, U. S. Geological Survey.

1. Well 8, fig. 17 and table on p. 619; P. W. Petheram, owner.
2. Well 9, fig. 17 and table on p. 619; F. H. Fewell, owner.
3. Well 27, fig. 17 and table on p. 619; at Box S ranch, J. E. Goulding, owner.
4. Shallow well 24 feet deep near No. 27; J. E. Goulding, owner.
5. Well 33, fig. 17 and table on p. 619; John Koehly, owner.
6. Well 43, fig. 17 and table on p. 619; W. M. Mulholland; owner.
7. Rabbit Springs, secs. 10 and 11, T. 4 N., R. 1 W. San Bernardino meridian. See p. 621 for description.
8. Box S Springs, sec. 4, T. 3 N., R. 1 E. See p. 621 for description.
9. Cushenbury Springs, sec. 15, T. 3 N., R. 1 E.; John McFee, owner. See p. 620 for description.

With the exception of the water from wells 8 and 9, all the samples analyzed are good or fair for domestic use and irrigation, although the samples from the Goulding shallow well and Cushenbury Springs may be hard for washing. They are also fair for boiler use, but the two samples just mentioned might give some trouble because of the quantity of scale-forming constituents present. The rather uniform predominance of calcium and magnesium carbonate in all the samples except those from wells 8 and 9 may be attributed to the fact that a considerable part of the San Bernardino Mountains nearest these wells and springs is composed of limestone.

There is a remarkable similarity between the waters from Rabbit Springs, the Goulding deep well (No. 27), and the Mulholland well (No. 43). The water in these two wells and the spring doubtless comes from the same source. The water from a shallow well at the Goulding ranch is more mineralized than that from the deep well, doubtless because a small quantity of salts left by the evaporation of water near the surface has later been carried downward by percolating water.

FRY VALLEY

Fry Valley lies in the southwestern part of San Bernardino County, between Lucerne Valley and Johnson or Old Woman Springs Valley. (See pl. 7.) The name is derived from Fry Mountain, which forms part of its eastern border. The valley is small and of little prospective use. The following brief description is inserted only to point out certain physiographic features which illustrate the development of closed basins in the desert.

The valley is a part of the great trough that extends from Lucerne Valley eastward to Dale Valley. Its extent parallel to the trough is very short, but at right angles to the trough it is much longer. It is really a short section of the trough that at one time was a part of Johnson Valley, but it has been cut off from that valley by an alluvial fan built out from the San Bernardino Mountains. A large part of the valley consists of an alluvial slope on the north side of the trough bordered by low rock hills. The part of the valley that forms the south side of the trough is mostly part of the north slope of the San Bernardino Mountains and consists of a long, narrow area that is tributary to one or two minor streams in the mountains. The drainage area may actually be larger than that shown on Plate 7, including the area tributary to Arrastre Creek, for distributary channels on the fan built by this creek appear to discharge some drainage into Fry Valley. The main channels, however, appear to discharge into Johnson Valley.

The lowest part of the valley is occupied by two playas—one which covers about half a square mile and west of it a smaller one which covers only a few acres. The western one probably lies at a little higher altitude than the other. Water that reaches the larger, eastern playa is prevented from moving eastward into Johnson Valley by a low divide formed by alluvium washed out from the San Bernardino Mountains. The divide between the two playas has probably been formed in the same way. The divide is not very high, and it has apparently been only a relatively short time geologically since the drainage of Fry Valley reached Johnson Valley.

No information is available in regard to ground water in the valley. There is no indication of any rock barrier between the valley and Johnson Valley, and the water table is probably continuous between the two. In Johnson Valley, in the eastern part of T. 4 N., R. 3 E., the water table is estimated to be between 2,750 and 2,775 feet above sea level, and doubtless it rises slightly toward Fry Valley. The altitude of the large playa in Fry Valley is 2,874 feet. The depth to water in the lowest part of the basin may be as much as 50 or 75 feet unless the grade of the water in this valley is greater than in most of the desert valleys of the region. The playas in the valley were not seen, and therefore any evidence that they might furnish as to whether the water table is within 8 or 10 feet of the surface is lacking. Away from the playas the land surface rises so steeply that on most of the alluvial slope the depth to water is likely to be 100 feet or more. If ground water is available for irrigation in the valley the area in which it can be used is not large.

JOHNSON VALLEY

GENERAL FEATURES

Johnson Valley, sometimes called Old Woman Springs Valley, is somewhat west of the south-central part of San Bernardino County. (See pl. 7.) The name of the valley used in this report is that given on the soil survey map of the region.[7] The nearest railroad town is Victorville, about 35 miles west of the valley. It is reached by a road that leads westward and joins the Victorville-Bear Valley road at the Box S ranch. (See pl. 11.) This road as a whole is good, but at the western border of Johnson Valley a short stretch of it is sandy. At the western border of the valley the main road branches, and one road leads southeastward past Old Woman Springs and Rock Corral around the base of the San Bernardino Mountains to Pipe Wash and the Banning-Dale road at Warrens Well. In 1918 the road beyond Rock Corral was reported to be in bad condition for automobiles, but it was traveled by wagons. Another branch of the main road leads directly eastward across the valley to several ranches. At the eastern border of the valley it crosses low hills into Means Valley and continues in a southeasterly direction. This road is reported to be very sandy in the hills and to be practically impassable for automobiles. It is said that the worst sand is encountered on the east side of the hills and that even if an automobile descends into Means Valley it can not ascend the sandy grade on the return journey. An old road goes around the north end of the hills, and possibly Means Valley may be reached by it without difficulty. Little-used roads that cross the valley in a northeasterly direction are said to lead to Daggett by way of Ord Mountain.

[7] Dunn, J. E., and others, Reconnaissance soil survey of the central southern area, California: U. S. Dept. Agr. Bur. Soils Field Operations, 1917, advance sheets, 1921.

No mineral deposits of value are known to occur in the valley. Land has been cleared and wells drilled at several ranches, but in February, 1918, all of them were deserted. A number of cattle are grazed in the valley by a cattle company which has headquarters at Old Woman Springs.

The soil of the valley is largely an arkose similar to that in most of the desert valleys. Along the road that leads due east from the main road from Victorville considerable wind-blown sand was observed, and on the east side of the valley stand low sand dunes. Much sand has been blown from newly cleared land. Around the playa in the eastern part of the valley the soil is more clayey and there is some alkali.

The vegetation of the greater part of the valley, outside of the mountains, is creosote bush and species commonly associated with it. Some mesquite grow around the playa in the eastern part of the valley.

No climatic records are available for the valley. The annual precipitation is probably no greater than that at Victorville and may be even less.

PHYSICAL FEATURES AND GEOLOGY

Johnson Valley is a part of the great trough that extends from Lucerne Valley. The San Bernardino Mountains constitute its southern border, and the northern border is formed by low hills. As nearly as can be determined from township plats of the General Land Office the drainage area does not extend northward to the great ridge that forms the north side of the Lucerne-Dale trough. On the west the valley is separated from Fry Valley in part by low hills but in part by a divide formed by an alluvial fan built out from the San Bernardino Mountains. The eastern border consists in part of low rock hills, but in several places the divide is underlain by alluvium.

According to Vaughan,[8] the hills that border the valley on the west, north, and east, as well as a part of the San Bernardino Mountains tributary to the basin, are composed of granitic rocks of two different ages. In these rocks occur small patches of schist. A large part of the area in the San Bernardino Mountains that is within the drainage basin is underlain by rocks to which Vaughan has given the names Sargossa quartzite, of supposed Silurian or Devonian age; Furnace limestone, of supposed Upper Cambrian and Ordovician age; and Arrastre quartzite, which he believes to be of Lower Cambrian age. A prominent hill at Old Woman Springs from which the springs issue and a small hill 3 miles north of the springs are composed of

[8] Vaughan, F. E., Geology of San Bernardino Mountains north of San Gorgonio Pass: California Univ. Dept. Geology Bull., vol. 13, No. 9, 1922.

basalt, which is probably of early Quaternary age.[9] At the northwest and southeast ends of the basalt area at Old Woman Springs stand low hills composed of alluvium that is older than the recent deposits but younger than the basalt.[10]

Faulting has occurred at several places in the valley. The northeastern border of the basalt area at Old Woman Springs and the areas of older alluvium that adjoin it on the northwest and southeast is marked by a steep slope which appears to be a fault scarp of Quaternary origin. The north base of the San Bernardino Mountains between the southeastern area of older alluvium and Rock Corral is marked by a scarp, and Vaughan believes that the Old Woman Springs fault continues southeastward to a point beyond Rock Corral.[11] He also states that a fault approximately parallel to the Old Woman Springs fault lies along the northeast side of the granite hills in secs. 26, 34, and 35, T. 5 N., R. 3 E., and secs. 20, 21, 27, and 28, T. 4 N., R. 4 E. A third fault, also parallel to the Old Woman Springs fault, marks the southwestern border of Fry Mountain, which forms the northwestern border of Johnson Valley. These faults are also approximately parallel to the Box S-Rabbit Springs fault in Lucerne Valley.

The lowest part of the basin is occupied by a playa. All the information available indicates that it is a playa of the wet type, for the water table is near the surface and mesquite grows 2 or 3 miles southwest of it. The playa lies in an embayment between rock hills which form the eastern border of the valley and which nearly surround it except on the north and northwest. It is on the east side of the basin, farthest from the San Bernardino Mountains, from which the greatest amount of alluvium is washed, because the building of the alluvial slope has pushed the playa eastward.

A small playa or clay flat lies in the SW. ¼ sec. 33, T. 4 N., R. 4 E. This flat is on the alluvial slope, and apparently when it is flooded there is some flow northward from it to the main playa. It is therefore not a true playa.

WATER RESOURCES

GENERAL FEATURES

No perennial streams are known anywhere in the drainage basin of Johnson Valley. After heavy rains streams probably persist for several days in some of the canyons in the San Bernardino Mountains. A number of springs occur in these mountains. Several wells have been drilled at ranches in the alluvium-filled valley northeast of Old Woman Springs. When the writer visited the valley no one was living at these ranches, and no definite information as to logs of the wells, yield, or quality of water could be obtained.

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[9] Vaughan, F. E., op., cit., p. 384. [10] Idem, p. 385. [11] Idem, p. 397.

WATER IN THE ALLUVIUM

Five or six wells have been drilled in secs. 22, 23, and 24, T. 4 N., R. 3 E., and sec. 19, T. 4 N., R. 4 E. On February 22, 1918, the depth to water in a well near the southwest corner of sec. 24, T. 4 N., R. 3 E., measured 50.7 feet below the top of the casing, 3 feet above the surface. This well is reported to be 250 feet deep. On the same day the depth to water in a cattle well that is probably in the NE. ¼ sec. 19, T. 4 N., R. 4 E., measured 40.8 feet. This well apparently was only 41 feet deep, but there may have been a deeper drilled well inside the dug hole that was measured. In a well in the SE. ¼ sec. 19, T. 4 N., R. 4 E., the depth to water is reported to be 36 feet.

It is reported that in the 250-foot well water was struck at depths of 96 and 198 feet. Apparently this water is under some artesian pressure. The depth to water is greater in the western part of the valley than in the eastern part. No information could be obtained in regard to the materials penetrated or the yield of the wells. A considerable acreage has been cleared around the different wells, but when the writer visited the valley, there was no evidence of successful irrigation. It is not known whether this condition is due to lack of sufficient water supply or to some of the other numerous difficulties that beset homesteaders. However, unless the alluvium in this part of the valley is unusually fine, properly constructed wells should yield enough water for irrigation. The area in which irrigation would be feasible is limited by the fact that the depth to water in a large part of the valley is too great for profitable pumping, and on the other hand a considerable area around the playa, where the depth to water is not so great, is probably spoiled by alkali.

It is uncertain whether the quantity of water available for reacharge of the ground-water supply is sufficient to irrigate the total area where conditions are favorable. This problem is affected by the relation of ground-water conditions in Johnson Valley and those in the valleys that adjoin it on the east and west. The San Gorgonio topographic map shows that the altitude of the playa in Means Valley, on the east, is less than 2,600 feet above sea level and fully 100 feet below the playa in Johnson Valley. The altitude of the water table in the well in sec. 19, T. 4 N., R. 4 E., is estimated to be between 2,750 and 2,775 feet, or at least 150 or 175 feet above Means Dry Lake. The divide between the two basins is formed of alluvium at several places, and if the alluvium extends below the water table there undoubtedly would be movement of ground water from Johnson Valley to Means Valley. The difference in the water level between the two valleys is great, in view of the relatively short distance between the wells in sec. 19, T. 4 N., R. 4 E., and Means Dry Lake, and this fact suggests that there may be a complete rock barrier which holds the water at a higher level in Johnson Valley. As shown on page 619, the water table in Lucerne Valley, on the west, is possibly somewhat higher than it is in Johnson Valley, and there may be some underground movement eastward from it. However, more detailed data are necessary before this problem can be solved.

SPRINGS

The location of several springs (Terrace Springs, Two Hole Springs, Viscera Spring, and Mound Spring) in the part of the San Bernardino Mountains tributary to Johnson Valley is shown on Plate 11. These springs are either not near roads or else are reached only by secondary roads that are seldom traveled. None of them were visited by the writer, and no information is available in regard to them.

Three springs (Cottonwood Spring, Old Woman Springs, and a spring at Rock Corral) are situated along the northern border of the San Bernardino Mountains or a short distance north of them.

Cottonwood Spring.—Cottonwood Spring is in the SE. ¼ sec. 25, T. 4 N., R. 2 E., about half a mile southeast of the forks of the road from Victorville, where one branch turns southeast to Old Woman Springs and another goes due east across Johnson Valley. (See pl. 11.) An old ranch house and several trees are near the spring, which is easily found. The water comes from a tunnel that is driven into a hill that rises steeply 15 or 20 feet to the southwest. The water-bearing material is alluvium. The rather steep scarp continues southeastward for several miles and is believed to be due to faulting. (See p. 627.) When the spring was visited, in December, 1917, water was flowing from the tunnel into a small pond at the rate of about 2 gallons a minute. The water has been used to irrigate a small patch of alfalfa, but no one was living at the spring when it was visited.

Analysis 1 (p. 630) shows that the water is a moderately mineralized sulphate water, in which the sodium is equivalent to the calcium and magnesium. It is good for both domestic use and irrigation. The temperature of the water was 61° F.

Old Woman Springs.—Old Woman Springs are in the NW. ¼ sec. 31, T. 4 N., R. 3 E., along the road from Victorville to Rock Corral. A cattle camp which belongs to A. R. Swarthout is situated at the spring, and it is very easily found. The water issues from a tunnel that is driven into the steep side of a long ridge of lava which strikes northwest. The scarp of this ridge is continuous with that at Cottonwood Spring and is doubtless due to faulting.

The water in the tunnel apparently comes entirely from cracks in the lava, which is much broken. When the place was visited in December, 1917, the flow of the springs was about 125 gallons a minute. In wet years the yield is said to increase to as much as 175 gallons a minute. The water is conducted to a reservoir about 40 feet in diameter and 4 feet deep. The water is used to irrigate about 9 acres of alfalfa and to water 30 to 40 head of cattle.

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As shown by analysis 2 (below), the water from the spring is similar to that from Cottonwood Spring, except that it contains a little more magnesium and a little less calcium. It is good for domestic use and irrigation. The temperature of the water when tested in December, 1917, was 73°. The temperature was tested at the mouth of the tunnel, and it is possibly a little higher where the water issues from the rock. The temperature of the water is several degrees above the mean annual temperature and more than 10° above that of the water at Cottonwood Spring. The temperature may be high because the water is of deep-seated origin and rises along a fault line, though this is doubtful, or it may be related to the presence of volcanic rocks in the region.

Old Woman Springs should not be confused with a spring at the northeast end of the Old Woman Mountains, about 75 miles to the east, which is sometimes called Old Woman Spring. That spring, however, now is generally called Sunshine Spring.

Rock Corral.—Rock Corral is the name given to a cattle corral in sec. 21, T. 3 N., R. 4 E. (unsurveyed), near the mouth of a canyon near the east end of the San Bernardino Mountains. Water is piped to a trough in the corral from two springs about half a mile up the canyon. In winter one of these springs is shut off to prevent the freezing of the pipe line, which can not be buried. In December, 1917, with only one spring feeding the pipe line, the flow was only 1 gallon a minute. The spring was not visited, but the water probably comes from granite. As noted on page 627, a fault line is believed to lie near the spring, but it is not known whether the spring is related in any way to this line.

The water is somewhat less mineralized than that from Cottonwood Spring or Old Woman Springs. (See analysis 3, below.) It is good for both domestic use and irrigation. In contrast to the water from the other two springs, it is a calcium carbonate water.

Analyses of waters from springs in Johnson Valley, Calif.

[Parts per million]

	1	2	3
Silica (SiO_2)	33	38	41
Iron (Fe)	.03	.42	.05
Calcium (Ca)	72	52	42
Magnesium (Mg)	1.9	21	23
Sodium and potassium (Na+K) (calculated)	83	94	61
Carbonate radicle (CO_3)	0	0	8.
Bicarbonate radicle (HCO_3)	139	157	187
Sulphate radicle (SO_4)	230	234	95
Chloride radicle (Cl)	9.6	32	46
Nitrate radicle (NO_3)	1.6	2.3	.61
Total dissolved solids at 180° C	546	569	417
Total hardness as $CaCO_3$ (calculated)	188	216	199
Date of collection	(a)	(b)	(c)

[a] Dec. 7, 1917. [b] Dec. 6, 1917. [c] Dec. 6, 1917.

Analysts: 1, Addie T. Geiger and C. H. Kidwell, U. S. Geological Survey; 2, Addie T. Geiger, U. S. Geological Survey; 3, Margaret D. Foster, Addie T. Geiger, and H. B. Riffenburg, U. S. Geological Survey.
1. Cottonwood Spring, SE. ¼ sec. 25, T. 4 N., R. 2 E. San Bernardino meridian. See p. 629 for description.
2. Old Woman Springs, NW. ¼ sec. 31, T. 4 N., R. 3 E. See p. 629 for description.
3. Rock Corral Spring, sec. 21 (unsurveyed), T. 3 N R. 4 E See above for description.

BESSEMER VALLEY

In this report the name Bessemer Valley is given to a valley that is about 15 miles south of Newberry Spring. (See pl. 7.) On the south it adjoins Johnson Valley. The name is taken from the Bessemer mine, in sec. 28, T. 6 N., R. 4 E. San Bernardino meridian. The valley was not visited by the writer, and the information here given was obtained from township plats of the United States General Land Office and statements in publications of the California Bureau of Mines.

According to township plats completed since the relief map (pl. 11) was drawn, the valley is reached by a road that goes south from Daggett to Ord Mountain and thence southeastward. The road leads across the southeastern part of T. 7 N., R. 3 E., and the northeastern part of T. 6 N., R. 3 E. In sec. 14 or 15, T. 6 N., R. 3 E., it branches; the left branch leads southeastward to the Bessemer mine and the right branch leads in a more southerly direction to Means Valley and Johnson Valley.

Bessemer Valley is a part of the great Lucerne-Dale trough (p. 612) and appears to lie mostly north of the axis of the trough. The north border is formed by the range that constitutes the north wall of the trough. The range in this locality appears to form a more or less isolated mountain, which in different reports and maps has been called Iron Mountain and the Bessemer Mountains. Crossman [12] states that the northern part of the range, at least in this vicinity, is covered partly by volcanic rocks, tuff, and sandstone derived from volcanic materials. Farther south the rocks are mostly granitic. At the Bessemer mine and near-by prospects some dolomitic limestone occurs. In these prospects iron ore, both hematite and magnetite, is found in a contact zone between limestone and syenite. Although these deposits have been known for many years, apparently there has been no production from them. Some gold ore has been mined in the valley.

The south border of the valley is formed in part by low hills, but in part, according to the township plats, it is formed by alluvium. Most of the valley slopes in a southerly or southeasterly direction to a playa in the northwestern part of T. 5 N., R. 5 E. The general southward slope probably continues in Ames Valley, but the drainage from Bessemer Valley has been stopped by low alluvial fans built out from the near-by hills.

The only information in regard to ground water is a statement by DeGroot [13] that moderate quantities of water can be obtained at a

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[12] Crossman, J. H., San Bernardino County: California State Mineralogist, Ninth Ann. Rept., pp. 235–236, 1890. Also quoted in Mines and mineral resources of San Bernardino County: California State Mineralogist Rept. for 1915–16, p. 45, 1917.

[13] DeGroot, Henry, San Bernardino County—its mountains, plains, and valleys: California State Mineralogist Tenth Ann. Rept., p. 529, 1890.

depth of 20 to 30 feet around the playa in the lowest part of the valley. DeGroot's statement is made in a description of gold deposits in or near Eagle Mountain, in T. 6 N., R. 4 E. However, the township plat shows no playa in that township, and undoubtedly the one referred to is that in T. 5 N., R. 5 E., mentioned above.

Although water is obtainable at a relatively shallow depth it is not likely that a supply for irrigation is available. The drainage area is not large, and the quantity available for recharge is probably small. Furthermore, the fact that the depth to water is 20 feet or more suggests that there is some leakage from the basin. If the depth to water is as stated, the playa is undoubtedly of the dry type.

MEANS VALLEY

Means Valley is a small valley that lies a little west of the south-central part of San Bernardino County and adjoins Johnson Valley on the west. (See pl. 7.) The name is taken from Means Wells. The valley was not visited, and very little information is available in regard to it.

The valley is reached by a road that leads eastward from Victorville across Johnson Valley, through a low pass in the hills that separate the two valleys. (See pl. 11.) The road is said to be very sandy in these hills and to be almost if not wholly impassable for automobiles. The road is especially difficult for automobiles in ascending the hills from Means to Dry Lake. Another road leads to the valley around the north end of the hills, and it is probable that Means Wells may be more easily reached by this road.

There are no permanent habitations in the valley, but cattle are grazed there part of the year. Several mine prospects are situated in low mountains at the north end of the valley.

The valley lies in the great Lucerne-Dale trough. (See p. 612.) It does not receive any drainage from the range that forms the north border of the trough, and only a very small part of the San Bernardino Mountains is tributary to it. The basin apparently has been formed by alluvial fans, which have been built out from the surrounding hills and mountains and which have cut-off connections with adjoining drainage systems. The lowest part of the basin is occupied by a small playa, commonly called Means Dry Lake.

The Means wells are situated on the border of Means Dry Lake. The depth to water in them is said to be about 15 feet, and water can not be obtained from them without a rope and bucket. In addition to the wells a sloping pit has been dug so that cattle may descend to water. No information is available in regard to the quality of the water.

AMES VALLEY

The name Ames Valley, from Ames Well, is given to a hitherto unnamed valley that lies a little west of the south-central part of San Bernardino County. (See pl. 7.) The valley was not visited, and the only information available relates to two or three wells.

The valley is reached by a road that leads from Victorville by way of the Box S ranch and crosses the north end of Johnson Valley and Means Valley. According to information received since the preparation of the relief map (pl. 11) this road leads across the northern part of T. 4 N., R. 5 E., to a well at the northwest corner of the playa in Ames Valley. Thence a road leads southeastward across the playa to Ames Well. A road also probably leads to the playa from Means Dry Lake, as shown on Plate 11.

The valley is one of several that lie in the great Lucerne-Dale trough. Its northern and southern borders are the Lava Bed and San Bernardino Mountains, respectively. The divides that separate it from the adjoining valleys on the east and west are composed in part of small mountains and in part of alluvium. A playa, which may be called Ames Dry Lake, lies in the northwestern part of T. 4 N., R. 6 E.

In addition to the drainage area shown on Plate 7, Ames Dry Lake may possibly receive the drainage from Pipes Wash, in the San Bernardino Mountains, southwest of the southern border of the valley, as indicated. However, this area probably drains to Surprise Valley, and it is thus shown on Plate 7 and described on pages 636–637.

Three wells are reported to exist in Ames Valley. Blair Well, in sec. 31, T. 5 N., R. 6 E., at the northwest corner of the playa, is said to be about 58 feet deep and the depth to water about 40 feet. The water is highly mineralized and contains nearly 6,000 parts per million of total solids. Another well is situated at an old stamp mill in the SE. ¼ sec. 13, T. 4 N., R. 5 E. This well is marked "location uncertain" on Plate 11 and, according to information received since the map was prepared, is situated about a mile southeast of the position shown. Ames Well is about 2½ miles farther southeast than it is shown on Plate 11. No information is available in regard to these wells except that they are used as watering places for cattle.

SURPRISE VALLEY

GENERAL FEATURES

Surprise Valley is in the south-central part of San Bernardino County, about 15 or 20 miles south of Ludlow. In the eastern part of the valley lies a playa called Mesquite Dry Lake, and the valley is sometimes called Mesquite Valley. However, as that name is used for a valley in the northeastern part of the Mohave Desert region, to prevent confusion the name Surprise Valley is used in this report. On Plate 7 Surprise Valley is shown as including a considerable area drained by Pipes Wash, in the San Bernardino Mountains. It is not certain whether this area is tributary to Surprise Valley or to one of the adjoining valleys, but in the absence of more definite information, it is described in this place.

The valley was not visited by the writer. Pipes Wash was visited by John S. Brown, of the United States Geological Survey, in connection with a survey of desert watering places in the Salton Sea region, and the description of that area and of Surprise Spring has been furnished by him.

The valley is most easily reached by a road that leads from Banning or Palm Springs, on the Southern Pacific Railroad, to Warrens Well, in the southeastern part of T. 1 N., R. 5 E. (See p. 643.) From this ranch a road leads northeastward about 15 or 20 miles to Surprise Spring. Another road from Victorville and Means Wells crosses the valley in an east-southeast direction. This road is believed to pass Surprise Spring and to strike Mesquite Dry Lake in the southern part of T. 3 N., R. 8 E., and thence to lead to Mesquite Spring and Twenty-nine Palms. This road is reported to be sandy in places. It probably can be traveled by automobiles from west to east, as it descends in that direction, but it is very difficult if not impossible for automobiles to go in the opposite direction. This road was formerly a much traveled route between Victorville and Dale Valley, but in recent years it is seldom used.[13a] A road leads along the east base of the San Bernardino Mountains from Warrens Well to Rock Corral and Old Woman Springs in Johnson Valley and thence to Victorville. This road can be traveled by automobiles as far as Pipes Wash, but from that place to a point a few miles east of Rock Corral it is said that the road is passable only for wagons. Pipes Wash may be traveled by automobiles as far as The Pipes. A road continues west and northwest from there to the Rose mine and to roads that lead to Bear Valley, but it is believed to be impassable for automobiles.

So far as is known, the only activity of any note in the Pipes Wash area is the raising of cattle. A number of mineral prospects have been opened up in the mountains east of Mesquite Dry Lake, but they have not been shown to be valuable.

No information is available in regard to precipitation in the valley. On the basis of records in other parts of the region it may be assumed that in the part of the area that lies in the San Bernardino Mountains the precipitation is somewhat higher than in the rest of the valley and may be comparable to that in the vicinity of the Forks of Mohave River. The high Bullion Mountains, on the northeast side

[13a] See footnote 2a, p. 610, in regard to this road.

of the valley, may have some influence in causing the precipitation in the eastern part of the valley to be a little higher than in other basins in the Mohave Desert region at the same altitude.

PHYSICAL FEATURES AND GEOLOGY

Surprise Valley occupies part of the great trough that extends from Lucerne Valley to Dale Valley. Its northeast side is formed by the high Bullion Mountains, which reach an altitude of about 5,000 feet. On the north it is separated from Lavic Valley by much lower mountains. On the west, according to the General Land Office, township plats, it is separated from Ames Valley partly by low, small isolated mountains between which the divide is underlain by alluvium. The extreme southwest corner of the valley is believed to include the drainage area of Pipes Wash, but this area may be in another basin. On the southeast, the valley is separated from Twenty-nine Palms Valley by a low alluvial divide, which continues westward and separates it from Copper Mountain Valley.

Little is known in regard to the rocks of the surrounding mountains. Those of the Bullion Mountains are believed to be granite. A large part of the area tributary to Pipes Wash is underlain by granite. Both north and south of Pipes Wash occur two small areas of basalt which Vaughan[14] believes to be Pliocene. The southern of these areas is underlain by coarse fanglomerate. Several square miles of the area tributary to Pipes Wash is underlain by fanglomerate younger than the basalt but older than the Recent alluvium.[15] These beds are considerably dissected.

Mesquite Dry Lake is at the far east side of the valley as shown on Plate 7. Definite data in regard to the altitude of the playa are lacking, but it is believed to be lower than that of the playas in the valleys farther northwest—that is, there seems to be a gradual decrease in the altitude of the lower parts of the several basins from Lucerne Valley eastward to Surprise Valley. The water table is near the surface beneath both Mesquite Dry Lake and the playa a few miles southeast, in Twenty-nine Palms Valley, and the divide between the basins is composed of alluvium, so that there is free movement of ground water, which favors the belief that the two playas lie at about the same altitude.

GROUND WATER

Data in regard to ground-water conditions in Surprise Valley are meager and relate to three or four watering places.

Surprise Spring.—Surprise Spring, so named because it is situated in the open desert, where one would not expect to find water, is

[14] Vaughan, F. E., Geology of San Bernardino Mountains north of San Gorgonio Pass: California Univ. Dept. Geology Bull., vol. 13, No. 9, pp. 380–382, 1922.

[15] Idem, p. 392.

variously reported by different persons to be about 18 miles northeast of Warrens Well, 16 miles east or southeast of Means Wells, and 6 miles west of Mesquite Dry Lake. Thus it is either in the center or northeastern part of T. 3 N., R. 7 E. It is probably reached most easily by a road that leads northeast from Warrens Well. The road at Warrens Well may be obliterated by cattle tracks but can be found by scouting northeast of the well. The spring is situated in or near a wash. A few years ago a mining company drilled a well near the spring and struck flowing water. Since the well was drilled the spring has dried up. The water from the well is reported to be of good quality.

Dead Man Hole.—Mendenhall [16] reports a watering place called Dead Man Hole on the west side of Mesquite Dry Lake and east of the road between Mesquite Spring and Surprise Spring. He states that it is little more than a mudhole in the playa deposits. The water is highly mineralized and very laxative, but it can be used by animals.

It appears from Mendenhall's description that the water table is very close to the surface around Mesquite Dry Lake. The name of the playa suggests that mesquite grow around it, and this is an additional indication that water is near the surface. The occurrence of water under pressure at Surprise Spring adds further corroboration. Apparently there is a considerable supply of ground water in the valley. The data available are insufficient, however, to show whether in most of the valley the water table lies at a reasonable depth for pumping, whether the quantity is sufficient to irrigate a large area, or whether the quality is generally good.

The Windmill or Pipes Wash Well.—A well, which is sometimes called Pipes Wash Well but which, because it is equipped with a good windmill, is more commonly called The Windmill, is situated in the lower end of Pipes Wash, about a quarter of a mile northeast of the point where the road from Warrens Well to The Pipes turns up Pipes Wash, 4.8 miles from Warrens Well. A trail leads to the well, but it is probably too poor for automobiles. The well is owned by Shay & Barker, who use it as a watering place for cattle.

The well is 10 inches in diameter and is drilled to a depth of 72 feet. Water was struck at a depth of 70 feet and rose to a level 55 feet below the surface. The artesian pressure is undoubtedly due to the water entering the gravel some distance up the wash. At the well is a masonry reservoir 20 feet square and about 5 feet deep, from which water is carried to a near-by watering trough. The water is of good quality for general use.

Water supply of The Pipes area.—There is a high desert area east of The Pipes through which flows the run-off of Pipes Canyon, Burns

[16] Mendenhall, W. C., Some desert watering places in southeastern California and southwestern Nevada: U. S. Geol. Survey Water-Supply Paper 224, p. 74 (No. 201), 1909.

Canyon, and other drainage ways on the northeast San Bernardino slope. Abundant supplies of good water are probably obtainable in nearly all the larger washes in this area at depths of 100 feet or less. The rolling hillsides of this upland area are floored by granite at most places, which is not particularly favorable for water, although water at a depth of 60 feet was observed in a prospect shaft on the north side of the road 8½ miles from Warrens Well. The area contains no very good agricultural land, but it has a good growth of grass at places, which adapts it for grazing. The vegetation includes juniper, yucca, and Mormon tea.

The Pipes.—The watering place known as The Pipes is in sec. 13, T. 1 N., R. 4 E. (unsurveyed). The place is said to have received its peculiar name from a great quantity of iron pipe that was hauled there many years ago and left to rust after the abandonment of an ill-conceived irrigation project. The place is reached by a road from Warrens Well that turns up Pipes Wash about 5 miles north of the well. A mile up the wash the road bends to the left up a side wash and over low hills. About 5 miles up the wash the road forks; the right branch continues westward to Burns Spring, and the left turns southwest to The Pipes. On this road, 2 miles from the fork, another road leads from The Pipes northwestward to the Burns Spring road and the main road leads southward 0.4 mile to The Pipes. The water is brought in an open conduit from Pipes Canyon, half a mile farther west. It is said that in the canyon the flow is 2 second-feet or more, but the water usually sinks into the gravel farther downstream. The water is sometimes used to irrigate an acre or two of alfalfa. It is of good quality for domestic use.

Burns Spring.—Burns Spring is in sec. 5, T. 1 N., R. 4 E. (unsurveyed), well up in Burns Canyon, on the eastern slope of the San Bernardino Mountains. It is reached by a branch of the road that leads to The Pipes. This road continues westward to the Rose mine, but is said to be impassable for automobiles. It is said that the water is of good quality and that the flow is perennial.

Chaparrosa Spring.—Chaparrosa Spring, in sec. 25, T. 1 N., R. 4 E. (unsurveyed), is apparently in the drainage area of Surprise Valley. It is about 2½ miles southeast of The Pipes, from which it is reached by a trail. Another trail leads southwestward to Little Morongo Creek and southeastward down to the Banning-Dale road. The spring was not visited. According to the San Gorgonio topographic map there are two springs about a quarter of a mile apart on the northeast and southwest sides of a low divide. The name Chaparrosa is probably applied only to the southwest spring. According to Vaughan,[17] the country rock is granite, and the water is accordingly probably of good quality.

[17] Vaughan, F. E., Geology of San Bernardino Mountains north of San Gorgonio Pass: California Univ. Dept. Geology Bull., vol. 13, No. 9, geologic map, 1922.

Saddlerock Spring.—Saddlerock Spring, in sec. 15, T. 2 N., R. 4 E. (unsurveyed), is believed to emerge in the drainage basin of Surprise Valley. It is several miles from any road and was not visited. As shown on the San Gorgonio topographic map it is about 6 miles due north of The Pipes. It is a short distance above the mouth of a canyon that drains southward into a broader and larger canyon or wash that drains eastward. According to Vaughan,[17] the rock is granite, and the water is therefore probably of good quality.

MORONGO, WARREN, COPPER MOUNTAIN, TWENTY-NINE PALMS, AND DALE VALLEYS

By John S. Brown

GENERAL FEATURES

A great area of desert country near the southern edge of San Bernardino County, east of the San Bernardino Mountains, is best reached by way of a long road that leads from Banning or Whitewater, on the Southern Pacific Railroad, in northern Riverside County. It comprises several closed drainage basins, including Morongo Valley, Warren or Yucca Valley, Twenty-nine Palms Valley, Copper Mountain Valley, and Dale Valley. These valleys are connected by very poor and little traveled roads with Bear Valley and with stations on the Atchison, Topeka & Santa Fe Railway, especially Victorville and Amboy. The roads to Victorville and Amboy are rarely used at present and for automobile travel are regarded as nearly impassable.

The road from Banning or Whitewater is a fair desert road, many miles of it excellent, some parts rather sandy and difficult, but all passable for automobiles or other vehicles. In 1918 gasoline and supplies could be obtained at the Covington ranch, also known as the Warren ranch, which is in Morongo Valley, 27 miles from Banning. (See pl. 11.) Miners and cattlemen are occasionally found at Warrens Well, Twenty-nine Palms, and Dale, but in 1918 there were no permanent habitations in this long stretch of desert. Water is fairly well provided along the way, but one must take sufficient food and other supplies at the start to last both on the outgoing and the return trip.

COUNTRY BETWEEN WHITEWATER RIVER AND MORONGO CANYON

The Dale road leaves the main highway along the Southern Pacific Railroad at a point about 13 miles east of Banning and 1 mile west of Whitewater station. This point is marked by road signs erected by the United States Geological Survey and the Automobile Club of Southern California. The Auto Club sign gives 71 miles as the dis-

[17] Vaughan, F. E., Geology of San Bernardino Mountains north of San Gorgonio Pass: California Univ. Dept. Geology Bull., vol. 13, No. 9, geologic map, 1922.

tance to Dale and the Geological Survey sign gives 62 miles. The distance on the Geological Survey sign is measured to the old camp of Virginia Dale, and that of the Auto Club probably to New Dale, a mining camp about 6 miles southeast of Old Dale. Both places were deserted in 1918. The distance to Old Dale is given on the Geological Survey sign in conformity with the rule to mark only watering places. No water is obtainable at the more distant place called Dale.

After leaving the main highway the road to Dale ascends the sandy alluvial fan of Whitewater River. There are several ranches on this slope, upon most of which water is diverted for irrigation by small ditches led directly from the river. Several of these ditches are crossed by the road. The soil becomes increasingly rocky, and near the river the surface is covered with huge rounded boulders carried there by the stream in times of flood. A small wooden bridge affords a crossing over the river. At this place the stream ordinarily flows clear and swift and is about 6 feet wide and 1 foot deep. In times of flood, however, its discharge is very much greater, as is witnessed by the many acres of land covered by smooth, white rounded boulders, many of them 1 to 3 feet in diameter.

Just east of Whitewater River the road forks. The road to Dale is the left fork, which ascends a cut along a steep hillside. This peculiar hill, which is well shown on the San Jacinto topographic map, rises abruptly to a height of more than 300 feet above the lower valley. On the west it is cut off by the gorge of Whitewater River, on the south it extends as a gradually diminishing bench several miles eastward, and on the north it rises gradually to the base of the mountains. It thus has the nature of a mesa or terrace and has been described as the Whitewater Mesa.[18] The material that composes the hill is a very coarse conglomerate which contains boulders of granite and gneiss as much as 3 feet in diameter, similar to those that are strewn along the stream. The material is poorly assorted and only roughly stratified. The constituent particles comprise all sizes, and the large boulders are mingled with fine sand and clay. An excellent section is observable on the north side of the road, which is a cut wall 10 to 20 feet high. The material stands poorly and often rolls down and litters the roadway.

The climb is not more than 500 or 600 feet long, and at the top the road turns sharply to the left and goes north but farther on turns northeastward across the bench, which is rather sandy. There is a good view of the surrounding country, and the bench underlain by conglomerate is seen to cover several square miles. Doubtless Whitewater River once deposited the material of this conglomerate and later cut away some of the material deposited and intrenched itself at its present level. The conglomerate is certainly of Recent

[18] Hill, R. T., unpublished manuscript on the geology of southern California.

age, and the erosion probably almost within historic time. The writer believes that the bench was formed during the existence of the ancient Lake Cahuila,[19] whose well-preserved shore lines are found more than 300 feet above the bottom of the Salton Basin, and that the erosion was due to a lowering of the base-level when the lake level went down.

For several miles the road runs northeastward across a broad valley or plain. It eventually leads into Morongo Canyon, at the base of some low mountains. This broad plain between Whitewater River and Morongo Canyon is called Conchilla Desert. It is thickly covered with many varieties of cactus, especially the large picturesque barrel cactus, and for this reason it is sometimes called the Devil's Garden. Probably more cactuses and more species of cactus are observable here than anywhere else on the Colorado Desert. Creosote bush and ironwood trees are also abundant.

MORONGO CANYON

At 22.6 miles from Banning the road enters a narrow canyon and passes northwestward between low mountains for 2 or 3 miles. The road for the next 12 miles or more runs between the San Bernardino and Little San Bernardino Mountains. About 1 mile from the entrance to the canyon there is usually running water in a stream known as West Morongo Creek. The road ascends Dry Morongo Creek and farther north are Big Morongo and Little Morongo Creeks. (See pl. 11.)

