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1

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THE MOHAVE DESERT REGION
CALIFORNIA

A GEOGRAPHIC, GEOLOGIC, AND HYDROLOGIC RECONNAISSANCE

BY

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Sujan M. Hentawathtthegedara , July 2007 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.

[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.)

[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

[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.

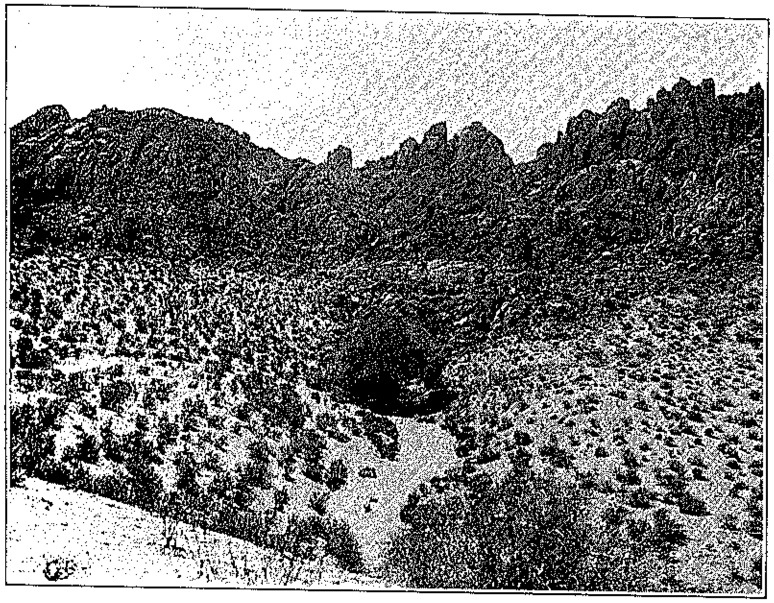
In many of the desert basins water that contains substances dissolved from soil on the uplands collects on the lowest land, and by long-continued evaporation produces a concentration of soluble salts, either in salt lakes or in the soil of the lowlands. Dissolved mineral matter is also deposited in other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



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 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

[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.

[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

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.

[62] Phalen, W. C., Salt resources of the United States: U. S. Geol. Survey Bull. 669, p. 158, 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.

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.

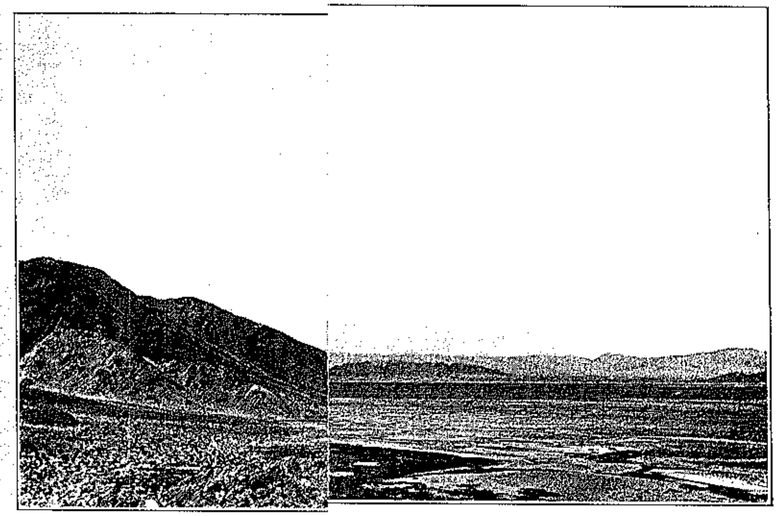
The ruins of large vats on the playa near Soda station testify to an attempt made many years ago to produce salt from the playa deposits at Soda station by solar evaporation. The project doubtless failed because of the greater purity of the salt occurring in other playas where it can be recovered more cheaply.

