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NATHAN C. GROVER, Chief Hydraulic Engineer

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NOTE.—The papers included in the annual volume "Contributions to the hydrology of the United States" are issued separately, with the final pagination, as soon as they are ready. The last paper will include a volume index, title-page, and table of contents for the use of those who may wish to bind the separate parts. A small edition of the bound volume will also be issued, but copies can not be supplied to those who have received all the parts. On account of the congestion of printing caused by the war no volume of the "Contributions" for 1918 was issued.

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ILLUSTRATIONS.

INSERT.

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES, 1919.

NATHAN C. GROVER, Chief Hydraulic Engineer.

GEOLOGY AND WATER RESOURCES OF THE GILA AND SAN CARLOS VALLEYS IN THE SAN CARLOS INDIAN RESERVATION, ARIZONA.

By A. T. SCHWENNESEN.

INTRODUCTION.

In recent years the Indian farmers in the valleys of Gila and San Carlos rivers, in the San Carlos Indian Reservation (Pl. I and fig. 1), have been seriously handicapped by an inadequate supply of water for irrigating their crops. A shortage of water at times when it is most needed has tended to discourage those Indians who are making an earnest effort to farm and has done much toward neutralizing the efforts of the reservation officials to interest others in agriculture. The water shortage has been due to a lack of water in the streams at certain times of the year and to the difficulties of keeping diversion dams and ditches in operation on account of washouts caused by sudden floods in the rivers and by torrents in the tributary arroyos during heavy rains. In the river valleys many tracts of good land now lying idle could be made productive if sufficient water were obtainable. An extension of the present system to include these lands, however, would be likely to fail, from the same causes that contribute to the inadequacy of the present system.

Several officials of the United States Office of Indians Affairs, who are familiar with conditions in the reservation, have suggested the use of ground water for irrigation, and in response to these suggestions the Indian Office requested the United States Geological Survey to make an investigation of the ground-water conditions. The purpose of this investigation, as expressed in the letter of authorization, was "to determine the feasibility of drilling for an irrigation water supply, the examination to be restricted to land not included within the proposed San Carlos reservoir."

The field work covered a period of three months and was completed in December, 1914. Soon after its completion a report was made to the Indian Office containing (1) a brief description of the geologic conditions which influence the occurrence of ground water in this