The walls of the canyon are about 300 feet high, nearly vertical, and close together, but the wash at the bottom is wide enough to afford a good road except that it is rather sandy and has a steep grade. The rock walls are composed of granitic gneiss, beautifully laminated and very much distorted and twisted as if it had been extraordinarily folded and contorted after the banding appeared. It is full of dark biotite mica and at places contains stringers of pure quartz. Willows in considerable number and mountain brush of different kinds grow in the bed of the wash. The mountain sides are nearly bare at the base, but farther up, where they are less precipitous, they support considerable growths of juniper.

At a sharp bend of Dry Morongo Creek, 2½ miles from the entrance to the canyon and near the San Bernardino County line, the road leaves the creek and climbs a very steep hill. On the side of the hill an Auto Club sign points west along a dim foot trail to Hole in the Wall Spring. There is said to be a tunnel that contains good water in the hillside about 100 yards away, but the writer has not seen it. On the summit Morongo Valley comes into view—a long, narrow depression that extends northeastward and is nearly inclosed by mountains. The rocks in the vicinity of the summit are not gneissic like

[19] Blake, W. D., Report of a geological reconnaissance in California, pp. 235–240, New York, 1858.

those farther down but are pink granite, which weathers out in smooth rounded hills with residual soil in which grow different bushes, particularly the juniper.

MORONGO VALLEY

ROAD THROUGH THE VALLEY

The road descends a moderate slope into Morongo Valley and goes north and east along land-survey lines for a mile or two. At 25½ miles from Banning there is a house on the south side of the road. A well near the place provides water for domestic use, but no detailed information about it was obtained. At 26.8 miles from Banning is the Covington ranch, formerly called Warren's ranch, where good water can be obtained from an artesian well.

Just east of the Covington ranch the road crosses Big Morongo Creek, in which 0.6 to 0.8 second-foot of good water was flowing at the time the ranch was visited. This creek leaves the valley through a gorge in the southern mountain wall only a short distance away.

The road ascends a considerable alluvial filling, which divides the valley into two parts. Beyond the divide, at 29.7 miles from Banning, the road passes an unoccupied house and a well that contains water, but in February, 1918, it had no equipment for drawing the water. The road continues northeastward through the middle of the valley and crosses the dry wash of Little Morongo Creek. A mile south of the road a stream of water is said to rise and flow through the canyon southward to the Conchilla Desert.

From the channel of the stream the road rises rapidly and crosses a granite divide at the east end of Morongo Valley. From the summit, at 34.0 miles, an excellent view of Morongo Valley is obtained, and San Gorgonio Peak to the west and San Jacinto to the south tower up far above all surrounding outlines on the horizon.

WATER SUPPLY

The water of Morongo Valley is nearly all contributed by Big and Little Morongo Creeks, which drain the lower slopes of the San Bernardino Mountains. The valley is about 7 miles long and averages 2 miles or more in width. Big and Little Morongo Creeks take a course directly across the axis of the valley, and the divide between them separates the valley into two drainage basins.

The valley is a débris-covered depression that is highest on the northwest, at the heads of the great alluvial fans, and lowest on the southeast, where the creeks issue from it through narrow rock gorges. The surface water from the mountains to the northwest sinks into the alluvium, reappears at the lower side of the valley, and flows over the rock-bottomed gorges into the Colorado Desert. This rising water produces marshy areas of several acres around each creek on the lower side of the valley and supports a grove of trees at the Covington ranch. A flow of probably more than 1 second-foot rises at that place in all the wet area and goes down the gorge. The amount is probably a little smaller in the eastern creek.

In 1918 a number of homesteaders in the valley were attempting to find means of irrigating the land, and several wells had been sunk. The one along the road at the south end of the valley is a dug well of no great depth. Its supply is probably small. Just north of the road, on the summit of the divide between Big and Little Morongo Creeks, is a dry hole 12 inches in diameter and 140 feet deep. It is on land about 300 feet above the water table at Big or Little Morongo Creeks, on the south side of the valley. In the well at the house east of the divide water stood 103 feet below the surface in December, 1917, and is said to be abundant and of good quality. Artesian wells with very weak flows have been obtained in the marshy area of Big Morongo Creek near the Covington ranch. Some other wells west of the ranch are reported to obtain water at increasing depths. A body of ground water of good quality evidently is present beneath the valley. It is valuable for domestic supply and may be recovered through wells in sufficient quantities to irrigate small areas near Big and Little Morongo Creeks in the south side of the valley. Some of this water which issues from springs is at present utilized at the Covington ranch. The most promising way of utilizing the water supply of the valley, however, is to divert the two creeks at the west side of the valley and to lead the water to desirable lands by gravity.

ORIGIN OF THE VALLEY

According to Hill,[20] Morongo Valley was produced by faulting transverse to a preexisting drainage system whereby a block on the southeast side of the valley was raised to form a long scarp across the course of Big and Little Morongo Creeks. This movement can not have been more rapid than the rate at which the creeks could cut their canyons, for otherwise a lake would have been formed which would have overflowed the low divide at the southwest end of the valley, or a closed basin with playa lakes would have resulted.

WARREN VALLEY

GENERAL FEATURES

From the summit east of Morongo Valley the road descends into a long valley called Warren Valley in this report. Yucca trees are very prominent in this valley, and for this reason it is sometimes called Yucca Valley.

At 35.4 miles from Banning the main road crosses a north-south road. About 2 miles to the south on this road is a little-used water

[20] Hill, R. T., op. cit.

hole called Warrens Tank. It is really a tunnel in the mountains and is said to contain good water the year round. Toward the north the road once led to Pipes Canyon. In 1918 this road was impassable for any vehicle, and a road from Warrens Well was used to reach The Pipes.

The Dale road continues east over a nearly level valley that drains eastward. For 30 miles east of Morongo Valley it is one of the best desert roads known and crosses mainly valleys floored with fine granitic sand. The dominant vegetation passes from juniper, yucca, and Mormon tea (*Ephedra californica*) in the areas at the west to creosote, cactus, and mesquite in the desert at the east.

Warrens Well is reached at 38.3 miles from Banning. It is at the north edge of a small playa that covers an area of several acres. The well is provided with a windmill, which delivers water to a masonry reservoir for use by stock. It is about 160 feet deep, and water is reported to stand 130 feet below the surface. As shown by analysis 1 (p. 644), the water is fair for domestic purposes and suitable for irrigation. The well is at the lowest point in the valley and is the only successful well in the valley. Unsuccessful holes of varying depths are reported to have been sunk in different parts of the valley. Much of the land has been filed upon for agricultural use, although there appears to be no possible source of water for extensive irrigation. The depth to water at Warrens Well is 130 feet, and unquestionably it is much more in most other parts of the valley. Not a single perennial stream discharges into the valley, and the drainage basin is small and receives little precipitation. Certainly a more auspicious place might be chosen to take up farm lands than this pretty but unpromising little valley.

South of the narrow depression along the axis of Warren Valley steep alluvial slopes rise to the base of the Little San Bernardino Mountains, 2 or 3 miles away. So far as known, these mountains are composed of pink granite or granitic gneiss like that around Morongo Valley and in the San Bernardino Mountains. The crest of the range is only 3,000 or 4,000 feet above sea level and has no pronounced peaks, although it is uneven. Its north wall extends generally eastward but is greatly broken by canyons, up which extend large alluvial fans.

On the north side of the valley, about a mile from the road, is a long, low ridge of pink granite that terminates about 3 miles east of Warrens Well. It is composed largely of massive blocks of granite rounded to smooth outlines and projecting 100 to 200 feet above the residuum in which they are nearly buried. East of this ridge for 2 or 3 miles and in line with it are several isolated rock hills.

Analyses of water from wells and springs on the Banning-Dale road

[Parts per million]

	1	2	3	4
Silica (SiO_2)	28	22	29	12
Iron (Fe)	.40	5.5	.07	7.1
Calcium (Ca)	108	9.2	20	35
Magnesium	20	2.4	3.6	7.9
Sodium and potassium (Na+K) (calculated)	14	44	42	607
Bicarbonate radicle (HCO_3)	116	130	156	140
Sulphate radicle (SO_4)	41	13	14	734
Chloride radicle (Cl)	47	3.6	8.4	395
Nitrate radicle (NO_3)	220	5.0	1.7	1.4
Total dissolved solids	534	180	194	1866
Total hardness as $CaCO_3$ (calculated)	352	33	65	120
Date of collection	(a)	(b)	(c)	(d)

[a] Dec. 14, 1917. [b] Dec. 15, 1917. [c] Dec. 16, 1917. [d] Dec. 18, 1917.

Analysts: 1 and 4, Margaret D. Foster; 2 and 3, Margaret D. Foster and Addie T. Geiger, U. S. Geological Survey.

1. Warrens Well, Shay & Barker, owners; SE. ¼ sec. 25, T. 1 N., R. 5 E. San Bernardino meridian. See p. 643.
2. Coyote Well, Shay & Barker, owners; sec. 28, T. 1 N., R. 7 E. See p. 645.
3. Twenty-nine Palms Springs, NE. ¼ sec. 33, T. 1 N., R. 9 E. See p. 646.
4. Cattle Well, sec. 25, T. 1 N., R. 11 E. See p. 649.

ROAD FROM WARRENS WELL TO THE WINDMILL, THE PIPES, BURNS CANYON, AND BEAR VALLEY

Just west of the house at Warrens Well a United States Geological Survey sign points north along a branch road to Pipes Canyon. This road is the one at present used to reach that place, and it also connects with Bear Valley by a very poor wagon road. From Warrens Well to The Pipes the road is rather difficult for automobile travel and is little used, though generally passable. In the so-called Pipes Wash, a quarter of a mile northeast of the road, at a point 4.8 miles from Warrens Well, is a well owned by Shay & Barker, of Banning. (See p. 636.)

WARRENS WELL TO COYOTE WELL

East of Warrens Well the road ascends rather high on the alluvial slope that has been built out from the mountains to the south. Not far from Warrens Well the axis of the valley again slopes eastward, and the playa at that place forms but a small break in the continuity of a long valley sloping east.

A large well casing protrudes above the ground 2 miles east of Warrens Well on the north side of the road. The hole is reported by O. S. McKinney, of Palm Springs, the driller, to be 333 feet deep and dry. It is several hundred feet above the dry valley bottom north of it, and hence water could be expected only at great depth.

A good branch road turns south at 43.0 miles. It leads to Quail Spring, Key's ranch, and Piñon Well, and, by an intricate series of branch roads, gives access to a very large area north of the Little San Bernardino Mountains, in northern Riverside County.[21]

[21] Brown, J. S., Routes to desert watering places in the Salton Sea region, Calif.: U. S. Geol. Survey Water-Supply Paper 490-A, pp. 74-76, 1920; The Salton Sea region, a geographic, geologic, and hydrologic reconnaissance, with a guide to desert watering places: U. S. Geol. Survey Water-Supply Paper 497, pp. 190-192, 266-268, 1923.

The Dale road continues east from the fork marked with a sign and descends into the rather deep valley of a wash that heads from the south. A mile or less up this wash is the old watering place called Coyote Holes. It was never more than a slight seep of water over a rock barrier in the stream bed and has long been unused and is almost forgotten. Just east of this valley rises a jutting spur of granite mountains, not of great height but very rough, which approach near the road. Farther east the mountain front retreats southward a mile or two, and the road lies about midway up the alluvial slope. About 1 mile north of the road a long wash drains eastward toward a large playa, which is not shown on Plate 11 but is shown on Plate 7.

COPPER MOUNTAIN VALLEY

GENERAL FEATURES

The large playa just mentioned occupies the lowest part of a large drainage basin, which is shown in Plate 7 as Copper Mountain Valley. On the east the basin is cut off from a further slope eastward by a low, transverse range of mountains. The playa lies almost on the very foot of this range, on its west side.

The name of this mountain has been given as Copper Mountain on account of a copper prospect once opened there. The rounded flat-topped summit of the south end gives a strong suggestion of being a lava flow. The ridge that trends northward consists of a series of jagged peaks of diminishing height and may be composed of different material. The mountains south of the road approach within nearly a mile of this mass at its southern point, and a high alluvial divide across this narrow constriction separates the Copper Mountain Basin from the next basins to the east.

COYOTE WELL

At 47.2 miles from Banning a branch road leads northeast to a well a quarter of a mile away, over which a windmill is visible. The well is used to water cattle that range in the desert and was made by Shay & Barker, of Banning, about 1915. Because of its proximity to the abandoned water hole called Coyote Holes, it is usually known as Coyote Well. At the well there is a large concrete trough about 6 feet wide, 3 feet deep, and 36 feet long. In 1917, in addition to the windmill, a gasoline engine was housed in a little sheet-iron shed and used to pump water when necessary.

Coyote Well is the only water supply known in this basin. Its depth of 170 feet to water indicates that water probably lies considerably nearer the surface near the central part of the basin. There is, however, no fringe of vegetation around the playa to indicate that water is near the surface or that any discharge takes place by evaporation. It is probable that ground water drains eastward through the alluvium on the south side of Copper Mountain. The supply is afforded by the tributary drainage basin and is doubtless considerable. It is probable also that ground water enters this basin from Warren Valley. The water from Coyote Well is of good quality, except for rather high iron content, as shown by analysis 2, on page 644. This well should not be confused with one of the same name situated in Coyote Valley, about 16 miles northeast of Daggett. (See p. 283.)

TWENTY-NINE PALMS VALLEY

COYOTE WELL TO TWENTY-NINE PALMS

East of Coyote Well the road climbs a steep alluvial grade to the divide south of Copper Mountain, where it touches a jutting point of the granite mountains south of the road. It then continues eastward, with a valley on the north and a mountain wall at different distances on the south. It is an excellent road all the way to Twenty-nine Palms. The valley may be called Twenty-nine Palms Valley, from the name of a well-known watering place in the valley.

The mountains south of the road form a long irregular wall in general parallel to the east-west direction of the road. This front, however, is deeply scalloped, and great lobate embayments 2 to 5 miles in depth alternate with jutting rocky points all along its northern face. The country north of the road is a broad, broken plain with rather even southeast slope, and along the line of junction of these features a great valley, broken here and there by minor obstructions, slopes eastward.

TWENTY-NINE PALMS

Twenty-nine Palms is a well-known watering place that has long been an oasis to which roads lead from all parts of the adjacent desert. A large group of springs, nearly all of which furnish fairly good water, is alined over a distance of nearly a mile from east to west. This line of springs is distinguished by a very prominent line of vegetation—mesquite, arrow weed, salt grass, cottonwood trees, willows, and palms. At its west end, on the north side of the road, in a grove of large cottonwoods and willows, three or four large pools discharge a considerable quantity of water, which runs for a half mile or more into the desert. Farther east the spring line crosses the road and forms a pronounced bank 15 to 30 feet high, covered with a growth of arrow weed, mesquite, and other vegetation. Near the east end of the spring line stand the palms, which gave the locality its name. They grow in some places singly, in other places in clumps of two or three in a long east-west line. Some of them are young and small, others are 70 or 80 feet in height. The larger palms are clustered near the east end and number at present about 15. Along all this line of vegetation there are pools or seeps of water, few of which run any distance from the source. At the extreme east end of the spring line stands a large adobe house (unoccupied in 1917) surrounded by a grove of big cottonwoods. Near it issue two springs, one of which supplies a horse trough and the other, about 200 feet west, is covered and its water is used for domestic supply. The water is of good quality. (See analysis 3, p. 644.)

About a quarter of a mile west of the large pools, on the north side of the road, stands a small house that was occupied in December, 1917, by P. T. Sullivan, who operated a small gold mine in the mountains to the south. On both sides of the road Mr. Sullivan has dug wells, in one of which the water stands 17 feet and in another 28 feet below the surface. The former is equipped with a hand pump, the latter with a 3-inch pump driven by an engine. No effect is said to be produced by this outfit on the head of the water. The quality of the water is good.

The springs apparently issue along the line of a very recent fault which had a displacement of probably not more than 50 feet and of which the upthrown side is the bank mentioned south of the spring line. Water occurs near the surface in a large basin north of Twenty-nine Palms, as is shown by the large areas of mesquite and salt grass and by Mesquite Spring. (See pl. 11.) Mr. Sullivan reported water at a depth of 40 feet in a well he dug half a mile north of Twenty-nine Palms.

To the south of Twenty-nine Palms there is a large reentrant in the mountains which is occupied by an alluvial slope 5 or 6 miles long and 3 or 4 miles wide, at the foot of which the springs emerge. The ground water that percolates down this slope apparently encounters a barrier in the fault line and rises there. It is also possible that deeper water from a more distant source issues along the fault.

MESQUITE SPRING

From Twenty-nine Palms a branch road leads north to Mesquite Spring, 7 miles away, and continues to Surprise Spring and beyond, although that part of the road is said to be nearly impassable for automobiles.

Mesquite Spring issues on the west edge of a playa about 2 miles long and nearly a mile wide. East of the playa stands the end of a long tapering point of sharp-crested mountains which protrude into the desert. Water rises from the level surface of the desert at two pools 3 or 4 feet across and about 2 feet deep and flows about 200 feet on the desert. In 1917 the springs were badly polluted by the carcasses of cattle, but the place is said to have been repaired since

The water when not polluted is reported to be good. The springs are surrounded by an extensive growth of salt grass and mesquite; the latter usually grows over small sand dunes. The soil shows a strong coating of white alkali, denoting evaporation of ground water. Discharge of ground water appears to be taking place over an area of several square miles that extends west and south. Parts of this area are very sandy. A great ridge of sand 50 feet high parallels the road on the west about 2 miles north of Mesquite Spring.

WATER SUPPLY OF THE VALLEY

It seems certain that a large area in this basin contains ground water at depths of 50 feet or less. Moreover, deep drilling might reasonably be expected to produce flowing wells, particularly west of Mesquite Springs, where the vegetation mentioned is rankest. Unfortunately much of the soil where the water is near the surface is covered with sand hummocks, although there are some areas of good soil. Northwest of Mesquite Springs there is a tract of worthless land covered by large dunes. The water at Twenty-nine Palms was once used for irrigation in a small way by Indians who lived there on a reservation but who have since joined the Cabezon Indians in Coachella Valley. This valley appears to be one of the most promising areas for agricultural development in this part of the desert, where there are no perennial streams.

TWENTY-NINE PALMS TO DALE

From Twenty-nine Palms the main road continues eastward to Dale. About one-tenth mile east of the house at the east end of the springs, on a little elevation is an abandoned pumping plant. From this point a road leads south to the El Dorado mine and other places. At 61.9 to 62.9 miles from Banning a small ridge of granite and gneiss is crossed. This ridge extends northwestward 3 or 4 miles but is nowhere more than 200 feet high. It approaches within about 3 miles of a long, sharp range east of Mesquite Spring. The drainage divide between the Twenty-nine Palms and Dale Basins passes through these protruding rocks. Probably some ground water is contributed by the western to the eastern basin.

East of this ridge the road takes a course very similar to that which it took across the other basins. A few miles south of the road rise high mountains; a similar distance to the north lies a dry wash that drains eastward. Beyond the wash lies a great southeasterly slope that is tributary to a dry lake east of Dale. Far to the northeast can be seen a range of mountains several thousand feet high which trends northeastward. Beyond a point 67.0 miles from Banning the sand becomes very deep and at places is difficult for automobile travel, especially after a sand storm. The sand is shifted slightly by the wind but shows no great tendency to form dunes.

OLD VIRGINIA DALE

At 73.8 miles from Banning is Old Virginia Dale, the original settlement of the basin, made in early mining days. (See pl. 12.) Near this place two small hills rise from the surface of the desert to a height of less than 100 feet, and on the one farthest east stands a sheet-iron building that houses an unused pumping plant. Several walls of adobe block 1 to 3 feet high are all that is left of the houses in which once lived a considerable settlement of people. A windmill stands over a well which formerly supplied water to the place. In December, 1917, the well had caved badly at the bottom, so that the suction pipe no longer drew water and the windmill was useless. The well curb of boards was in bad condition. Near the well stood a concrete trough and a small sheet-iron shed that housed a gasoline engine. Water stood in the well 74.5 feet below the surface and could probably be obtained with a bucket and a long rope.

Three roads lead beyond Old Dale—one north-northeastward across the desert to Amboy (pp. 650, 689), one eastward to the Dale pumping plant (p. 650), and one southeastward to New Dale. On the road that leads north-northeastward about 2 miles from Old Virginia Dale there is a well at which water was obtainable in 1918. It was the property of Shay & Barker and was maintained to supply range cattle. The road is safely passable the first half of the way to the well but almost impassable for automobiles the rest of the way. The well is easily found, as there is a large windmill over it. In 1917 it was equipped with an engine, housed in a sheet-iron shed like those previously described. A concrete water trough 36 feet long, 6 feet wide, and 3 feet deep divided into four compartments is kept full for cattle. The water is somewhat bitter but usable. As shown by analysis 4 (p. 644), the water is highly mineralized. The well casing is 10 inches in diameter, and the well measured 59.5 feet deep and 35.8 feet to water on December 18, 1917.

NEW DALE

The road going southeast from Old Dale leads to New Dale, a mining camp on the edge of the mountains 6 miles away. A severe sand storm had rendered this road practically impassable at the time of the writer's visit to the region, and the trip was not attempted. From the most reliable information obtainable New Dale was in 1917 entirely uninhabited. Near the place are a number of mines, including the Brooklyn and Supply mines, all of which were closed down at the time. The Supply mine is said to have a mill which cost $250,000, and a watchman has been kept at the property. From these places roads lead south to Cottonwood Spring, but they were variously reported as bad, passable, and impassable.

DALE PUMPING PLANT

Four miles or more north of New Dale, at the south edge of Dale Dry Lake, in the lowest part of the Dale Basin, there is a well, 400 feet deep, that is reported to furnish good water.[22] Water has been pumped from this well to New Dale and to the mines mentioned.

ROAD TO AMBOY

The road from Old Dale to the Shay & Barker cattle well leads to a pass between the Bullion and Sheephole Mountains and continues to Amboy, a station on the Atchison, Topeka & Santa Fe Railway. The distance from Old Dale to Amboy is about 40 miles. Because this road is shorter than the Banning road it is usually kept in condition for travel when the mines are in operation, but it becomes very bad when long untraveled. In fact, the sand is nearly impassable in the bottom of the Dale Basin, where for 3 or 4 miles it is drifted into dunes several feet in height. Possibly a better road goes from the Dale pumping plant to the Sheephole Pass, but of this no information was obtained.

DALE VALLEY

Dale Valley is the easternmost of a series of valleys just described that lie at successively lower altitudes toward the east. North of the lowest parts of these valleys is a large plain with few interruptions that slopes in general southeastward. On the south sides of the valleys the alluvial slopes are shorter and steeper and the mountains are not far away. The topography of this general region is attributed by Hill [22] to two great faults—one trending east along the mountain front south of the road from Morongo Valley to Dale, the other trending northwest along the north side of the Sheephole and Bullion Ranges. He regards the Sheephole and Bullion Ranges and the plain south of them as a great block tilted down on the south, and the mountain wall on the south side of these valleys as a fault scarp produced by the upthrust of these mountains. There seems to be good general evidence of an eastward-trending fault along the south side of these valleys, although the scalloped front of the mountain ranges does not suggest a fault scarp. Behind this escarpment stands a great triangular plateau of granitic rocks, bordered by lower valleys. This plateau may very well be a great upthrown block, bordered mainly by areas of subsidence. The theory of a major fault is supported by the apparently recent fault scarp at Twenty-nine Palms.

The basin of Dale Valley is a large area with high mountains on the northeast and south sides and a large alluvial slope on the north-

[22] Hill, R. T., op. cit.

west. It is bounded on the north and northeast by the Bullion and Sheephole Mountains, which trend northwestward and are 3,000 to 5,000 feet above sea level. (See pl. 12.) It is bounded on the south by the Pinto Mountains, an irregular range that rises at least 4,000 feet above sea level. To the east it is shut off by the Coxcomb and other ranges, which probably reach altitudes of more than 3,000 feet. The altitude of the lowest part of the basin is given by Hill as 1,250 feet.

The precipitation is very light, however, as is shown by the extreme barrenness of the mountains, unlike the mountains farther west around Warren Valley, which have a fair growth of vegetation. The basin, too, is covered with only a meager growth of creosote bush.

The known watering places are the well at Old Dale, the Shay & Barker well, and a well at the Dale pumping plant. The Shay & Barker well is at a lower altitude than that of Old Dale and reaches water at about half the depth of the well there. The depth to the water table at the Dale pumping plant is not known. Evidently a permanent body of ground water lies beneath the basin. Whether ground water is discharged by evaporation in the vicinity of the Dale Dry Lake was not ascertained. No indications of heavy plant growth were visible, but the lower part of the basin was not reached. There is a possibility of underground drainage out of the Dale Basin on the east and north sides, where the inclosing mountains are at places interrupted by alluvial divides. Some ground water is probably contributed to Dale Valley by Twenty-nine Palms Valley through the low alluvial divide, although solid rock probably lies at no great depth under this divide, and there is a large area of ground-water discharge in Twenty-nine Palms Valley.

LAVIC VALLEY

GENERAL FEATURES

Lavic Valley is situated a few miles west of Ludlow, somewhat southwest of the center of San Bernardino County. (See pl. 7.) The name is derived from Lavic station, on the Atchison, Topeka & Santa Fe Railway, which crosses the north side of the valley. The only permanent habitation in the valley is at Lavic, where the railroad maintains telegraph operators and a section crew. Water can be obtained there, but no other supplies are available. Some mining is carried on more or less spasmodically in the mountains 8 or 10 miles southwest of Lavic.

The National Old Trails Road crosses the north side of the valley near the railroad. (See pl. 11.) From Lavic a road leads southward to Lavic Dry Lake, a playa about 3½ miles from Lavic. The road forks on the playa. One branch leads west and northwest along the south side of the Mount Pisgah lava flow to the main road about 15 miles west of Lavic. This road is practically abandoned. A branch from it leads southward up a very steep grade across another lava flow to the Imperial Lode mine, near the summit of the mountains. At the forks on the playa the left branch leads southward to the Sunshine mine camp 7 miles from Lavic. Thence it goes southwestward, and beyond it swings back northward to the Sunshine mine, near the summit, on the south side of the mountain. Both the Sunshine and Imperial Lode mines were being worked in 1917.

Certain old maps show a road leading south and southwest from the Sunshine mine road to Means Wells and other points in the long trough that extends eastward from Victorville to Dale. So far as could be ascertained this road no longer exists, or at least it is very seldom traveled. Nothing could be learned of the existence of a spring which was marked Peacock Spring on old maps of this road.

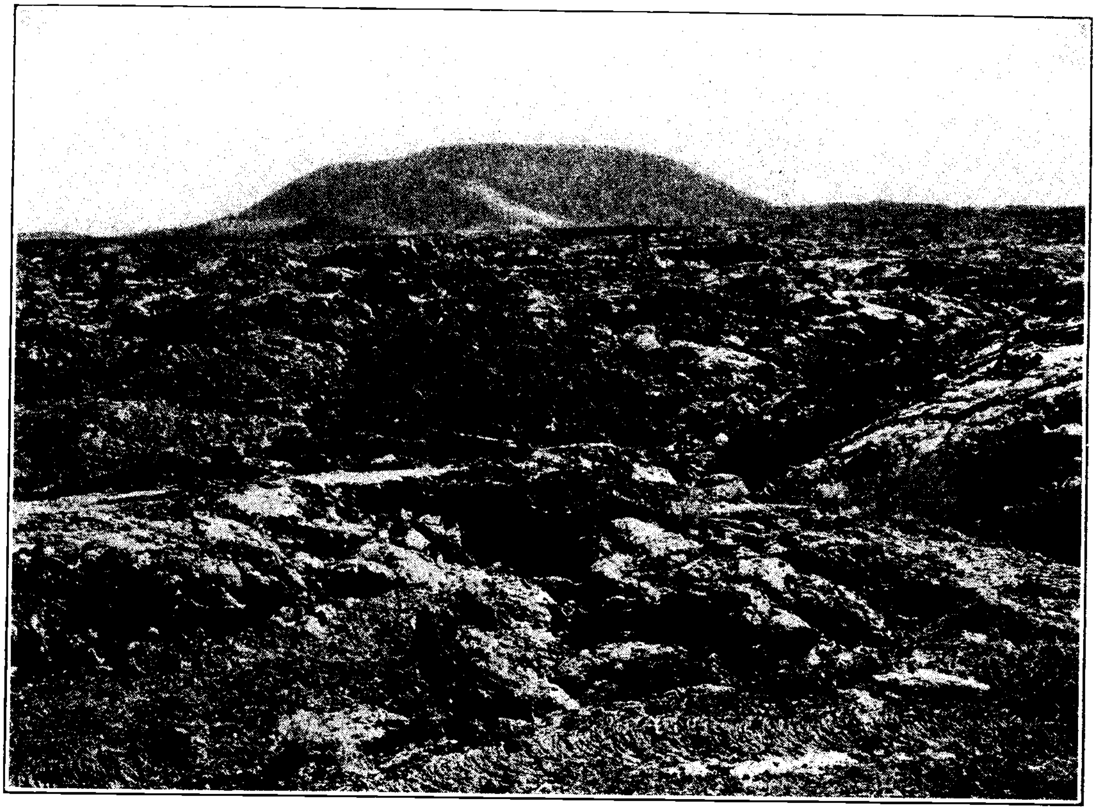
PHYSICAL FEATURES AND GEOLOGY

Lavic Valley lies in the great trough that extends from Barstow southeastward almost to Colorado River. (See p. 120.) The mountainous area of the basin is relatively small. It includes a very small part of the Cady Mountains on the northeast and of the Lava Bed Mountains on the southwest. The Lava Bed Mountains are composed mainly of intrusive rocks. The geology in the vicinity of the Imperial Lode and Sunshine mines has been described by Storms.[24] The country rock at the mines is quartz porphyry. On the northern flank of the mountains lie beds of "tufa" [tuff?] and flows of basaltic lava. Apparently the Lavic Mountains form a continuation of the Bullion Mountains, but a break between them affords a pass to the region farther south. The eastern border of the valley is formed largely of Tertiary volcanic hills south of the Atchison, Topeka & Santa Fe Railway. North of the railway the divide a short distance east of Lavic station appears to be composed of alluvium, but it is likely that bedrock, probably Tertiary volcanic rocks, lies not far below the surface

The western border of the valley is formed in part of alluvium and in part of a lava flow poured out from a crater known as Mount Pisgah, in the southwestern part of T. 8 N., R. 6 E. This crater and flow lie in the bottom of the trough between the Lava Bed Mountains and the Cady Mountains. Lavic Valley appears originally to have been part of a large valley that drained northwestward to the Lower Mohave Valley near Newberry Spring (see p. 443), but the lava flow cut off the upper part of the valley and formed a closed basin.

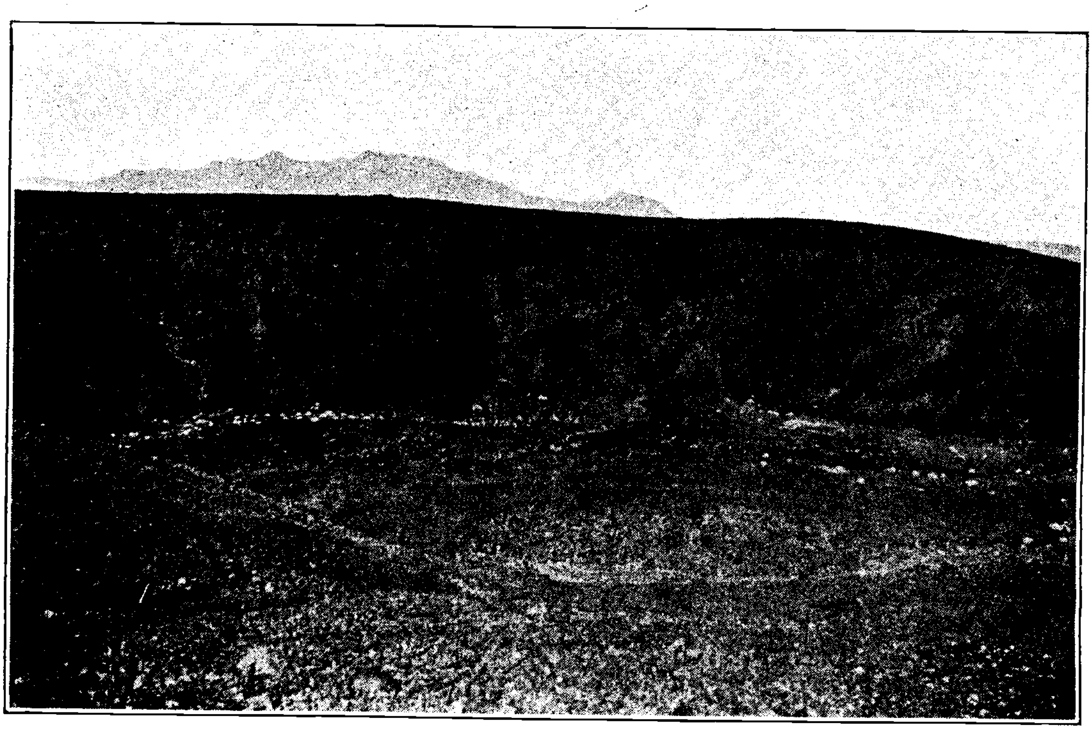
The Mount Pisgah crater and flow afford good examples of the volcanic features that are found in many parts of the Great Basin,

[24] Storms, W. H., California State Mineralogist Eleventh Rept., pp. 349–359, 1893.



A. MOUNT PISGAH CINDER CONE AND LAVA FLOW FROM THE NORTHWEST

Photograph by N. H. Darton



B. INTERIOR OF MOUNT PISGAH CINDER CONE

Photograph by N. H. Darton

and a trip to the cone is well worth while. It is most easily reached by leaving the main road about 3½ miles northwest of Lavic. The distance to the crater is 1½ or 2 miles. The visitor should wear good shoes and carry a canteen unless the day is cool, for the lava surface is rough and the walk arduous.

The lava is composed of black basalt. The surface is very rough, exhibiting blistered and ropy texture to such a marked degree that one needs little imagination to see the lava pouring down the valley. (See pl. 32, *A*.) Numerous caverns or tunnels were formed when the upper surface cooled and the still liquid lava beneath flowed out from under the crust thus formed. Mount Pisgah is a cone composed of loose cinderlike material that rests on the lava flow. It rises about 160 feet above the lava flow, and the top of the cone is about 1,000 feet across. (See pl. 32, *B*.) An inner wall extends across the west side of the crater, showing that a second outburst followed the one that built up the main cone. Part of this inner rim is shown in the lower left corner of Plate 32, *B*.

The surface of the lava flow is scarcely weathered, and there is so little soil on it that it is almost bare of vegetation. The loose materials of the cinder cone likewise have hardly been affected by erosion. It is obvious that the eruption occurred in comparatively recent geologic time, probably during the Pleistocene epoch.

The lava flow extends only about 2½ miles southeastward from Mount Pisgah, and it is broadest in this part. On the northwest it reaches in a narrow belt for 5 miles from the crater to the edge of Troy Dry Lake. The recent alluvium laps up onto it, and doubtless it is underlain by older alluvium onto which it was poured.

In the depression southeast of the flow formed by the blocking of the valley a playa, Lavic Dry Lake, has formed. The playa has partly buried the lava at the borders of the flow. The surface of this playa in dry seasons is hard and smooth, and it is in all respects one of the dry type.

GROUND WATER

There is a well dug at the Sunshine mill, 7 miles southwest of Lavic, approximately in sec. 4, T. 6 N., R. 6 E. (See pl. 11.) It is a short distance south of the point of a lava flow that forms the southeast end of the Lavic Mountains. The well is used to supply the Sunshine mine and mill. The water for the mine is hauled by wagon a distance of about 8 miles, but the mill is near the well. In November, 1917, the well was inclosed in a pump house, which was locked except when the pump was being operated. No one was living at the mill, but water could be obtained from a large tank that was pumped full every few days for use at the mine. The depth of the well is reported to be between 120 and 130 feet, and the depth to water about 85 feet. The well is said to yield 25 or 30 gallons a minute without any appreciable drawdown.

The water is highly mineralized. (See analysis below.) A sample from the tank, which had been pumped the preceding day, contained 1,679 parts per million of total solids. The principal constituents are sodium sulphate and chloride. The water is poor for domestic use or for irrigation. The water has been reported to contain arsenic and for that reason to be unfit for drinking. A qualitative test in the laboratory of the United States Geological Survey, however, failed to show any arsenic. There seems to be no reason why the water can not be used, although it is not very good.

Analysis of water from well at Sunshine mill, in sec. 4 (?), T. 6 N., R. 6 E. San Bernardino meridian

[Sample collected Nov. 27, 1917. C. H. Kidwell, analyst]

	Parts per million
Silica (SiO_2)	48
Iron (Fe)	.33
Calcium (Ca)	50
Magnesium (Mg)	7.4
Sodium (Na)	494
Potassium (K)	17
Carbonate radicle (CO_3)	0
Bicarbonate radicle (HCO_3)	88
Sulphate radicle (SO_4)	547
Chloride radicle (Cl)	349
Nitrate radicle (NO_3)	9.0
Total dissolved solids at 180° C	1,679
Total hardness as $CaCO_3$ (calculated)	155

An old drilled well is situated on the west side of the dry lake, approximately in sec. 20, T. 7 N., R. 6 E., 6 miles from Lavic. It is near the place where the road to the Imperial Lode mine leaves the playa. The well is 59 feet deep, and on February 9, 1918, the depth to water measured 53 feet from the level of the ground, which is about 5 feet above the surface of the playa. The well did not have any pump or other means of obtaining water.

According to information furnished by the Atchison, Topeka & Santa Fe Railway, a dug well known as the Sutter well is situated about 4½ miles southeast of Lavic. The well is 72 feet deep, and the depth to water is 64 feet. The well is said to have yielded 200,000 gallons in 24 hours, or about 140 gallons a minute. No other information is available in regard to this well, but from the location given it is probably in the rocky hills southeast of Lavic and not in the alluvium-filled valley.

No other wells are known in the valley. Water for the railroad employees at Lavic is brought by train from Water station (Newberry Spring). Water for the Imperial Lode mine is hauled by wagon from Lavic. If an additional water supply were needed in the valley doubtless it could be obtained from the alluvium elsewhere in the lower part of the valley. The principal consideration in locating wells would be to dig or drill far enough away from the rock hills to avoid striking bedrock before water was reached. The quantity of water from any one well would probably not be large. The natural conditions in the valley are unsuitable for irrigation or grazing, and the only possible need for a large supply would arise in the event that the mineral deposits in the surrounding mountains prove valuable.

The water table in Lavic Valley lies about 50 feet below the playa, which is clearly of the dry type. As the water table is so far below the surface there may be underground drainage from the valley, most probably toward the northwest, beneath the lava flow. If, as seems likely, the lava flow is underlain by alluvium deposited before the volcanic eruption, the water would find free passage through the alluvium. This condition is illustrated in Figure 18. Even if the flow lies on bedrock, the lava is broken so much by cracks and tunnels that the water would pass through it easily. According to barometric observations the water level in the well on the west side of Lavic Dry Lake is about 80 feet above the water level beneath Troy Dry Lake, northwest of the lava flow. The gradient of the water level between the two places is only about 6 feet to the mile. Such a gentle gradient is common in the desert basins where the recharge is not great.