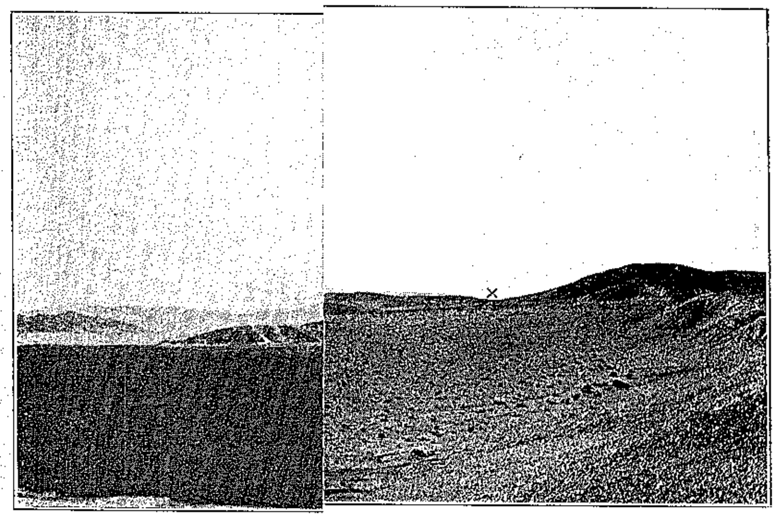
PHYSICAL FEATURES AND GEOLOGY

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.





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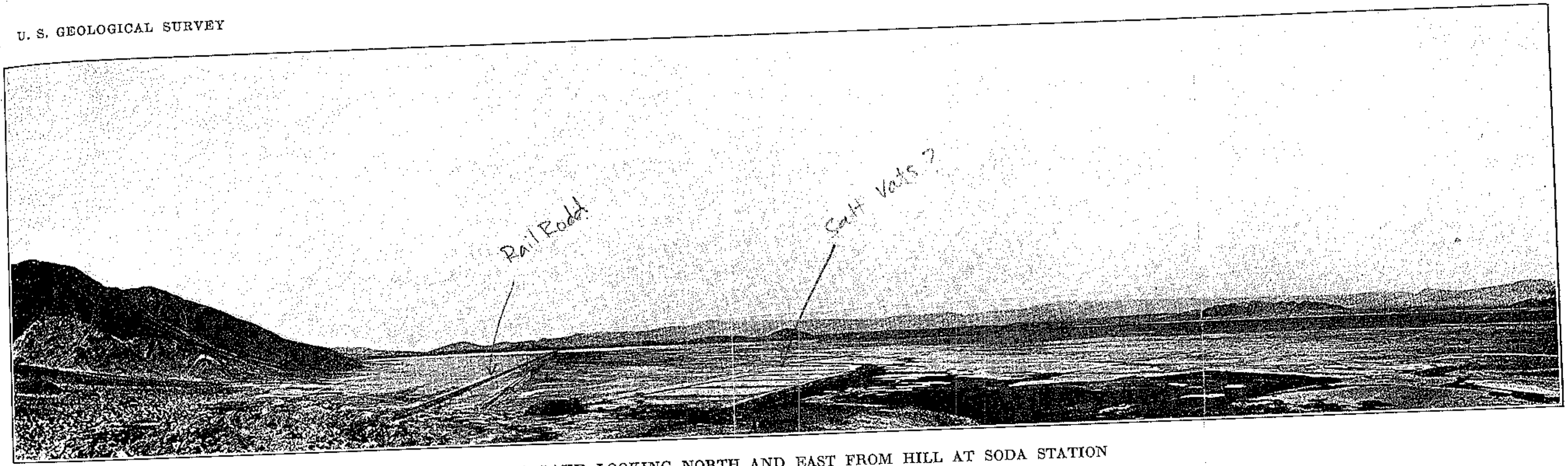
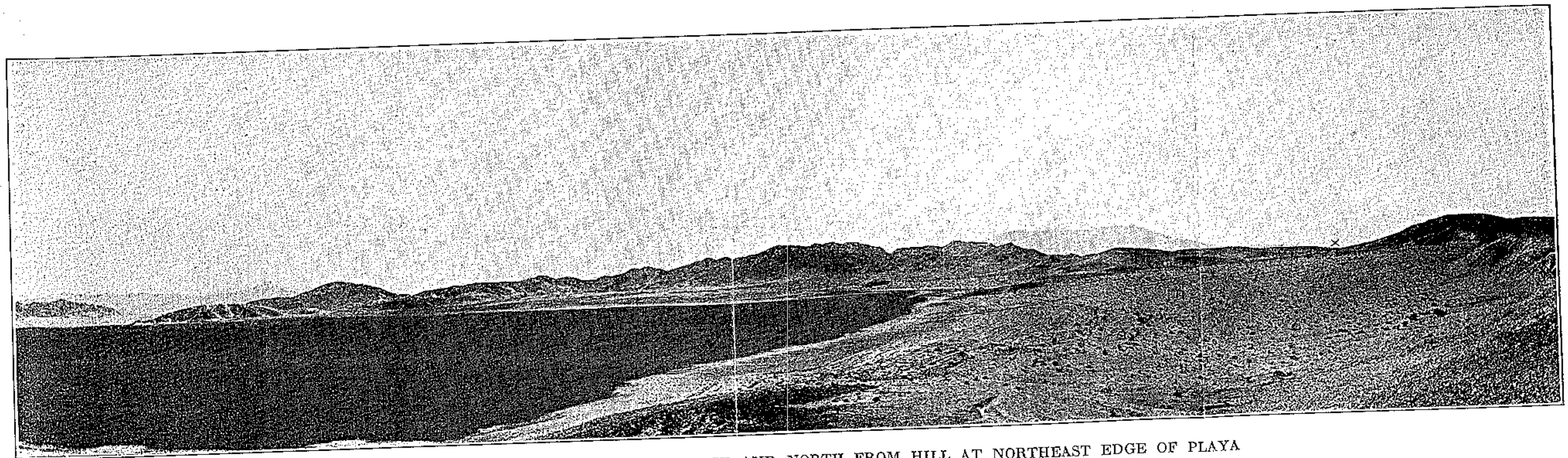