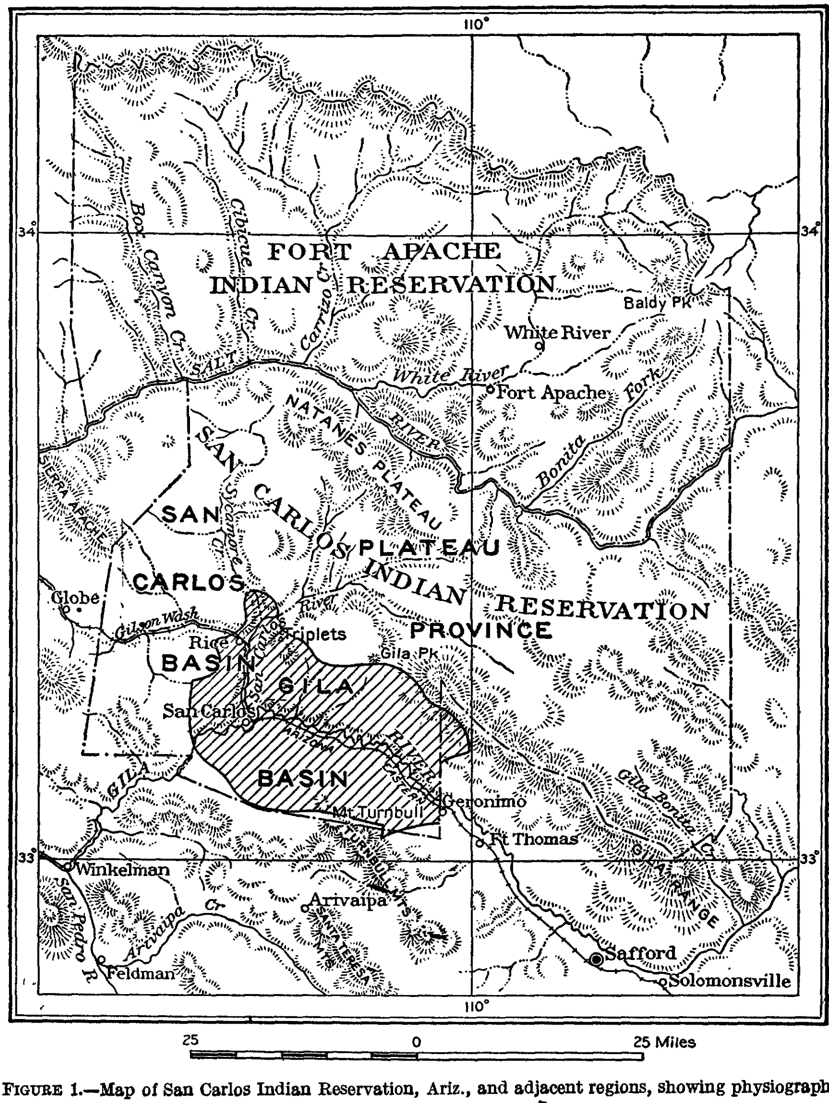
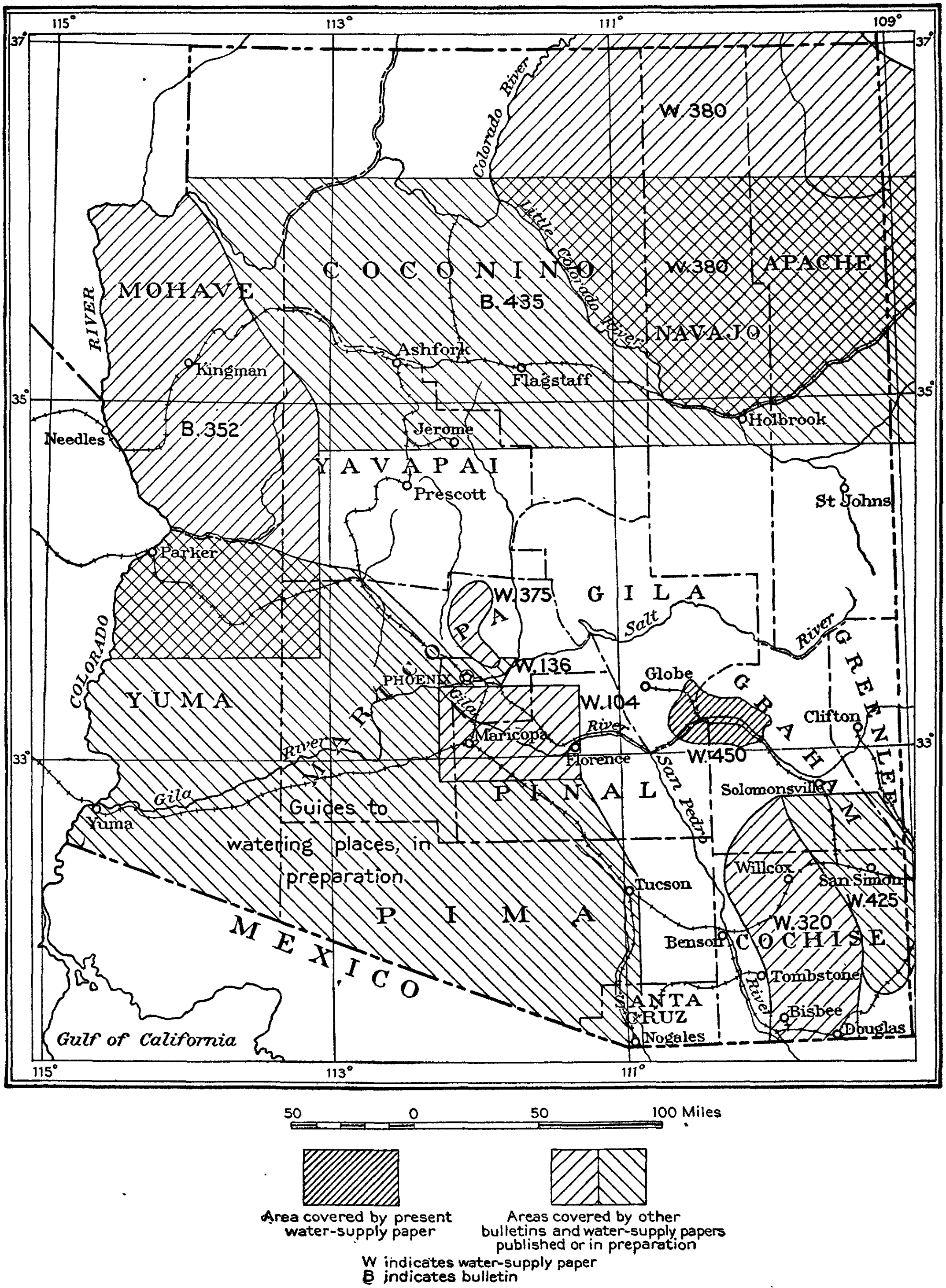