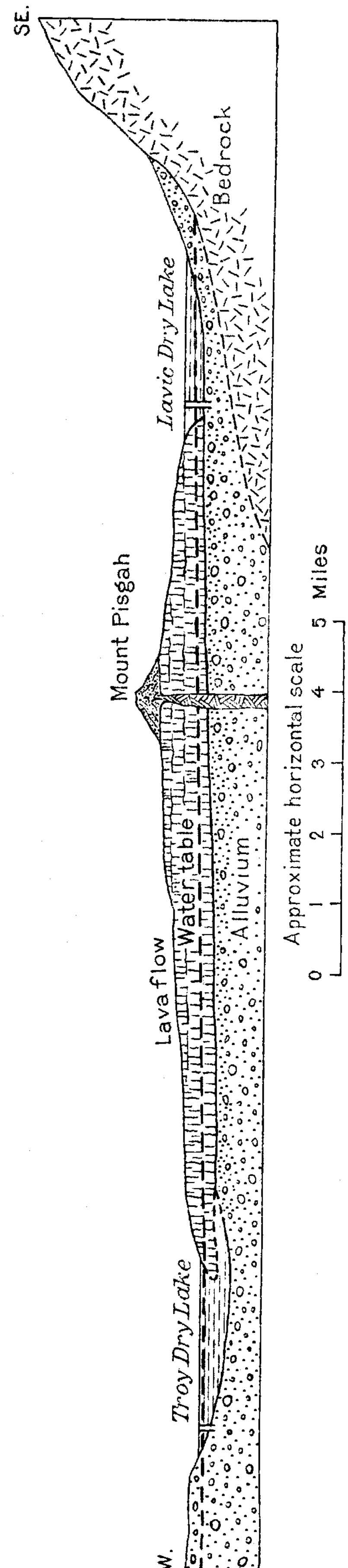


FIGURE 18.—Hypothetical section between Lavic and Troy Dry Lakes, showing a possible explanation of deep-lying water table beneath Lavic Dry Lake

BROADWELL VALLEY

GENERAL FEATURES

Broadwell Valley lies a little south of the central part of San Bernardino County. (See pl. 7.) The name is derived from a railroad siding on the Tonopah & Tidewater Railroad on the border of a playa in the bottom of the basin. The valley may also be called Ludlow Valley, from the name of the only town in it.

The Atchison, Topeka & Santa Fe Railway crosses the south side of the valley. The Tonopah & Tidewater Railroad goes northward across the center of the valley from its southern terminal at Ludlow. The Ludlow & Southern Railroad goes south from Ludlow to the mining town of Stedman, about 8 miles distant, just beyond the border of Broadwell Valley.

The National Old Trails Road parallels the Atchison, Topeka & Santa Fe Railway. From Ludlow a road goes northward along the Tonopah & Tidewater Railroad. (See pl. 11.) In 1917 this road was in good condition about as far as the northern divide of the basin. Beyond that point it was in poor condition because of washouts and farther north because of sand. It is practically impossible to reach Crucero by automobile over this road. A road leads south from Ludlow to Stedman and to prospects in the Bullion Mountains.

Ludlow, or Stagg post office, the only town in the valley, has a population of two or three hundred. Its existence depends largely on railroad and tourist trade. It is the southern terminus of the Tonopah & Tidewater Railroad. In the town are good general stores and garages and several small hotels for tourists.

Argos is a section headquarters on the Atchison, Topeka & Santa Fe Railway, and water can be obtained there in an emergency. Broadwell is merely a railroad stop, without any facilities for obtaining water.

Besides the activities related to the railroad and automobile traffic the only industry in the valley is mining, which is done on a small scale. Celestite, a strontium ore, was mined during the war on the south side of the Cady Mountains, about 3 miles northwest of Argos. The production has not been great, as the demand for this mineral is relatively small, and since the war the mine has not been operated. The mines at Stedman are a short distance outside the drainage basin. (See p. 691.)

PHYSICAL FEATURES AND GEOLOGY

The alluvium-filled valley area of the Broadwell Basin is relatively small. It consists mainly of a long valley that slopes from the vicinity of Ludlow northward to a place a mile or two north of Broadwell. There is also a slope from the mountains on either side. An arm of the valley extends westward from Ludlow for several miles.

The western, southern, and southeastern borders of the valley are composed largely of volcanic rocks. These lavas are of Tertiary age except in the area east of Ludlow, where the rock consists of Quaternary basalt.

At the extreme southwest corner of the basin, near Lavic station, the divide, where it is crossed by the road, appears to be composed of alluvium. At the divide there is a rather abrupt ascent westward of about 40 feet. This abrupt slope continues northward to the base of the mountains and is suggestive of a fault scarp, but no definite evidence of a fault was seen.

The southeastern part of the Cady Mountains, which border the valley on the west, is made up largely of Tertiary volcanic rocks. Limestone occurs at the celestite deposits in the southwestern part of T. 8 N., R. 7 E. A large part of the Cady Mountains is composed of granite or metamorphic rocks. The General Land Office plats of Tps. 9 and 10 N., Rs. 5 and 6 E., show broad valleys high up in the Cady Mountains and a dry lake or playa in the southwestern part of T. 10 N., R. 6 E.

The northern part of the mountains east of Broadwell, like the adjoining Cady Mountains, is composed of granitic rocks. For convenience these mountains may be called the Broadwell Mountains.

The northern border of the valley is an almost continuous mountain mass, but there is a narrow pass just north of Broadwell, which is filled with coarse subangular gravel and sand. This alluvium has been washed in from the mountains on each side in such a way as to completely block the drainage from Broadwell Valley, which otherwise would flow northward into the much lower Soda Lake Basin. About 3 miles south of the divide thus formed is a narrow, elongated playa. According to altitudes along the Tonopah & Tidewater Railroad the playa is at least 90 feet below the divide in the pass. On the basis of the data on ground water it is believed that the alluvium in the pass reaches 100 feet or more below the playa. (See p. 658.) The playa is of the dry type, hard and mud cracked. On its surface lie many small boulders of volcanic rocks that have been washed in from the near-by slopes.

The relation of Broadwell Valley to the adjoining valley presents some interesting features. A marked depression filled with alluvium extends from the vicinity of Barstow southeastward almost to Colorado River, but it is broken at several places by low divides. The divides at the southeast and southwest corners of Broadwell Valley constitute two of the breaks in this depression. The divide at the southwest corner is apparently formed of alluvium, although the conditions there could not be determined in the short time spent in that locality. The divide at the southeast corner of the basin is composed in part of Quaternary lava. It therefore appears entirely possible that as recently as early Quaternary time the depression may have been continuous across this area.

A glance at the geologic map (pl. 8) offers an alternative explanation. Although information is lacking for some areas the main mountain masses on each side of the depression are composed mainly of pre-Tertiary rocks. The large area of Tertiary volcanic rocks that borders Broadwell Valley lies between the older rocks as if filling part of an older depression. It is possible that the great Barstow-Bristol trough, whether it is an erosion valley or a fault trough, is older than the Tertiary lavas.

The break in the northern wall of the valley between the Cady Mountains and the Broadwell Mountains raises a question as to the former possible drainage of the valley through the pass into the Soda Lake Basin. As the water table is about 100 feet below the playa in the valley there is possibly underground drainage from the valley at some place, and it may be at Broadwell Pass. On the other hand, the drainage may flow to the southeast beneath or through the lavas east of Ludlow.

PRECIPITATION

The place nearest to the valley at which precipitation records have been kept is Bagdad, 22 miles southeast of Ludlow. The average annual rainfall there for a period of 16 years is only about 2.28 inches. The Broadwell Basin is a little higher than Bagdad, and the precipitation is doubtless a little greater. However, most of the valley is lower than Barstow, where the average annual precipitation is about 4.25 inches, and at Ludlow it is probably no greater.

GROUND WATER

WELLS

No springs are known in Broadwell Valley, and there are no wells in the valley at present that yield potable water. All the water used at Ludlow is hauled in.

Near Broadwell station, on the east side of the railroad about a quarter of a mile north of the edge of the playa, there is a dug well 115 feet deep. On November 27, 1917, the depth to water was 103 feet. There was no pump or other means of obtaining water from the well. The water is said to be very salty.

A small amount of water was obtained nearer the edge of the playa in a dug well 65 feet deep. In 1917 this well was dry. The water was brackish. On the west side of the playa, near milepost 7 on the Tonopah & Tidewater Railroad (approximately in sec. 8, T. 8 N., R. 8 E.), a well has been drilled to a depth of 400 feet by the Pacific Mines Corporation. It is said that salty water was struck, but the depth to water is not known. This company has drilled a number of holes around Ludlow and Stedman in connection with the development of its mines, but no definite information could be obtained other than that no good water was found.

In 1883, about the time of the completion of the railroad then owned by the Southern Pacific Co., a deep well was drilled at Ludlow. This well was never used. It was generally reported that the well was abandoned because the water was salty, but information recently furnished by the Atchison, Topeka & Santa Fe Railway Co. disproves this belief.

Sandstone was struck in the well at 760 feet and water at 785 feet. This water was cased off, and a second water-bearing bed, the nature of which is unknown, was struck at 1,084 feet. This water also was cased off, and drilling continued to a depth of 1,600 feet. No data are available as to the yield of the well. Approximate analyses of the water from the depths of 785 and 1,084 feet give about 435 and 550 parts per million of total solids respectively (recomputed from grains per gallon). Roughly, two-thirds of each sample consisted of carbonate and sulphate of lime. Unfortunately, several of the radicles are recorded together, so that it is not possible to determine the exact character of the water. The results show, however, that both the waters are fairly good both for domestic use and for boilers. The water could be improved for boiler use by treatment. Apparently the well was abandoned not because of the poor quality of the water but because when it was drilled it was not believed to be economical to pump from so great a depth. In recent years, with the increased cost of hauling water from Newberry Springs, it might now be more economical to pump from such a depth, and the railroad has contemplated a new well at Ludlow.

INTERPRETATION OF GROUND-WATER CONDITIONS

As stated previously, the playa near Broadwell is of the dry type. The great depth to water near the playa shows that undoubtedly there is underground drainage from the valley. The conditions in the pass to Crucero Valley north of Broadwell appear to be entirely favorable for underground drainage to occur at that place, but this is not certain.

According to approximate altitudes obtained from railroad profiles the water table in the dug well near Broadwell is about 1,200 feet above sea level. The first water-bearing bed in the deep well at Ludlow is about 1,000 feet above sea level. If the formations between the two wells are so permeable that water can move freely between them the difference in altitude would indicate that the underground drainage occurred at some place in the southern part of the basin. The water table in Lavic Valley, west of Broadwell Valley, is considerably higher, so that leakage can not occur in that direction. Southeast of Ludlow, however, in Bristol Valley, the water table is much lower. The divide along the railroad at Ash Hill, east of Ludlow, is composed of Quaternary volcanic rocks that may be underlain by alluvium or permeable Tertiary volcanic rocks. It thus seems entirely possible that drainage flows in this direction.

The apparent fact that the water in the well at Broadwell is salty and that the water in the well at Ludlow is not salty would indicate that there is not free movement between the two wells. However, no analyses of the water from the well at Broadwell are available to prove the supposed difference in quality. In view of the meagerness of data concerning the Ludlow well and other wells in the valley these suggestions in regard to ground-water conditions must be considered as mere conjectures. They should be considered, however, if further prospecting for water is carried on in the valley.

Further prospecting for water in Broadwell Valley will be warranted only for projects that can afford a considerable initial expense, with possibility of failure, and high pumping cost for relatively small quantities of water if successful. Development of water for irrigation is impracticable. In the lower part of the valley the lift is so great that only high-priced crops could be raised, and according to available information the water is too poor in quality for irrigation. Elsewhere in the valley, even if water of good quality can be obtained, the lift will be too great for profitable pumping.

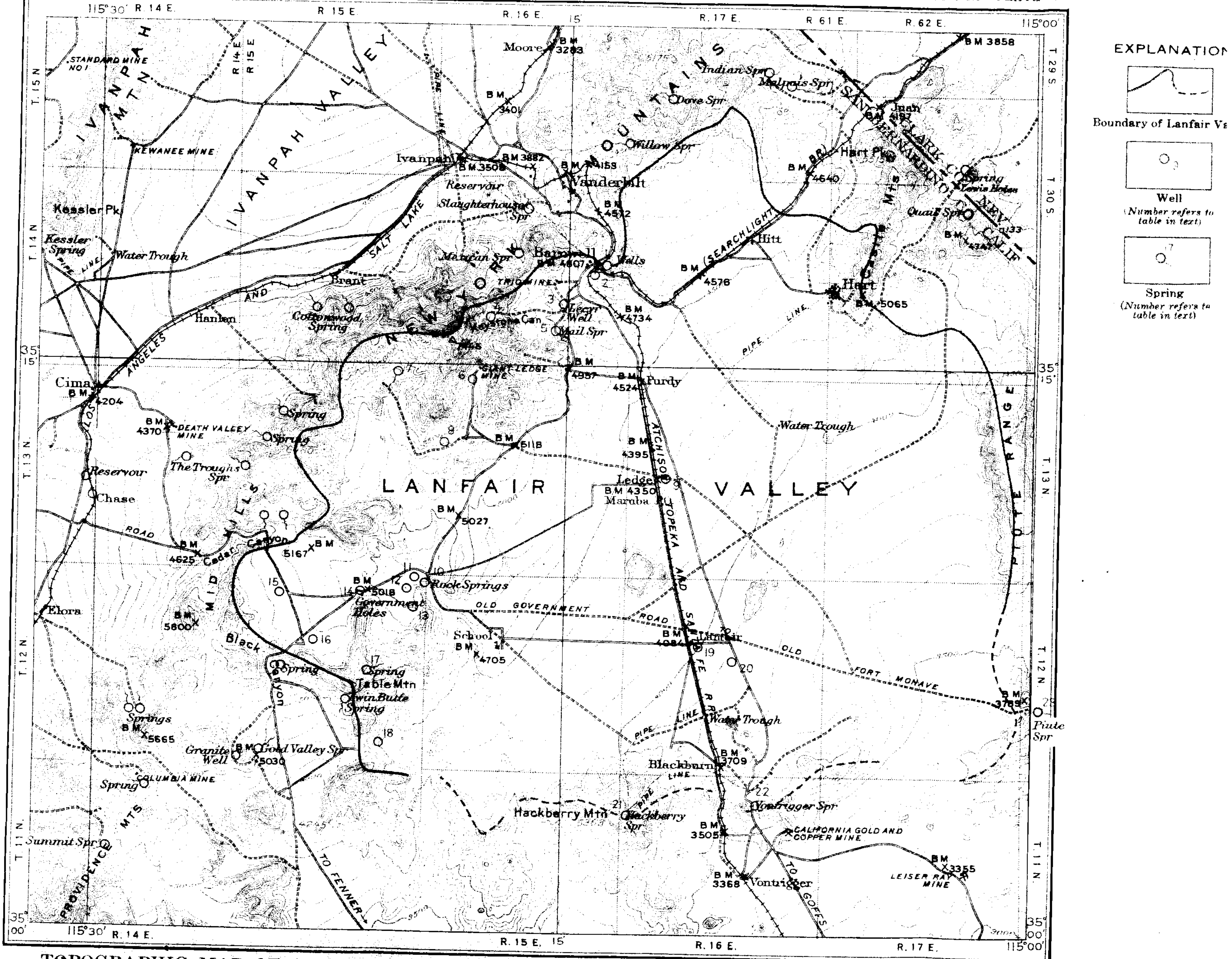
WATER SUPPLY FOR LUDLOW

As a supply of potable water is lacking in the valley, water for all purposes at Ludlow, including use in locomotives and at the mines at Stedman, is hauled by train from Newberry Springs, a distance of 32 miles. According to information furnished by the Atchison, Topeka & Santa Fe Railway, in 1919 about 16 cars, or nearly 170,000 gallons, were hauled to Ludlow daily. The water is emptied into a cistern and thence pumped into storage tanks from which it is distributed to the railroad yards and to the town. The rate for domestic use in 1917 was $2.50 a month for each house. The Tonopah & Tidewater Railroad obtained water for its engines at the rate of $1.55 for 1,000 gallons. When the mines at Stedman are running about two cars or 20,000 gallons a day are hauled to that place for domestic use and for a concentration mill.

BRISTOL-LANFAIR BASIN

GENERAL FEATURES

The Bristol-Lanfair drainage basin covers a large area in the eastern and southeastern parts of San Bernardino County. (See pl. 7.) The basin is roughly triangular in outline, and the apexes of the triangle are near Ludlow, near Barnwell, and on the extreme southern border of the Mohave Desert region in T. 1 S., R. 17 E.

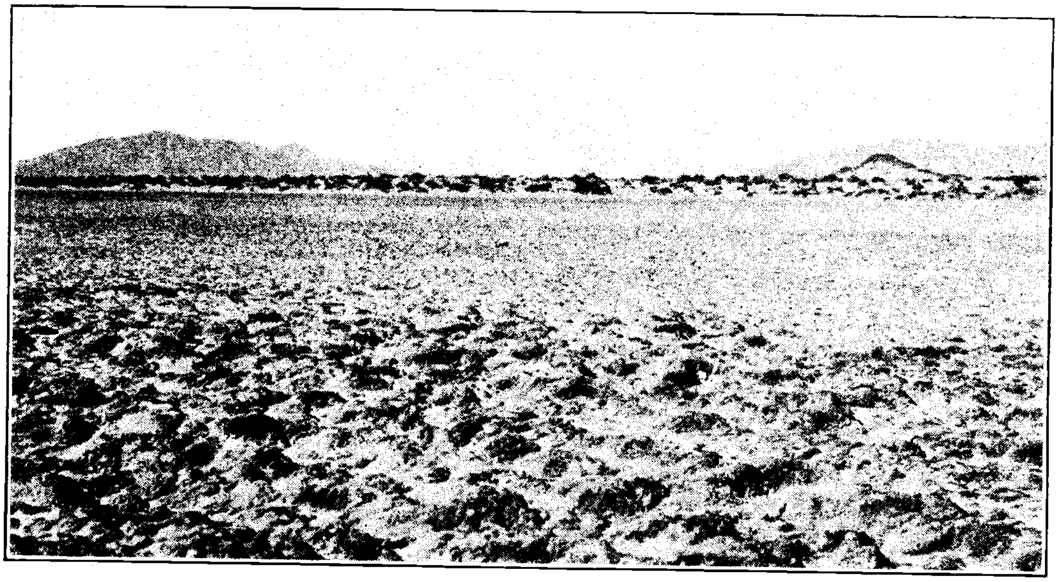


TOPOGRAPHIC MAP OF LANFAIR VALLEY AND VICINITY, SAN BERNARDINO COUNTY, CALIF.

Showing location of wells and springs

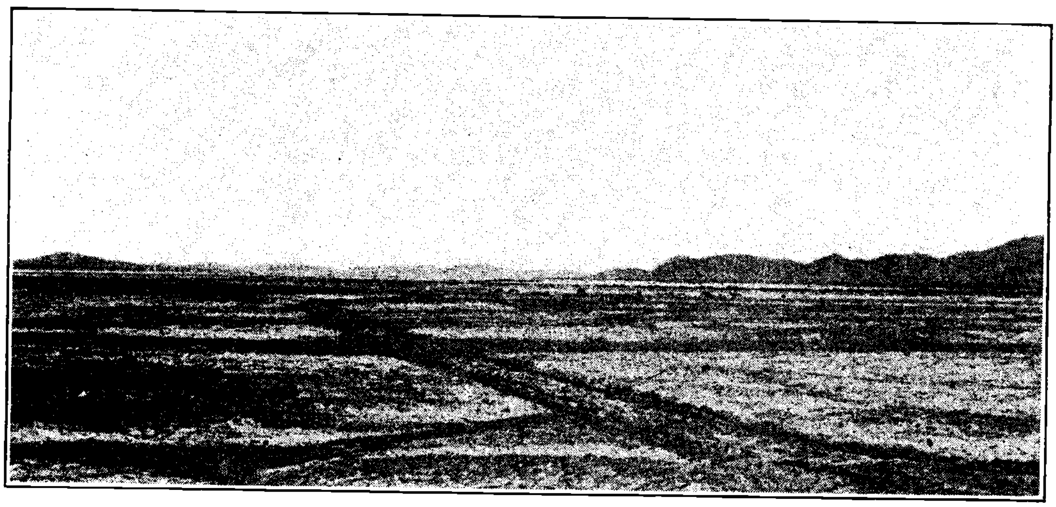
Scale $\frac{1}{250000}$

Part of U. S. G. S. topographic map of Ivanpah quadrangle



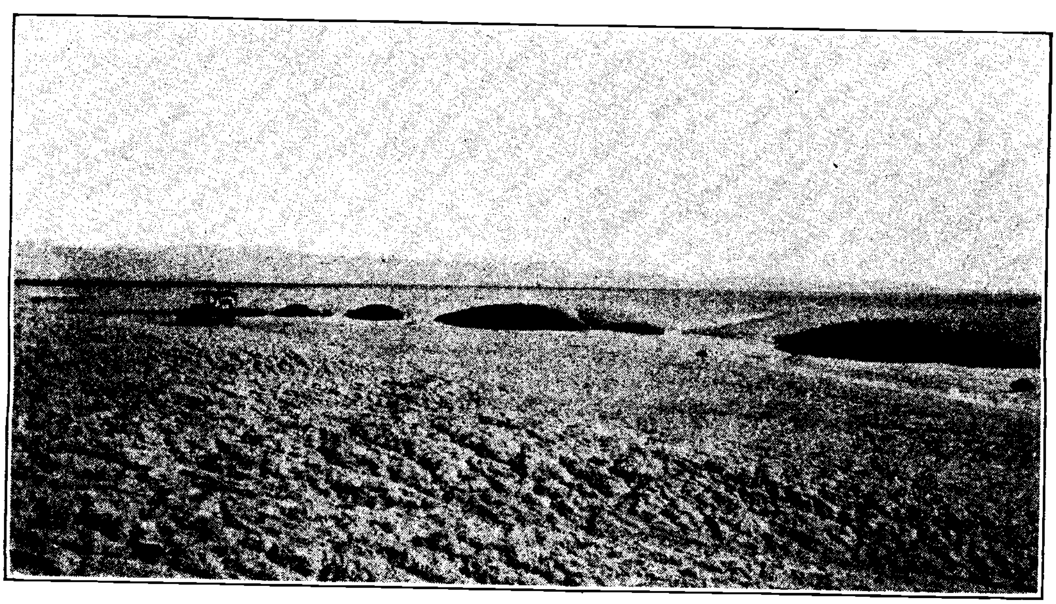
A. "SELF-RISING GROUND" ON SURFACE OF CADIZ DRY LAKE

Looking northeast toward Ship Mountain at left. Photograph by L. F. Noble



B. VIEW LOOKING SOUTH ACROSS DANBY DRY LAKE FROM A POINT ON PARKER ROAD ABOUT A MILE WEST OF WARD

Shows small channels crossing the playa. Iron Mountain at right. Photograph by L. F. Noble



C. LARGE EROSION CHANNEL CUTTING SURFACE OF DANBY DRY LAKE

The basin is broken into three units, each almost completely separated from the others and each more or less physiographically and geologically different. (See pls. 7 and 12.) These three units, with their approximate locations, are Lanfair Valley, which covers a small area in the northeast corner of the triangle; a somewhat larger valley, which extends almost north and south, for which the name Fenner Valley is proposed; and a much larger valley at the base of the triangle, extending from northwest to southeast, which constitutes what has been called the Bristol trough. As shown below, the Bristol trough is apparently divided into two valleys by a low alluvial divide. Each of these two valleys contains a playa, the northwestern one called Bristol Dry Lake and the southeastern called Cadiz Dry Lake. The two valleys may be designated by these names.

The total area of the drainage basin is about 3,045 square miles, of which Bristol Valley contains 1,170 square miles, Cadiz Valley 540 square miles, Fenner Valley 1,000 square miles, and Lanfair Valley 335 square miles.

A drainage line extends continuously from the summit of the New York Mountains in Lanfair Valley to the lowest part of the basin near Cadiz, about 600 feet above sea level. Whether the surface drainage from this great area goes to Cadiz Dry Lake or to Bristol Dry Lake is uncertain, but it is believed to reach Cadiz Dry Lake. However, the ground-water body is undoubtedly continuous between the two playas. The total length of this drainage line is about 70 miles, but seldom, if ever, does water flow the entire distance. Indeed, the traveler in crossing the wash in most places would scarcely recognize it as the main drainage line of so large an area. A less prominent drainage line extends from the northwest corner of the basin to Bristol Dry Lake, a distance of about 20 miles.

Of all the basins in the region covered by this report the Bristol-Lanfair basin is exceeded in size only by the Mohave River drainage basin, including the large area east of the Soda and Silver Lake Playas that is not directly tributary to Mohave River. The Amargosa drainage basin, including Death Valley, is much larger, but most of it is outside the area covered by this report. The total area of the Mohave River drainage basin is only about 600 square miles more than the area of the Bristol-Lanfair basin. It may seem strange that there is no stream in the Bristol-Lanfair basin comparable to Mohave River, but a comparison of the two basins shows dissimilar conditions. The run-off which really makes Mohave River originates in the San Bernardino Mountains. The maximum altitude of this part of the basin is about the same as that of the New York Mountains in Lanfair Valley. However, because of its location farther in the interior of the desert, the precipitation in the Bristol-Lanfair basin is undoubtedly less than that at equal altitudes in the San Bernardino Mountains. In addition there is this difference, which is perhaps fully as significant: In the San Bernardino Mountains the drainage from an area of about 215 square miles underlain by bedrock is concentrated into a single stream before it leaves the mountains. In the Bristol-Lanfair basin there is no such concentration of drainage, but the run-off is poured out onto the alluvial slopes by many small channels, where it is quickly absorbed. In Lanfair Valley several washes that drain most of the valley unite before reaching a pass about 10 miles north of Goffs, but these washes have passed over alluvium in which the run-off is mostly absorbed.

The valleys that comprise the Bristol-Lanfair drainage basin are described separately below, beginning with Lanfair Valley, the highest; then Fenner Valley; and finally Bristol and Cadiz Valleys, the lowest in the basin.

LANFAIR VALLEY

GENERAL FEATURES

Lanfair Valley lies in the east-central part of San Bernardino County. (See pls. 7 and 12.) The valley has been called Barnwell Sink,[25] but that name is not appropriate, for it is not a "sink," as that term is commonly used in the desert region to designate the bottom of a closed basin occupied by a playa in which a stream disappears because the water is evaporated or sinks into the ground. In an earlier more detailed report by the writer, which described ground-water conditions in the valley, the name Lanfair Valley is proposed because most of the settlement has been near Lanfair, and that town is not far from its center.[26]

Some years ago many settlers took up homesteads in this valley, most of them near Lanfair, and attempted to raise crops by dry farming. In the fall of 1917 more than 130 registered voters were living here. When the writer visited the valley in November, 1917, very few wells had been drilled in the valley, and very few data were available concerning the water supply.

Lanfair Valley was formerly traversed from north to south by the Barnwell and Searchlight branch of the Atchison, Topeka & Santa Fe Railway, which connected with the main transcontinental line at Goffs, 9 miles southeast of Vontrigger, but in 1927 service on this road had been discontinued. In 1917 there were small settlements at Lanfair, Ledge (Maruba post office), and Barnwell, and post offices at the first two places.[27] There was a small store at Lanfair,

[25] Tait, C. E., Irrigation resources of southern California: California Conservation Comm. Rept., p. 324, 1912.

[26] Thompson, D. G., Ground water in Lanfair Valley, Calif.: U. S. Geol. Survey Water-Supply Paper 450, pp. 29–50, 1920.

[27] In 1927 neither of the post offices was listed in the U. S. Postal Guide, and presumably they had been discontinued.

at which groceries and gasoline could be obtained. Purdy, Blackburn, and Vontrigger were merely railroad sidings, not settlements. Fair automobile roads connect the valley with the surrounding country. The Ivanpah and adjoining valleys may be reached by way of Barnwell. From Lanfair a road leads to Cima and the Valley Wells mining region by way of Rock Springs, Government Holes, and Cedar Canyon. A road leads southward, parallel to the railroad for part of the distance, to the much traveled National Old Trails Road at Goffs. Another road leads southwestward and then southward from Government Holes to the Atchison, Topeka & Santa Fe Railway and the National Old Trails Road at Fenner.

PHYSICAL FEATURES

The essential physical features of Lanfair Valley are shown on Plate 33. The valley is mostly a large alluvial plain that slopes southeastward with a nearly uniform grade of about 100 feet to the mile, though its continuity is at several places broken by small buttes of lava or by granite knobs. This plain is bordered on the west and north by the Mid Hills and the New York Mountains and on the south and east by several more or less detached mountain masses. The largest of these detached mountains are the Piute Range on the east and Hackberry Mountain on the south.

Most of the valley stands 3,500 to 5,000 feet above sea level, and two extensions of it west and northwest of Rock Springs rise nearly 5,500 feet above sea level. These two branch valleys reach almost to the summit of the Mid Hills, which form a small range in the rim between the Providence Mountains and the New York Mountains. At one place the almost flat surface of the southern branch valley has been slightly dissected by drainage lines that lead to Cedar Canyon. This canyon, which drains westward, has cut entirely through the former divide of the Mid Hills and is tapping the drainage on the east side of the mountains. In contrast to the long gradual slopes that reach almost to the summit on the east side of the range, the west side is steep.

The plain and adjacent mountain slopes form a nearly inclosed drainage basin, but there are several outlets on the south side through which the surface drainage moves southward. The principal outlet opens through a wide pass 6 miles east of Blackburn but partly through two narrow passes on the east and west sides of Hackberry Mountain. Nearly all the drainage channels lead southward to a large valley that extends from Goffs southwestward to a closed basin several miles south of Cadiz (see p. 12), the bottom of which lies about 600 feet above sea level. A very small part of the drainage of the valley possibly goes toward Colorado River by way of two canyons at its extreme eastern edge (see pls. 12 and 13), where the old

Government road to old Fort Mohave passes south of a small hill (marked "BM 3789") 10 miles east of Lanfair. These canyons drain through Piute Wash into Colorado River a few miles north of Needles, a distance of about 30 miles. On account of the arid conditions, however, the rain that falls in the basin seldom if ever reaches the basin south of Cadiz or Colorado River as surface run-off.

The drainage basin includes about 325 square miles. The alluvial slopes cover about 260 square miles, or 80 per cent of the basin; the mountains cover about 65 square miles. The basin includes no playas.

GEOLOGY

The main mass of the New York Mountains and the Mid Hills is composed of granite, which is flanked on the north and northeast by metamorphosed limestone, quartzite, gneiss, and schist, into which the granite is intruded. The sedimentary rocks have been mapped as of Cambrian age,[28] but Larsen[29] has found one or two fossils in them which he believes to be Carboniferous. At the south end of the Providence Mountains the granite is intruded into limestone which has been determined as Carboniferous.[30] The granite forms part of a large intrusive mass which covers many square miles and which extends at least as far as Marl Spring and Kessler Spring, west and northwest of Cima. In some of the low hills east of Blackburn and Vontrigger occur granite, diorite, and altered limestone.[31]

Volcanic rocks, mostly of Tertiary age, are abundant around the edges of the valley. Purplish extrusive rocks, probably rhyolite, occur on the road between Ivanpah and Barnwell. Rhyolite is found in the Castle Mountains, in the Hart mining district.[32] The Piute Range, which forms an imposing steep-sided mountain on the east border of the valley, is composed of volcanic rocks, as are Hackberry Mountain and the low hills west of it. The flat-topped mesas at the east foot of the Providence Mountains are composed of similar extrusive rocks. A prominent butte 2 miles north of Government Holes appears from a distance to be composed of the same series of light-colored rhyolite, latite, and tuff as those seen in Table Mountain and the hills south of this mountain, which have been described by Darton[33] as of Tertiary age. The extrusive rocks of Table Mountain obviously lie on the old erosion surface of the granite which forms the main mass of the New York Mountains and Mid Hills. The volcanic rocks near Barnwell and in the Castle Mountains are perhaps

[28] Geologic map of the State of California, State Mining Bureau, 1916.

[29] Larsen, E. S., personal communication.

[30] Mines and mineral resources of San Bernardino County, p. 53, California State Mining Bureau, 1917.

[31] Darton, N. H., Guidebook of the western United States, Part C, The Santa Fe Route: U. S. Geol. Survey Bull. 613, pp. 147–148, footnote, and maps 21 and 22, 1916.

[32] Hill, J. M., The mining districts of the western United States: U. S. Geol. Survey Bull. 507, p. 128, 1912.

[33] Darton, N. H., op. cit., pp. 147–148, footnote, and maps 21 and 22.

of the same age as those along the east and south sides of the basin, but their erosion and weathering suggest that they are somewhat older. Part of Lanfair Valley is underlain at no great depth by lava of Tertiary or Pleistocene age, which rests on older gravel, and this lava may have covered a large area.

The greater part of Lanfair Valley is covered with sand, gravel, and boulders washed down from the mountains on the west side of the valley. Well records indicate that near Lanfair the alluvium is underlain by volcanic material at depths of 4 to 50 feet, below which, at depths of 410 to 520 feet, lie still other beds of gravel. Moreover the hills composed of granite and lava, which crop out at many places in the valley, indicate that in some places at least igneous bedrock lies at no great depth beneath the gravel floor. The total depth to which the alluvium reaches is not known. The gravel which has been penetrated at depths of 400 to 500 feet is older than the overlying igneous rocks and is probably of late Tertiary or early Pleistocene age.

A mile or two south of Barnwell several tongues of very coarse alluvial conglomerate, the boulders of which consist mainly of blue quartzite, extend out from the foot of the mountains. These tongues rise 15 to 50 feet above the general level of the slope. They are apparently older than the present alluvial deposits and have been exposed by faulting along the east edge of the mountains. They are probably of Pleistocene age and may perhaps be correlated with the gravel that underlies the volcanic materials penetrated in the wells at Lanfair.

The northwestern slopes of the New York Mountains, the Mid Hills, and the Providence Mountains are much steeper than their southeastern slopes, and the rocky walls extend 1,000 to 2,000 feet lower on the northwest than on the southeast side. These differences in slope might be explained by assuming that the mountain mass on the northwest side of Lanfair Valley is a large fault block that has been uplifted on its northwest edge and tilted down on its southeast edge, but not enough is known of the geology to permit this assumption.

Another explanation of the difference in the slope of the northwest and southeast sides of the mountains is based on meager evidence obtained from wells in the valley. The gravel found at depths of 400 to 500 feet in the wells at Lanfair indicates that the floor of Lanfair Valley at one time stood at a lower level and that the southeast face of the New York Mountains and Mid Hills was probably once as precipitous as the northwest face is to-day. The sloping plain may have been formed by alluvial filling to a considerable depth. Faulting would thus not be involved in the explanation of the surface features of this large, high valley.

It is entirely possible, however, and indeed probable that the New York Mountains were originally formed by the uplifting of a large block of the earth's crust.

Lanfair Valley is bounded on the east by the Piute Range, which forms a barrier that prevents the drainage from its northern part from going toward Colorado River. This range is composed of volcanic rock, is nearly flat-topped, and has almost vertical sides. It may be an uplifted fault block, or it may be a remnant of a large body of lava which covered a much larger area but which is now mostly eroded. In either event the drainage from the valley at some earlier period probably reached Colorado River.

MINERAL RESOURCES

A number of mines in the mountains around Lanfair Valley have been active at one time or another, but the mineral production has not been great. Gold is found in the Castle Mountains, near Hart, where a shaft 900 feet deep had been sunk in 1917 and about 20 men were employed. The ore is said to be rich in spots. A mill had been built, but it was not being operated in the later part of 1917. Deposits of tungsten occur on the south side of the New York Mountains, and some ore has been shipped.[34] Gold, copper, tungsten, and some vanadium are found in the hills east and northeast of Vontrigger station, and considerable mining has been done in this district.[35]

CLIMATE

Mr. E. L. Lanfair kindly furnished the writer with incomplete records of precipitation at Lanfair for the period from March, 1912, to March, 1915. These records are given in the following table:

Monthly precipitation, in inches, at Lanfair, Calif.

[Altitude about 4,040 feet]

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1911–12	------	------	------	------	------	------	(a)	(a)	3.60	0.68	0.13	0.00	------
1912–13	0.60	0.25	(b)	1.28	(b)	0.10	0.39	[c] 2.98	(b)	(b)	(b)	(b)	[d] 5.60
1913–14	1.29	1.43	0.63	(b)	1.56	(b)	2.32	3.39	.53	1.01	(b)	.46	[d] 12.62
1914–15	1.05	.19	2.29	3.16	(b)	(b)	.30	5.70	(a)	(a)	(a)	(a)	[d] 12.69

[a] No record.
[b] It is not clear from Mr. Lanfair's record whether an absence of data for certain months indicates no precipitation or a suspension of observations.
[c] Does not include a 6-inch fall of snow on Feb. 22, which was not measured in inches of rain
[d] Record for year probably incomplete.

As the record for Lanfair is not complete for any single year, it furnishes no ground for definite conclusions. The average annual precipitation of the three years as given in the table is 9.77 inches. A comparison of the record with the records for the same period at

[34] Mines and mineral resources of San Bernardino County, California State Mining Bureau, p. 68, 1917.
[35] Idem, pp. 11, 69–78.

Needles, Jean, Bagdad, and Barstow shows that in the months in the seasons 1912–13 and 1913–14 for which the record is lacking there was probably no precipitation. On the other hand, in November, December, March, April, and May of the season 1914–15 there was considerable rainfall at one or more of these points. The total for 1914–15 at Lanfair may therefore be low. A study of the records at Las Vegas, Nev.; Needles, Calif.; and Parker, Ariz., shows that the precipitation for 1913–14 and 1914–15 was 23 to 65 per cent above the average precipitation during periods of 11 to 30 years. On this basis the average annual precipitation at Lanfair for the two years as recorded would be about 9 inches. This is somewhat greater than the average precipitation at other stations in the Mohave Desert region except those on the slopes of the San Bernardino, San Gabriel, and Tehachapi Mountains. Settlers in the valley state that the precipitation at Lanfair is less than at points farther west, on the eastern slope of the mountains. In winter, especially, several inches of snow may fall in the mountains while practically no rain or snow falls at Lanfair. The rainfall in the valley is probably about 10 inches. That the precipitation in the New York Mountains is greater than in most of the desert region is believed to be shown by the presence of sagebrush and piñon.

The rainfall at Lanfair is well distributed throughout the year, but a large percentage of it occurs in July, August, and September, probably in summer thunderstorms. The conditions are similar to those at Las Vegas, Fort Mohave, Needles, and Parker, where long-time records show that there is a late summer wet period as well as a winter wet period. (See pp. 88–91.)

No records of temperature at Lanfair are available. Because of the high altitude, the maximum summer temperatures are probably not very high. The winters at Lanfair are probably slightly colder than at lower levels, and frosts are probably more common.

VEGETATION

The vegetation of Lanfair Valley is characterized by an abundance of spine-bearing forms, such as the cactus commonly called cholla, which grows profusely; the yucca, known as the Spanish dagger; and the Joshua tree, or giant yucca. Arid-land grasses are also found, such as galleta and a form known as grama grass. In the upper part of the valley near Government Holes, more than 5,000 feet above sea level, there is a flourishing growth of sagebrush (*Artemisia tridentata*) and piñon and probably some juniper. The creosote bush, which is the prevailing species in most of the Mohave Desert region, is very rare; it was noticed by the writer only on the north side of the Hackberry Mountains near Blackburn and in one small tract near Ledge. The comparative absence of creosote bush and the abundance of the cactuses, grasses, sagebrush, and piñon is believed to be due to the slightly greater rainfall that occurs elsewhere in the Mohave Desert region. Cat's-claw was seen in washes just west and south of Blackburn. None of the forms that indicate ground water at slight depth, such as mesquite and salt grass, were seen.

The grasses available for cattle forage are more abundant in the upper part of the valley than in almost any other locality in the Mohave Desert region, and several hundred head of cattle are grazed.

WATER RESOURCES

There are no permanent streams in Lanfair Valley, nor any which flow except immediately after storms. The water supply of the valley is derived entirely from the rain and snow that fall there and from the ground water, which is itself derived from the precipitation. A number of wells have been drilled within the border of the mountainous area, and as the conditions that govern the occurrence of ground water there are different from those in the main part of the valley the two parts will be considered separately. The locations of wells for which data are available are shown on Plate 33, and the data are summarized in the table on pages 672–673.