A. SODA LAKE, LOOKING NORTH AND EAST FROM HILL AT SODA STATION



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 X). 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 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

[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.

[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.

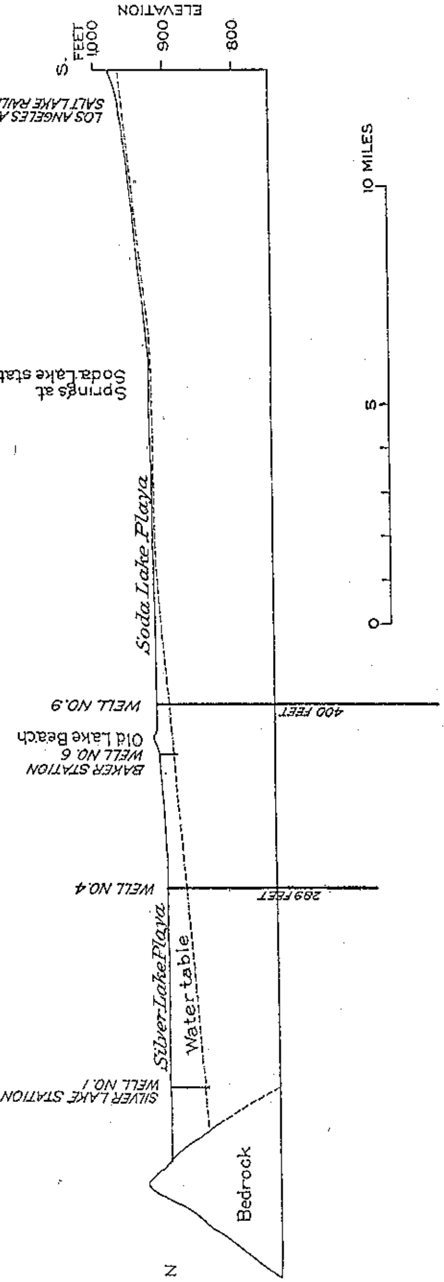


FIGURE 16.—Profile of the surface and of the water table from north to south across Soda Lake and Silver Lake playas

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 [illegible] If topographic and drainage conditions dur-

ing 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 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.

[77] Buwalda, J. P., Pleistocene beds at Manix, with eastern Mohave Desert region: California Univ. Dept. Geology Bull., vol. 7, p. 455, 1914.

[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.