FIGURE 1.—Map of San Carlos Indian Reservation, Ariz., and adjacent regions, showing physiographic provinces.

region, (2) a discussion of the available pumping supplies in the Gila and San Carlos valleys, (3) a discussion of the artesian possibilities, and (4) a summary of conclusions, with certain definite recommendations as to the mode of procedure to develop a sufficient



MAP OF ARIZONA SHOWING AREAS COVERED BY REPORTS OF THE UNITED STATES GEOLOGICAL SURVEY RELATING TO GROUND WATER.

ground-water supply and to increase the irrigated acreage in the reservation. The work was done under the direction of O. E. Meinzer, geologist in charge of the Survey's investigations relating to ground water.

To determine the available supplies for pumping from wells in the river valleys a study was made of the valley sediments with reference to their water-bearing capacity. To determine the quality of this supply for irrigation water samples were collected from representative wells and sent to the University of Arizona for analysis.

The artesian problem required the mapping of the geologic formations in the Gila and San Carlos basins and a study of their structure. The results are shown in Plate II and figure 2. Before recommending the development of either a pumped or artesian water supply it was

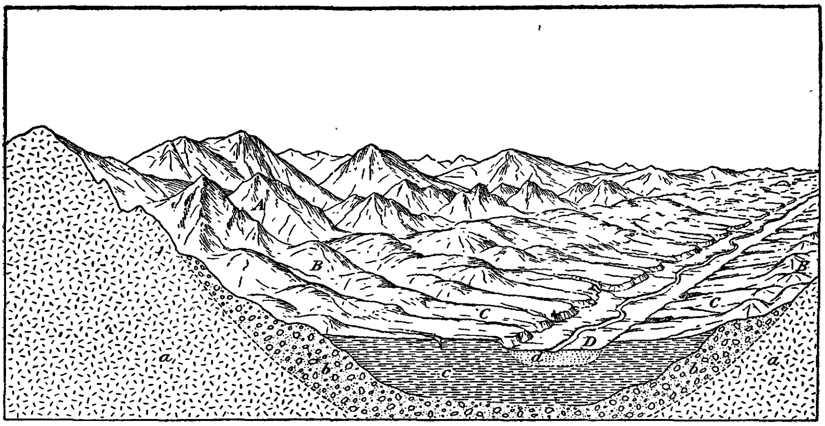


FIGURE 2.—Generalized view and cross section of Gila Basin, San Carlos Indian Reservation, Ariz., showing physiography and geology. *A*, Mountains; *B*, hilly belts, produced by erosion of older alluvial material (*b*); *C*, dissected ancient lake bottom; *D*, valley of Gila River, produced by erosion of lake beds (*c*) and later deposition of alluvium (*d*); *a*, pre-Quaternary igneous and sedimentary rocks; *b*, Gila conglomerate; *c*, lake beds; *d*, Recent alluvium.

important to know whether the amount of arable land in the San Carlos and Gila valleys above the proposed reservoir site was sufficient to warrant the drilling of deep wells or the construction of pumping plants. For this purpose a plane-table map on a scale of 2,000 feet to the inch was made of the portions of the San Carlos and Gila valleys above the proposed site (Pls. III and IV).