GROUND WATER IN UPPER PART OF VALLEY

Water is found at a number of places in the New York Mountains and Mid Hills at comparatively slight depths. At Barnwell the Rock Springs Cattle Co. has dug a well (No. 1 [36]) 62 feet deep, in which water stands 48 feet from the surface. On the west side of the railroad at Barnwell there are two wells, one about 60 feet and the other about 90 feet deep, but the depth to water in them is not known. At this station the Atchison, Topeka & Santa Fe Railway Co. in 1905 drilled a well 457 feet deep (No. 2), which is now abandoned. According to the log furnished by the railroad company, the material penetrated from 4 to 242 feet was granite, from 242 to 347 feet clay and sand, from 347 to 362 feet cemented gravel, and from 362 to 457 feet granite. The reported occurrence of granite from 4 to 242 feet is doubtless an error in the interpretation of the drill cuttings, as it would be practically impossible for unconsolidated sand and gravel to underlie granite. The formation called granite is probably either débris which has been washed in and which was formed from the weathering of granite and hence resembles it or perhaps the material is some kind of volcanic rock, for such rocks occur near by. The depth to water in this well was 73 feet, and the supply was ample. During a pumping test of 24 hours the well furnished 20 gallons a minute. The well was abandoned, probably because the water was unsuitable for use in locomotive boilers. The Lecyr well

[36] The numbers given in the text correspond to those given on the map (pl. 33) and in the table on pp. 672–673.

(No. 3) is dug in a sandy wash. When visited by the writer it was tightly covered and could not be measured, but the pumping equipment indicates that the depth to water is probably not great.

Water is obtained at moderate depths in several wells west and southwest of Rock Springs (Nos. 11 to 14). The deepest of these wells is 32 feet deep, and the depth to water is from 4 to 29 feet. Granite was reached in several of them.

The quantity of water available in any of these wells is apparently not great. The well of Mr. Moore (No. 16) yields 11 gallons a minute, and if the rate of pumping is increased the well is pumped dry. The largest quantities pumped from the Emdee and Barnett wells are about 1,000 gallons a day each. Although the actual capacity of these wells is not known they could probably be pumped dry easily with power pumps.

All the wells mentioned that are west and southwest of Rock Springs are near the foot of granite hills, where solid rock lies close to the surface. They are apparently supplied from rain water, which percolates downward to the surface of the solid rock, along which it moves toward lower levels. If the wells mentioned were pumped heavily the water would probably be lowered considerably, as the small tracts in which the wells are dug do not contain a sufficient supply to withstand heavy drafts. During years of normal precipitation the water in the ground is sufficient to keep the water table rather near the surface, and in some places it returns to the surface in springs, such as Rock Springs, which emerge in a small canyon that heads in the wide valley west of the springs. During a series of unusually dry years the supply of ground water would probably be rapidly diminished. At the end of the dry fall of 1917 Rock Springs were practically dry, and other springs in the New York Mountains and Mid Hills were also reported to be dry.

There is no reason to believe that any large quantity of water could be obtained by drilling wells into the bedrock.

GROUND WATER IN MAIN PART OF VALLEY

In the main part of Lanfair Valley the depth to the water table is apparently much greater than in the marginal parts, where rock lies close to the surface and prevents the rain water from sinking to great depths. Information is available concerning only three wells drilled on the alluvial slopes that compose the surface of the greater part of the valley. As far as is known, no other wells had been drilled on these slopes at the time the field investigation was made. At Ledge (Maruba post office) Mrs. E. J. Jacoby has drilled a well (No. 9), which could not be measured, but the owner, who had purchased the land since the well was drilled, stated that it was 879 feet deep and that water was struck at a depth of 365 feet and rose within 100 feet of the surface. According to information from other sources, the water did not rise nearly so high and stands 350 feet from the surface. The well furnished about 20 gallons a minute. No log of the strata penetrated is available. At Lanfair Mr. E. L. Lanfair has drilled a well (No. 19) 550 feet deep. Gravel was penetrated to a depth of 52 feet, below which to a depth of 520 feet was material described as volcanic ash. Fragments of the drill cuttings examined by the writer seemed to be composed of a rhyolitic rock. A bed of water-bearing gravel was entered at a depth of 520 feet and extends to the bottom of the well. The water rose within 500 feet of the top. Mr. Lanfair has drilled another well (No. 20), also 550 feet deep, about a mile southeast of the one just described. In this well volcanic ash was struck at a depth of only 4 feet and extended to a depth of 410 feet, where gravel was found, which reached to the bottom of the well. Water was found in the gravel at 410 feet and rose 10 feet in the well. According to approximate altitudes determined from the topographic map, the water level in the Jacoby well is at least 450 feet higher than it is in the well at Lanfair, and if the water is within 100 feet of the surface, as reported by the owner, it is 700 feet higher. The difference in the surface elevation is only about 300 feet.

Though the data afforded by the wells in the valley are meager they disclose three significant facts:

First, the depth to water is great.

Second, the water is confined in deeply covered gravel under sufficient pressure to rise somewhat in wells when the overlying beds are penetrated but not under sufficient pressure to rise near the surface. The conditions mentioned above, together with the occurrence of large masses of volcanic rock on the borders of the valley, indicate that a large part of the alluvial slope is underlain at a slight depth by volcanic material. In both of Mr. Lanfair's wells this material was reported as volcanic ash, but it may include ash, tuff, rhyolite, or other extrusive rocks.

Third, the fact that the water stands at a much higher level in the well at Ledge than in the well at Lanfair indicates that the underground conditions are not uniform throughout the valley—that the structure of the rocks affects the ground-water level. Low hills 3½ miles northeast of Lanfair and a low ridge that extends from the Castle Mountains to a point about 4½ miles south of Hart suggest that a rock barrier may cross the deeply buried gravel in such a way as to dam the water west of these hills, so that it is held under greater pressure than the water on the lower side of the barrier.

The great depth to water in Lanfair Valley is due chiefly to the high altitude of the valley above the bottom of the basin into which it drains—the basin south of Cadiz—and to the steepness of the alluvial slope. The water in the detrital material is drained toward

Goffs and thence to the basin near Cadiz. Data furnished by the Atchison, Topeka & Santa Fe Railway Co. in regard to the level of water in its wells show that the water table in the valley both southwest and east of Goffs lies at a considerable depth. At Goffs the depth to water in 1917 was 606 feet, at Homer in 1902 it was 608 feet, at Fenner in 1906 it was 460 feet, and at Danby in 1903 it was 268 feet. Thus the conditions facilitate the draining away of any large quantity of water that might pass into the upper gravel in Lanfair Valley. The low rainfall also prevents any great accumulation of ground water.

Not only is some ground water lost by percolation toward Goffs, but some may come to the surface in springs. As nearly as could be ascertained Piute Spring (No. 23) is just outside the eastern border of the valley in a canyon south of the hill marked "BM 3789," about 11 miles from Lanfair. (See pl. 13.) This canyon has been cut back so far that it receives some drainage from Lanfair Valley. The spring was not visited by the writer, but it is said to be one of the strongest in San Bernardino County, and the water is said to flow down the canyon for nearly a mile. This spring issues below the level to which water rises in the wells at Lanfair, and the strong flow may come from the gravel, which is deeply buried at that place.

In November, 1917, several persons planned to drill wells in the near future, but as late as June, 1918, none of them had done any drilling. A number were confident that wells drilled about 3 miles west of Lanfair would find water at depths of less than 200 feet, because the surface drainage here goes southward toward Hackberry Mountain, which they believed holds the ground water at a somewhat higher level than at Lanfair, on the assumption that the ground water moves in the same direction as the surface flow. The land on which these wells would be drilled lies 200 to 400 feet above the base of Hackberry Mountain, so that even if the water table on the north side of the mountain is near the surface the depth to water in the wells would still be great. Moreover, there are no indications that the water table at the foot of the mountain is close to the surface. Water does not come to the surface in the short canyon between Blackburn and Vontrigger, through which much of the surface run-off goes, nor is there any vegetation in this canyon—such as running mesquite and arrow weed—to indicate that water lies near the surface. Although the depth to the water table is doubtless much less in this canyon than at Lanfair, it is probably at least 50 feet, and at points farther northwest, up the alluvial slope, it increases. Unless some concealed structural feature causes the water level to stand higher here than at Lanfair, and there are no surface indications of any such barrier, the depth to water at places 3 or 4 miles west of that town will probably be fully as great as it is in the wells described.

At Lanfair the water-bearing bed slopes less steeply than the surface. If the water-bearing bed bears the same relation to the surface in areas near the south and southeast borders of the valley, where the low mountains may tend to hold the water back, it will probably lie not so deep in these areas as at Lanfair, a probability indicated by Piute Spring, but as the little information that is available indicates that the depth to water on the alluvial slopes is great, no one should begin to drill a well unless he is prepared to go to a depth of 300 to 500 feet.

WELL DATA AND ANALYSES

Data in regard to the wells in Lanfair Valley are given in the following table:

Record of wells and springs in Lanfair Valley, Calif.

Number on pl. 33	Location			Owner of well or name of spring	Depth of well (feet)	Depth to water level in well, Nov., 1917 (feet)	Remarks
	Sec.[a]	T. N.	R. E.				
1	[b] 13 (?)	14	16	Rock Springs Cattle Co.	62	48	At Barnwell; equipped with windmill.
2	[b] 13 (?)	14	16	Atchison, Topeka & Santa Fe Ry.	[c] 457	[c] 73	At Barnwell; drilled in 1903. Abandoned. See analysis on p. 674.
3	[b] 23 (?)	14	16	Lecyr well, controlled by Rock Springs Cattle Co.			Dug well in a wash about 1½ miles southwest of Barnwell; equipped with galvanized-iron tank, concrete water trough, and windmill. Pumps at least 12 gallons a minute. See analysis, p. 674.
4	[b] 29 (?)	14	16	Spring			
5	[b] 27 (?)	14	16	Mail Spring			
6	[b] 5 (?)	13	16	Spring			
7	[b] 2 (?)	13	15	do			
8	[b] 18 (?)	13	16	do			
9	S. ½ 18 [d]	13	17	Mrs. E. J. Jacoby	879	100	12-inch drilled well at Ledge. Water reached at 365 feet; rose in well to 100 feet from surface. No solid rock encountered. Capacity, 11,000 gallons in 10 hours. See analysis, p. 674.
10	[b] 1 (?)	12	15	Rock Springs, controlled by Rock Springs Cattle Co.			Water comes from between granite boulders in a wash. Probably supplied by shallow ground-water flow. Nearly dry in January, 1918.
11	[b] 1 (?)	12	15	Beaty well	30 (?)	29 (?)	Dug.
12	[b] 1 (?)	12	15	Emdee well	18 (?)	8 (?)	Dug. Reported to supply 25 barrels a day.
13	[b] 12 (?)	12	15	Barnett Mining Co.	20 (?)	8 (?)	Do.
14	[b] 3 (?)	12	15	Government Holes, owned by Rock Springs Cattle Co.	[c] 32	[c] 15	Dug well. Equipped with small engine.
15	[b] 5 (?)	12	15			[c] 4	Shallow dug well at foot of low granite knob. A small pond stands near it.
16	[b] 16 (?)	12	15	A. E. Moore	[c] 13	[c] 7	Dug. Supplies 11 gallons a minute. See analysis, p. 674.
17	[b] 23 (?)	12	15	Spring			
18	[b] 25 (?)	12	15	do			

[a] Field investigations of the United States General Land Office show that great errors have been made in the location of the township lines in Lanfair Valley. The lines shown on Plate 33 are probably not accurate, but as the true positions of the lines are not known, the locations are referred to the lines shown on the map.

[b] On unsurveyed land. The location given is only approximate, according to imaginary lines continued from the township and range lines in the vicinity of Lanfair.

[c] Measured by the writer.

[d] Location given by owner.

Record of wells and springs in Lanfair Valley, Calif.—Continued

Number on pl. 33	Location: Sec.	Location: T. N.	Location: R. E.	Owner of well or name of spring	Depth of well (feet)	Depth to water level in well, Nov., 1917 (feet)	Remarks
19	SW. ¼ 8 [d]	12	17	E. L. Lanfair	550	500	6-inch drilled well. Water struck at 520 feet; rose to 500 feet. Gravel, 0 to 52 feet; volcanic ash, 52 to 520 feet; gravel, 520 to 550 feet. Supplies 16 gallons a minute.
20	SW. ¼ 16 [d]	12	17	do	550	400	10-inch drilled well. Gravel, 0 to 4 feet; volcanic ash, 4 to 410 feet; gravel, 410 to 550 feet. Supplies about 35 gallons a minute.
21	7 (?)	11	17	Hackberry Spring, controlled by Rock Springs Cattle Co.			Water is diverted into two pipe lines. A pipe at a cattle trough 1½ miles northwest of Blackburn flowed 3½ gallons a minute from a 1½-inch pipe in November, 1917, probably not maximum flow of spring.
22	3 (?)	11	17	Vontrigger Spring, owned by Mrs. M. L. White.			Flows about 5 gallons a minute. Used for irrigating fruit trees.
23	19 (?)	12	19	Piute Spring			Said to be a strong spring.

[d] Location given by the owner.

QUALITY OF WATER

Samples of water from three wells (Nos. 3, 9, and 16 on pl. 33) in Lanfair Valley were collected by the writer and were analyzed in the laboratory of the United States Geological Survey. An analysis of water from a well (No. 2) drilled at Barnwell by the Atchison, Topeka & Santa Fe Railway Co. but now abandoned was furnished by that company. The results of the analyses are given in the table on page 674.

The waters analyzed range in total content of solids from 229 to 1,992 parts per million, but three of them contain less than half as much mineral matter as the fourth. The most highly mineralized water, that from the Lecyr well (No. 3), is used only for cattle. The water from the Lecyr well is bad for domestic use because of its extreme hardness and its high content of sulphate. It is essentially a calcium sulphate water, such as is found near gypsum deposits, although no such deposits are known to exist in the region.

The water from the well of Mrs. E. J. Jacoby, at Ledge (No. 9), is good for domestic use and for irrigation. This water comes from a depth of about 365 feet. The water from the deep wells at Lanfair is probably somewhat similar to it.

The water from the well of A. E. Moore (No. 16), the only other water used for a domestic supply, is of fair quality for drinking and cooking but causes trouble in washing because of its hardness. This sample probably represents the water obtained from shallow wells in the high valleys on the western edge of Lanfair Valley.

The water from the abandoned well of the Atchison, Topeka & Santa Fe Railway at Barnwell (No. 2) is of fair quality for drinking and cooking, but because of its hardness it is not very satisfactory for washing. It is bad for use in boilers because of its large content of scale-forming constituents and its tendency to corrode boilers. The well was probably abandoned because its water was of poor quality for use in locomotive boilers.

The results of the four available analyses of water from wells in this valley appear to show that the ground water is satisfactory for use in irrigation.

Mineral analyses of ground waters in Lanfair Valley

[Parts per million except as otherwise designated. Numbers at heads of columns refer to corresponding well numbers on Plate 33]

	2	3	9	16
Quantities determined:				
Silica (SiO_2)	14	32	32	36
Iron (Fe)	----	.59	.29	.19
Calcium (Ca)	134	308	35	86
Magnesium (Mg)	50	74	7.0	33
Sodium and potassium (Na+K)	71	[a] 172	[a] 35	[a] 126
Carbonate radicle (CO_3)	.0	.0	.0	.0
Bicarbonate radicle (HCO_3)	382	186	173	422
Sulphate radicle (SO_4)	208	1,006	23	152
Chloride radicle (Cl)	117	175	19	84
Nitrate radicle (NO_3)	----	.08	.08	.31
Total dissolved solids at 180° C.[b]	782	1,992	229	731
Total hardness as $CaCO_3$	540	1,070	116	350
Date of collection	Mar. 23, 1903.	Nov. 5, 1917.	Nov. 5, 1917.	Nov. 22, 1917.
Analyst	(c)	C. H. Kidwell.	F. E. Keating.	F. E. Keating.

[a] Calculated.
[b] By summation.
[c] Analysis furnished by Atchison, Topeka & Santa Fe Railway Co., Arizona division, water analysis No. 4560; recalculated from hypothetical combination in grains per U. S. gallon. This water contains 5.1 parts per million of free CO_2.

AGRICULTURE

Although many homesteaders were living about Lanfair in 1917, only three of them possessed their own domestic water supplies. The others were forced to haul water for all purposes and often had to pay for it. A number of them hauled water from the wells west of Rock Springs and from springs in the mountains.

Most of the settlers have attempted dry farming. The crops that have been tried include milo maize, varieties of field corn, and beans. The small grains have been sown in the fall, and the corn and beans in the spring. Some fair crops have been obtained, the most successful of which were grown well up on the alluvial slope, a short distance east of Rock Springs—that is, in that part of the valley where the rainfall is usually greatest because of the influence of the mountains. None of the crops have proved as successful as had been hoped.

The average annual precipitation at Lanfair is probably not more than 10 inches and in some years it is doubtless considerably less. Dry farming has generally been considered impracticable where the precipitation is as low as 10 inches and where the evaporation is as great as it doubtless is in Lanfair Valley.[37] The rainfall at Lanfair, as shown in the table on page 666, is not confined principally to any particular season but is distributed through the year, and some of it comes when it can do no appreciable good. On the other hand, some of the rain falls in heavy thundershowers, when it may do more damage than good. The prospects of the dry farmer in the valley do not seem to be bright. At the best, he will be laboring precariously in that borderland which separates success from failure.

Only a little irrigation has been attempted in Lanfair Valley. Mrs. E. J. Jacoby has used water from her well at Ledge to irrigate about an acre of melons and garden truck. Mr. A. E. Moore has irrigated a few fruit trees at his ranch, 2 miles southwest of Government Holes (well 16, pl. 33), but he states that the climate is too uncertain early in the spring to allow the trees to thrive. Mr. Moore used water from a shallow dug well, which yields about 11 gallons a minute. In the high valleys west and northwest of Rock Springs the supply from the shallow wells is doubtless sufficient for household use and for the irrigation of small tracts, but it would be insufficient to irrigate a large tract. In this part of the region, however, because of the high altitude, the precipitation is probably considerable, so that if proper methods are used a large amount of water would not be required. The water from Vontrigger Spring (No. 22) was used in 1917 by Mrs. M. L. White to irrigate about 140 peach, apple, and other fruit trees, and some grapes on her ranch half a mile south of the spring. The spring fills in about 60 hours a concrete reservoir that has a capacity of about 20,000 gallons. In November, 1917, the trees had been planted 2½ years and had produced good fruit. Mr. Lanfair, who owns the well at Lanfair and the well about a mile southeast of it, expected to irrigate a few acres in 1918 with water from a spring in the mountains 8 miles west of his ranch. The water is piped to a concrete reservoir near the railroad that has a capacity of about 15,000 gallons. The spring furnishes about 1,000 gallons a day.

The quality of the ground water in the valley seems to be satisfactory for irrigation, but the supply is apparently nowhere sufficient, and the cost of the high lift required to bring the water to the surface in the main part of the valley prohibits its use for irrigation, except possibly for especially valuable crops, such as garden produce or fruit trees. The conditions are not favorable for the development of practical irrigation. Wells for domestic supply and for watering stock can probably be obtained throughout the valley, but because of the great depth to which they must be drilled their cost will be rather great.

[37] Briggs, L. J., and Beltz, J. O., Dry farming in relation to rainfall and evaporation: U. S. Dept. Agr. Bur. Plant Industry Bull. 188, p. 8, 1911. This bulletin deals with the conditions affecting dry farming that are not within the control of the farmer and that should be understood by him.

FENNER VALLEY

GENERAL FEATURES

Fenner Valley is a broad valley that extends from the Marble and Ship Mountains northeastward to low mountains and hills that lie just north of latitude 35°. The boundary of the valley is shown on Plate 7.

The main line of the Atchison, Topeka & Santa Fe Railway runs along the southeast side of the valley. From Goffs, at the northeast end of the valley, a branch line formerly led northward to Lanfair Valley and Searchlight, Nev., but it has been abandoned. The National Old Trails automobile road parallels the main line of the railway. At Danby a road leads south from it to the Parker branch of the Santa Fe at Kilbeck siding, where it joins a road from Cadiz to Parker and Phoenix, Ariz. (See p. 689 and pl. 12.) The road from Danby is somewhat better than the road from Cadiz. Many persons who are going to Parker, however, continue along the National Old Trails Road to Needles and thence go south. (See p. 729.) From Danby a road leads east to prospects in the north end of the Old Woman Mountains and thence south along the east side of those mountains to Milligan, in Ward Valley. (See p. 705.) From Fenner a road goes west to prospects at the south end of the Providence Mountains. A road also leads northwest from Fenner to the Bonanza King mine, a distance of 22 miles, and to near-by prospects. A branch from this road, about 4 miles from Fenner, leads to cattle ranches in the New York Mountains, to Cima, a distance of 40 miles, and to Lanfair Valley. From Goffs a road leads northward to Lanfair Valley and Ivanpah Valley. There are also a number of short roads to mine prospects in different parts of the valley.

Goffs is the only settlement of note in the valley, and it has only a few families. In 1918 it had a small hotel and a good general store. Smaller stores were situated at Fenner and Danby. There are railroad pumping plants at each of these places and also at Siam, and in addition water can be obtained in emergency from section crews at Essex and Pinto sidings. Arimo, on the main line of the railroad, and Vontrigger, on the Searchlight branch, are only sidings, where neither water nor supplies may be obtained.

The only agricultural industry in the valley is cattle raising. A comparatively small number of cattle are grazed in the northern and northwestern parts of the valley.

The numerous mines and prospects in the mountains that border the valley, especially in the Providence Mountains, are described briefly below in the section on mineral resources.

PHYSICAL FEATURES AND GEOLOGY

Fenner Valley consists largely of a great sloping plain that is broken at several places by hills or low mountains. The plain slopes in a general southwesterly direction. A main drainage way extends approximately parallel to the Atchison, Topeka & Santa Fe Railway and a short distance north of it, from Goffs to the junction of the valley with Bristol Valley near Cadiz. The plain rises toward the northwest and southeast from this drainage way. This wash, however, lies nearer the southeast side of the basin, so that the greater part of the plain lies north of it.

The hills and mountains that surround the valley are mostly of relatively small areal extent. The Providence Mountains, on the northwest side of the basin, rise to an altitude of more than 6,000 feet and form one of the highest ranges in the interior of the Mohave Desert region. Despite their great height they are relatively narrow as compared with such other high mountains as the Panamint Range, the Kingston Range, the Avawatz Mountains, the Bullion Mountains, and the Old Woman Mountains. The Marble Mountains, which border the valley on the southwest, constitute a long, narrow range, mostly less than a mile in width. The Piute Mountains on the east and Hackberry Mountain and adjoining hills that form the northeastern border are comparatively narrow. The valley is broken by one large mountain—Clipper Mountain—that rises almost from its center. Smaller rock hills rise at several other points. The mountainous area tributary to the basin comprises about 300 square miles, or about 30 per cent of the total area.

The greater part of the Providence Mountains is composed of Paleozoic sedimentary rocks, but the south end of the range consists of monzonite and a small mass of rhyolite forms one of the highest peaks in the center of the range.[38] A small patch of Tertiary volcanic rocks lies near the summit of the range. Hackberry Mountain and the hills that form the northern border of the valley are composed of Tertiary volcanic rocks. The Piute Mountains and Old Woman Mountains are composed largely of granite and schist, but they contain patches of Tertiary volcanic rocks and of limestone. The granite and schist in these mountains, according to Darton,[39] are of pre-Cambrian age. The Ship Mountains are composed of Paleozoic sediments, post-Carboniferous intrusive rocks, Tertiary volcanic rocks, and at the northeast end Quaternary volcanic rocks. The Marble Mountains,[40] north of Cadiz, comprise a basement of

[38] Jones, C. C., An iron deposit in the California desert region: Eng. and Min. Jour., vol. 87, pp. 785–788, 1909.

[39] Darton, N. H., Guidebook of the western United States, Part C, The Santa Fe Route: U. S. Geol. Survey Bull. 613, sheet 3, 1915.

[40] See footnote 49, p. 103, in regard to the use of the names Marble Mountains and Iron Mountains.

pre-Cambrian granite, overlain by Cambrian and Carboniferous sedimentary rocks, which in turn pass beneath Tertiary eruptive rocks.[41] The sedimentary rocks, which consist of quartzite, sandstone, shale, conglomerate, and limestone, dip at a high angle toward the east. Clipper Mountain is made up largely of Tertiary volcanic rocks, but a part of its northeast end is pre-Cambrian granite, and adjoining it Darton has mapped one very small area of Paleozoic sedimentary rocks.

Fenner Valley has the appearance of being a great alluvium-filled valley, but according to the logs of wells drilled by the railroad at Goffs, Fenner, Danby, and Siam, the valley is underlain at no great depth by volcanic rock or other bedrock. The logs of these wells, as furnished by the railroad, are given on pages 680–682. The logs apparently are not very reliable, for although at each station there are two wells not more than 400 feet apart, there is considerable disagreement between the logs of adjoining wells. Furthermore, in view of the geologic history of the region it is unlikely that granite would be found above volcanic rocks, as is reported in several logs. In such wells the so-called granite may either be some phase of volcanic rock that resembles granite or it may be arkosic sand, such as results from the disintegration of granite, consolidated so as to appear to be granite. Apparently the alluvium reaches a depth of more than 1,100 feet at Goffs. The "malpais" is probably lava of Pleistocene or Tertiary age, and the lower part of the alluvium may be as old as Tertiary. Darton has mapped low hills of pre-Cambrian rocks about 1½ miles north of Goffs, and similar rocks lie only a short distance south of the town. Accordingly the relief prior to the filling of the valley was much greater than at present.

Although there is a disagreement between the logs of the two wells at Fenner, it is likely that at that place the pre-Tertiary bedrock lies within 350 feet of the surface. About a mile northeast of Fenner a knob of Tertiary rhyolite rises from the alluvium, and a series of rhyolite hills strike northward from the vicinity of Fenner to Hackberry Mountain. In fact, the upper part of the valley is nearly shut off from the lower part of these hills. It is possible that a divide formerly existed in this part of the valley and that the area between Fenner and Goffs drained eastward.

The alluvium at Danby is somewhat thicker than at Fenner, and it is underlain by lava, which rests on the older bedrock without any intervening alluvium. At Siam the alluvium is about as thick as at Danby. The rock reported as granite is probably either some phase of consolidated alluvium or of volcanic rock.

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[41] Darton, N. H., Discovery of Cambrian rocks in southeastern California: Jour. Geology, vol. 15, pp. 470–473, 1907. Clark, C. W., Lower and Middle Cambrian formations of the Mohave Desert: California Univ. Dept. Geology Bull., vol. 13, No. 1, pp. 1–7, 1921.

MINERAL RESOURCES

There has been more or less mining activity at several places in the valley, and undeveloped mineral deposits are known to exist at other places. The largest producer has been the Bonanza King mine, in the Providence Mountains, which has been operated more or less intermittently since the early seventies.[42] During the eighties the mine was a large producer and at one time, it is said, produced $1,000,000 in 18 months. After the drop in the price of silver in the nineties it was idle for a number of years, but since 1915 it has been more active. It was closed during most of 1917 but is reported to have been worked in 1919,[43] when a 50-ton flotation mill was in operation. The total production from the mine has been several million dollars. The ore is argentiferous galena in limestone near a contact with monzonite. Several other mines and prospects are situated near the Bonanza King.

Copper and gold have been mined in the Signal district, 9 miles north of Goffs.[44] Tungsten and vanadium have also been found in this district, but there has been no commercial production.[45] Copper, gold, silver, antimony, and mercury ores have been found in prospects in the northern end of the Old Woman Mountains, but here also there has been no commercial production.

A deposit of iron ore of considerable size, known as the Vulcan deposit, lies near the south end of the Providence Mountains.[46] The ore is hematite that has replaced limestone near the contact with monzonite. So far as is known there has been no commercial production from this district. A small quantity of ore has been shipped from a mine in the Marble Mountains about 8 miles north of Cadiz.

PRECIPITATION

Precipitation records were kept at Fenner from August, 1883, to September, 1884. The precipitation for the 12 months ending July 31, 1884, was 6.40 inches. Records were kept at Goffs from May, 1915, to October, 1920. However, the record is complete for only one year—from July, 1916, to June, 1917—when the precipitation was 5.54 inches. According to records for longer periods at Bagdad and Needles, Calif., and Fort Mohave, Ariz., the years for which the total annual rainfall is known at Fenner and Goffs were not unusually wet or dry. It is probable that the average annual precipitation at these places is 5 inches or perhaps a little more.

In the lowest part of the valley the precipitation may be less than 5 inches, for at Bagdad, about 30 miles farther west and at an alti-

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[42] Cloudman, H. C., and others, Mines and mineral resources of San Bernardino County: California State Mineralogist Rept. for 1915–16, p. 53, 1917.

[43] U. S. Geol. Survey Mineral Resources, 1919, pt. 1, p. 208, 1922.

[44] Cloudman, H. C., and others, op. cit., p. 11.

[45] Idem, pp 69–78.

[46] Jones, C. C., An iron deposit in the California Desert region: Eng. and Min. Jour., vol. 87, pp 785–788, 1909.

tude about 300 feet lower than the lowest part of Fenner Valley, the average for 17 years is only 2.28 inches. The average annual precipitation in the Providence Mountains is doubtless somewhat higher than at Goffs, probably at least 10 inches.

SOIL AND VEGETATION

The soil in some parts of the valley is more rocky than in many parts of the Mohave Desert region. This character is particularly noticeable along the base of the Providence Mountains and east of the Marble Mountains in the lower part of the basin, where the surface is cut by many small gullies formed by rainstorms. There are no areas of alkali soil in the valley. The soil as a whole is favorable for agriculture, but other conditions, principally the lack of water at a reasonable depth, are unfavorable.

The vegetation is characterized by the predominance of creosote bush. In the higher parts of the valley around Fenner and Goffs the form of yucca known as Spanish bayonet is common. Water-indicating plants, such as salt grass and mesquite, are generally absent in the valley but may be present in small areas in canyons in the mountains where water is near the surface. *Baccharis sarothoides*, which grows near Colton Well, 15 miles northwest of Fenner, probably indicates ground water near the surface.

GROUND WATER

WELLS IN THE VALLEY

There are no permanent streams in the valley, and all water supply is obtained from wells and springs.

Well data.—The only notable wells are those at the pumping plants of the Atchison, Topeka & Santa Fe Railway at Goffs, Fenner, Danby, and Siam. There are three drilled wells at Goffs and two at each of the other stations. The logs and other available data in regard to each of these wells, as furnished by the railroad, are given below.

Log of well 1 at Goffs, Calif.

[Atchison, Topeka & Santa Fe Railway Co., owner. Drilled by L. A. Clampitt, May 7 to Sept. 8, 1902]

	Thickness (feet)	Depth (feet)
Sand and gravel	125	125
Clay and gravel	195	320
Granite	355	675
Malpais (lava)	101	776
Red sandrock	97	873
Shale	53	926

Casing, 8-inch to 692 feet; not cased, 692 feet to bottom. Depth to water at completion, 565 feet. Yield at completion, 64,800 gallons in 24 hours (45 gallons a minute). See p. 685 for analysis.

Log of well 2 at Goffs, Calif.

[Atchison, Topeka & Santa Fe Railway Co., owner. Drilled Nov. 10, 1906, to Sept. 1, 1907. Situated 300 feet southwest of well 1]

	Thickness (feet)	Depth (feet)
Sand and gravel	125	125
Granite	735	860
Malpais (lava)	65	925
Yellow clay	35	960

Casing, 12½-inch to 120 feet; 10-inch to 860 feet; not cased, 860 feet to bottom. Depth to water on completion, 550 feet. Yield in test March 29, 1907, 74,400 gallons in 24 hours (52 gallons a minute).

Log of well 3 at Goffs, Calif.

[Atchison, Topeka & Santa Fe Railway Co., owner. Drilled by Clampitt & Moss, May 11, to Aug. 20, 1917]

	Thickness (feet)	Depth (feet)
Soil and sand	4	4
Cemented sand	76	80
Decomposed granite	10	90
Cemented sand	15	105
Granite	20	125
Cemented sand	20	145
Decomposed granite	50	195
Cemented sand	50	245
Granite	25	270
Sand and gravel	15	285
Hard malpais	5	290
Cemented sand	120	410
Decomposed granite	180	590
White sandrock	120	710
Decomposed granite	80	790
Malpais	140	930
Sand and clay	75	1,005
White cemented sand	45	1,050
Cemented sand	35	1,085
Sand and clay	38	1,123

Casing left in well; 16-inch, 0 to 105 feet; 12¼-inch, 0 to 544 feet; 10-inch, 504 to 822 feet, perforated with four rows of holes 3 inches apart from 590 to 750 feet and two rows 3 inches apart from 750 to 772 feet; 8¼-inch, 772 to 1,123 feet, perforated with four rows of holes 3 inches apart from 812 to 840 feet. See p. 685 for analysis.

Log of well 1 at Fenner, Calif.

[Atchison, Topeka & Santa Fe Railway Co., owner. Drilled by American Well Works Co., Aug. 20, 1900, to June 6, 1901]

	Thickness (feet)	Depth (feet)
Cemented gravel	100	100
Cemented boulders	24	124
Variable rotten granite	206	330
Red shale	10	340
Hard granite rock	460	800

Diameter, 16 inches, 0 to 330 feet; 10 inches, 330 to 800 feet. Casing, 13 inches from surface to 124 feet. Working barrel set at 500 feet. Water struck at 390 feet. Depth to water on completion 317 feet. (See p. 683.) Yield, 100,000 gallons in 24 hours (70 gallons a minute). See p. 685 for analysis.

Log of well 2 at Fenner, Calif.

[Atchison, Topeka & Santa Fe Railway Co., owner. Drilled by L. A. Clampitt & Co., Nov. 28, 1906, to Mar. 28, 1907. Situated 300 feet southwest of well 1]

	Thickness (feet)	Depth (feet)
Sand and gravel	184	184
Decomposed granite	22	206
Volcanic rock	138	344
Granite rock	716	1,060

Casing, 12½-inch, 0 to 122 feet; 10-inch, 122 to 742 feet. Depth to water at completion, 460 feet. Yield in test at completion, 54,700 gallons in 24 hours (38 gallons a minute). Yield in test in May, 1907, 72,000 gallons in 2 hours (50 gallons a minute).

Log of well 1 at Danby, Calif.

[Atchison, Topeka & Santa Fe Railway Co., owner. Drilled by American Well Works Co., June 17 to Sept. 18, 1901]

Cemented sand, gravel, and boulders for the entire depth (637 feet). Casing, 10-inch screw pipe, 0 to 287 feet; 8-inch screw pipe, 0 to 597 feet, with strainers from 397 to 417 feet and 546 to 566 feet. Depth to water on completion, 260 feet. Yield in test Sept. 10, 1901, 72,000 gallons in 24 hours (50 gallons a minute). See p. 685 for analysis.

Log of well 2 at Danby, Calif.

[Atchison, Topeka & Santa Fe Railway Co., owner. Drilled by L. A. Clampitt, Feb. 15 to Apr. 2, 1903. Situated about 400 feet southwest of well 1]

	Thickness (feet)	Depth (feet)
Cemented gravel	635	635
Lava	160	795
Granite	103	898

Casing, 12-inch screw pipe, 0 to 181 feet; 9⅝-inch screw pipe, 0 to 629 feet, perforated from 268 to 629 feet. Not cased, 629 to 898 feet. Depth to water on completion, 268 feet. Yield in test at completion, 98,400 gallons in 24 hours (68 gallons a minute).

Log of well 1 at Siam, Calif.

[Atchison, Topeka & Santa Fe Railway Co., owner. Drilled by L. A. Clampitt, Feb. 3 to June 21, 1903]

	Thickness (feet)	Depth (feet)
Cement and gravel	260	260
Clay, gravel, and boulders	340	600
Granite	120	720
Malpais	175	895

Casing, 13-inch, 0 to 296 feet; 10-inch, 0 to 563 feet; 8-inch, 563 to 895 feet. Every other length of the casing below 400 feet is perforated. Depth to water on completion, 400 feet. Working barrel is 510 feet below surface. Yield in test at completion, 86,400 gallons in 24 hours (60 gallons a minute). See p. 685 for analysis.

Log of well 2 at Siam, Calif.

[Atchison, Topeka & Santa Fe Railway Co., owner. Drilled by L. A. Clampitt, Jan. 11 to Aug. 25, 1907. Situated about 200 feet northeast of well 1]

	Thickness (feet)	Depth (feet)
"Cement" and gravel	325	325
Granite	510	835
Black clay	10	845
Malpais rock	43	888

Casing, 12½-inch screw pipe, 0 to 480 feet. According to data furnished by the railroad the 12½-inch hole continues to 835 feet, where it changes to 8 inches. There is said to be 200 feet of 8-inch casing between 688 feet and 888 feet, but no casing at all between 480 and 688 feet. Depth to water on completion, 420 feet. Yield in test in 1915, 53,280 gallons in 24 hours (24 gallons a minute).

Water-bearing strata.—As discussed in the section on geology (p. 678), there are apparent inaccuracies in some of the logs, particularly in the reported occurrence of granite above volcanic rocks and alluvium. For most of the wells there is no information as to the formations in which the water occurs. From the statements as to the perforations in the casing in well 3 at Goffs the water comes from sand between 590 and 772 feet and from lava between 812 and 840 feet. The first water struck appears to have been confined under artesian pressure. The so-called decomposed granite is probably unconsolidated sand and fine gravel similar to the surface soil that covers much of the valley. In well 1 at Danby the water clearly comes from the alluvium. In well 2 at this place some of it at least comes from the alluvium, but as the well is not cased below 629 feet it is possible that some water may come from the lava. It is doubtful whether any comes from the granite. In the other wells the water-bearing beds can not be determined from the data available.

Depth to water.—The difference in the depth to water in the different wells at the same station is marked, although at each station the wells are not more than 500 feet apart. The greatest differences are at Goffs and at Fenner. Conflicting data were obtained for the depth to water in well 1 at Fenner, four different records giving 310, 317, 360, and 450 feet. According to a blue print dated June 6, 1901, the date when the well was completed, and hence probably the most accurate, the first water was struck at 390 feet, and on completion the water level was 317 feet below the surface.

The reasons for the differences in the water level in wells at the same station are not clear. There is no reason to believe that the water level would be different in near-by wells at a given time. Where the differences are not great they may be due to seasonal fluctuations. However, the rainfall in the valley is not great, there is no heavy pumping, and there is no known ground-water discharge within the limits of Fenner Valley so that no great seasonal fluctuation in the water level is to be expected. It is possible that the difference in water level in near-by wells, particularly where it is as great as at Goffs and Fenner, is due to a gradual lowering of the water table under continuous draft. However, because of the large tributary area it is not likely that the draft from the few wells along the railroad would cause any noticeable lowering of the water table unless at each place the supply is drawn from a relatively small isolated body of water. It is not unlikely that when the depth to water in a newly completed well was measured the older well was being pumped more or less continuously. The water level accordingly for some distance around the old well would doubtless be somewhat lower than if the well had not been pumped for some days. It may thus be that the difference in level in the older and newer wells is due largely to drawdown in the older well.

The profile of the water table along the railroad in Fenner Valley is shown in Figure 19. Certain features on this profile deserve comment. Goffs is situated at the divide between Fenner Valley and the Colorado River drainage basin, and apparently the ground water might flow into either valley. As shown in the figure, if the profile of the water table between Danby and Fenner is projected northeastward it practically coincides with the water table at Goffs. On the other hand, if the water table between Homer and Ibis is projected westward it falls fully 300 feet below the water table at Goffs. On the basis of these facts it is believed that the water table at Goffs is continuous with the water table in Fenner Valley and that between Goffs and Homer there is a rock barrier.