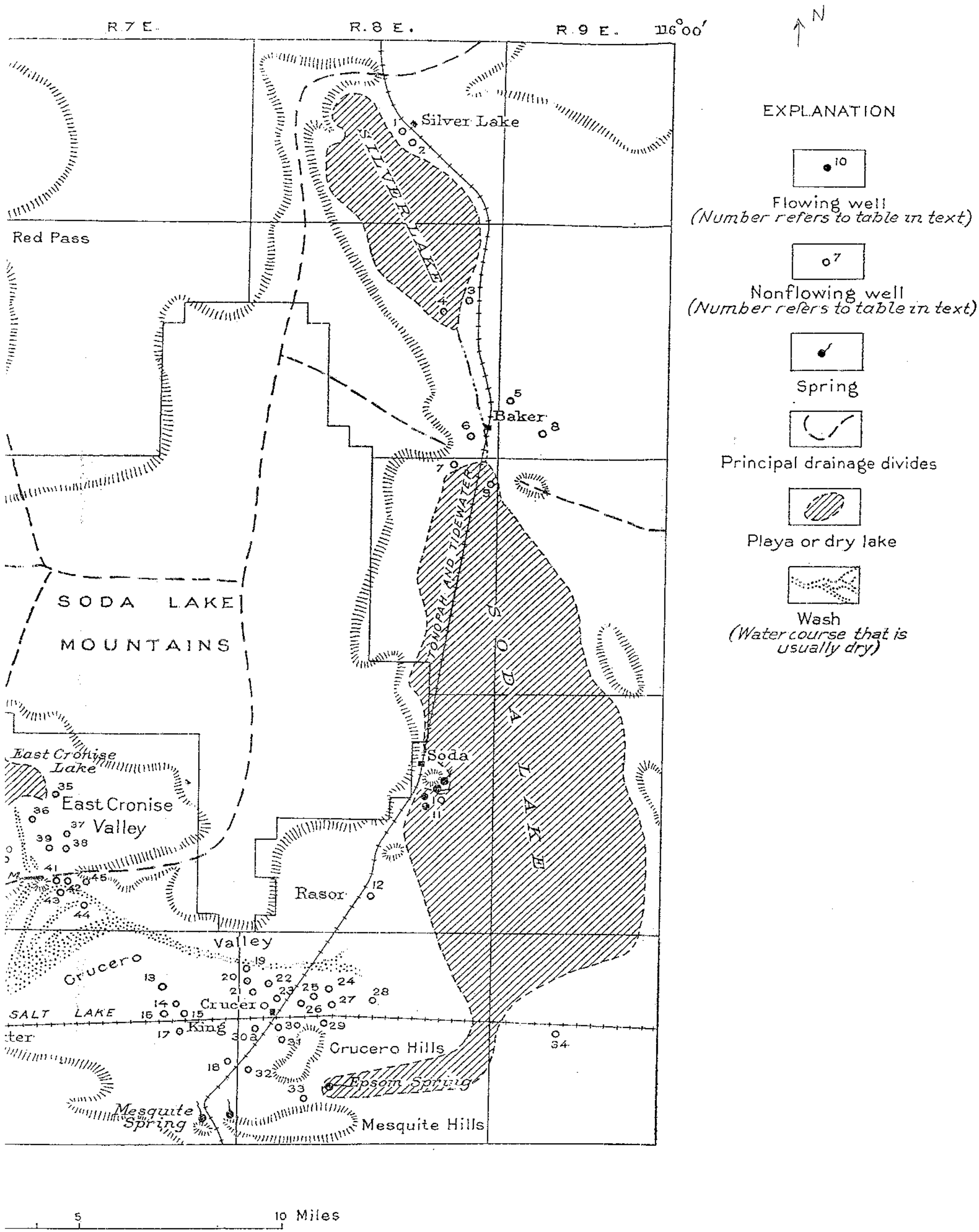
From the point where the river leaves the mountains, near Dumont, it flows southwestward down the alluvial slope for about 10 miles, dropping in that distance an average of about 50 feet to the mile. Near the west-central part of T. 18 N., R. 6 E., the river turns northwestward into the south end of 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



. LAKE, AND SILVER LAKE VALLEYS SHOWING PHYSICAL
)CATION OF SPRINGS AND WELLS