It was originally planned to include the results of this investigation in a more comprehensive paper on parts of southeastern Arizona. On account of the writer's resignation from the Geological Survey and the changes produced by the war the publication of such a paper has been indefinitely postponed, and it appears desirable to publish the present brief report, not only to make the local data more accessible but also because of the bearing of these data on the geologic history and ancient lakes or other bodies of standing water that have been observed in the fill of other parts of Gila Valley, in the fill of San Simon and San Pedro valleys, and, with less certainty, in the fill of Sulphur Spring and San Bernardino valleys.[1] These deposits in Gila, San Pedro, and San Simon valleys are no doubt related to one another and have an important bearing on the late geologic history and also on the water supply of the region.

Acknowledgments are due to the superintendent of the reservation, Mr. A. L. Lawshe, and to others for assistance in conducting the field work and for many courtesies; to Mr. C. H. Southworth, engineer of the Indian Office, for furnishing water analyses and for extending the hospitality of his camp; and to the University of Arizona and Mr. A. E. Vinson, of the university staff, who made analyses of the well waters that were collected.

PHYSIOGRAPHY AND DRAINAGE.

GENERAL FEATURES.

The San Carlos Indian Reservation can be divided into two parts—a plateau area, characterized by mountains and lava plateaus, and a basin area, characterized by broad intermontane basins or valleys underlain by river and lake deposits.

The plateau area covers most of the northern and eastern parts of the reservation, including the Ash Flat and Natanes plateaus. Its southern margin is formed by the Gila Range, and its western boundary by a line drawn approximately northward from the Triplets to the Salt River divide. (See fig. 1.)

The basin area includes the Gila Basin, an intermontane trough traversed by Gila River, which flows westward through the southern part of the reservation, and the San Carlos Basin, a similar trough traversed by San Carlos River, which flows southward through the western part of the reservation to San Carlos, where it discharges into the Gila. The basin area is bounded on the south by the Turnbull Range, on the west by the eastern ridges of the Mescal, Pinal, and Apache mountains, and on the north in part by the Gila Range. (See fig. 1.)

With the exception of a narrow strip of country south of Salt River, all of the reservation drains through a gorge which the Gila has cut in the Mescal Range and which is known as the box canyon. The southern part of the reservation, between the Gila and Turnbull ranges, drains directly into Gila River, which crosses the east boundary 2 miles west of Geronimo and flows west-northwestward for 25 miles to its junction with the San Carlos and thence southwestward for 10 miles to the southern boundary of the reservation.

[1] Blake, W. P., Lake Quiburis, an ancient Pliocene lake in Arizona: Arizona Univ. Monthly, vol. 4, February, 1902. Meinzer, O. E., and Kelton, F. C., Geology and water resources of Sulphur Spring Valley, Ariz.: U. S. Geol. Survey Water-Supply Paper 320, pp. 57-62, 1913. Schwennesen, A. T., Ground water in San Simon Valley, Ariz. and N. Mex.: U. S. Geol. Survey Water-Supply Paper 425, pp. 1-35, 1917.

A large territory extending from the vicinity of Globe eastward nearly to Gila Bonita Creek and northward as far as the Salt River divide drains into San Carlos River, which at San Carlos enters the Gila from the north.

GILA BASIN.

The surface of the Gila Basin can be divided into sharply contrasting belts that run parallel to its axis. (See fig. 2.)

On the north and south sides of the basin, adjacent to the mountains, are belts of hilly country which stand higher than the middle of the basin and which have evidently been produced by the erosion of what were at one time smooth alluvial slopes extending from the mountains toward the middle of the basin. Inside these hilly belts are belts of lower country which are the remnants of a lake bottom that once extended across the axis of the basin. This lake apparently came into existence after the alluvial slopes had been considerably eroded. As a result of the large amount of sediment deposited in the lake its bottom became smooth and had only gentle slopes toward the middle of the basin. Although this former lake bottom has been eroded since the disappearance of the lake, it still forms a strong contrast to the more anciently dissected marginal belts.

Inside the belts formed by the remnants of the ancient lake bottom is the valley of Gila River, which was cut by the river after the lake disappeared. The parts of the ancient lake bottom adjacent to the river valley have become much dissected, and with reference to the valley they form a rugged upland.

The river valley in its course within the reservation has an average width of 1 to 1½ miles. Farther up the river, between Solomonville and Fort Thomas, the valley is much wider, in some places reaching a width of 4 or 5 miles. The floor of the valley is formed of sediment deposited by the river in the trough channeled out of the lake beds.