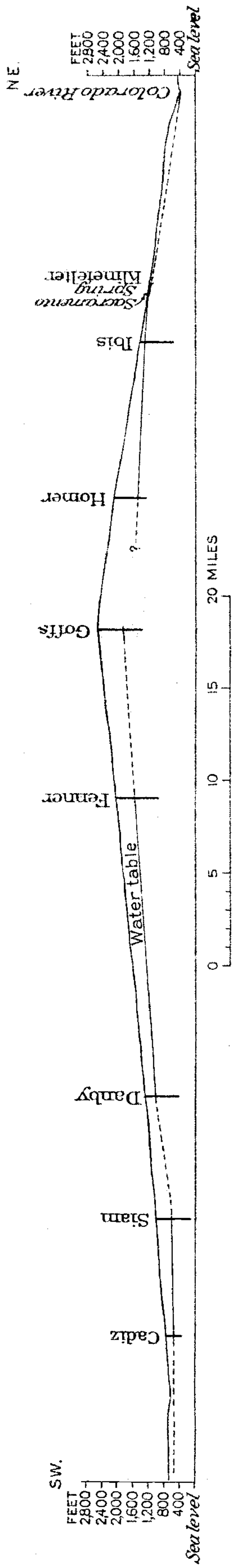

FIGURE 19.—Profiles of the surface and of the water table along main line of Atchison, Topeka & Santa Fe Railway between Cadiz and Colorado River

The water table has a practically uniform gradient from Goffs to Danby. Between Danby and Siam the gradient increases considerably, but from Siam westward to Cadiz the grade is very gentle. The flatness of the water table between Siam and Cadiz furnishes evidence that between the Ship Mountains and the south end of the Marble Mountains the bedrock valley lies 300 feet or more below the surface. The cause of the steeper gradient of the water table between Siam and Danby is not clear. It may be due to a barrier that holds the water table higher toward the east. South of Danby there is a large alluvium-filled valley, through which some of the ground water may possibly flow toward Cadiz Dry Lake.

Yield of wells.—The yield of the different wells along the railroad ranges from about 40 to about 70 gallons a minute. No data are available as to the drawdown in any of the wells. It is unlikely, however, that any of the wells will yield any large supply, and any increase in the rate of pumping would doubtless cause an extraordinary drawdown.

Quality of water.—The analyses of samples of water from five of the wells along the Atchison, Topeka & Santa Fe Railway between Goffs and Siam, furnished by the railway company, are given in the following table as analyses 4–8. The analyses are incomplete, but they show that the mineral content is only moderate, for the total ranges from about 300 to a little more than 500 parts per million of total dissolved solids. Except for the sample from well 1 at Fenner, they are of about the same concentration and the same composition, and the predominating constituents are sodium and bicarbonate. In the sample from the Fenner well calcium sulphate predominates.

All the waters are good for domestic use, although the water from the Fenner well is so hard that it requires considerable soap in washing. They are only fair or poor for use in boilers because of the amount of foaming constituents present. Difficulty from this source, however, probably can be reduced by proper treatment. The waters are either good or fair for irrigation.

Analyses of ground waters from Fenner Valley, Calif.

[Parts per million]

	1	2	3	4	5	6	7	8
Silica (SiO_2)	60	98	55	[a] 26	[a] 39	[a] 32	[a] 34	[a] 27
Iron (Fe)	.15	.10	.16					
Calcium (Ca)	111	25	83	7.5		97	17	19
Magnesium (Mg)	30	3.9	34			6.9		5.4
Sodium and potassium (Na+K)	153	49	122	[b] 85	[b] 96	[b] 42	[b] 118	[b] 73
Carbonate radicle (CO_3)	0	0	0					
Bicarbonate radicle (HCO_3)	342	147	483	116	114	102	158	148
Sulphate radicle (SO_4)	135	26	78	46	57	184	89	51
Chloride radicle (Cl)	205	22	74	42	39	62	52	38
Nitrate radicle (NO_3)	1.6	.62	1.1					
Total dissolved solids at 180° C	872	297	672	305	[b] 287	537	416	334
Total hardness as $CaCO_3$ (calculated)	400	78	347			271		70
Date of collection	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)

[a] Includes silica (SiO_2) and iron and aluminum oxides ($Fe_2O_3+Al_2O_3$).
[b] Calculated.
[c] Nov. 23, 1917.
[d] Nov. 23, 1917.
[e] Nov. 22, 1917.
[f] June 8, 1903.
[g] Sept. 13, 1917.
[h] July 17, 1901.
[i] August, 1898.
[j] Sept. 26, 1903.

Analysts: 1–3, Addie T. Geiger, U. S. Geological Survey; 4–8, Atchison, Topeka & Santa Fe Railway.
1. Colton Well, probably in sec. 20 or 28, T. 10 N., R. 15 E. San Bernardino meridian. See below for description.
2. Beecher Springs, probably in sec. 35 or 36, T. 11 N., R. 14 E. See p. 687 for description.
3. Granite Well, 23 miles northwest of Fenner. See p. 687 for description.
4. Well 1 at Goffs. Atchison, Topeka & Santa Fe Railway, owner. See p. 680 for log and other data. Analysis furnished by the owner; recalculated from hypothetical combinations in grains per U. S. gallon.
5. Well 3 at Goffs. Atchison, Topeka & Santa Fe Railway, owner. See p. 681 for log and other data. Analysis furnished by the owner; recalculated from hypothetical combinations in grains per U. S. gallon.
6. Well 1 at Fenner. Atchison, Topeka & Santa Fe Railway, owner. See p. 681 for log and other data. Analysis furnished by the owner; recalculated from hypothetical combinations in grains per U. S. gallon
7. Well 1 at Danby. Atchison, Topeka & Santa Fe Railway, owner. See p. 682 for log and other data. Analysis furnished by the owner; recalculated from hypothetical combinations in grains per U. S. gallon.
8. Well 1 at Siam. Atchison, Topeka & Santa Fe Railway, owner. See p. 682 for log and other data. Analysis furnished by the owner; recalculated from hypothetical combinations in grains per U. S. gallon.

WELLS AND SPRINGS IN THE MOUNTAINS

Besides the wells along the Atchison, Topeka & Santa Fe Railway the only other wells so far as known are in or near the borders of the mountains.

Colton Well.—Colton Well is near the road from Fenner to the Bonanza King mine, 15.7 miles from Fenner, probably in the SW. ¼ sec. 20 or NW. ¼ sec. 29, T. 10 N., R. 15 E. San Bernardino meridian. The well is in a wash about 500 feet east of the road where it passes between low rocky hills. It can be found by walking up the wash for several hundred feet from the point where the road first enters the hills. The well is dug in granite and is 23 feet deep. On November 23, 1917, the depth to water was 14 feet. The temperature of the water was 65° F. When visited the well was equipped with a windmill, which pumped water to an iron tank, but the brake on the windmill was wired so that it would not run. A hundred feet south of the well there was also a substantial concrete watering trough fitted with an automatic float valve. The only means of obtaining water was with a rope and bucket. The well is used principally as a watering place for cattle.

The analysis of a sample of water from this well is given on page 685. The water is highly mineralized and contains 872 parts per million of total dissolved solids. It contains almost equivalent amounts of calcium and sodium and of chloride and bicarbonate. The water is only fair for domestic use because of the high total solids and particularly the hardness. It is fair for irrigation.

Apparently the conditions that bring the water so near the surface at Colton Well are entirely local. The well is in a wash in rocky hills. The wash is filled with sand, but rock lies near the surface, and probably a rock barrier downstream forms a small pocket in which the water is retained. It is very doubtful whether a large supply could be obtained in this locality.

Wells near Bonanza King mine.—Several wells have been drilled or dug near the Bonanza King mine and were used to supply the mining community until water was struck in the mine at a depth of about 500 feet. It is said that about 58,000 gallons a day (about 40 gallons a minute) was pumped from the mine. In November, 1917, when only a watchman was at the mine, water for drinking was obtained at Domingo's ranch, about 2 miles east of the mine. Water for other purposes was obtained from a large tank filled from the mine before it closed down.

The Bonanza King Well is in a valley about half a mile east of the mine. The well is dug and is said to be about 400 feet deep and the depth to water about 300 feet. In November, 1917, the well was equipped with a gas engine and plunger pump, but there was no way to obtain water. A board platform extended across the shaft some distance below the surface, and a bucket could not be lowered. This well is reported to yield about 1,500 gallons in 10 or 12 hours (a little more than 2 gallons a minute).

Barbers Well is about a mile north of Domingo's ranch, in sec. 1, T. 10 N., R. 14 E. The well is reported to be about 70 feet deep and to yield about 2 gallons a minute. Two other shallow wells lie about a mile northeast of Domingo's ranch. Mr. Domingo states that a well or spring known as Cook's Well is situated at the base of the Providence Mountains about 4 miles southwest of his ranch. Blind

Spring is about 3½ miles south of Cook's Well. These two watering places are not near any roads. They are used as watering places for stock and doubtless could be found by following cattle trails.

Beecher Spring.—Water at the ranch of John Domingo, 21 miles northwest of Fenner, is obtained from Beecher Spring, which issues in a canyon in a lava butte about a mile east of the ranch, to which the water is carried by a pipe line. An analysis of the water, given on page 685, shows that it is good for domestic use and irrigation but only fair for boilers.

Springs at south end of Providence Mountains.—From Fenner a road leads almost due west to the Hidden Hill mine, at the south end of the Providence Mountains, a distance of about 25 miles. There is no water at the mine, but Van Winkle Spring is said to be situated about 4 miles southwest of it and to be reached by a road. A road is reported to continue around the south end of the mountains and northward down a long valley to Kelso. The road to Kelso is probably difficult to travel because of sand, and it may be washed out in places. Cove Springs and Cottonwood Springs are reported to be reached by branch roads. A spring reported as Dripping Spring may be the same as Cove Spring, and one shown on certain maps as Arrow Weed Spring may be the same as Cottonwood Spring. On the other hand, a spring called Cottonwood Spring is shown on a recent guide map as nearly 7 or 8 miles west of the one shown on Plate 12. Nothing was learned of this spring. Water is reported in shafts at Gannon's camp, about 4 miles north of the Hidden Hill mine, but whether it is easily obtainable is not known. The springs mentioned were not visited by the writer. They are located on Plate 12 according to the best information that could be obtained.

Granite Well and Everet Well.—Two wells are situated about 23 miles northwest of Fenner, among granite hills that form the northern part of the Providence Mountains. They are reached by a branch road that turns northwest from the Fenner-Cima road 20.7 miles from Cima. This road goes past some mine-camp buildings and then turns westward. About 2.3 miles from the road fork, at a point where the road bends southward, is Granite Well. There is an old well about 200 feet west of the road and in sight from it, but a well that contains better water is about 300 feet farther west, in a wash that is hidden from the road. As shown by an analysis on page 685, the water from this well is suitable for domestic use and for irrigation. Everet Well is reported to be half a mile southwest of Granite Well and to be reached by the road that runs past Granite Well. The water in these wells probably occurs in pockets of sand in the granite, and the quantity available is probably not very large.

Bonanza or Danby Spring and other watering places in Clipper Mountain.—Bonanza Spring issues in sec. 22, T. 7 N., R. 15 E., in a canyon on the south side of Clipper Mountain, 5 miles northwest of Danby. The water is carried to Danby for locomotive use by a 4-inch cast-iron pipe line. The total fall is about 800 feet. The development at the spring consists of a tunnel 360 feet long dug in clay, "cement," and gravel. The spring is reported to yield about 13,500 gallons a day (about 10 gallons a minute). Bonanza Spring is also known as Danby Spring. It should not be confused with the Bonanza King Well mentioned on page 686.

Water is said to be obtainable from the shafts of the Tom Reed and Clipper mines, about 1 and 2 miles, respectively, east of Bonzana Spring. In 1917 each shaft was equipped with a windlass, so that water could be drawn. The water in the Clipper shaft is reported to be good, but that from the Tom Reed shaft is poor. John Domingo states that an unnamed spring emerges at the northeast end of Clipper Mountain. Its exact location, however, was not learned.

Water in the Piute Mountains.—Fenner Spring is situated in sec. 28, T. 8 N., R. 18 E., about 6 miles southeast of Fenner. The water comes from a tunnel 200 feet long. The flow is small. The water formerly was piped to Fenner for use by the railroad, but the pipe line was torn up several years ago. An old road leads to the spring.

A spring known as Barrel Spring is reported to issue about 8 miles east of Essex station, near the upper end of a long gulch at the southwest end of the Piute Mountains.

In November, 1917, water stood at a depth of 127 feet in the shaft of the Louise mine, 6 miles south of Goffs. The water could be obtained only by a long rope and bucket.

Wells and springs at north end of Old Woman Mountains.—From Danby a road leads almost due east to mine prospects at the north end of the Old Woman Mountains. Water is said to be obtainable at a number of places at the north end of the mountains. Weavers Well is about 12 miles east of Danby. In November, 1917, the well was reported to be equipped with a good pump. About 1.5 miles before it is reached a road branches to the right to the Golden Fleece mine. Water for use at this mine is piped from Honeymoon Spring, which is about 1 mile south of Weavers Well. According to Leroy Palmer, of the United States General Land Office, the spring is in the NW. ¼ NW. ¼ sec. 3, T. 6 N., R. 17 E. San Bernardino meridian. The water is derived from a tunnel in granite. The flow is small, but the water is good.

From Weavers Well a road continues southeast to Sunflower Spring, about 25 miles distant, and thence to the Wilhelm camp, on the east side of the Old Woman Mountains, and south to Milligan. (See p. 705.) The road, however, is impassable for automobiles from Weavers Well almost to the Wilhelm camp, although it can be traveled by wagons.

BRISTOL AND CADIZ VALLEYS

GENERAL FEATURES

Bristol and Cadiz Valleys form the largest part of the Bristol-Lanfair drainage basin. (See pl. 7.) Structurally they constitute a single physiographic unit, but a low alluvial divide separates it into two parts; the lowest part of the northwestern division is occupied by Bristol Dry Lake and that of the southeastern division by Cadiz Dry Lake. The ground-water conditions are apparently uniform in the two basins. So clearly do the two divisions form a single major unit that they are here described together.

The main line of the Atchison, Topeka & Santa Fe Railway crosses the valley in an easterly direction a little north of the center. From Cadiz, on the east side of the valley, a branch line leads southeastward to Parker and Phoenix, Ariz., with a connection at Rice, Calif., which leads to the rapidly developing Blythe Valley. The National Old Trails automobile road lies from a quarter of a mile to 3 miles north of the main line of the railroad.[47] Near Cadiz a road leads southeast along the Parker branch of the railroad to the points reached by it. (See pls. 12 and 13.) This road is sometimes known as the Parker cut-off. In 1918 the first 22 miles of this road, as far as Kilbeck siding, was very rough and in places sandy. To avoid this, some travelers continued on the National Old Trails Road to Danby and then turned south, coming into the Cadiz-Parker road at Kilbeck. This route is 9 miles longer, but the road is generally better. Most travelers continue on the transcontinental road to Needles and then turn south to Parker. (See p. 729.) This route is 37 miles longer than the Cadiz-Parker road, but it is likely to be in much better shape, and the tourist will travel more comfortably and probably make better time by taking it. In 1918 on the Cadiz-Parker route supplies or reliable accommodations other than water could not be obtained until Vidal was reached, a distance of 80 miles, but since then these may be available at Rice. Travelers who contemplate using this road should inquire at Cadiz as to supplies and the condition of the road.

From Amboy a road leads southward to mining camps in Dale Valley. The road crosses Bristol Dry Lake and ascends a grade to a broad pass in the Sheep Hole Mountains and thence goes southwestward to a well at the west edge of Dale Dry Lake. (See p. 649.) This well is the only watering place on the road. Heavy sand is reported to occur south of Bristol Dry Lake, and the last few miles on the west side of Dale Dry Lake is said to be even more sandy. Even the highest-powered automobiles have difficulty in going through this sand, and many of them cross it on deflated tires. This

[47] A road map furnished in 1927 by the Automobile Club of Southern California shows that the road then used was one south of the railroad. (See pl. 12.)

road was formerly much used, especially before automobiles came into common use, to haul freight to mines in the Dale district. In 1918 the mines were closed, and the road was little used.

Other roads lead to mines in Bristol Valley. The most traveled of these roads is one that leads from Bagdad northeastward to the Orange Blossom mine, about 10 miles distant, and to a spring, which is probably Willow Spring, 4 miles northeast of the mine. A road is said to lead northeastward from the spring to the Providence Mountains and to connect with a road that leads west from Fenner and with another said to lead north to Kelso. At best the roads northeast of Willow Spring, except the road from Fenner to the south end of the Providence Mountains, are used very little and probably are in bad condition.

Bagdad is a fuel and water station on the railroad and in 1917 had a railroad eating station. A gypsum-plaster mill is located at Amboy. In 1918 hotel accommodations and general supplies could be obtained there. The only post office in the valley is at this place. Although Cadiz is the junction of the Parker branch and the main line of the railroad, in 1918 it had no stores and no supplies could be obtained there other than water. Section crews or water stations are located at Klondike, Siberia, Bolo, and Archer, and water can be obtained at those places in an emergency. The other stations shown on the map are only sidings.

There is no irrigation or agriculture of any sort in the region, and conditions are unfavorable for any future development. In the lower part of the valley, where the water table is close to the surface, the water is so bad as to be unfit for irrigation. Where water of good quality can be obtained the depth to it is probably too great to permit economic pumping.

CLIMATE

The summary of observations on temperature and precipitation at Bagdad for a period of about 20 years are given on pages 71–91. The conditions elsewhere in the lowest part of Bristol Valley are doubtless about the same as at Bagdad. The records of temperature show that at the stations in or near the Mohave Desert region for which good records are available the mean annual temperature at Bagdad is exceeded only by that at Greenland ranch, in Death Valley, and Fort Mohave, Ariz.—at Fort Mohave only by a few tenths of a degree. The yearly range in temperature is apparently not as great as at most of the other stations. The maximum temperature record is only 119°, as compared to 124° at Fort Mohave, 122° at Needles, 127° at Parker, and 134° at the Greenland ranch. The average length of the frostless season at Bagdad is 345 days each year—a record that is exceeded by only four other stations in southern California, all of them south of the San Gabriel and San Bernardino Mountains and west of the San Jacinto Mountains. (See p. 72.)

The mean annual rainfall at Bagdad is about 2.3 inches. Except for the rainfall at the Greenland ranch, this is the lowest rainfall recorded in or near the Mohave Desert region. In four out of the 20 years there was no rainfall, and in one year only 0.01 inch. In this respect the record at Bagdad exceeds that at the Greenland ranch, for at that place in nine years there has never been a year without some rain. At Bagdad there was no rain in a period of 32 months, from September, 1909, to April, 1912, except for a trace in two months, and there was no rain during two other periods of four months each. According to the record, during the 20 years no rain has fallen in the month of June.

The unusual climatic conditions at Bagdad are evidently due to its topographic situation. It lies at almost the lowest part of a great valley, at an altitude of about 785 feet above sea level. The southern border of the valley is formed by a range of mountains that trend northwest. These mountains, which rise to an altitude of 4,000 feet or more, form an effective barrier to the rain-bearing winds that move from the west in winter and from a more southerly direction in summer. The winds may rise and pass over the mountains, but as they descend again they reach lower altitudes than on the windward side of the mountains; they then become warmer and have a greater retaining capacity for moisture.

Although the rainfall is so low in the valley it is doubtless from 2 to 5 inches higher in the mountains that border the valley both on the north and south.

MINERAL RESOURCES

Mineral deposits have been developed at several places in Bristol Valley. The mines of the Pacific Mines Corporation at Stedman have been notable producers of copper and gold together with some silver.[48] These mines are on the extreme western edge of the valley. The Orange Blossom mine, 9 or 10 miles northeast of Bagdad, has also produced copper, gold, and a little silver.[49]

Iron ore occurs in the Iron or Marble Mountains north of Cadiz and in the Bristol Mountains north of Amboy. At the latter place the ore has replaced limestone,[50] and the conditions are probably similar in the Marble Mountains. A small quantity of ore was shipped from the deposits in the Marble Mountains in 1921.[51]

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[48] Cloudman, H. C., and others, Mines and mineral resources of San Bernardino County, Calif.: California State Min. Bur., p. 16, 1917.

[49] Idem, p. 15.

[50] Darton, N. H., Guidebook of the western United States, Part C, The Santa Fe Route: U. S. Geol. Survey Bull. 613, p. 154, 1916.

[51] A review of mining in California during 1921: California Min. Bur. Preliminary Rept. 8, p. 46, 1922.

Extensive deposits of gypsum and salt beneath Bristol Dry Lake are worked near Amboy. The gypsum deposits are being developed by the Consolidated Pacific Cement Plaster Co. The product is shipped to Portland cement mills and is also sold for "land plaster" or fertilizer. The deposits are described briefly on page 695.

The California Rock Salt Co. works salt deposits about 4 miles southeast of Saltus. In 1922 the product amounted to about 1,000 tons a month and was sold mostly to ice-cream manufacturers.[52]

PHYSICAL FEATURES AND GEOLOGY

The Bristol and Cadiz Valleys occupy a single great valley or trough that trends in a northwesterly direction. As shown on page 120, this trough is apparently a part of a much longer trough that extends from the vicinity of Barstow southeastward to Colorado River, which is now separated into four or more parts by divides composed of Tertiary or later rocks. The name Bristol trough has been suggested for the part of the large trough that includes Bristol and Cadiz Valleys. Free [53] has used the term in a broader sense to include the whole of the Bristol-Lanfair drainage basin, but this usage is hardly proper, for the entire drainage basin does not have a typical troughlike structure. In this report the term is used only for the area that drains directly to Bristol and Cadiz Dry Lakes.

The southwestern border of the trough is formed by the Bullion, Sheep Hole, and Coxcomb Mountains, which extend almost continuously from the northwest to the southeast ends of the basin. At only two places are there small breaks in the mountains, one almost due south of Amboy and another in T. 1 S., R. 15 E. According to Darton,[54] these mountains are composed principally of granite and schist of pre-Cambrian age. The mountains rise rather steeply on their northeast side from an altitude of less than 1,000 feet to more than 4,000 feet above sea level.

The northeastern border of the trough is more irregular, as it is composed in part of several nearly independent ridges that have a northwesterly trend, not quite parallel to the trend of the great valley. Between the ridges large valleys reach far back from the main valley. The largest of these ridges are the Bristol Mountains and the Old Dad Mountains, which rise to an altitude of 4,000 to 5,000 feet. According to Darton, the Bristol Mountains are composed of post-Carboniferous granite rocks which contain patches of pre-Cambrian granite and schist. The Old Dad Mountains consist

[52] Mining in California: California Min. Bur. Eighteenth Rept., p. 613, November, 1922.

[53] Free, E. E., The topographic features of the desert basins of the United States with reference to the possible occurrence of potash: U. S. Dept. Agr. Bull. 54, p. 46, pl. 1, 1914.

[54] Darton, N. H., Guidebook of the western United States, Part C, The Santa Fe Route: U. S. Geol. Survey Bull. 613, sheet 22, 1916.

of the pre-Cambrian granite and schist. West of the Bristol Mountains stand much lower mountains and hills which are composed largely of Tertiary volcanic rocks but which contain small areas of Quaternary volcanic rocks. The divide across the great trough at Ash Hill, which separates Ludlow Valley from Bristol Valley, is composed of Quaternary volcanic rocks.

The Bristol trough is separated from Fenner Valley by the Marble and Ship Mountains, described on page 677. A wash which passes between these mountains brings into the Bristol trough the drainage from Fenner and Lanfair Valleys.

Southeast of the Ship Mountains the eastern border of the Bristol trough is formed in part by the Old Woman Mountains and in part by low hills south of the Parker branch of the Atchison, Topeka & Santa Fe Railway, which may be called the Kilbeck Hills, and farther south by Iron Mountain. Between the Old Woman Mountains and the Kilbeck Hills the divide is formed by the alluvial slope built out from the mountains. There is no indication of the depth of the alluvium between the railroad and the north end of Iron Mountain. There are two or three low passes in the Kilbeck Hills which from a distance appear to be filled with alluvium. However, from the physical and geologic relations of these hills, bedrock probably lies close to the surface in the passes.

The Old Woman Mountains are composed largely of pre-Cambrian granite and schist.[55] Metamorphosed sediments, especially marble, occur in patches in the older rocks. The mountains are very rugged, with great towering peaks that resemble the battlements on a fortress and large canyons that extend far back into the range. The mountains are said to derive their name from the fact that one prominent block of rock has the appearance of a human face.

Iron Mountain and the Kilbeck Hills are composed of granitic rocks or gneisses, except a small area immediately south of Kilbeck siding, which is underlain by limestone of unknown age.

The divide at the extreme south end of the valley, between the Coxcomb Mountains and Iron Mountain, appears to be formed of alluvium. However, it lies many miles from the nearest roads, and the exact conditions could not be learned.

Two large rock masses rise above the alluvium-covered floor of the valley. One consists of the Lead Mountains, an elongated ridge of Tertiary volcanic rocks that stands about 10 miles south of Bagdad. The other is a flow of Quaternary basaltic lava which lies south of the Atchison, Topeka & Santa Fe Railway southwest of Amboy. A cinder cone stands near the northeastern part of the flow. The cinder cone and lava flow are very similar to the Mount Pisgah cone and flow. (See pp. 652–653.) The surface is but little affected by weathering

[55] Darton, N. H., op. cit., sheet 22.

and, like the Mount Pisgah flow, is of comparatively recent origin. Inside the main cone are smaller walls of cinders formed during the last stages of eruption. In the depressions formed by these walls are two small clay flats, really small playas. Several small knobs of Quaternary volcanic rocks rise from the valley near Haynes siding and Siberia.

The part of the Bristol trough between the mountains may be separated into two divisions—a central lowland, in which the slopes are relatively gentle, and the border slopes, where the land rises more steeply to the mountains. The border slopes are particularly steep on the west side of the Old Woman Mountains, where the grade is as much as 200 feet to the mile. Three or four shallow but prominent washes cut across this slope. Between Ash Hill and Klondike, north of the railway, two wide washes from 20 to 40 feet deep come from the hills on the north. These washes are so much larger than the washes elsewhere on the alluvial slopes in the valley that a question arises as to their origin.

The lowest part of the Bristol trough is occupied by two playas—Bristol Dry Lake, near Amboy, and Cadiz Dry Lake, about 12 miles southeast of Cadiz. These playas are among the largest in the Mohave Desert region. Cadiz Dry Lake lies several miles from the nearest road, and little is known about it. The following information is based on data collected from different sources by the United States Geological Survey, particularly an unpublished report by L. F. Noble.

As nearly as can be determined the two playas lie at about the same altitude, about 600 feet above sea level. The land between them is nearly level and in places covered by sand. It is uncertain which, if either, of the two lies at the higher altitude. According to one report, Cadiz Dry Lake is the higher, and a well-defined channel leads from it to Bristol Dry Lake. The writer was informed by another person that the two playas were at so nearly the same altitude that water flowed from either playa to the other, depending on which received the most flood water. As the water table is very near the surface in both playas and as Cadiz Dry Lake if anything is the wetter of the two, it is probable that they lie at about the same level.

On the northeast side of the valley the alluvium that has been washed in from Fenner Valley between the Marble and Ship Mountains has formed a broad alluvial fan, which reaches toward the two playas. At present the main drainage channel from Fenner Valley leads toward Cadiz Dry Lake, but in the past the drainage doubtless has alternately gone into one or the other of the playas.

Both the playas are of the wet type. Both exhibit "self-rising ground," more or less covered with alkali. In some parts of Bristol Dry Lake the water is a little less than 8 feet below the surface. It is said that the water rises within a few inches of the surface in bore holes on Cadiz Dry Lake. Noble reports that when he visited the lake in March, 1919, the central part of the playa deposit consisted of sticky saline mud, in which he sank to the ankles. Farther from the center the surface becomes less muddy and shows the typical puffy "self-rising ground," composed of earth mixed with crystals of salt or gypsum. (See pl. 34, *A*.) Apparently the ground water is closer to the surface beneath Cadiz Dry Lake than beneath the other playa, a fact which suggests that Cadiz Dry Lake is fully as low as Bristol Dry Lake, if not a foot or two lower.

Deposits of salt and gypsum are found beneath both playas. Both these minerals are mined from Bristol Dry Lake, but the deposits of Cadiz Dry Lake are undeveloped. The gypsum deposits of Bristol Dry Lake have been described by Hess,[56] and the salt deposits very briefly by Phalen.[57] The surface of the playa is formed of sand and clay mixed with gypsum, but rather pure gypsum occurs from a depth of a few inches to at least 6 or 8 feet, where the groundwater level is reached. The maximum depth to which the gypsum continues is not known, for it has been worked only to the water table. In mining operations the impure surface material is stripped with scrapers. The gypsum is then loaded on dump cars and carried to a mill at Amboy. The gypsum covers a large area of the playa, and the total quantity available is evidently great. Darton states that in a well drilled at Amboy gypsum was penetrated at a depth of 70 feet. The salt is worked in much the same way at a locality several miles east of Amboy. One bed of salt, between 5 and 7 feet thick, lies 5 feet below the surface, and another of unknown thickness lies about 20 feet below the first bed.

Crystalline gypsum and salt, with brine, were encountered in test holes on Cadiz Dry Lake.[58] The extent of these deposits is not known. They are not as accessible as those at Amboy and would probably be more difficult to work, so that they are scarcely of commercial value under present conditions.

Considerable prospecting for potash has been done on both of the playas, particularly Cadiz Dry Lake. In samples of brine and of the earthy material analyzed in the laboratory of the United States Geological Survey potassium has been found in appreciable quantities. However, the content of potassium is considerably lower than in the brines of Searles Lake, and the saline deposits are less pure. For this reason it is doubtful whether under present conditions the deposits at Cadiz Dry Lake could compete with those of Searles Lake. The brine from Cadiz Dry Lake is unusual in that

[56] Hess, F. L., A reconnaissance of the gypsum deposits of California: U. S. Geol. Survey Bull. 413, pp. 25-27, 1910.

[57] Phalen, W. C., Salt resources of the United States: U. S. Geol. Survey Bull. 669, p. 185, 1919.

[58] U. S. Geol. Survey Mineral Resources, 1917, pt. 2, pp. 418-419, 1920.

a considerable percentage of the dissolved salts consists of calcium chloride.[59]

In order for beds of relatively pure salt and gypsum to form there must have been a lake which persisted for some time. No beaches or other surficial evidences of any such lake have yet been observed. However, beneath each of the two playas beds of green or blue clay have been found in bore holes. The green or blue color of such beds is generally ascribed to deposition beneath water, and its occurrence here confirms the supposition that a perennial lake existed in the region for a longer or shorter time. Any single stratum of the green or blue beds apparently is not very thick, and the gypsum and salt beds are interstratified with brown sand or sandy clay. These sandy beds doubtless indicate periods when the lake disappeared for longer or shorter periods.

No evidence has been obtained to show whether separate lakes existed where the two playas now occur. It is probable, however, that a single lake must once have covered both areas. For this lake, which existed probably during the Pleistocene epoch, the name Amboy Lake is suggested, to avoid confusion with the present playas in the basin, which are also commonly called lakes.

Much wind-blown sand occurs around both playas, especially on the east side of Cadiz Dry Lake. At this locality there is a belt of dunes from 2 to 3 miles wide, some of which, according to Noble, are 50 feet high. The sand has been blown up the eastern slopes for more than 100 feet above the playa.

The depth to which the valley is filled with alluvium is considerable. In a well at Bagdad granite was struck at 805 feet. (See p. 697.) It is reported that in a well drilled at Amboy many years ago bedrock was not struck until a depth of 1,500 feet, or about 900 feet below sea level, was reached. This great depth may be questioned, for two reasons—first, because the bedrock in the Bagdad well was struck about 900 feet higher, and second, because the bottom of the rock valley as thus reported is so far below sea level. However, if the Bristol valley is a great down-faulted trough the depth to bedrock may well be as great as reported.

GROUND WATER

WELLS

The only notable wells in Bristol Valley are those drilled by the Atchison, Topeka & Santa Fe Railway. This company and its predecessor have put down eight wells, but only two have been successful. In two of the wells that were failures the water supply was practically nothing. In the others plenty of water was obtained, but it was too salty to be used. The following notes are based on data furnished by the railway company.

[59] U. S. Geol. Survey Mineral Resources, 1917, pt. 2, pp. 418–419, 1920.

At Klondike a well that was completed April 12, 1902, was drilled to a depth of 2,275 feet, or about 625 feet below sea level. The diameter of the hole ranged from 11⅝ to 5⅝ inches. The depth to water is not known. The log of the well reported clay and gravel from 0 to 242 feet, "rock" from 242 to 1,022 feet, shale from 1,022 to 1,040 feet, and "rock" from 1,040 to 2,275 feet. The well is reported to have been abandoned because a sufficient supply of water was not found. However, an analysis of water from the well shows that it is very highly mineralized, and this was perhaps a more forceful reason for abandoning the well. (See analysis 1 in table on p. 700.)

In 1908 a well was drilled near Haynes to a depth variously reported as 677 feet and 864 feet. Water was struck at a depth of 267 feet. The formation penetrated apparently consisted entirely of lava. Small knobs of Quaternary lava rise from the valley not far from the station. The water is said to have been hot and salty, and the well was abandoned for that reason.

At Bagdad a well that was completed March 4, 1902, was drilled to a depth of 1,000 feet, or more than 300 feet below sea level. The hole ranged from 13½ to 6 inches in diameter. The log of the well reported sand and gravel from the surface to 805 feet and red granite from 805 to 1,000 feet. The gravel from 450 to 805 feet was more or less cemented. The granite from 805 to 840 feet was decomposed. The depth to water was 150 feet, and the yield was 80,000 gallons in 24 hours (55 gallons a minute). As shown by analysis 2, the water was very highly mineralized, for it contained more than 6,000 parts per million of total dissolved solids, and the well was abandoned for that reason.

In 1883 the Southern Pacific Co., the predecessor of the Atchison, Topeka & Santa Fe Railway, drilled a well at Amboy to a depth of 1,535 feet, or more than 900 feet below sea level. The only information that could be obtained about this well is that bedrock was struck at 1,500 feet and that the well was abandoned because the water was salty. As shown on page 696, the great depth to bedrock may be questioned.

At the gypsum plant at Amboy there is a well 102 feet deep in which the depth to water is reported to be about 20 feet. A sample of water pumped from a depth of 50 feet in this well contained 4.38 per cent, or about 43,800 parts per million, of total dissolved solids. At the salt plant near Amboy there is a well 60 feet deep. A sample of water from this well contained 29.8 per cent, or about 298,000 parts per million, of dissolved solids. This sample is about as highly mineralized as samples of brine taken from the playa.

In 1910 a well was drilled to a depth of 320 feet at Bolo. No information is available in regard to this well, except that it was abandoned because the water was salty.

At Cadiz a well that was completed August 24, 1910, was drilled to a depth of 425 feet. The log shows "cement" and gravel, 0 to 210 feet; gravel and sand, 210 to 260 feet; sand, 260 to 360 feet; and cemented sand, 360 to 425 feet. The diameter of the well ranged from 12½ to 10 inches, and the well is cased to a depth of 400 feet with screw casing. Water was struck at 225 feet and apparently rose 5 feet. According to another report the water level stands at 235 feet. These different depths may be due to measurements made at different seasons of the year. The well yielded 60 gallons a minute. As shown by analysis 3 on page 700, the water is good for domestic use and fairly good for boilers, but for some reason this well has never been used.

At Archer, on the Parker branch of the railroad, a well has been drilled to a depth of 340 feet. The diameter of the well is 10 inches to a depth of 272 feet and 8 inches for the remainder. The materials penetrated were coarse gravel and sand to 280 feet; fine gravel and sand, 280 to 330 feet; and cemented gravel, 330 to 340 feet. The well is cased to a depth within 10 feet of the bottom. The casing is perforated between 250 and 290 feet. Water was struck at a depth of 280 feet. It is reported to stand only 40 feet below the surface, but this is uncertain. No clay beds are reported in the log of the well, and without them to serve as an impervious cover it would not be expected that the water would be under so great artesian pressure. Furthermore, according to the data furnished by the railroad, the casing is perforated from 250 to 290 feet, and 30 feet of the perforations are above the depth at which the first water is reported. If the water level in the well stands only 40 feet from the surface but the water-bearing bed is 280 feet from the surface, there must be leakage into the unsaturated alluvium through the perforations above that depth. As shown by analysis 4, the water from the Archer well is more highly mineralized than that from the Cadiz well and contains about 615 parts per million of total dissolved solids. It is, however, fairly good for domestic use. It is poor for use in boilers because of the quantity of foaming constituents present, and the scale-forming constituents are also fairly high.

In 1915 the railroad drilled a well about 4 miles northeast of Bagdad. The well was probably in sec. 3 or 10, T. 6 N., R. 11 E., in a long wash between the Bristol Mountains and a lower ridge west of them. In choosing this locality it was believed that a well drilled to strike the lowest part of the bedrock valley would encounter the ground water absorbed from the flood run-off that was moving toward the valley, even though the quantity was relatively small. It was hoped that this water would be good enough for use. The well was drilled to a depth of 681 feet and, except for a slight seepage 92 feet from the surface, no water was encountered. The log of the well is as follows:

Log of well about 4 miles northeast of Bagdad, Calif.

	Thickness (feet)	Depth (feet)
Sand, gravel, and boulders	95	95
Clay and boulders	40	135
Cemented gravel, sand, and boulders	130	265
Sand, gravel, and granite boulders	68	333
Decomposed granite with hard strata	37	370
Decomposed granite, thin hard strata	61	431
Decomposed granite of varying degrees of hardness and thin hard strata	232	663
Solid granite	18	681

It is impossible to determine from this log whether the so-called decomposed granite is actually disintegrated bedrock in place or whether it is an arkosic sand, such as is common in the desert region, which has resulted from the disintegration of granite and strongly resembles that rock when compact. The absence of water in the well may be accounted for by the fact that it was so located that it did not strike the lowest part of the bedrock valley. Indeed, it would be very difficult to locate a well so that it would strike the bottom of the valley, and unless the quantity of ground water moving down the valley were large it would not rise high enough to be reached by a well on the side of the buried ridge.

In addition to the railroad wells there are several dug wells in the valley. About 3¼ miles east of Amboy, 50 feet north of the main road, is a dug well. When measured by the writer on November 24, 1917, the total depth was 103.5 feet and the depth to water 99.3 feet. There was no means of obtaining water from the well. A number of cat's-claw bushes were growing near by, and their presence may have prompted the location of the well at this place. However, because of the great depth to water the bushes evidently do not obtain their moisture from the water table but rather from water absorbed from flood run-off.

A 4-inch drilled well 60 feet deep is reported in the SE. ¼ NE. ¼ sec. 22, T. 5 N., R. 13 E., about a mile south or southwest of Altura. The depth to water is about 50 feet. With a hand pump the well can be pumped dry in about an hour. The water in this well is reported to be of good quality. Another well is reported about half a mile southeast of the well just mentioned. This well has been dug 58 feet deep and at the bottom has a tunnel 6 feet long. The depth to water is about 50 feet. This well also can be emptied easily.

Analyses of ground water in Bristol Valley, Calif.

[Analyses furnished by the Atchison, Topeka & Santa Fe Railway Co. Parts per million recalculated from hypothetical combinations in grains per U. S. gallon]

	1	2	3	4
Silica (SiO_2)				
Iron (Fe)				
Calcium (Ca)	31	820	39	64
Magnesium (Mg)	4.3	6.1	1.7	6.9
Sodium and potassium (Na+K) (calculated)	441	1,582	65	150
Carbonate radicle (CO_3)				
Bicarbonate radicle (HCO_3)	593		119	140
Sulphate radicle (SO_4)	357	409	73	159
Chloride radicle (Cl)	136	3,603	52	166
Nitrate radicle (NO_3)				
Total dissolved solids	[a] 1,261	[a] 6,420	289	615
Total hardness as $CaCO_3$ (calculated)	95	2,075	104	188
Date of collection	([b])	([c])	([d])	([e])

[a] Calculated. [b] Apr. 15, 1902. [c] December, 1901. [d] Aug. 15, 1910. [e] Sept. 27, 1910.

1. Abandoned well 2,275 feet deep at Klondike. Atchison, Topeka & Santa Fe Railway, owner. See p. 697 for description.
2. Abandoned well, 1,000 feet deep, at Bagdad. Atchison, Topeka & Santa Fe Railway, owner. See p. 697 for description.
3. Well 425 feet deep at Cadiz. Atchison, Topeka & Santa Fe Railway, owner. See p. 698 for description.
4. Well 340 feet deep at Archer. Atchison, Topeka & Santa Fe Railway, owner. See p. 698 for description.

OTHER WATERING PLACES

Orange Blossom mine.—According to information furnished by the Atchison, Topeka & Santa Fe Railway, water stands at a depth of 565 feet below the surface in two shafts at the Orange Blossom mine, 9 miles northeast of Bagdad. One of these shafts was pumped at the rate of 158,400 gallons in 24 hours (110 gallons a minute) without exhausting the supply. It is not known whether water can be obtained if the mine is not in operation.

Willow Spring.—As nearly as can be learned, Willow Spring is situated about 4 miles northeast of the Orange Blossom mine. It is reported that the water is piped to the mine.

Springs in Old Woman Mountains.—Several springs are reported to occur in the Old Woman Mountains, but the exact location of most of them is unknown. On the General Land Office township plat of T. 6 N., R. 17 E., two springs are shown in sec. 33. One of them is near the northwest corner of the southwest quarter of the the section, on the north fork of a canyon known as Carbonate Gulch. The other is about half a mile to the southeast, a short distance northeast of the junction of the north fork with the main gulch. These springs are probably reached by a road that leads east from the Danby-Kilbeck road, 7 miles south of Danby, to prospects in the mountains and thence by foot trail to the spring.

Mascot Spring.—A spring known as Mascot Spring was reported to issue at the base of the lava flow near the southwest edge of Bristol Dry Lake, about 4½ miles south of Bagdad.[60] A. B. Mulvane

[60] Mendenhall, W. C., Some desert watering places in southeastern California and southwestern Nevada: U. S. Geol. Survey Water-Supply Paper 224, p. 69, 1909.

states that he has made a careful search for this spring but could not find it, and it apparently no longer exists.

Water supply at railroad stations.—As the water in all wells drilled along the railroad west of Cadiz has been too salty to use, it is necessary to haul water by train for all purposes. The wells in Fenner Valley, the nearest source, do not yield more than is required at each station, and the nearest ample supply is at Water station, in the Lower Mohave Valley. (See p. 499.) In 1919 an average of 16 cars of 10,500 gallons each was hauled daily for use at Bagdad and 1 car for Klondike. Water in less quantity is also hauled for all domestic and general use at Amboy and at the places where section crews are stationed.

At Bagdad the water is run from the tank cars into a cistern and then pumped into a tank. At Klondike, as a result of the grade of the track, the water runs into the storage tank by gravity through a pipe from an intake several hundred feet from the storage tank. The consumption of water at Bagdad is especially large because of the steep westward grade. Practically all trains take on fuel and water at that place.

INTERPRETATION OF CONDITIONS

The interpretation of ground-water conditions in Bristol Valley is desirable because of the possible future need of additional supplies for the railroad and for the mining communities at several localities in the basin.

Drill holes have shown that only salt water can be obtained in a large part of the basin. Apparently the lower part of the valley has been a closed basin for a long time. The water that poured into the basin from a large drainage area has been evaporated, and the salts contained in it have been left in the playa deposits. The salty water in the wells drilled at Amboy and Bolo show either that the saline playa deposits extend some distance beneath the present sand and gravel cover of the alluvial slopes or that the salt absorbed by the water beneath the playas has spread beneath the alluvial slopes by diffusion.

As water of fairly good quality was obtained in the wells at Cadiz and Archer and southwest of Altura, it is possible to obtain potable water in at least some parts of the basin. In the Cadiz well, according to the available information, the water table is about 550 or 560 feet above sea level. This altitude apparently is below that of the water table in Bristol Dry Lake. The altitude of the railroad at Amboy is about 614 feet. Although the playa surface is several feet below the railroad and the water table about 8 feet lower, the water can scarcely be 50 feet below the railroad. In the Archer well the water table was struck at a depth of 280 feet, or at an altitude of about 570 feet. However, as noted on page 698, there is some question as to the depth at which the water stands. Apparently the water level in these two wells is at least as low as it is beneath Bristol Dry Lake near Amboy, if not somewhat lower. The lowest place on the railroad near the playa is 603 feet above sea level. Ground water is reached about 8 feet below the playa. The difference in altitude between the railroad and the playa is not definitely known, but it does not appear to be as much as 20 feet, which would be necessary if the water table is as low as it is in the two wells. It is at least evident that there is no effective descent of the water table from the Cadiz well to Bristol Dry Lake. On the other hand, if, as reported, the water rises in the Archer well 140 feet it is under such pressure that it would move toward Cadiz Dry Lake.

The question arises, why the water in the Cadiz well is only moderately mineralized if the water is no higher than it is beneath Bristol Dry Lake. In the first place, the water is so near the surface of the playa that there is more or less continual discharge by upward capillary movement and evaporation. As a result there must be movement toward the playa from the sides of the valley. The well at Cadiz is in a position to receive water relatively low in mineral content that comes from Fenner Valley, between the Ship and Marble Mountains. Similarly, at Archer there is doubtless a movement of ground water from the Old Woman Mountains toward Cadiz Dry Lake. In each place the underflow that comes from a large drainage area would tend to push back, as it were, the salt water toward the playa. Furthermore, the difference in the specific gravity of the salty water and the less mineralized water might have some influence in preventing the diffusion of the salt from the playa toward the borders of the valley.[61]

If these principles hold true it ought to be possible to obtain potable water at other places in the valley if they are far enough from the playas to avoid any possible effects of diffusion or encountering the buried borders of the playa deposits. As gypsum is reported in a well at Amboy the salty water there and possibly also at Bolo may be due to the presence of buried playa deposits. On the other hand, the presence of relatively good water in the well about a mile southwest of Altura suggests that a large supply of fresh water either from the east or from the north is sufficient to push back the salt water. On the north the ground water comes from a large drainage area between the Bristol and Marble Mountains, including the high Old Dad Mountains, and the total underflow must be considerable.

The conditions in the northwestern part of the valley are uncertain. When the Amboy lava flow was poured out it may have dammed the drainage and resulted in the formation of a playa west of the flow.

[61] For the relation between salt and fresh water see B rown, J. S., A study of coastal ground water: U. S. Geol. Survey Water-Supply Paper 537. 1925.

If so, the playa deposits have since been covered up. Such damming would impede the movement of the ground water toward the lowest part of the basin, and it might then absorb more mineral matter.

The exact location and surface altitude of the wells at Bagdad and Haynes is not known. However, according to the available data the water level in the Haynes well stands more than 700 feet above sea level, or fully 100 feet above the surface of Bristol Dry Lake; in the Bagdad well the altitude of the water level is about 630 feet, or at least 25 feet above the water level beneath the playa at Amboy. Thus it seems there should be some movement from the west end of the valley toward Bristol Dry Lake. The fact that despite this condition the water in that part of the valley is so bad probably indicates that the salt content is due not to the presence of playa beds but to other conditions not yet known. As shown on page 660, the water in part of Broadwell Valley, northwest of Bristol Valley, is of poor quality, and there is some reason to believe that the water table slopes in a southerly direction. The water from Broadwell Valley may move southeastward into Bristol Valley. In its longer journey it might dissolve a rather large quantity of mineral matter.

As the wells at Bagdad, Haynes, and Klondike each obtained salty water, it is believed that further attempts to obtain good water along this stretch of the railroad will be useless. The rocks in this part of the valley are largely volcanic, including volcanic ash. Possibly these rocks have in some way given the highly mineralized character to the water. Perhaps wells drilled on the south side of the valley, near the Bullion Mountains, might strike less mineralized water. Water derived from crystalline rocks like those that compose the mountains is generally of good quality, provided it has not become concentrated in the lowest part of the basin.

The presence of alluvial divides at two places raises a question whether there is any ground-water drainage between Bristol Valley and adjoining basins. These divides are situated between the Old Woman Mountains and the Kilbeck Hills, and at the extreme south end of Cadiz Valley between the Coxcomb Mountains and Iron Mountain.

In a well at Ward, on the Parker branch of the Atchison, Topeka & Santa Fe Railway, the altitude of the water table is not less than 600 feet (see p. 710), or about 30 feet above the water table in the Cadiz and Archer wells. It thus seems possible that there may be some drainage from Ward Valley into Bristol Valley. However, the distance between Ward and Archer is about 25 miles, and the grade of the water table would not be more than a foot or two to the mile, or so gentle that there would probably be no active movement. Furthermore, the divide at Kilbeck is more than 400 feet above the water table in Bristol Valley. Possibly in this depth bedrock may rise high enough to separate the water table in the two valleys.

The divide at the south end of Cadiz Valley from the road many miles north appears to be composed of alluvium, and possibly there is some ground-water movement below it to Chuckawalla Valley on the south. About 18 miles south of the divide, or 30 miles southeast of the south end of Cadiz Dry Lake, is Palen Dry Lake. This playa lies between 400 and 420 feet above sea level and is reported to be of the moist or discharging type, so that the water table lies at about that altitude.[62] If the water table slopes continuously from Cadiz station to Palen Dry Lake, a distance of more than 50 miles, the grade is only about 4 feet to the mile. The alluvial divide is rather high, and it is obviously possible that the bedrock beneath may stand above the water table.

The fact that the surface of Cadiz Dry Lake is so wet suggests that there is no drainage from the valley. However, as is demonstrated in other valleys in the Mohave Desert region, it is entirely possible for the water table to be close to the surface in a basin which may have underground drainage.

WARD VALLEY

GENERAL FEATURES

Ward Valley lies in the southeastern part of San Bernardino County. The name is taken from the railroad station of Ward, on the Parker branch of the Atchison, Topeka & Santa Fe Railway. (See pl. 7.) The lowest part of the valley is occupied by a large playa known as Danby Dry Lake, but the town of Danby, on the main line of the Atchison, Topeka & Santa Fe Railway, is in Fenner Valley.

The Parker branch of the railway crosses the south end of the valley from northwest to southeast. On this railway Ward is a pumping station and Milligan is a section headquarters. Water is available at both places, but in 1918 there was no store at either place where supplies could be obtained. Fishel, Sablon, and Arica are only sidings. Water can generally be obtained from a cistern at Sablon.

The railroad is paralleled by a road sometimes known as the Parker cut-off. (See pls. 12 and 13.) On the southeast this road leads to Rice, whence a road leads south to Blythe and points in Palo Verde Valley and another leads east to Parker and other points in Arizona. Toward the northwest the road forks at Kilbeck, on the border of Ward Valley. One branch leads northward to the National Old Trails Road at Danby, and the other continues northwestward along the railroad to the same road near Cadiz. For persons who are going westward the road by way of Cadiz is 9 miles shorter than the road by way of Danby. However, the road between Kilbeck and Cadiz is likely to be rough, and the traveler will generally save time by going by way of Danby.

[62] Brown, J. S., The Salton Sea region, Calif., a geologic, geographic, and hydrologic reconnaissance: U. S. Geol. Survey Water-Supply Paper 497, p. 102, 1923.

From Milligan a road runs northeastward along the east side of the Old Woman Mountains. In January, 1918, there were really two parallel roads a few hundred yards apart. The eastern one was in the best shape for about 11.5 miles, but at the end of this stretch travelers generally turned over to the road nearest the mountains. The road leads to the Wilhelm camp, 17.5 miles from Milligan, where in 1918 water could be obtained at a pipe line from a natural spring in the mountains about 3 miles south.

From the Wilhelm camp a road leads east a short distance to the easterly of the two roads mentioned above. This road continues northward to Sunflower Spring, about 5 miles north and a little west of the Wilhelm camp. (See p. 688.) From the spring the road continues northwestward to prospects at the north end of the Old Woman Mountains and thence westward to Danby. It is reported that automobiles can not reach Sunflower Spring nor travel a stretch of several miles between the Wilhelm camp and the prospects on the north end of the range. Wagons, however, can be taken over this rough stretch.

There was no agricultural activity in the valley in 1918, and conditions for irrigation are unfavorable. There has been some mining at the Wilhelm camp and at the Desert Butte mine, in the hills south of Kilbeck,[63] and prospecting on the west side of the Turtle Mountains, but at no place has there been any notable development. From time to time salt has been mined from extensive deposits in Danby Dry Lake,[64] but in January, 1918, the mines were idle.

The mean annual precipitation in the valley is probably intermediate between that at Bagdad and at Parker. In most of the valley it is probably less than 5 inches. There is no evidence that the mountains which border the valley have any great influence in increasing the precipitation.

The vegetation in the valley consists largely of the creosote bush and other plants usually associated with it. The form of yucca known as Spanish bayonet is found on the higher slopes. Mr. R. A. Martin, of Oatman, Ariz., gave the writer a specimen of *Holocantha emoryi*, which he found growing in some abundance in the long wash that extends from Ward northward for about 35 miles. This peculiar plant, which consists wholly of thorny branches and small red berries, has been reported from only two or three other localities in California. (See p. 47.) The exact locality is not known, but it is probably at least 10 or 15 miles north of Ward station.

Although the water table lies within 10 or 20 feet of the surface beneath Danby Dry Lake, and in some places probably even less, no mesquite or salt grass was observed around the playa.

[63] Cloudman, H. C., and others, Mines and mineral resources of San Bernardino County: California State Mineralogist Rept. for 1915-16, p. 12, California State Min. Bur., 1917.

[64] Bailey, G. E., The saline deposits of California: California State Min. Bur. Bull. 24, p. 128, 1902.

PHYSICAL FEATURES AND GEOLOGY

Ward Valley is a long, narrow troughlike valley, that extends due north and south. It is bordered on the west by the Piute Mountains, the Old Woman Mountains, the Kilbeck Hills, and Iron Mountain. The eastern border is formed principally by the Sacramento Mountains, the Turtle Mountains, and a small part of the Arica Mountains. The divide is composed of alluvium at four places—at the extreme north end of the basin, a few miles south of the main line of the Atchison, Topeka & Santa Fe Railway; between the south end of the Old Woman Mountains and low hills near Kilbeck, on the Parker branch of the railroad; at the extreme south end of the basin, 15 or 18 miles south of Ward; and between the south end of the Turtle Mountains and the Arica Mountains.

The Sacramento and Turtle Mountains are described briefly on pages 732 and 738. On the west side of the Turtle Mountains low hills, probably composed of Tertiary volcanic rocks, extend out for some distance from the main mass of the mountains. The Piute and Old Woman Mountains are composed of a complex of granite, gneiss, quartzite, and limestone, intruded by granitic rocks of later age. The older complex is probably, in part at least, pre-Cambrian. The later granite is probably Mesozoic. On the geologic map (pl. 8) the area shown as pre-Tertiary rocks includes only areas of limestone, the areas of quartzite not being differentiated from the later rocks. There are also a few small areas of Tertiary volcanic rocks. The Old Woman Mountains rise to a great height in immense blocks that resemble battlements of a fortress. A peculiar feature occurs at the southeast end of the range, where several broad valleys are cut far back into the mountains and the alluvial slope appears to extend almost to the summit of the range.

Iron Mountain is a long, narrow, relatively low range. Its northern slope rises rather steeply, and the mountain is not greatly dissected. The alluvial slope between it and Danby Dry Lake is low and short as compared to the slopes that rise to the other near-by mountains. These features suggest that the range may be a comparatively recently uplifted fault block.

The lowest part of the basin, which is occupied by Danby Dry Lake, lies near the southern part of the valley. The drainage from most of the basin reaches the playa through a long wash that extends northward almost to the extreme north end of the valley, near the main line of the Atchison, Topeka & Santa Fe Railway, a distance of nearly 35 miles. The alluvial slopes between the Piute and Old Woman Mountains on the west and the Sacramento and Turtle Mountains on the east descend approximately at right angles to the wash, which is sometimes known as Homer Wash, a name derived from a station on the railroad a few miles north of its head. The station itself is not in the drainage basin.

The playa near Ward is about 625 feet above sea level. The divide at the north end of the basin, at the head of Homer Wash, is probably about 2,200 or 2,300 feet above sea level. The total area of the drainage basin is about 1,155 square miles, of which about 365 square miles or 31.5 per cent, is occupied by mountains, 750 square miles, or 65 per cent, by alluvial slopes, and 40 square miles, or 3.5 per cent, by the playa.

Danby Dry Lake presents several unusual features. At the east end of the playa and extending inward for about three-quarters of a mile the surface is smooth and mud cracked, as on typical dry playas. Farther west it changes to the puffy "self-rising ground" that is found in moist playas. On the wagon road about 2 miles west of Ward there is a sudden rise in the surface of about 2 feet, and the ground is very rough and covered with more or less alkali. (See pl. 34, *B*.) From this place westward numerous small drainage channels cross the road. At the northwest end of the playa one of these channels is 4 or 5 feet deep and 100 feet wide. (See pl. 34, *C*.)

The channels all slope in a southerly direction. Such channels are generally absent on other playas in the Mohave Desert region, and the cause of their formation was not ascertained. So far as is known the playa is completely inclosed, so that there has been no recent change in the drainage lines. Possibly there has been comparatively recent movement in the region that has resulted in the slight southward tipping of the playa surface, which is now being eroded, or perhaps the playa beds were deposited with an initial southward dip and the present downcutting is due to a climatic change which gave the ephemeral streams more eroding power.

The presence of the smooth surface and the "self-rising ground" in different parts of the playa is apparently due to differences in the depth to ground water. In the railroad well at Ward water stands at a depth of about 20 feet. In a pit about 2 miles south of Ward the depth to water is reported to be about 7 feet, and in a pit 2 or 3 miles south of Milligan it is said to be only 6 feet. The "self-rising ground" probably occurs where the depth to water is not more than 8 or 10 feet.

Beds of common salt have been found beneath the playa at a depth of a few feet, the depth differing in different parts of the playa. Although they have not been definitely traced by detailed exploratory work, the salt beds are apparently continuous beneath most of the playa. The thickness of the beds has not been fully determined, but in most places they are several feet thick. It is said that in a shaft dug many years ago to a depth of 65 feet solid rock salt was penetrated for 22 feet.[65] The salt has been mined at several places on

[65] Bailey, G. E., The saline deposits of California: California State Min. Bur. Bull. 24, p. 128, 1902.

the playa, but in January, 1918, none of the deposits were being worked.

In order for the thick beds of salt to have accumulated a considerable body of water must have covered the area for a period long enough to become saturated with sodium chloride. In his hurried trip through the valley the writer did not observe any unmistakable evidence of a lake in the form of beaches or wave-cut cliffs. In an unpublished report in the files of the United States Geological Survey relating to potash investigations, Charles E. Watson states that about 400 yards north and east from Ward station there is a marked terrace or shore line, where a shelf of limy rock (probably caliche) underlies a thin bed of gravel. It appears likely that careful investigation would reveal a definite shore line. Blue clay is reported from test holes in the playa beds, and this is believed to be additional evidence of a lake, as the bluish color is probably due to deposition beneath water.

For the lake that once existed in Ward Valley the name Ward Lake is suggested, to distinguish it from the present playa known as Danby Dry Lake. This lake apparently was not comparable in size, depth, or period of duration to the members of the Searles-Panamint lake system. If the level of the lake had risen somewhat less than 400 feet above the level of Danby playa the lake would have overflowed the divide at Kilbeck, which at the time doubtless was even lower than at present, and would have united with the lake that existed in Bristol Valley. There is, however, no evidence that the lake stood that high.

GROUND WATER

WELLS IN THE VALLEY

Ward well.—The railroad well at Ward is the only reliable watering place in the valley, except the cistern at Milligan. Two or three other watering places exist, but they are in out-of-the-way places, difficult to reach, or otherwise not certain sources of supply.

In 1910 the Atchison, Topeka & Santa Fe Railway drilled a well at Ward to a depth of 118 feet. Water was struck at 42 feet and stood 40 feet from the surface. The well sanded up and was abandoned. In November and December, 1913, a second well was drilled to a depth of 603½ feet. The log of the well, furnished by the railroad and given below, shows that the materials penetrated are in large part undoubtedly lake or playa deposits. Although salt deposits are known to occur only a mile or two south of the well, none were reported in the well. The well is situated beyond the border of the lake in its final stage.

Log of well at Ward, Calif.

[Atchison ,Topeka & Santa Fe Railway, owner]

	Thickness (feet)	Depth (feet)
Surface soil	40	40
Yellow clay	30	70
Sandy clay; struck water	10	80
Yellow clay	60	140
Brown silt and sand	35	175
Yellow clay	50	225
Black sand	10	235
Blue clay	25	260
Yellow clay	15	275
Yellow sand	20	295
Yellow clay	17	312
Sand and gravel, water bearing	13	325
Yellow clay	20	345
Yellow sand	65	410
Yellow clay	35	445
Yellow sand	70	515
Blue sand	25	540
Blue clay	60	600
Not reported	3½	603½

The well is 12½ inches in diameter to a depth of 307½ feet and 10 inches the remainder of the distance. The casing is screw pipe, and it is perforated with four rows of ½ by 1 inch holes between 312 and 325 feet, in the only gravel bed that was struck. The depth to water when the well is not being pumped is 20 feet. Apparently the water was struck at 70 feet and rose to that height. The yield in a test on March 23, 1914, was 4,400 gallons an hour (about 75 gallons a minute).

As shown by the following analysis, the mineral content of the water from the well is moderate. The water is good for domestic use, although it is said to have a peculiar taste, and fair for irrigation. The dissolved mineral matter consists mainly of sodium chloride, sulphate, and bicarbonate. The water is not greatly different from that found on the alluvial slopes in other parts of the Mohave Desert region. Brines from pits in the salt beds 2 miles or more south and southwest of Ward contain more than 25 per cent (250,000 parts per million) of soluble salts. In view of this fact it is surprising that the water at Ward is of such good quality. Perhaps the clay beds effectively seal off the water from the salt beds. On the other hand, the water may be kept fresh by circulation upward where there is discharge from the surface of the playa by evaporation.

Analysis of water from the Atchison, Topeka & Santa Fe Railway well at Ward station, Calif.

[Collected Nov. 19, 1917. Analyzed by A. A. Chambers. Parts per million]

Silica (SiO_2)	13
Iron (Fe)	.14
Calcium (Ca)	7.1
Magnesium (Mg)	2.2
Sodium and potassium (Na+K) (calculated)	150
Carbonate radicle (CO_3)	0
Bicarbonate radicle (HCO_3)	110
Sulphate radicle (SO_4)	114
Chloride radicle (Cl)	93
Nitrate radicle (NO_3)	14
Total dissolved solids at 180° C	482
Total hardness as $CaCO_3$ (calculated)	27

As nearly as can be determined, the water table at Ward is about 30 feet above the water table at Cadiz Valley, to the west, and about the same height above the water table at Rice, in the valley east of Ward Valley. The divide that separates Ward Valley from each of the other two valleys is apparently composed of alluvium to a considerable depth, so that there may be some movement of ground water to either valley. However, the gradient in either direction is very gentle, and the underground drainage, if any, can not be very great, for the water table is so close to the surface beneath Danby Dry Lake that there is undoubtedly discharge of ground water by evaporation.

Other wells.—A well known as Miller's well was reported by Mendenhall[66] as situated on the southwest edge of Danby Dry Lake. So far as the writer could learn this well no longer exists. The water in it was reported to be too salty for human consumption, and as good water can now be obtained at Ward and Milligan the Miller well is of no importance.

About half a mile southeast of Milligan, on the road to Parker, there is an old dug well, 60 feet deep, which in November, 1917, contained only an inch or two of water. This well is at an altitude considerably above the playa.

WATERING PLACES IN THE MOUNTAINS

Martin's well.—R. A. Martin reports that he has a well in a wash on the west side of the Turtle Mountains, about 10 miles a little north of east of Ward station. It is not reached by any road, and the exact location is unknown. The well is only 7 feet deep and contains only about 2 feet of water, but it has never been known to go dry.

Water at Wilhelm camp.—In November, 1917, water was obtainable from a pipe-line faucet in the corral at the Wilhelm camp, on the east side of the Old Woman Mountains, 17.5 miles northeast of Milligan.

[66] Mendenhall, W. C., Some desert watering places in southeastern California and southwestern Nevada: U. S. Geol. Survey Water-Supply Paper 224, p. 76, 1909.

The water is piped from a natural tank in the mountains about 3 miles south and a little west of the camp. The supply is said to be good ordinarily, but when the locality was visited only a very small flow was coming through the pipe.

Sunflower Spring.—Sunflower Spring is in the NE. ¼ SE. ¼ sec. 6, T. 5 N., R. 18 E., at the northeast end of the Old Woman Mountains. Leroy A. Palmer, of the United States General Land Office, states that it consists of an open cut in granite which develops a small flow of water. There is some alkali about the spring, and it is said that cattle have died from drinking the water. However, the place is used frequently as a camp site, and the water can be used without bad effects. It is doubtful whether the water has been the cause of the death of the cattle, and the alkali might easily be formed from the long-continued evaporation of water containing only small quantities of dissolved solids. Water that comes from granite is generally of good quality, but if the rocks in the vicinity were highly mineralized the water might be of poorer quality.

Granite Tank.—Leroy Palmer reports a natural tank called Granite Tank in the NE. ¼ SE. ¼ sec. 11, T. 6 N., R. 18 E., in a small group of hills called the Little Piute Mountains. The tank is a depression about 10 feet long and 7 feet wide, hollowed in the granite bed of a stream channel. The tank is shown on the General Land Office township plat, which was made in November—that is, at the end of the dry season. For this reason it is believed that the tank generally contains water the year round.

IRRIGATION PROSPECTS

There was no agricultural development in Ward Valley in 1917, and the prospects for such development are not favorable. The precipitation is undoubtedly too small to permit dry farming. Water that is good enough for irrigation is obtained in the well at Ward, but only one gravel bed was encountered, and the wells drilled at Danby Dry Lake probably would not yield much water. Farther from the playa the alluvial deposits doubtless would yield more water, but the depth to water will be greater—perhaps too great to permit profitable pumping.

RICE VALLEY

GENERAL FEATURES

Rice Valley lies mostly in the northeastern part of Riverside County, but a very small part lies in the southeastern part of San Bernardino County. (See pl. 7.) The name is taken from the town of Rice, formerly called Blythe Junction. About half the valley lies south of the area shown on Plate 13, and this part has been described by Brown.[67] Some of the data presented below were collected by Mr. Brown.

Rice station is at the junction of the Parker branch of the Atchison, Topeka & Santa Fe Railway and a branch that leads to Blythe and Palo Verde Valley, on Colorado River, about 40 miles distant. In January, 1918, meals and sleeping accommodations for a few persons were available, but no automobile supplies or groceries could be obtained. Such supplies may sometimes be obtained when mining activities warrant the maintenance of a store. On this road water can be obtained at Ward, 15 miles northwest of Rice, and at Grommet, 9½ miles east of Rice. Grommet is the headquarters for a section crew, and aid can be obtained there in an emergency.

A road, sometimes called the Parker cut-off, parallels the Parker branch of the railroad and leads eastward to Vidal and points in Arizona and westward to the National Old Trails Road at Cadiz and Danby. (See p. 689.) From Rice a road leads southwestward for several miles and then southeastward to Blythe, in the Palo Verde Valley, a distance of 41 miles. The availability of water on this road is uncertain, and the traveler should carry enough water for the entire distance to Blythe.[68] The road is said to be sandy for several miles south of Rice, but the worst stretch is planked.

Some mining has been carried on in the region from time to time. The principal mines are those which obtained gold from the Arica Mountains, 6 or 7 miles southwest of Rice.[69]

The temperature and precipitation in the valley are probably intermediate between those at Bagdad and at Parker, Ariz., 38 miles east of Rice. The mean annual precipitation is probably not more than 5 inches. The mountains that border the basin are not large enough to cause any material variation in the temperature or precipitation in different parts of the basin.

PHYSICAL FEATURES AND GEOLOGY

The southern border of Rice Valley is formed by the Maria and Little Maria Mountains. J. S. Brown states that the rocks in the mountains include a thick series of interbedded quartzite, limestone, and gypsum, presumably of Paleozoic age or older, and large masses of granite gneiss and schist.[70] The whole mass is intricately folded and metamorphosed. The gypsum beds are remarkably pure and in places 150 feet thick.[71] The western border of the basin is formed

[67] Brown, J. S., The Salton Sea region, Calif., a geologic, geographic, and hydrologic reconnaissance: U. S. Geol. Survey Water-Supply Paper 497, pp. 99-101, 180-181, and 259-261, 1923.

[68] For watering places on this route see Brown, J. S., Routes to desert watering places in the Salton Sea region, Calif.: U. S. Geol. Survey Water-Supply Paper 490, pp. 63-65, 1920.

[69] Merrill, F. J. H., Mines and mineral resources of Riverside County: California State Mineralogist Rept. for 1915-16, pp. 81-82, 1917.

[70] Brown, J. S., The Salton Sea region, Calif., a geologic, geographic, and hydrologic reconnaissance: U. S. Geol. Survey Water-Supply Paper 497, p. 259, 1923.

[71] Merrill, F. J. H., op. cit., p. 118.

in part by the Arica Mountains, a small, low mass composed of altered porphyritic intrusive rocks in contact with limestone. The divide between these mountains and the Little Maria Mountains on the south appears to be formed of alluvium, and the divide between them and the Turtle Mountains, north of Rice, is distinctly of this material. The Turtle Mountains form a large range that extends northward for many miles, but only a small area at their very south end lies in the Rice drainage basin. As observed from the road several miles distant, this end of the range appears to be composed of Tertiary volcanic rocks. The eastern border of the valley is formed in part of the Riverside Mountains. Between these mountains and the Turtle Mountains the divide is composed of alluvium, as apparently also is the divide between the Riverside Mountains and the Maria Mountains.

The lowest part of the basin, near the center of T. 2 S., R. 21 E., is occupied by a playa. It was not visited. Probably it is a playa of the dry type, for according to the available information the water table is 137 feet below the surface in a well not far from it.

The area of Rice Valley, according to planimeter measurement, is about 285 square miles. Of this area about 85 square miles, or a little less than 30 per cent, is occupied by mountains, and the rest consists of alluvial slopes and playa. The area of the playa is not known.

According to railroad profiles the lowest part of the basin is about 700 feet above sea level. The divide along the railroad to Blythe where it crosses the Maria Mountains is nearly 1,100 feet above sea level. At Grommet the divide between Rice Valley and the Colorado River Valley is about 950 feet, and west of Rice the divide between the valley and Ward Valley is about 910 feet above sea level.

GROUND WATER

No springs are known to exist in Rice Valley. There are several wells in the valley, but the supplies are not very good.

In 1910 a well was drilled by the Atchison, Topeka & Santa Fe Railway at Rice. The well was 575 feet deep. Water was struck at 355 feet and a second water-bearing stratum at 450 feet. The water stood at 355 feet. The materials penetrated were gravel, sand, clay, and "malpaís" or lava. Apparently the lava was underlain by alluvial deposits. A mile or two east of Rice boulders of lava are seen on the road. The lava reported in the well may be similar boulders, or it may be a true flow, related to the volcanic rocks in the Turtle Mountains. The well was subsequently abandoned, according to report, because the water was of poor quality. However, according to a statement furnished by J. H. Grover, division foreman of water service of the railroad, the well was abandoned because it sanded up and could not be pumped. All water for use at the town is hauled in on the railroad.

A dug well, known as Browns Well, is situated on the west side of the road to Blythe, 6½ miles southwest of Rice. When measured by J. S. Brown, in October, 1917, the total depth was 304 feet and the depth to water was 297 feet. At that time the well was equipped with a small gasoline engine and pump and also with a bucket and cable for raising water by horse power. A supply of water was generally available from a near-by tank, which was pumped full at intervals. According to information received by letter from W. B. Kehoe, the well was caved in April, 1921, and water could not be obtained from it. The following analysis shows that the mineral content of the water from this well is fairly high—661 parts per million of total solids. However, the water can be used for domestic supplies without trouble and is fair for irrigation. The principal constituent is sodium sulphate. In this respect it differs from most waters in the desert basins, which are characterized by the presence of sodium carbonate, or, particularly near playas, sodium chloride.

Analysis of water from Browns Well, probably in sec. 16, T. 2 S., R. 20 E. San Bernardino meridian

[Collected by J. S. Brown, Oct. 30, 1917; analyzed by C. H. Kidwell. Parts per million]

Silica (SiO_2)	25
Iron (Fe)	.80
Calcium (Ca)	27
Magnesium (Mg)	7.2
Sodium and potassium (Na+K) (calculated)	191
Carbonate radicle (CO_3)	0
Bicarbonate radicle (HCO_3)	190
Sulphate radicle (SO_4)	246
Chloride radicle (Cl)	69
Nitrate radicle (NO_3)	2.3
Total dissolved solids at 180° C	661
Total hardness as $CaCO_3$ (calculated)	97

About a mile north of Browns Well, on a branch road leading from the Blythe road to mines in the Arica Mountains, is the Priest Well. The well is 587 feet deep, and the depth to water is 507 feet. The well is situated at a higher altitude than Browns Well. The water is too poor to be used for domestic supplies.

Grays Well is about 2½ miles northeast of Browns Well, near the lowest part of the basin. The depth to water is reported to be about 137 feet. The water is salty and too poor for domestic use. It has been used for milling gold.

Gyp Well, 585 feet deep, is near the southern border of the basin, several miles south of the area shown in Plate 13. It is probably in sec. 13, T. 2 S., R. 20 E. It is reported that poor water was reached at 125 feet, although there is some question as to this statement. This water was cased out, and water that was good for domestic use was found at a greater depth.

According to data obtained from railroad profiles, the altitude of the well at Rice is about 935 feet and of the water table 580 feet above sea level. The altitude on the railroad to Blythe near Grays Well is about 705 feet, and the altitude of the well is believed to be about 710 feet. The water table is thus about 573 feet above sea level. The distance between the two places is about 4 miles. On the basis of these approximate data the water table appears to have so slight a grade that there can be very little movement of the ground water.

The great depth to water in Grays Well, near the bottom of the basin, probably indicates that there is underground drainage from the basin. As the divide of the basin is composed of alluvium, at its northwest and northeast corners and apparently also at its southwest and southeast corners, there seems to be ample opportunity for underground drainage. The altitude of the water table in a well at Ward, 15 miles northwest of Rice, is about 605 feet. (See p. 710.) The water table in this well is about 25 feet higher than at Rice, so that there is obviously no chance for movement of ground water from Rice Valley to Ward Valley. There may be some movement in the opposite direction, although the grade is very gentle and the rate of movement can not be great. The altitude of the water table in a well at Vidal, 21 miles east of Rice, is about 375 feet above sea level, or about 200 feet lower than at Rice. The divide at Grommet is wide and apparently filled with alluvium to a considerable depth, so that there seems to be ample opportunity for underground drainage from the Rice Basin into the Colorado Basin near Vidal. Southeast of the Riverside Mountains the altitude of the Colorado River Valley is about 350 feet above sea level. The divide in this direction was observed only from a distance of many miles, but it appears to be composed of alluvium, so that there is probably opportunity for underground drainage also at this point.

In general the conditions are unfavorable for any great development of the ground water in Rice Valley. Even in the lowest part of the basin the depth to water is so great that it would hardly be economical to pump water for irrigation, and the water is of poor quality. Possibly water good enough for domestic use can be obtained in wells near the upper borders of the alluvial slopes, but the depth to water will be great. As the water table appears to be nearly flat, wells will probably not yield large quantities.

COLORADO RIVER BASIN

GENERAL FEATURES

An area which extends north and south along the extreme eastern border of the Mohave Desert region and which ranges in width from 20 to 40 miles lies in the drainage basin of Colorado River. (See pl. 7.) In recent years studies have been made in regard to the irrigation of some parts of this area in connection with comprehensive plans for the most efficient utilization of the river. The results of these studies have been published elsewhere.[72] In the present study little attention was paid to the areas that lie close to the river, and the following notes refer principally to ground-water conditions in parts of the drainage basin remote from the river.[72a]

The basin has been divided for description into four units, each of which constitutes a more or less distinct drainage unit. These units are from north to south, Piute Valley, the area immediately adjacent to the river between Mohave City and Topock, Chemehuevis Valley, and Vidal Valley. For most of the distance between Parker and Topock the river flows in a rocky canyon with large mountains on both sides. This part of the basin was not visited, and no description is given in this report. It has, however, been described by Lee.[73]

PIUTE VALLEY

GENERAL FEATURES

Piute Valley lies partly in the extreme east-central part of San Bernardino County, Calif., and partly in the south end of Clark County, Nev. (See pl. 7.) Part of the area in Nevada is not shown on the relief map in this report (pl. 13), but it is covered by the Camp Mohave topographic map, published by the United States Geological Survey. The valley drains into Colorado River a few miles north of Needles, but in this description the valley is considered as ending at a constriction in the drainage area near Klinefelter, in the northeastern part of T. 9 N., R. 21 E.

The writer visited only the part of the valley that lies in California. In 1922, in response to a request from the Chamber of Commerce of

[72] Preliminary report on problems of Imperial Valley and vicinity, U. S. Reclamation Service, printed for use of Committee on Irrigation of Arid Lands, House of Representatives, 66th Cong., 3d sess., 1921. Problems of Imperial Valley and vicinity: 67th Cong., 2d sess., S. Doc. 142, 1922. Reports on the Parker, Fort Mohave, and Cibola irrigation projects, Ariz.: Appendix A, Hearings before Committee on Irrigation of Arid Lands, House of Representatives, 66th Cong., 2d sess., on H. R. 11449, A bill to provide for the protection and development of the lower Colorado River, 1922. LaRue, E. C., Water power and flood control of Colorado River below Green River, Utah: U. S. Geol. Survey Water-Supply Paper 556, 1925.

[72a] Since this report went to press a bill has been passed by Congress providing for the construction of a dam in Black Canyon, on the Colorado River about 75 miles north of the California line. According to plans this dam will create a huge reservoir with a capacity of 26,000,000 acre-feet—several times as large as any other reservoir in the United States. The project will provide relief from destructive floods, water for irrigation in the lower Colorado River Valley, and hydroelectric power. In addition to the reports mentioned in footnote 72, several more recent reports have been made on this project.

[73] Lee, W. T., Geologic reconnaissance of a part of western Arizona: U. S. Geol. Survey Bull. 352, pp. 41–45, 1908.

Searchlight, Nev., D. F. Hewett, of the United States Geological Survey, made an investigation of ground-water conditions in the northern part of the valley, and a notice was published in newspapers giving the results of his investigation. The data collected by him are incorporated in the description that follows.

The main line of the Atchison, Topeka & Santa Fe Railway crosses the south end of the valley from east to west. A branch line of the railroad from Goffs to Searchlight, Nev., formerly led northward in Lanfair Valley and crossed the northwest end of Piute Valley, but service on it has been discontinued.

The National Old Trails Road parallels the main line of the railroad. A road from Searchlight to Barnwell parallels the branch railroad. A road known as the Arrowhead Trail leads northward from the National Old Trails Road, about 1¾ miles east of Bannock, to Searchlight and Las Vegas, Nev. This road was formerly much used for travel to Salt Lake City, especially in the winter, when the Midland Trail is closed by snow at the north end of Owens Valley, but most travelers now go over a new road by way of Manix, Baker, Valley Wells, and Roach. (See p. 143.) From Searchlight another road leads westward to Nipton, on the Los Angeles & Salt Lake Railroad. In 1922 a stage carried mail and passengers between these points three times a week. A number of other minor roads lead to scattered ranches and prospects.

Searchlight, Nev., the only town in the valley, in 1922 had a population of about 125 or 150 persons, a post office, a good store, a garage, and a hotel. Supplies are also obtainable at Goffs, just across the southwestern border of the valley.

A railroad pumping plant is located at Ibis, and section crews are stationed at Homer and Bannock, so that water and aid in emergencies, but no supplies, can be obtained at these places. Water can also be obtained at Klinefelter. On the Arrowhead Trail no supplies can be obtained between Goffs or Needles and Searchlight, a distance of more than 50 miles; and water can not be obtained between Bannock and Searchlight, a distance of about 40 miles, except by side trips of 2 to 4 miles from the main road.

The principal activity in the valley is mining, which is largely confined to the Searchlight district. This district is said to have produced between $6,000,000 and $8,000,000, mostly in gold. In recent years production has been small. In 1922 a few mines were being worked on a small scale and some gold was being obtained by reworking the old tailings dumps. The early developments in this district have been described by Ransome.[74]

[74] Ransome, F. L., Preliminary account of Goldfield, Bullfrog, and other mining districts in southern Nevada: U. S. Geol. Survey Bull. 303, pp. 63-75, 1907. See also U. S. Geol. Survey Mineral Resources, 1905, p. 270; 1906, pp. 296, 478; 1907, pt. 1, p. 360; 1908, pt. 1, p. 474; 1909, pt. 1, pp. 396-397; and later volumes.

Except for one or two small patches there is no irrigation in the region, and conditions are unfavorable for agricultural development because the depth to water in most of the region is great and the supply is not large.

The record of precipitation at Searchlight is given on page 82. The average annual precipitation during a period of eight years ending June 30, 1922, was 9.41 inches. This high average is due to unusually large rainfall in the two years 1918–19 and 1921–22. The average of the other six years is only about 7.4 inches. This is at least 2 or 3 inches more than that recorded at other stations in the Mohave Desert region except those on its extreme southwest border. Searchlight is situated at an altitude of about 3,450 feet, and the greater rainfall doubtless is explained in part by the high altitude. The rainfall in the lower part of Piute Valley is doubtless somewhat less. At Mohave City (formerly Fort Mohave), a few miles east of the valley, the average annual precipitation for 22 years was about 6 inches, and at Needles, farther south, that for 30 years was 4.29 inches.

The vegetation of Piute Valley consists largely of creosote bush, with some Spanish bayonet and Joshua trees on the higher slopes. Cat's-claw is abundant at places in Piute Wash. No mesquite or salt grass was observed anywhere in the valley, but they may grow at Piute Spring and in the wash near Klinefelter, where the water table is near the surface.

PHYSICAL FEATURES AND GEOLOGY

Piute Valley is a long, narrow valley that extends in a northerly direction. The valley is not closed but is drained by Piute Wash, which extends approximately along the axis of the valley from the north end to Klinefelter, about 10 miles north of the south end. From that place it drains eastward through a low canyon to Colorado River.[75] A branch wash heads near Goffs and joins the main wash near Ibis.

The eastern border of the valley, north of the outlet of the valley at Klinefelter, is formed by the Dead Mountains. The highest peak is Dead Mountain, 25 miles north of Klinefelter, which rises about 5,700 feet above sea level. Mount Manchester, 10 miles north of Klinefelter, rises about 4,700 feet above sea level. Between these two mountains and northwest of Dead Mountain the divide lies not much more than 2,500 feet above sea level and is formed by broken hills. The Dead Mountains descend eastward, more steeply than on the west side, to Colorado River, and for part of their length form the west side of Pyramid Canyon. The northeastern border of the valley

[75] This wash has also been known as Sacramento Wash, but in order to avoid confusion with Sacramento Wash in Arizona, which enters Colorado River about 10 miles southeast of Needles, the United States Geographic Board has decided that the wash in California shall be called Piute Wash.

is formed by the Searchlight Hills, which join the north end of the Dead Mountains.

The Dead Mountains are composed principally of granitic rocks, gneiss, and schist, which Darton states are probably pre-Cambrian.[76] Near the north end of the range these rocks are overlain by Tertiary volcanic rocks, which are also present in the Searchlight Hills.[77]

The southern border of the valley is composed in part of the Sacramento Mountains on the east and Ibis Mountain farther west, with lower hills between them. The mountains consist of granitic rocks and schist, presumably of pre-Cambrian age, and some Paleozoic limestone.[78] The hills between the two ranges are made up of Tertiary and Quaternary volcanic rocks. At the northwest base of the Sacramento Mountains, near Klinefelter, lies red conglomerate of Quaternary age. The beds dip westward and are definitely older than the recent alluvium.

The divide at the southwest corner of the valley, between Ibis Mountain and Goffs and for several miles north of Goffs, is composed of alluvium, except a small area immediately south of Goffs. Granitic rock crops out in low hills about a mile north of Goffs and suggests that bedrock lies at no great depth below the alluvial divide. However, in a well drilled at Goffs to a depth of 1,123 feet, alluvium apparently extended to the bottom of the well, except that at two places lava was encountered. (See log on p. 681.)

The western border of the valley is formed by the Piute Range, the Castle Mountains, the northern part of the New York Mountains, and the south end of the McCullough Range. Low hills south of the Piute Range are composed of granitic rocks. The Piute Range itself is an elongated ridge of Tertiary volcanic rocks. It is broad topped and has steep slopes on the east and west but more gentle slopes on the north and south. The range descends from a maximum altitude of about 4,800 feet above sea level to about 3,500 feet at its south end.

The Castle Mountains, which are also composed of Tertiary volcanic rocks, are a more dissected range. The highest point is Hart Peak, 5,515 feet above sea level. The part of the New York Mountains that borders Piute Valley consists of gneissic granite. The part of the range immediately north of the Searchlight branch of the Atchison, Topeka & Santa Fe Railway is capped by Tertiary volcanic flows, but these are absent in Crescent Peak. The McCullough Range is formed of Paleozoic sedimentary rocks cut by later intrusive rocks. An unnamed range east of the McCullough Range is composed of Tertiary flows.

[76] Darton, N. H., Guidebook of the western United States, Part C, The Santa Fe Route, with a side trip to the Grand Canyon of the Colorado: U. S. Geol. Survey Bull. 613, p. 147 and sheet 21, 1915.

[77] Ransome, F. L., Preliminary account of Goldfield, Bullfrog, and other mining districts in southern Nevada: U. S. Geol. Survey Bull. 303, pp. 65–68, 1907.

[78] Darton, N. H., op. cit., pp. 146–147 and sheet 21.

From the mountains on each side the valley floor slopes gradually toward Piute Wash. The floor is mostly underlain by sand, gravel, and clay to an unknown depth. In some places, however, where the gentle slope reaches back into the mountains, as it does at the base of the McCullough Range, it is probably not an alluvial slope but is underlain by bedrock at a comparatively slight depth. The development of the slopes in part of the basin has been discussed by Lawson.[79]

WATER RESOURCES

No perennial streams occur in the valley. It is reported that a small stream from Piute Spring persists at the surface for several hundred feet. Possibly in wet seasons a small stream flows in Piute Wash in the narrows east of Klinefelter. Water is available at a number of places in mine shafts, especially near Searchlight, and from several springs; but at only two localities, so far as known, is water obtained from the alluvium.

WATER IN BEDROCK

In May, 1922, D. F. Hewett obtained data in regard to water in a number of mine shafts at Searchlight. The location of the shafts is shown in Figure 20, and the data in regard to depth to water and yield, so far as available, are given in the table below. The total depth of shaft and depth to water are computed from the angle of slope of the shaft and the depth along the slope. The angles of slope near the surface were measured by Mr. Hewett, but the depths along the slope are those reported by miners. As reports from different sources for some of the shafts disagree the depths are only approximate.

Approximate total depth, depth to water, and yield of shafts and wells near Searchlight, Nev.

No. on fig. 20	Name of shaft or well	Slope of shaft	Total vertical depth [a]	Vertical depth to water [a]	Reported yield [b]	Remarks
		°	*Feet*	*Feet*	*Gallons per day*	
1	Santa Barbara	90	300	250±	500-1,000	Formerly yielded 5,000 gallons a day.
2	Pompeii	58	285	190	65,000	
3	Searchlight	75	--------	280(?)	350,000	
4	Southern Nevada	43	(?)	170	(?)	Caved at surface.
5	Santa Fe	47	(?)	(?)	(?)	Source of town supply.
6	Parallel	30±	200 (?)	200 (?)	(?)	
7	Cyrus Noble	30	260	200	130,000	
8	Drake	90	(?)	300	20,000	
9	Duplex (main shaft)	45	500	250	2,000	
10	Good Hope	65	360	225	5,000	
11	Quartette	65	1,225	545	25,000-30,000	
12	Quartette extension	90	250	--------	Dry.	
13	Atchison, Topeka & Santa Fe Ry. well.	--------	446	285	35,460	Rock struck at 164 feet.
14	Osborne well 1	--------	109	--------	Dry.	Dug 3½ feet square in alluvium.
15	Osborne well 2	--------	38	--------	Dry.	
16	J. E. Hauff well	--------	67	--------	Dry.	Dug.
17	W. H. Harris well	--------	300	--------	Dry.	Drilled; 8 inches in diameter; all in alluvium.
18	Midas shaft	--------	--------	--------	Small.	

[a] Computed from angle of slope of shaft and depth along the slope; results given to the nearest 5 feet. The depth to water is that at which water was first struck.

[b] The yield of the shafts is generally that obtained with pump at lowest part of the workings.

[79] Lawson, A. C., The epigene profiles of the desert: California Univ. Dept. Geology Bull., vol. 9, pp. 37-38, 1915.

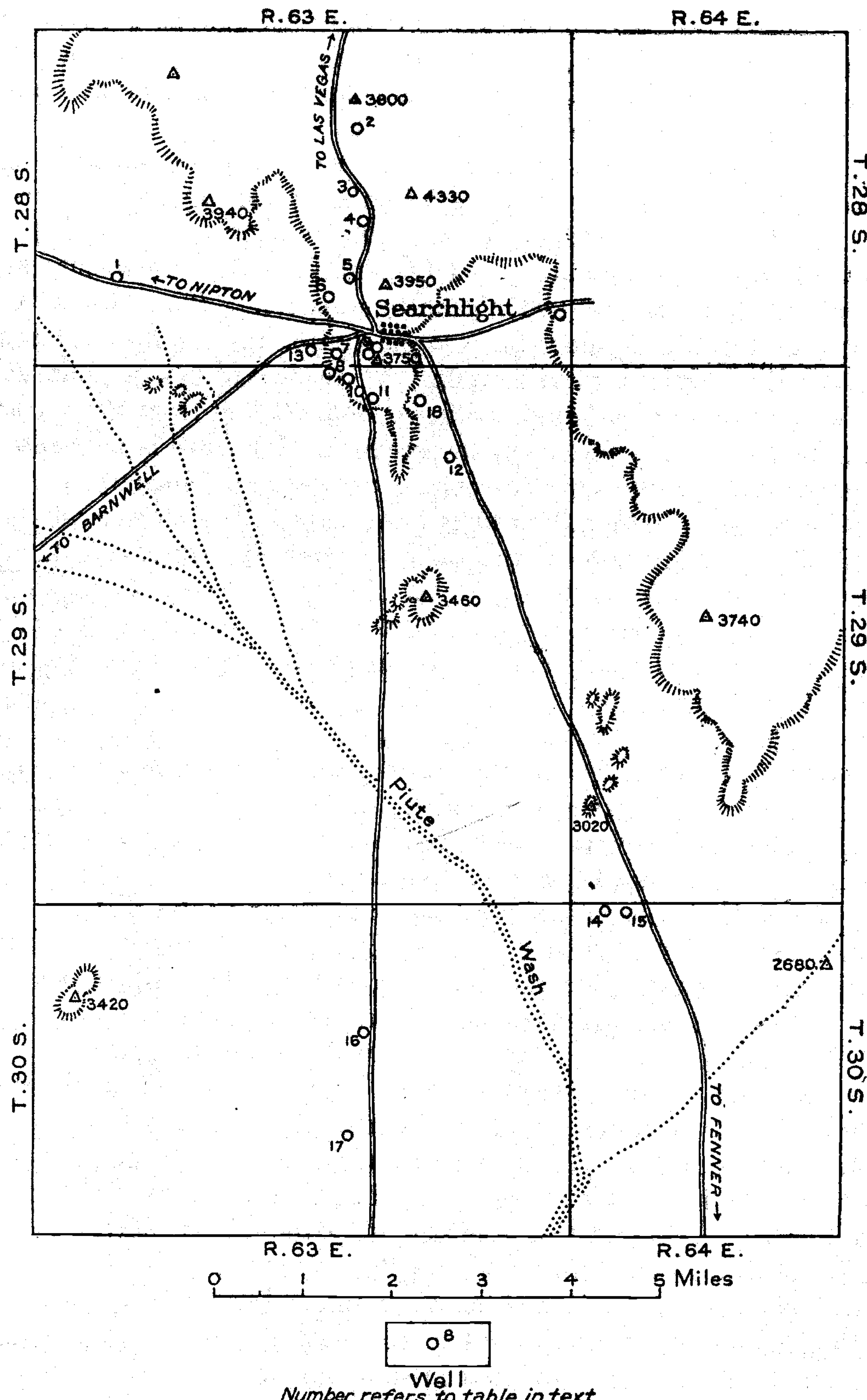

FIGURE 20.—Sketch map of Piute Valley, showing location of wells and shafts mentioned in text. From a plane-table sketch by D. F. Hewett

At least 21 shafts reach a depth of more than 150 feet vertically below the surface, and all but two or three of these yielded some water. The quantity ranged from only a few hundred gallons a day in the Midas shaft (No. 18, fig. 20), 300 feet deep, to 350,000 gallons a day in the Searchlight shaft (No. 3). The supply for the town of Searchlight is obtained from the Santa Fe shaft.

In addition to water in the mine shafts water is obtained from rock in the well of the Atchison, Topeka & Santa Fe Railway at Searchlight. The log of the well, furnished by the railway company, is as follows: 0 to 164 feet, loose boulders and cemented earth; 164 to 360 feet, "porphyry;" 360 to 446 feet, "granite andesite." The terms "porphyry" and "granite andesite" are indefinite, but the rock is largely if not wholly Tertiary volcanic rock. Water was struck at a depth of 290 feet and on completion of drilling stood 285 feet from the surface, or 120 feet below the surface of the bedrock. The well is 13 inches in diameter and is cased only to rock. In a test on February 3, 1908, the well yielded 35,468 gallons in 24 hours (about 25 gallons a minute). As shown by analysis 3, in the table, the mineral content is high—nearly 700 parts per million of total dissolved solids. It is fair for domestic use, although it is rather hard. It is poor for use in boilers because it contains a considerable quantity of both scale-forming and foaming constituents.

The approximate altitude of the water table in the different shafts and wells is shown in Figure 20. The altitudes are based upon altitudes of shaft collars determined by a series of levels carried by angular observation with telescopic alidade and the reported depths to water. They may be several feet in error. In general they show that the water table is lower at the south end of the district than farther north. There is more or less difference in the altitudes of the water table in shafts that are near each other. This difference may be due either to errors in the data in regard to depth to water and height of surface or to the fact that water may not be present in one large body with a more or less connected upper surface but in separated bodies. There is some reason to believe that the latter condition exists. For example, it is reported that the water level in the Drake shaft (No. 8) is 100 feet lower than that in the Cyrus Noble shaft (No. 7), only 1,500 feet to the northeast, although the surface at the Drake shaft is 20 or 30 feet higher. The miners believe that a fault or an impervious mass of rock cuts across the district in a nearly due north direction and that the water table east of this feature is higher than on the west. The fact that in some mines east of this supposed fault considerable water was struck, whereas in others west of it very little was found, is believed to show that the occurrence of the ground water is affected considerably by local variations in the character of the rock.

Water was also struck in the Golden West mine, probably in sec. 33 or 34, T. 12 N., R. 22 E., about 25 miles south of Searchlight. (See pl. 13.) Water began seeping in at a depth of about 40 feet. The shaft is about 100 feet deep. Water can be obtained at this shaft only when someone is at the mine to operate the hoist.

WATER IN ALLUVIUM

Although water has been found in bedrock in a number of shafts, only a few wells have struck water in the alluvium, and in most of these the depth to water has been considerable.

The location of four wells put down near Searchlight is shown in Figure 20. The Harris well (No. 17), in sec. 15, T. 30 S., R. 63 E. Mount Diablo meridian, is drilled 8 inches in diameter and 300 feet deep. The Hauff well (No. 16), in sec. 10 of the same township, is dug 5 feet in diameter and 67 feet deep. The Osborne well (No. 14), in sec. 6, T. 30 S., R. 64 E., is dug 5 feet in diameter and 109 feet deep. The Osborne well 2 (No. 15) is shallow. No water was found in any of these wells. In addition, the Quartette extension shaft (No. 12), in sec. 11, T. 29 S., R. 63 E., was sunk to a depth of 250 feet, all in alluvium, and did not strike water.

J. J. McDonald has two wells at his ranch, about 17 miles south of Searchlight and about 4 miles east of the Arrowhead Trail. The wells are sunk on a bench on the south side of a gulch. Bedrock rises a few hundred feet to the northeast, but the wells are dug entirely in alluvium. One well is 90 feet deep, and the other is 60 feet deep. The depth to water in each is 30 feet. Each well yields about 20 gallons a minute, and at this rate the 90-foot well pumps down to 60 feet in 8 hours and the other well down to 42 feet in the same time. It is obvious that the quantity of water available is not great. The presence of the water so near to the surface is probably due to some strictly local condition, perhaps a constriction in the bedrock floor farther down the gulch or perhaps to the fact that the drainage of a fairly large area is concentrated in the relatively narrow gulch.

In a well drilled in 1901–2 by the Atchison, Topeka & Santa Fe Railway at Homer station water was struck at a depth of 608 feet in cemented gravel. The total depth of the well was 780 feet. The materials penetrated were cemented gravel to 655 feet, shale from 655 to 752 feet, and granite from 752 to 780 feet. The well was abandoned because the quantity of water obtained was small.

The Atchison, Topeka & Santa Fe Railway has two wells at Ibis station. One of these wells, drilled in 1899, is 300 feet deep, and the material penetrated was cemented gravel. The well is lined with 8-inch screw-pipe casing, with a 24-foot screen at the bottom. At completion the water stood at 82 feet, and in a pumping test it lowered to a depth of 175 feet from the top, when the yield was 120,000 gallons in 24 hours (about 85 gallons a minute). As shown by analysis 1 in the table on page 726, the water is moderately mineralized, containing 329 parts per million of total dissolved solids. It is good for domestic use and fair for boilers and irrigation.

The second well, drilled in 1917, is 858 feet deep. Water was struck at 130 feet. The well had not been tested when the above data were obtained. The log of this well is as follows:

Log of well 2 at Ibis, Calif.

[Atchison, Topeka & Santa Fe Railway Co., owner]

	Thickness (feet)	Depth (feet)
Soil and sand	2	2
Cemented sand and gravel	173	175
White clay	30	205
Clay and sand	430	635
Clay	150	785
Clay, sand, and gravel	5	790
Clay	10	800
Volcanic rock	58	858

The old well was probably pumping when the measurement of the new one was made, and the water table near it accordingly may have been lowered somewhat, which may account for the difference in the water level in the two wells. On the other hand, the draft from the old well may have permanently lowered the water table in this vicinity. It hardly seems possible, however, that the draft from one well alone would have such an effect.

The wells at Ibis are close to Piute Wash. In the SE. ¼ SW. ¼ sec. 2, T. 9 N., R. 21 E. San Bernardino meridian, at Klinefelter, about 4 miles south of Ibis, near the wash, the Atchison, Topeka & Santa Fe Railway has obtained water in a dug well less than 30 feet deep. The exact depth to water is not known. This well is near the point where the wash passes eastward through a break between the Dead and Sacramento Mountains. About a third of a mile north of Klinefelter station Sacramento Springs issue from the red conglomerate west of the railroad, but it is not certain whether the water comes from the main body of ground water. The water from the springs and the well is piped by gravity to a tank several hundred feet southwest, where it is used for engines. Analysis 2 (p. 726) represents a sample that is probably a composite of both the spring and well water. The mineral content of the water is moderate, 438 parts per million of total dissolved solids, which is somewhat greater than that of the water from the well at Ibis. The water also differs from the water at Ibis in that it contains a considerably larger percentage of chloride. The water is good for domestic use and fair for boiler use and irrigation.

The nearness of the water table to the surface in the narrows is to be expected for two reasons. In the first place, it is probable that bedrock lies at no great depth in the narrows. In the second place, even if bedrock lies at a considerable depth, the alluvium-filled channel is constricted by the rock mountains on the north and south. The underground drainage from the entire Piute Valley must pass through this constriction, and the water table thus rises near the surface.

The profile of the water table between Goffs and Colorado River through the Homer, Ibis, and Klinefelter wells is shown in Figure 19. As shown there, a line drawn between the water table in the Homer and Ibis wells, if projected, cuts the surface near Klinefelter. The water level north and west of Klinefelter is thus apparently controlled more or less by the water level in the narrows at that point.

The gradient of the water table between Homer and Ibis is about 15 or 20 feet to the mile. If a profile that shows this gradient of the water table is drawn northward from Ibis along Piute Wash to the Searchlight Hills, with the altitudes of the surface as given on the Camp Mohave topographic map, nowhere in the northern part of the valley is the water table shown to be less than 250 to 300 feet below the surface. It is not certain that the gradient of the water table is the same in the main Piute Valley as between Ibis and Homer, but there is no reason to believe that it would be any greater. The fact that no water was obtained in the wells in the alluvium near Searchlight, however, tends to confirm the belief that the water table there lies at a considerable depth, if water is present in the alluvium.

RELATION OF WATER IN ROCK AND ALLUVIUM

The fact that water was found in many of the mines at Searchlight at altitudes somewhat higher than Piute Wash has led some persons to believe that water for irrigation might be obtained in the alluvium-filled part of the valley. The few deep wells that have been put down near Searchlight, however, failed to find water. The question arises whether water can be obtained from the alluvium elsewhere in the valley.

The bedrock is so massive that it can absorb relatively little water, and the water in the mines undoubtedly is present mostly in joints and other cervices in the rocks. As suggested above, the water may occur in more or less isolated bodies, separated perhaps by impervious gouge along faults or by intrusive dikes. There may be also some seepage from the rock into the alluvium. The alluvium, however, is much more porous, and the water can move through it much more freely. According to Ellis,[80] the quantity of water stored in crystalline rocks, such as occur in the Searchlight area, may be only about

[80] Gregory, H. E., and Ellis, E. E., Underground water resources of Connecticut, with a study of the occurrence of water in crystalline rocks: U. S. Geol. Survey Water-Supply Paper 232, p. 75, 1909.

one-tenth of 1 per cent of the total volume. On the other hand, the alluvium may easily hold water equivalent to 25 to 40 per cent of its volume. If the capacity of the rock were even as much as 1 per cent, the quantity of water contained in a depth of 100 feet of rock over a given area, if poured into the alluvium, would fill only about 4 feet. It is obvious that the bedrock actually holds comparatively little water and therefore can contribute very little to the alluvium.

The rainfall in Piute Valley, even though greater than in some parts of the Mohave Desert region, is small. Even though a considerable quantity is absorbed by the rock and alluvium near Klinefelter, it drains freely out of the basin toward Colorado River. At this point the water table lies near the surface, but at Ibis, which is situated in an area that ought to receive the concentrated underground flow from almost the entire basin, the water table is at least 80 feet below the surface. The drawdown in well 1 at Ibis is more than 90 feet, although the yield of the well is only about 85 gallons a minute. These facts show that the quantity of ground water is not very great.

Wells that are drilled deep enough into the alluvium may strike water if they are situated near the lowest part of the buried bedrock valley, but if they are drilled on the side slope of the buried valley they may strike the rock before reaching water. The bottom of the rock valley does not necessarily coincide with the bed of Piute Wash, and its position can not be foretold. It is therefore impossible to predict whether or not a well in a given locality will strike water in the alluvium.

ANALYSES

Analyses of ground water from Piute Valley, Calif.-Nev.

[Analyses furnished by the Atchison, Topeka & Santa Fe Railway Co.; recalculated from hypothetica combinations in grains per U. S. gallon. Parts per million]

	1	2	3
Silica (SiO_2)	----	[a] 41	----
Iron (Fe)	----	----	----
Calcium (Ca)	31	35	107
Magnesium (Mg)	8.4	----	24
Sodium and potassium (Na+K) (calculated)	78	92	106
Carbonate radicle (CO_3)	----	----	----
Bicarbonate radicle (HCO_3)	274	114	260
Sulphate radicle (SO_4)	16	44	240
Chloride radicle (Cl)	28	104	93
Nitrate radicle (NO_3)	----	----	----
Total dissolved solids	329	438	698
Total hardness as $CaCO_3$ (calculated)	112	----	366
Date of collection	([b])	([c])	([d])

[a] Includes silica, and iron and aluminum oxides.
[b] May 13, 1899.
[c] August, 1898.
[d] Jan. 15, 1908.

1. Well 1 at Ibis. Atchison, Topeka & Santa Fe Railway Co., owner. See p. 723 for description.
2. Composite sample from Sacramento Springs and dug well at Klinefelter Atchison, Topeka & Santa Fe Railway Co. owner. See p. 724 for description.
3. Well at Searchlight, Nev, No. 13, fig. 20. Atchison, Topeka & Santa Fe Railway Co., owner. See p. 722 for description.

PROSPECTS FOR IRRIGATION

The conditions in Piute Valley are not favorable for the development of irrigation. There is no supply of surface water in the valley, which lies at so great an altitude above Colorado River that water can not be obtained from the river. In the central lowland part of the valley, as shown by the data, the depth to water is apparently more than 100 feet, and the quantity yielded by wells is small. The most favorable conditions found so far are at the Ibis well 1. There, however, the pumping lift is so great and the yield so small that this well could not be operated economically for irrigation.

Although water is apparently present in large quantities in the mines at Searchlight, when the requirements of irrigation are considered, the quantity is actually small. The greatest quantity reported to have been pumped daily is 350,000 gallons, from the Searchlight mine. This quantity is less than 250 gallons a minute. When it is remembered that this quantity has seeped in from a considerable area of drifts it is obvious that the quantity that could be obtained from a single drilled or dug well in rock would be indeed small. Consequently, even if water could be obtained from the bedrock nearer the surface than in the alluvium the cost of wells and low yields would not warrant any attempt at irrigation, except perhaps on a small scale for a household garden.

SPRINGS AND OTHER WATER HOLES

Piute Spring.—Piute Spring is reported to yield about 150 gallons a minute and is one of the largest springs in the Mohave Desert region. The spring was not visited, and its exact location is unknown, except that it is in a prominent canyon near the south end of the Piute Range and a short distance south or southeast of bench mark 3789, which is in T. 12 N., R. 17 E. (See pls. 12 and 13.) It is along the old Government road that led from Fort Mohave, on Colorado River, westward across Piute Valley, about 11 miles north of the present National Old Trails road, and thence across Lanfair Valley. This road is seldom traveled now, and it is not certain that automobiles can reach the spring. The old road is said to be sandy where it crosses Piute Wash.

Beacuse of its location so far from the present main roads Piute Spring is now of little use, although before the days of the railroad it was one of the principal watering places in the region. The flow from the spring is said to persist for nearly a mile down the alluvial slope in the cooler months. It is probable that the Mohave Indians irrigated small garden patches at the spring.

Watering places along Arrowhead Trail.—No water is obtainable along the road from the National Old Trails Road to Searchlight, except by turning off from the main road. Water can be obtained at the Golden West mine only when people are living there. The mine is about 4 miles east of the main road at a fork 6.8 miles north of the National Old Trails Road.

Water can be obtained at McDonald's wells, about 4 miles east of the main road, at a branch road about 17 miles south of Searchlight. Water is also available at Juniper Well. The exact location of this well is unknown, but it is reported to be about 2 miles east of the main road and about 18 miles north of the National Old Trails Road. The road that leads to this well is probably about 3 miles south of the road to McDonald's wells. These wells are not shown on Plate 13.

Watering places on Castle Mountains and north end of New York Mountains.—The following notes on watering places in the Castle and New York Mountains were furnished to D. F. Hewett by Lawrence Mouser:

A spring known as Lewis Holes issues in a canyon in the northeastern part of the Castle Mountains, probably in sec. 15, T. 30 S., R. 62 E. Mount Diablo meridian. (See pl. 12.) There is a small flow in the canyon in the winter. The spring is equipped with a windmill and is used as a watering place for stock. It is the property of the Rock Spring Cattle Co.

Kennedy Water, about half a mile west of Lewis Holes, is said to furnish water for 100 to 150 head of cattle.

A water hole called Mouser Water is situated near Hart Peak, but its exact location is not known. The water is obtained from a trench 200 feet long and is piped to a trough. The watering place, which is the property of the Rock Spring Cattle Co., is said to furnish enough water for 150 head of cattle (about 1,500 gallons a day at 10 gallons a head).

Malpais Spring is in a canyon on the east side of the New York Mountains, a mile or two northwest of the Searchlight branch of the Atchison, Topeka & Santa Fe Railway. It is the property of the Rock Spring Cattle Co. and furnishes enough water for about 300 head of cattle. It is said that if the spring were improved the supply probably would be sufficient for 1,000 head.

A water hole known as Hopps Wells is situated near the base of Crescent Peak, but whether it is in Piute Valley or Ivanpah Valley is not known. It furnishes enough water for only 10 or 15 head of cattle.

COLORADO RIVER VALLEY BETWEEN MOHAVE CITY AND TOPOCK

GENERAL FEATURES

The area described in this section is that part of the Colorado drainage basin that drains directly to the river. (See pl. 7.) It does not include Piute Valley, the drainage of which passes through the area but which is a distinct drainage unit. (See pp. 716–728.) The area here described is commonly called Mohave Valley because it has been the home of the Mohave Indians since the time prior to the coming of the white man. This valley should not be confused with the Mohave River Valley, in the central part of San Bernardino County.

The main line of the Atchison, Topeka & Santa Fe Railway traverses the area from the center of the western border to the southeast corner and crosses Colorado River at Topock, Ariz. The National

Old Trails Road follows the same general route but at places is 2 or 3 miles from the railroad. It crosses the river at Topock on a substantial bridge that was completed in 1917. On this road supplies are obtainable at Needles and Topock, and water is obtainable at Java.

From Topock travelers who are going east have a choice of two routes. They may follow the road that leads eastward and northeastward along the railroad, or they may go northward to Oatman and Gold Road and thence eastward and join the road along the railroad a few miles southwest of Kingman, Ariz. There is not much difference in the distance by the different routes. The road along the railroad has the advantage that help may be obtained more easily in case of accident. The choice of routes largely depends on local conditions, which may best be determined by inquiry at Needles. A distance of about 25 miles may be saved by crossing Colorado River by ferry at Needles and taking a short-cut road to Oatman. However, operation of the ferry is generally suspended during part of the year on account of high water.

From the National Old Trails Road 5.7 miles south of Needles a road leads southeastward to Parker, Ariz. This is the road that is generally used by travelers in going between Parker and other points in Arizona and points in southern California by way of the National Old Trails Road. Some people, however, take an alternative route farther south, along the Parker branch of the Atchison, Topeka & Santa Fe Railway, to Cadiz or Danby. (See p. 142.)

The road from Needles to Parker has the disadvantage that no supplies other than water are available between the two places, a distance of 61 miles. Water may be obtained at Welch Well, 12.5 miles from Needles, and sometimes at the D. & W. mine, and also by a detour of 3 miles at the West Well, 34 miles from Needles. Hanks Well, on the main road 31 miles from Needles, was formerly a useful watering place. In November, 1917, however, it was dry, and it should not be depended upon unless definite information is obtained at Needles or Parker that it contains water. Numerous roads lead to mining camps in the Sacramento Mountains and to ranches along Colorado River.

Needles, the only town in the area described, takes its name from several prominent peaks called The Needles, which are on the Arizona side of Colorado River 15 miles southeast of the town. In 1920 it had a population of 2,807. The town is supported largely by railroad activities, being a division headquarters of the Atchison, Topeka & Santa Fe Railway. The town is also the center for a number of mining camps and contains a smelter that handles ore from a number of mines within a considerable radius. Needles possesses good hotels, stores, and garages.

Section crews are stationed at Java and Beal, on the railroad, and aid can be obtained at these places in emergencies.

The lowlands along Colorado River near Needles have been the home of the Mohave Indians as far back as our written records go. In 1905 about 900 Mohaves were living in the region.[81] Many of the Indians of the young generation work for the railroad, and the older squaws daily sell trinkets at the railroad station. In 1858 Fort Mohave was established on the Arizona side, about 15 miles north of Needles, to protect white travelers through the region. This fort was continued, with a break of two years, until 1890, when the reservation was transferred to the Indian Service for a school. An area of several thousand acres near the school is now included in the Fort Mohave Indian Reservation, as well as all the even-numbered sections on the lowlands in Arizona as far south as Topock. The odd-numbered sections many years ago were granted to the Atlantic & Pacific Railroad and sold by its successor, the Atchison, Topeka & Santa Fe Railway, to a land company.

The Indians who now live in the region have adopted the white man's ways to a large extent. An interesting reminder of the primitive Indians is found in the "mystic maze," on the National Old Trails Road about 14 miles southeast of Needles and about 2 miles west of the bridge at Topock. The maze is said to be an ancient ceremonial ground used in the burial of the dead. It lies about 200 feet south of the road and covers an area from 250 to 300 yards square. In this area are many long rows of stones which are mostly less than 3 inches in diameter. The rows are about 6 feet apart. In any one part of the area several of them are approximately parallel, but in different parts different groups of the parallel rows intersect. (See pl. 30, *B*.) From a little distance the appearance is not unlike that of a field cut by plow furrows. It is said that when an Indian died his body was carried by a devious route between the rows of the maze, for it was believed that on this journey the evil spirits following him would become lost in the maze and could not pursue him farther. F. M. Kelley, of Needles, informed the writer that old Mohave Indians have told him that the maze was not used by their tribe but by some unknown tribe that preceded them in the region.

CLIMATE

Available records of precipitation at Needles and of temperature at Needles and Mohave City are given on pages 71–91.

The average annual precipitation at Needles for 30 years is 4.29 inches. This quantity is more than an inch less than that at Parker,

[81] The Mohave Indians and plans for irrigation in the Fort Mohave Indian Reservation are described in Hearings before the Committee on the Irrigation of Arid Lands, House of Representatives, 67th Cong., 2d sess., on H. R. 11449, A bill to provide for the protection and development of the lower Colorado River basin, pp. 130–148, 1922.

Ariz., less than 50 miles to the south, and nearly 1¾ inches less than that at Mohave City, about 15 miles to the north. The three stations occupy approximately similar locations in the river valley, and the reason for the differences in precipitation is not known. The average precipitation at Needles for the years covered by the record at Parker is practically 100 per cent of the average for the total period. Therefore, the explanation of the difference can not be that the annual precipitation during the period of record at Parker was less than during the longer period of the record at Needles. The record at Mohave City covers so few of the years included in the period of the Needles record that an adequate comparison can not be made with that station. In the five years for which records are available at both stations the average at Mohave City is only 64 per cent of the average for the long-time record, whereas at Needles it is 84 per cent of the long-time record at that place. Furthermore, in the second and third years prior to the beginning of the record at Needles the precipitation at Mohave City was more than three times the average for the period of record at that place. The excess in these two years alone is sufficient to make a difference of nearly an inch in the average. It is probable that the average annual precipitation is not greatly different in the two places.

The distribution of precipitation during the year in the eastern part of the Mohave Desert region is greatly different from that in the western part, in that in the eastern part a large percentage comes in the late summer. This condition is particularly noticeable at Needles, where in the period of record a greater percentage of the total rainfall has come in August than in any other month.

The temperature at Needles is more equable than that at almost any other station in the Mohave Desert region. The lowest temperature recorded is only 23°, and the highest is 122°, a range of 99°. The average length of the frostless season at Needles, 298 days, is exceeded at only one other station in the Mohave Desert region—Bagdad. The frostless season at Mohave City is nearly 20 days less.

VEGETATION

The vegetation of the upland slopes of the valley is essentially like that of the great part of the Mohave Desert region, with creosote bush the predominant form. On the lowlands along Colorado River the water table is close to the surface and water-loving forms are abundant, including cottonwood and willow along the river and sloughs, and mesquite, arrow weed, and some salt grass and salt bush elsewhere. The mesquite grow to large trees. Their beans formed one of the principal supplies of food for the primitive Indians.

PHYSICAL FEATURES AND GEOLOGY

From about Mohave City southward to Topock Colorado River flows on a broad flood plain that is from 1 mile to 6 miles wide. This plain is widest near the north end and becomes gradually narrower southward. In recent years the main channel has been on the west side of the flood plain for most of the stretch between Mohave City and Topock. However, that it has from time to time been on other parts of the plain is shown by several lakes which occupy former channels that have been cut off by later deposition. The channel of the river changes more or less from time to time, and generally there are several channels, branching and joining each other in a braided pattern. The flood plain is composed of silt, sand, and gravel deposited by the river. The river always carries much silt in suspension, at times as much as 3 per cent by weight of the entire flow.

From the borders of the flood plain on both sides of the river the alluvium rises with a more or less uniform grade. The portion of the valley east of the river was not visited by the writer but has been described by Lee.[82] On the west side of the river the alluvial slope is very much dissected. In traveling north or south on the slope one crosses alternately many long and relatively narrow tongues of the undissected slope which are separated by steep-sided arroyos. The peculiar topography is shown very well on the Needles topographic map. Several terraces are well developed along the slope.

The western border of the valley is formed by the Dead and Sacramento Mountains, which are composed mostly of granitic rocks and schist.[83] Both these ranges are much dissected. Several canyons have cut back beyond the highest parts of the Sacramento Mountains.

The southern border of the valley is formed by the Mohave Mountains. At the United States Geological Survey gaging station on Colorado River 1¾ miles below Topock, at Welch Well 13 miles south of Needles, and on the west side of the range farther south, where it is called the Chemehuevis Mountains, the rocks are granitic. The main mass of the mountain apparently is composed of these rocks, which are overlain in places by the Tertiary extrusive rocks. The mountains are intricately dissected, and the drainage divide lies west of the main mountain mass.

WATER RESOURCES

SURFACE WATER

Colorado River is the only permanent stream in the valley. Water also stands at the surface in several lakes or sloughs on the flood plain

[82] Lee, W. T., Geologic reconnaissance of a part of western Arizona: U. S. Geol. Survey Bull. 352, pp. 41-42, 1908.

[83] Darton, N. H., Guidebook of the western United States, pt. C, The Santa Fe Route: U. S. Geol. Survey Bull. 613, pp. 146-147, 1915.

along the river. The water in the river is so muddy that it can not be utilized without filtering it or allowing the silt to settle. So far as is known the river water is not used, except perhaps by the Indians.

Even before the coming of the white man the Indians grew crops on the flood plain of the river by planting after the annual floods had receded. In dry seasons the crops were irrigated by water carried from the river. Beginning in 1891 several attempts have been made to use the river water to irrigate in a modern manner lands on the flood plain, including both the lands of the Indian reservation and the privately owned lands.[84] Some water has been pumped from the river, but serious difficulty has been experienced in keeping the intakes to the pumping plants open on account of deposition by the river as it changes its channel from time to time. Several attempts have also been made to divert water for irrigation by canals directly from the river, both for the Indian lands and for the privately owned lands, but these have not been successful. One of the principal difficulties is that there is no good place for the intake of the distribution canal, except at a point where the cost of construction would be prohibitive. For successful irrigation levees are necessary both to prevent the flooding of the reclaimed land and to protect the canals. Levees have been constructed several times but have been destroyed repeatedly by the river floods. Up to June 30, 1915, the Cotton Land Co., which owned the odd-numbered sections on the Arizona side of the river, had spent $575,000 in irrigation works and flood protection without success.[85] As practically all the flood plain lies east of the river the irrigation projects have been largely confined to lands in Arizona.

In 1917 the United States Geological Survey established a stream-gaging station on the west side of the river at the upper end of Mohave Canyon, about 1¾ miles below Topock, to obtain data in regard to the flow of the river. In December, 1922, the station was moved to the south end of the canyon, about a mile below the original station. In the period from the establishment of the station to September 30, 1926, the maximum annual flow was 21,500,000 acre-feet and the minimum 12,900,000 acre-feet.[86] The rate of flow has ranged from 1,800 to 174,000 cubic feet a second. The variation in the water level in low and high water stages has been about 25 feet. The flood period generally occurs in June. The floods are due to the melting of the snow in the mountains of the headwater regions, hundreds of miles to the north, and consequently it is already summer before they reach the lower part of the river.

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[84] Hearing before the Committee on Irrigation of Arid Lands, House of Representatives, 67th Cong., 2d sess., on H. R. 11449, A bill to provide for the protection and development of the lower Colorado River basin, Appendix A, pp. 138–148, 1922.

[85] Idem, p. 144.

[86] U. S. Geol. Survey Water-Supply Papers 459, 479, 509, 529, 549, 569, 589, and 609.

GROUND WATER

There has been little development of ground water. Plans were made to use water from wells for irrigating lands on the flood plain in the Indian reservation. A well was drilled to a depth of 780 feet near the Indian school at Mohave City.[87] The well did not penetrate any extensive gravel beds, and although the yield was sufficient for domestic use it was not enough for irrigation, and the project was therefore abandoned.

At Needles the water supply for practically the entire population is furnished by the Needles Water, Ice & Light Co., and there are only about 10 private wells. The wells of this company are in the northern part of the town, at the very outer edge of the river flood plain. The water is obtained from about 15 driven wells 8 inches in diameter, all connected to a single pump. The materials penetrated in a typical well are as follows: Adobe to 13 feet; quicksand, 13 to 18 feet; coarse sand, 18 to 34 feet; coarse gravel and boulders, 34 to 56 feet. The 8-inch pipes, with a 20-foot strainer, are driven down to the gravel. The water in the upper formations is shut out. The water stands about 2 feet from the surface.

Generally, even in summer, the quantity pumped does not exceed 300,000 gallons a day (about 210 gallons a minute), but the wells have been pumped at a rate of 1,500,000 gallons a day (about 1,000 gallons a minute) without affecting them. There is no storage reservoir, and the water is pumped direct into the mains. The pressure at the pumps is about 85 pounds to the square inch. In November, 1917, the pumping plant was equipped with two Worthington compound pumps, operated by steam, only one of which is used while the other is held in reserve. The system contains 6 or 7 miles of 8-inch distribution mains. About 95 per cent of the water is sold under meter rates of 15 cents per 1,000 gallons, with a minimum charge of $1.50 a month.

An analysis of water collected at the pumping plant is given below (No. 1). The water is highly mineralized. It is only fair for domestic use, because of the hardness and the large quantity of total solids. However, it can be used for domestic supplies without serious inconvenience. It is fair for irrigation but bad for boilers because of the large quantity of foaming and scale-forming constituents.

[87] Hearings before Committee on Irrigation of Arid Lands, op. cit., p. 141.

Analyses of ground waters in the Colorado River Valley near Needles, Calif.

[Parts per million]

	1	2
Silica (SiO_2)	45	29
Iron (Fe)	.19	.18
Calcium (Ca)	101	353
Magnesium (Mg)	40	119
Sodium and potassium (Na+K)	[a] 255	382
Carbonate radicle (CO_3)	0	0
Bicarbonate radicle (HCO_3)	275	167
Sulphate radicle (SO_4)	284	619
Chloride radicle (Cl)	317	871
Nitrate radicle (NO_3)	1.3	93
Total dissolved solids at 180° C	1,229	2,636
Total hardness as $CaCO_3$ (calculated)	416	1,370
Date of collection	([b])	([c])

[a] Calculated. [b] Nov. 9, 1917. [c] Nov. 12, 1917.

Analysts: 1, A. A. Chambers, U. S. Geological Survey; 2, Addie T. Geiger and C. H. Kidwell, U. S. Geological Survey.
1. Composite sample from wells of Needles Water Co. See p. 734 for description
2. Welch Well. 13 miles south of Needles. See p. 736 for description.

The quality of the water is said to change according to the flood and low-water stages of the river. A sample collected on August 12, 1916, and analyzed by the State board of health contained only 235 parts per million of chloride and the hardness was 365 parts per million. These quantities are less than those in the sample collected by the writer. The change is undoubtedly due to the fact that the ground water is derived largely from seepage from the river, and the quality changes as the river rises and falls from one season to another. The conditions agree with the results of analyses of samples of water from Colorado River at Topock which cover 7-day periods for a whole year from October 1, 1925, to September 30, 1926.[88] In these analyses the lowest mineral content was found in June—that is, in the month of flood discharge, when the run-off comes in large part directly from melting snow. The greatest mineral content was found in fall and winter, when the discharge was at a minimum, and at this time a relatively larger percentage of the run-off is derived from the ground water and therefore contains a higher percentage of dissolved materials. Although the quantity of calcium carbonate dissolved in the water was less in June than in January, the percentage was slightly greater. The total quantity of dissolved solids carried daily by the river during the period of observation ranged from about 12,500 to 66,000 tons.

In general it is probable that water can be obtained from wells at almost any point on the alluvial slopes that descend to Colorado River. Near the river the depth to water is not great, but it probably increases toward the mountains. It is likely that within a mile or two of the mountains the depth will be more than 100 feet. For this reason, it would be impracticable to pump water for irrigation. A

[88] Collins, W. D., and Howard, C. S., Quality of water of Colorado River, 1925–26: U. S. Geol. Survey Water-Supply Paper 596, pp. 33–43, 1927.

condition that is unfavorable to irrigation is the fact that the alluvial slope is so greatly dissected that there are no large areas suitable for cultivation. The only area where irrigation would be at all feasible lies near the river. On the flood plain conditions do not seem to be favorable for obtaining water from wells because of the fineness of the alluvium and because the water is generally of poor quality. These conclusions are borne out not merely by the few attempts to obtain irrigation wells in the Fort Mohave Indian Reservation but also by those made in the Colorado River Indian Reservation near Parker, where conditions are similar.[89]

Water has been obtained in several wells in alluvium-filled washes in the mountains or in the bedrock. The only well for which data are available is Welsh Well, a watering place 13 miles south of Needles, on the road to Parker. The well is 50 feet east of the road and is readily found. It is dug to a total depth of 59 feet. On November 11, 1917, the depth to water was 54 feet. The material in a large dump pile near by indicates that the well is dug in granitic rock. The hole was provided with a good tight-fitting cover.

As shown by analysis 2 in the table (p. 735) the water is very highly mineralized, containing 2,636 parts per million of total solids. It is too salty for drinking except in an emergency, when it probably could be used without serious effect. It is poor for irrigation and very bad for use in boilers.

CHEMEHUEVIS VALLEY

GENERAL FEATURES

On some maps the name Chemehuevis Valley is applied to an area of a few square miles of lowland immediately adjacent to Colorado River about halfway between Needles, Calif., and Parker, Ariz. In this paper, however, for convenience the name is applied to a much larger valley that stretches more than 25 miles west of the river, and extends north and south for about the same distance. (See pls. 7 and 13.) The drainage from this large area is concentrated into a single large wash, which enters Colorado River in the smaller Chemehuevis Valley referred to above, and this wash is accordingly called Chemehuevis Wash.

There are no towns in the valley. Some of the Chemehuevis Indians are said to live along the river, but there are no permanent habitations elsewhere in the largest part of the valley.

The eastern part of the main valley is crossed by the road that leads from Needles to Parker. From this road 17.5 miles south of Needles a branch road leads southwest to mine prospects at the north end of the Turtle Mountains, a distance of 19 miles. Water is obtainable at Carsons Wells, at the end of this road. Another

[89] Hearings before Committee on Irrigation of Arid Lands, op. cit., pp. 105-113.

branch road, 27 miles south of Needles, leads southeastward to West Well, 6.7 miles. From this well another road leads southwestward to the main road, which it joins 36.5 miles south of Needles and 24.8 miles northwest of Parker. Formerly water could be obtained at Hanks Well, on the main road about midway between the two branch roads, but in November, 1917, the well was dry. Persons needing water could obtain it at West Well by making a detour of only about 3½ miles. From West Well a road leads eastward down Chemehuevis Wash to Colorado River. Another road leads southward from West Well to Whipple Well and prospects in the Whipple Mountains. A road formerly led from the Needles-Parker road, about 35 miles south of Needles, southwestward to Rice (Blythe Junction). In 1917 only faint tracks were observed at two places where this road might have been, and apparently it is no longer used.

Ore deposits are reported in prospects at a number of places, but in 1917 there had been no commercial development. There has been no agricultural development, except perhaps in a small area along Colorado River.

The climatic conditions are probably not greatly different from those at Needles and Parker. The average annual rainfall is probably about 4 or 5 inches. The summer temperatures are doubtless rather high.

The vegetation of the valley includes types not common in other parts of the Mohave Desert region. Along the main road about 17 miles south of Needles is found the peculiar ocotillo (pronounced ocotee'yo), or *Fouquieria splendens*. (See p. 50.) This is the only locality in the Mohave Desert region where the ocotillo was observed. In this same locality several forms of the spinose plants known as cholla (cho'ya) are particularly abundant.

Palo verde trees were observed in Chemehuevis Wash where it is crossed by the road to Carsons Wells, along the main road near Hanks Well, and at West Well. Near Hanks Well some of the trees were 25 to 30 feet high. This place is the farthest north that this tree was observed. Cat's-claw grows around Hanks Well and West Well, with the palo verde, and at West Well there are several willows and cottonwoods.

Here, as in most other parts of the Mohave Desert region, the most common plant on the alluvial slopes is the creosote bush.

PHYSICAL FEATURES AND GEOLOGY

Chemehuevis Valley is mainly a large, gently sloping valley that drains southward for 20 miles and thence eastward into Colorado River It is almost completely shut off from Colorado River in the northern part by the south end of the Sacramento Mountains, the Mohave Mountains, and the Chemehuevis Mountains, and on the south by the Whipple Mountains. The Sacramento and Mohave Mountains are described briefly on page 732. In every place that the rocks were observed closely on the west side of the Chemehuevis Mountains they were intrusive rocks similar to those observed in the Mohave Mountains at Welch Well and at the United States Geological Survey stream-gaging station on Colorado River. East of the main road about 23 miles south of Needles the rock is mainly a biotite or chlorite granite cut by dikes of a dense black rock, probably diabase. From a distance these dikes can be traced at several places on the mountain side. The Chemehuevis Mountains are very intricately dissected, and some canyons reach westward from Colorado River almost to the west side of the mountain mass. As a result the area of the mountains that drains to Chemehuevis Valley is only a small part of the whole.

At the west base of the Chemehuevis Mountains there is a ridge from 100 to 200 feet wide, which has nearly vertical sides and is cut into jagged peaks. To this ridge the name Sawtooth Range is aptly applied. It is composed of a purplish volcanic rock, probably trachyte. The steep sides suggest that it is an upfaulted block, but it is probably due merely to differential erosion, perhaps of a dike.

On the western border of the valley a low divide extends from the Sacramento Mountains to the Turtle Mountains. The divide is topped in a number of places by rocky knobs, and although between these knobs the slopes appear to be formed of alluvium it is probable that rock is close to the surface. The Turtle Mountain range is about 25 miles long, and for most of its length it is rather narrow and near Carsons Wells rises steeply. Near the north end it is broader than elsewhere, but even in this part, high, steep-sided ridges are separated by fairly broad valleys. Near Carsons Wells the main rock mass rises in a narrow dikelike ridge somewhat similar to the Sawtooth Range, except that it is steeper and very much higher. The rocks of this part of the mountain are reported to be volcanic, including tuff, and are probably of Tertiary age. In a large embayment of the mountains, in which Carsons Wells are situated, the rocks are granite, and they appear to extend westward, forming the main mass of the mountains beneath the volcanic rocks. Low hills on the eastern border of the mountains appear from the road to Carsons Wells to be made up of lava.

The southern border of the valley, between the Turtle Mountains and the Whipple Mountains, is a low ridge from which rise several knobs. Although the slopes rise gently to the divide, as if it were formed of alluvium, everywhere along it bedrock is probably close to the surface.

The rocks observed along the Needles-Parker road in the Whipple Mountains were all granitic intrusive rocks, or metamorphosed gneiss and schist. However, Tertiary volcanic rocks are known to be present in the mountains. Like the Chemehuevis Mountains, the Whipple Mountains are minutely dissected, but the part that drains to Chemuehevis Wash is very small.

The upper part of the Chemehuevis Valley has relatively smooth alluvial slopes that descend gently to Chemehuevis Wash, which heads near the northern part of the valley and drains in a southeasterly direction to the western part of T. 4 N., R. 23 E., whence it trends northeast. These slopes appear to be alluvial slopes, but in some places at least they are probably erosional slopes beneath which the bedrock lies at no great depth, particularly on the east side of the valley, near the Sawtooth Range, where several small rock hills rise above the plain, and near the northeast end of the Turtle Mountains. The gentle slope reaches back into an embayment at the northeast end of the Turtle Mountains, but outcrops of bedrock in the washes show that the slope is due to erosion and not to deposition. On the valley slope in this part of the valley are numerous smooth areas, bare of vegetation and covered with a pavement of small pebbles which almost completely hide the underlying soil.

In the lower half of the valley the valley slopes are interrupted by numerous arroyos and by terraces similar to those west of Colorado River near Needles. (See p. 732.) These features become less distinct toward the upper part of the valley. The broad valley becomes very much dissected near Colorado River. East of West Well the slope toward the river is interrupted by low knobs of volcanic rocks between which Chemehuevis Wash passes.

WATER RESOURCES

WELLS IN THE VALLEY

With the exception of Colorado River, on the east, there are no perennial streams in the Chemehuevis Valley. The Indians that live along the river probably obtain their water supply either from the river itself or from shallow wells on the river bottom.

Only two wells, West Well and Hanks Well, are known in the alluvium-filled valley above the river. Hanks Well is on the east side of the Needles-Parker road where it crosses Chemehuevis Wash. The wash at this place is several hundred feet wide, and in it grow many cat's-claw bushes and some palo verde trees. In 1917 the well, which is dug, was 48 feet deep, but it contained no water. It is not known whether the well had been filled above the water table by sand and gravel washing in or whether the water table had been lowered during a period of deficient rainfall.

West Well is in Chemehuevis Wash about 4 miles northeast of Hanks Well. The well is on the southeast side of the wash, which is narrower here than at Hanks Well. The well is dug to a total depth of about 12 feet. On October 14, 1917, the depth to water was 6.3 feet. It is necessary to have a short rope and bucket to obtain water. A few hundred feet below the well the wash lies between hills of bed-rock, which undoubtedly act as a partial barrier that brings the water near the surface.

Analysis 1 in the table below shows that the water is rather highly mineralized, as it contains 643 parts per million of total solids. Nevertheless it is good for domestic use and fair for irrigation.

No wells are known in the part of the valley above Hanks Well. Water could doubtless be obtained in that area, but the depth to water would probably be great. The exact grade of the water table between Hanks Well and West Well was not determined, because Hanks Well is dry. However, between the two wells the depth to water increases westward on an average at least 10 feet to the mile. If this difference persists farther west and northwest, the depth to water along the west line of T. 4 N., R. 23 E., would be more than 80 feet, and where Chemehuevis Wash is crossed by the road to Carsons Wells it would be about 200 feet.

The quantity of water obtained from wells in any part of the valley, except perhaps near West Well, probably would not be great, for two reasons. The mountainous area is not large, and the rainfall is low, so that the recharge of the ground water is probably small. Furthermore, undoubtedly the ground water moves freely toward Colorado River below West Well, so that a large part of the water that is absorbed eventually leaves the valley.

In the lower part of the valley, where the water table is nearest the surface, the land is so broken by arroyos that the irrigation of large areas is not feasible. Elsewhere in the valley the depth to water is probably so great that water for irrigation can not be pumped at a profit.

Analyses of ground waters from Chemehuevis Valley, Calif.

[Margaret D. Foster and Addie T. Geiger, analysts. Parts per million]

	1	2
Silica (SiO_2)	46	106
Iron (Fe)	.10	.11
Calcium (Ca)	21	28
Magnesium (Mg)	.6	39
Sodium and potassium (Na+K) (calculated)	197	167
Bicarbonate radicle (HCO_3)	112	453
Sulphate radicle (SO_4)	150	72
Chloride radicle (Cl)	162	102
Nitrate radicle (NO_3)	8.1	1.8
Total dissolved solids at 180° C	643	722
Total hardness as $CaCO_3$ (calculated)	55	230
Date of collection	(a)	(b)

[a] Nov. 14, 1917. [b] Nov. 13, 1917.

1. West Well, 33 miles south of Needles, in sec. 17, T. 4 N., R. 24 E. San Bernardino meridian. See p. 739 for description.
2. Sample from one of two wells known as Carsons Wells, 43 miles southwest of Needles, probably in sec. 19, T. 4 N., R. 21 E. San Bernardino meridian. See p. 741 for description.

WATERING PLACES IN THE MOUNTAINS

Wells and springs in Turtle Mountains.—Several wells and springs exist in the Turtle Mountains, but definite information is available only in regard to Carsons Wells. These wells, two in number, are situated near the south end of an embayment or valley at the northeast end of the mountains, probably in sec. 19, T. 4 N., R. 21 E. They are reached by a road that branches southwest from the Needles-Parker road about 17½ miles south of Needles. The wells are dug in a gravelly wash that is cut about 15 feet below the valley surface. One well is 32.5 feet deep, and on October 13, 1917, the depth to water was 18 feet. At the bottom of the well there is a 10-foot drift. The second well, which is 75 feet southeast of the other, is 16 feet deep and has a depth to water of 13 feet. Neither well penetrated rock. The shallower well is dug partly in a greenish clay. The water from the deeper well is said to taste of sulphur at times. An analysis of water from the other well (analysis 2), shows that the mineral content is fairly high. However, it is fair for domestic use and irrigation.

A trail is said to lead southward from Carsons Wells up a broad canyon to Coffin Spring, a distance of about 4 miles. The spring is so named because the shape of the rocks which inclose it suggests that of a coffin. Another unnamed spring is said to be situated along the trail about 2 miles south of Carsons Wells.

Mohawk Spring is reported to be about 2 miles northwest of Carsons Wells. It is reached by a trail that turns west from the road near a prospect shaft about 1.1 miles north of the wells and is situated about a mile west of the road. No definite information is available in regard to it.

Watering places in Whipple Mountains.—Water can be obtained from several springs in the Whipple Mountains and from Whipple Well. None of these were visited. The location of those shown on Plate 13 is taken from the Parker topographic map. Whipple Well is the only one reached by a road, but most of the springs may be reached by trails. Notes on the watering places on the south side of the mountains are given on page 747.

VIDAL AND CALZONA VALLEYS

GENERAL FEATURES

Vidal and Calzona Valleys form the southernmost part of the area tributary to Colorado River that is shown on Plate 13 (see also pl. 7.) Structurally the two valleys form a single large unit, but a low divide that reaches northward from Vidal separates it into two parts. The eastern part of this area, around Calzona, has been called Calzona Valley, and the name Vidal Valley is suggested to designate the western part.

The branch line of the Atchison, Topeka & Santa Fe Railway that runs from Cadiz, Calif., to Parker and Phoenix, Ariz., lies along the south side of the valley. A road that is sometimes called the Parker cut-off parallels the railroad for most of the distance. Westward it leads to Rice, whence a road leads southward to Blythe and other points in Palo Verde Valley (see p. 712) and to the National Old Trails Road at Danby and Cadiz. (See p. 689.) Eastward it leads to a ferry across Colorado River near Parker, Ariz. From the ferry a road leads northwest to Needles, a distance of 61 miles. Either of these two roads may be used by travelers in going from Parker to Los Angeles and other points in the western part of the State. The road along the railroad is 28 to 37 miles shorter than the route by way of Needles, depending on the choice of alternative routes, and it has the advantage of being close to the railroad for most of the distance. However, one stretch of it, between Kilbeck and Cadiz, is rough, and better accommodations can be obtained along the other route. Many travelers therefore take the road to Needles where they strike the National Old Trails Road. On the Needles road no supplies other than water can be obtained in a distance of 60 miles, so the traveler should have plenty of gasoline and oil.

The road along the railroad is connected with the Needles road at three places. One road leads northward from Vidal for 11 miles and joins the Needles road a short distance south of the place where it enters a canyon in the Whipple Mountains. Another road, which leads northward from Calzona, branches within a short distance, and the two branches join the Needles road a mile or two apart. Other less-traveled roads lead to prospects in the Whipple, Riverside, and Turtle Mountains.

Colorado River is crossed near Parker by a ferry. In 1918 the charge for ferrying automobiles was $2. This ferry operates practically every day in the year, whereas the ferry between Blythe and Ehrenberg, about 40 miles farther south, can not operate sometimes during the summer when the river is in flood.

Vidal, the only town in the region, contains a store with post office and a few houses. Several years ago a town was laid out at Calzona, and a number of houses were built, but about 1915 it was abandoned, and in 1917 only one family was living there.

Some mining has been done on a small scale in the Whipple and Riverside Mountains. In the Whipple Mountains copper[90] and manganese[91] are obtained. The mines in the Riverside Mountains have produced mostly gold.[92]

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[90] Cloudman, H. C., and others, Mines and mineral resources of San Bernardino County, pp. 12, 17, California State Mining Bureau, 1917.

[91] Jones, E. L., Deposits of manganese ore in southeastern California: U. S. Geol. Survey Bull. 710, pp. 189–193, 1920.

[92] Merrill, F. J. H., Mines and mineral resources of Riverside County, pp. 82–84, California State Mining Bureau, 1917.

Some attempt has been made to irrigate land near Calzona, but apparently with no great success.

The precipitation and temperature in the area are about the same as at Parker. (See pp. 71–91.)

The vegetation is mostly creosote bush and the species associated with it. Ironwood is abundant in a large wash that lies about half a mile north of Vidal.

PHYSICAL FEATURES AND GEOLOGY

The northeastern border of the area is formed by the Whipple Mountains, which reach a maximum altitude of 3,350 feet above sea level. The geology of the mountains is summed up by Jones[93] as follows:

> The Whipple Mountains are composed of igneous and sedimentary rocks that range from pre-Cambrian to Quaternary in age. Gneiss, granite, hornblende schist, and included masses of metamorphosed sedimentary rocks of probable pre-Cambrian age are the basal rocks of the mountains. Overlying them unconformably in ascending order are conglomerate and red and brown sandstone with interbedded shale and limestone members of probable Tertiary age. These are closely associated with and succeeded by andesite and basalt breccias and tuffs and finally by basaltic flows, which form the summits of some of the flat-topped mountains. Some of the later lava flows may be of Quaternary age. The bench lands that flank the Whipple Mountains on the east are composed of gravel, sands, and outwash deposits, intercalated in which are a few thin basalt flows. The sand and gravel deposits are believed to be the equivalent of the Chemehuevis gravel, named and described by W. T. Lee,[94] which is of late Quaternary (Recent) age.

Jones states further that the red and brown sediments of probable Tertiary age are several hundred feet thick and that they have been greatly faulted and distorted. Manganese occurs in these sedimentary beds and in volcanic breccias associated with them.

The Whipple Mountains are highly dissected, and there are numerous sharp peaks and ridges. Monument Peak is a particularly prominent rock pillar that rises almost vertically 200 to 300 feet. A large part of the mountains drains directly into Colorado River.

The west end of the Whipple Mountains descends to a low, narrow ridge that reaches westward to the Turtle Mountains. This ridge has the appearance in some places of being composed of alluvium, but the presence of several knobs indicates that bedrock probably lies at no great depth.

The southern part of the Turtle Mountains, which forms the west border of Vidal Valley, is a high, steep, elongated ridge. On the east side a large spur extends southeastward to the lower ridge that lies between the Turtle and Whipple Mountains. The southern border of the area is formed by the Riverside Mountains, which are composed

[93] Jones, E. L., op. cit., pp. 191–192.

[94] Lee, W. T., Reconnaissance of a part of western Arizona: U. S. Geol. Survey Bull. 352, p. 18, 1908.

largely of schist, limestone, and quartzite. Between the Turtle and Riverside Mountains the divide is composed of alluvium.

The alluvial slope in most of the area slopes southward. The low divide that extends northward from Vidal (see pl. 7) separates the area into two parts in which conditions are somewhat dissimilar. In the eastern part, which forms Calzona Valley, the alluvial slope descends continuously southward from the base of the Whipple Mountains to Colorado River. The alluvial slope has been greatly dissected by numerous steep-sided arroyos, which extend separately from the mountains nearly to the river. The drainage pattern is similar to that on the west side of the river near Needles. Near the river the alluvial slope ends with an abrupt descent to the river flood plain of about 50 feet. On the Arizona side of the river the flood plain is several miles wide, but west of the river it is less than a mile wide. West and northwest of Vidal the alluvial slope is much less dissected than farther east. The drainage is concentrated into a large wash that lies between the railroad and low lava hills about a mile north of Vidal.

The upper beds of the valley fill consist principally of sand and gravel. In a well at Vidal blue clay beds that range in thickness from 12 to 85 feet were penetrated below a depth of 225 feet. (See log on p. 745.) They may be related to greenish clay reported to crop out in the terraces east of Colorado River near Parker.[95]

WATER RESOURCES

SURFACE WATER

The only perennial stream in the area is Colorado River. As early as 1870 water was diverted from the river a few miles above Parker for irrigation of lands on the flood plain in the Colorado River Indian Reservation on the east side of the river.[96] The water could be diverted into the canal only during high stages of the river, and since 1898 during low stages the water has been pumped into the canals. In 1920 the system included two pumps with capacities of 50 and 75 second-feet, 10 miles of canal with a capacity of 50 second-feet, and 43 miles of smaller canals. Because of inadequate boiler capacity both pumps can not be operated together continuously. The total area cultivated was 4,105 acres, of which 1,500 acres was cultivated by Indians and 2,605 acres by lessees. The total value of crops raised was nearly $900,000. The lands cultivated are all on the lowland, which is not more than 10 to 25 feet above the river. It is contemplated that 112,000 acres may eventually be irrigated on these bottom lands.[97]

[95] Ross, C. P., The lower Gila region, Ariz., a geographic, geologic, and hydrologic reconnaissance: U. S. Geol. Survey Water-Supply Paper 498, p. 25, 1923.

[96] Hearings before the Committee on Irrigation of Arid Lands, House of Representatives, 67th Cong., 2d sess., on H. R. 11449, A bill to provide for the protection and development of the lower Colorado River basin, Appendix A, pp. 2, 47-53.

[97] Idem, p. 3.

There has been no irrigation with water from the river west of the Colorado, because the flood plain area is so narrow. Water might be pumped to the alluvial slopes above the flood plain, but the lift would be 50 feet or more, and the land is so greatly dissected that agriculture is impracticable except in small areas. Some water has been pumped from the river a distance of 2 to 5 miles to mines in the Riverside Mountains.

GROUND WATER IN THE VALLEY

The Atchison, Topeka & Santa Fe Railway has a drilled well at Vidal which is 412 feet deep. The log of the well is as follows:

Log of the Atchison, Topeka & Santa Fe Railway well at Vidal, Calif.

	Thickness (feet)	Depth (feet)
Loose sand and gravel	225	225
Blue clay	85	310
Loose sand	30	340
Blue clay	20	360
Sandy shale	40	400
Blue clay	12	412

Water was struck at 315 feet, apparently just below the first layer of blue clay, and rose to 250 feet. In a test at completion the well yielded 55 gallons a minute. The casing is screw pipe, 10 inches in diameter to a depth of 265 feet and 8 inches to a depth of 385 feet. The bottom 65 feet of this casing is perforated. The last 27 feet of the well is not cased. As shown by the accompanying analysis, the water is rather highly mineralized, containing 642 parts per million of total solids. However, it can be used for domestic supplies without serious difficulty. It is poor for boilers because of the large quantity of foaming constituents present.

Analysis of water from 412-foot well (No. 2) of Atchison, Topeka & Santa Fe Railway at Vidal, Calif.

[Collected August 11, 1910. Analysis furnished by Atchison, Topeka & Santa Fe Railway Co., recalculated to parts per million from hypothetical combinations in grains per U. S. gallon]

Calcium (Ca)	[a] 22
Magnesium (Mg)	([a])
Sodium (Na)	216
Bicarbonate radicle (HCO_3)	132
Sulphate radicle (SO_4)	176
Chloride radicle (Cl)	164
Total dissolved solids	642
Total hardness as $CaCO_3$ (calculated)	55

[a] Calcium and magnesium carbonates reported together and calculated as $CaCO_3$.

At Calzona there is a well reported to be 212 feet deep. The depth to water is said to be about 170 feet. The well could not be measured.

Apparently it is abandoned, as the water used by the only family living at Calzona is hauled on the railroad from Vidal. About 4½ miles southeast of Vidal, probably in sec. 16, T. 1 S., R. 24 E., is a well 110 feet deep. On November 16, 1917, the depth to water measured 108.5 feet. According to railroad survey data the altitude at Calzona is 485 feet, and from the reported depth to water in the well there the altitude of the water table would be about 305 feet. According to contours on the Parker topographic map, this altitude is about 25 feet lower than the altitude of the flood plain of Colorado River at its nearest point. It is entirely probable that in times of flood the river stands higher than the water table beneath the bordering lands. However, as there is no point of discharge for the ground water except downstream, it is not likely that this condition persists so far from the river as Calzona. It therefore seems as if the reported depth to water at Calzona is inaccurate.

At Vidal the water is apparently confined under pressure beneath a clay bed. No information is available as to whether these conditions exist in other parts of the valley, but it is entirely possible. The water in the Vidal well stands at an altitude of about 375 feet. The grade between it and Colorado River, as nearly as can be estimated from the topographic map, is about 10 feet to the mile. However, the water was struck at a depth of about 310 feet—that is, at about the same altitude as the estimated altitude of the water table in the well at Calzona and possibly a few feet below the level of the flood plain of the river.

The divide between Vidal Valley and Rice Valley, farther west, is composed of alluvium, and possibly there is movement of the ground water eastward from Rice Valley. The altitude of the water table in a well at Rice (Blythe Junction) is about 580 feet above sea level (see p. 715), or about 200 feet higher than in the well at Vidal. The distance between the two places is 21 miles, and the grade between the two wells, if uniform, would be about 10 feet to the mile—that is, about the same as between the Vidal well and Colorado River. If the water table extends uniformly between Rice and Vidal, the depth to water at the divide, near Grommet, would be a little more than 400 feet.

Data in regard to yield are available only for the Vidal well, in which the quantity pumped in a test was small. It is not certain whether this quantity is the capacity of the well. However, as the formations below the water level consist of blue clay, sand, or sandy shale, without any gravel, it is improbable that the yield of wells in this vicinity would be very large.

The prospect of obtaining water from wells for irrigation is poor, not only because the yield of wells is likely to be small but also because throughout the area that is level enough for farming the pumping lift will be excessive. It is believed, however, that water sufficient for mining may be obtained in almost any part of the valley at depths of 100 to 500 feet, depending upon location, provided the well is not drilled so near the mountains as to strike bedrock before reaching water.

WATERING PLACES IN THE MOUNTAINS

Several springs and wells exist in the Whipple and Turtle Mountains, but none are known in the Riverside Mountains. Most of these watering places are far from the main traveled roads and are used only by prospectors. Two—the D. & W. mine and Chambers Well—are on the Needles-Parker road, 18.9 and 17.3 miles, respectively, northeast of the Parker ferry. Water at the D. & W. mine is pumped from the shaft and accordingly is obtainable only when someone is living there to operate the pump. Chambers Well is an old dug well on the west side of the road 1.3 miles north of the junction of the Needles-Parker road with the branch road from Vidal. The well is 48 feet deep. When measured in October, 1917, there was only about 6 inches of water in it, and it was fouled by dead animals. A force pump, apparently in good condition, was in the well, but no water could be obtained from it, probably because there was so little water in the well. The location of several springs in the Whipple Mountains is shown on the Parker topographic map. Trails lead to some of these springs, but no data are at hand in regard to them. Water is said to be available from several natural "tanks" in hollows in the rocks, including Hons Tanks, shown on Plate 13.

A spring indicated on some maps as Turtle Spring was reported by Mendenhall [98] to emerge near the southeast end of the Turtle Mountains, about 15 miles northeast of Browns Well, on the road to West Well. No definite information was obtained in regard to the spring. The road referred to, if it still exists, is seldom traveled.

[98] Mendenhall, W. C., Some desert watering places in southeastern California and southwestern Nevada: U. S. Geol. Survey Water-Supply Paper 224, p. 77, 1909.

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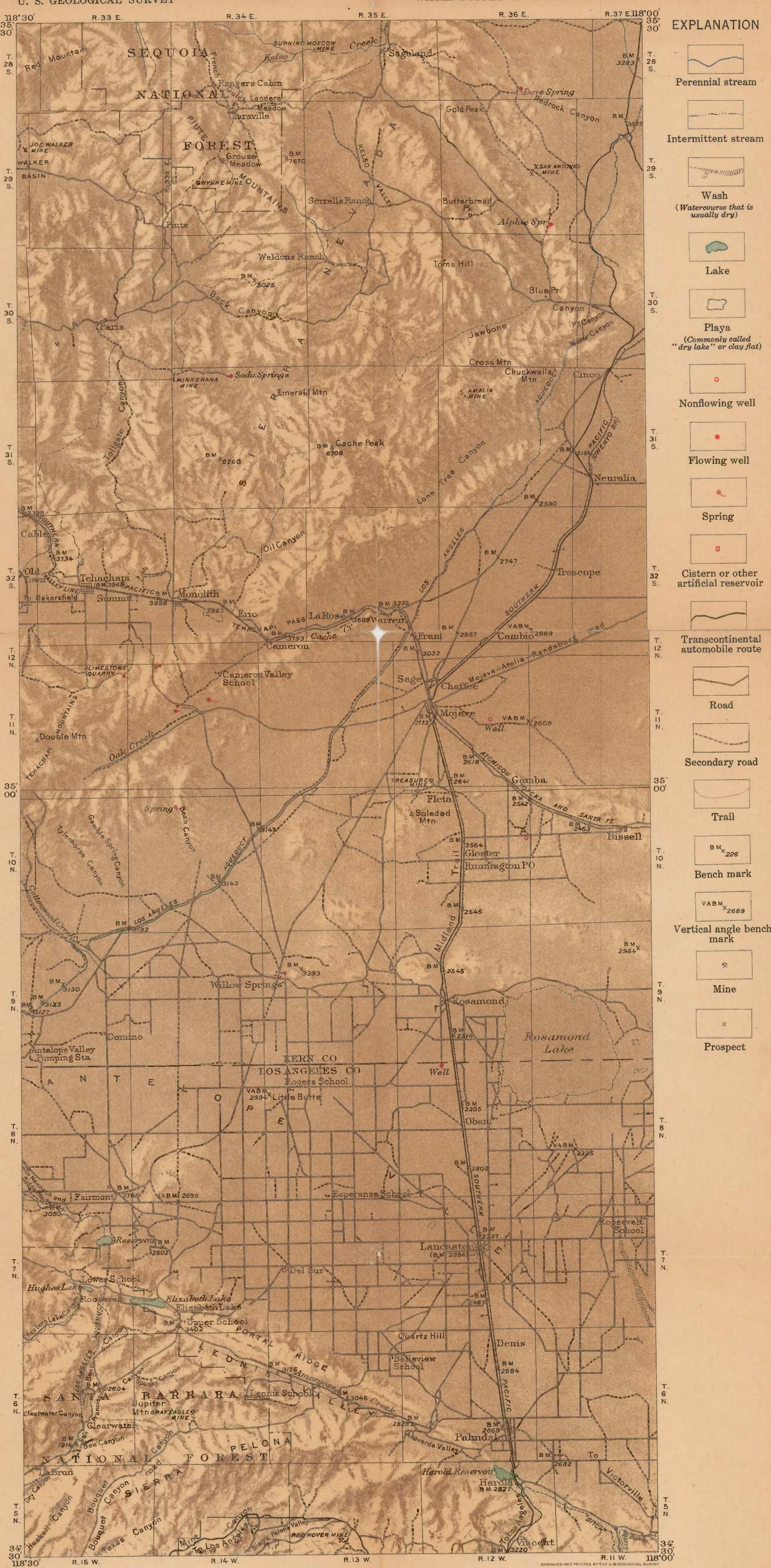
MAP OF THE MOHAVE DESERT REGION SHOWING BOUNDARIES OF DRAINAGE BASINS AND CHARACTER OF PLAYAS

By David G. Thompson

RECONNAISSANCE GEOLOGIC MAP OF THE MOHAVE DESERT REGION

Compiled by D. G. Thompson



Compiled from plane-table surveys by David G. Thompson, U. S. Geological Survey topographic maps, maps of the U. S. Geographical Surveys West of the 100th Meridian, data furnished by railroads and by the county surveyor of Los Angeles county, township plats of the General Land Office, and other sources
Relief shading by John H. Renshawe

Watering-place survey by David G. Thompson
Surveyed in 1917–1920

Scale $\frac{1}{250,000}$

5 0 5 10 Miles

Datum is mean sea level

1921

RELIEF MAP OF PART OF MOHAVE DESERT REGION, CALIFORNIA

SHOWING DESERT WATERING PLACES (SHEET I)

EXPLANATION

- Perennial stream
- Intermittent stream
- Wash (Watercourse that is usually dry)
- Lake
- Playa (Commonly called "dry lake" or clay flat)
- Abandoned well or dry hole
- Nonflowing well
- Nonflowing well with pumping plant
- Flowing well
- Spring
- Cistern or other artificial reservoir
- Irrigation canal, ditch, or pipe line
- Electric power transmission line
- Transcontinental automobile route
- Road
- Secondary road
- Trail
- Sign post erected by U. S. Geological Survey
- Bench mark
- Vertical angle bench mark
- U. S. triangulation Station
- Mine
- Prospect

Compiled from plane-table surveys by David G. Thompson, U. S. Geological Survey topographic maps, maps of the U. S. Geographical Surveys West of the 100th Meridian, data furnished by railroads and by the county surveyors of San Bernardino and Los Angeles counties, township plats of the General Land Office, and other sources
Relief shading by John H. Renshawe

RELIEF MAP OF PART OF MOHAVE DESERT REGION, CALIFORNIA

SHOWING DESERT WATERING PLACES (SHEET II)

Scale $\frac{1}{250{,}000}$

5 0 5 10 15 Miles

Datum is mean sea level

1921

Watering-place survey by David G. Thompson
Surveyed in 1917-1920

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

Compiled from plane-table surveys by David G. Thompson, U. S. Geological Survey topographic maps, maps of the U. S. Geographical Surveys West of the 100th Meridian, data furnished by railroads and by the county surveyor of San Bernardino County, township plats of the General Land Office, and other sources
Relief shading by John H. Renshawe

RELIEF MAP OF PART OF MOHAVE DESERT REGION, CALIFORNIA

SHOWING DESERT WATERING PLACES (SHEET III)

Scale 1/250000

5 0 10 15 Miles

Datum is mean sea level

1921

Watering-place survey by David G. Thompson
Surveyed in 1917–1920

Includes Dale

EXPLANATION

- Wash (Watercourses that is usually dry)
- Playa (Commonly called "dry lake" or clay flat)
- Abandoned well or dry hole
- Nonflowing well
- Nonflowing well with pumping plant
- Spring
- Natural reservoir or "tank"
- Cistern or other artificial reservoir
- Irrigation canal, ditch, or pipe line
- Transcontinental automobile route
- Road
- Secondary road
- Sign post erected by U. S. Geological Survey
- Bench mark
- U. S. triangulation station
- Mine
- Prospect

Compiled from plane-table surveys by David G. Thompson, U. S. Geological Survey topographic maps, maps of the U. S. Geographical Surveys West of the 100th Meridian, data furnished by railroads and by the county surveyor of San Bernardino County, township plats of the General Land Office, and other sources
Relief shading by John H. Renshawe

RELIEF MAP OF PART OF MOHAVE DESERT REGION, CALIFORNIA

SHOWING DESERT WATERING PLACES (SHEET IV)

Watering-place survey by David G. Thompson
Surveyed in 1917–1918

Scale $\frac{1}{250000}$

5 0 5 10 15 Miles

Datum is mean sea level

1921

Compiled from plane-table surveys by David G. Thompson, U. S. Geological Survey topographic maps, maps of the U. S. Geographical Surveys West of the 100th Meridian, data furnished by railroads and by the county surveyor of San Bernardino County, township plats of the General Land Office, and other sources
Relief shading by John H. Renshawe

RELIEF MAP OF PART OF MOHAVE DESERT REGION, CALIFORNIA

SHOWING DESERT WATERING PLACES (SHEET V)

Scale $\frac{1}{250,000}$

5 0 5 10 15 Miles

Datum is mean sea level

1921

Watering-place survey by David G. Thompson
Surveyed in 1917–1918