The river valley may be divided into river channel, flood plain, and terraces. The valley contains a series of low terraces at successive levels, each bordered by a steep bank. (See section C–C′, Pl. II.) These terraces have been formed by the continued lateral cutting and shifting of the river, together with slight downward cutting. The lowest flats, which are only 2 to 4 feet above the stream channel, are flooded during high stages of the river and therefore may properly be called the flood plain.

SAN CARLOS BASIN.

The San Carlos Basin, though not so well defined as the Gila Basin and of more irregular outline, has the same general types of topography.

The valley of the San Carlos, like that of the Gila, has been channeled out of the older sediments that filled the rock basin and is bordered by steep bluffs leading up to the dissected upland slopes that are underlain by these older sediments. The average width of the valley is from one-half to three-fourths of a mile. The valley floor, built up of recent sediments deposited by the river, has been terraced like that of the Gila.

San Carlos River is an intermittent stream which rises in several branches in the western part of the Ash Flat plateau and flows in a general westerly direction to Rice, where it turns due southward and flows in that direction for a distance of 12 miles to its junction with the Gila at San Carlos. Two large draws empty into it in the vicinity of Rice—Gilson Wash, which extends along the railroad from Globe and joins the San Carlos at Rice station, and MacMillan Wash, which comes in from the north and joins the San Carlos 1½ miles above Rice.

GEOLOGY.

IGNEOUS ROCKS.

The igneous rocks are represented chiefly in the mountain areas and in intervening parts of the plateau area north of the Gila Range, where large quantities of basalt have been poured out. Ash Flat, which lies between the Gila Range and the range to the north that forms the divide between the Gila and Salt river drainage basins, is largely floored by basalt, apparently of recent age. To the south, east, and north of the Triplets basalt has been poured out over the Quaternary basin deposits. Tuffs and breccias, products of this same period of volcanic disturbance, are interbedded with the basalts. East of San Carlos River remnants of basalt occur at a number of places overlying the soft Quaternary deposits. These lava caps, which have served to protect the underlying sediments against erosion, have produced flat-topped mesas which stand above the unprotected, irregularly eroded surface surrounding them. The most conspicuous example is the Flatiron Mesa, 4 miles northwest of San Carlos.

SEDIMENTARY ROCKS.

PRE-QUATERNARY ROCKS.

The rock complex that forms the core of the mountain ranges along the margins of these basins comprises not only igneous rock but various kinds of hard sedimentary rocks. The mountain areas in which these sedimentary rocks occur were not examined, but, to judge from the character of the débris that the streams have brought down from the mountains into the valleys, limestones are relatively abundant, especially in the Gila Range. Sandstones and various metamorphic rocks were also noted.

QUATERNARY DEPOSITS.

GENERAL CHARACTER.

The oldest sediments in the Gila and San Carlos basins consist of sand, gravel, and coarser rock débris laid down by streams and derived from the pre-Quaternary rocks that form the floors of the basins and constitute the mountains along their margins. These deposits were first studied by G. K. Gilbert in 1873 and named by him the Gila conglomerate.[1]

On the eroded surface of the Gila conglomerate rests a series of well-stratified fine-grained soft sandstones, tuffs, marly clays, and limestones that were apparently deposited in a body of standing water and will in this report be referred to collectively as the lake beds.

The youngest sedimentary deposits in the area consist of the alluvium of the river valleys, which rests on the eroded surface of the lake beds. The river channels, flood plains, and terraces of the Gila and San Carlos river valleys are underlain by this material.

GILA CONGLOMERATE.

In general character and method of deposition the Gila conglomerate is comparable to deposits commonly laid down by streams in the closed desert basins of the Southwest. Along the upper Gila, where Gilbert first examined it, he noted its continuity with the fill of the valleys that open into the Gila.

The Gila conglomerate in the San Carlos Indian Reservation consists of material ranging in coarseness from fine sand to boulders several feet in diameter. The materials are not firmly cemented but are coherent enough to form almost perpendicular cliffs in some localities. The conglomerate varies from place to place, both in the character of the constituent materials and in their arrangement, these features depending on the character of the rock from which the materials were derived and on the distance they have been transported. On the higher slopes along the flanks of the ranges the conglomerate is generally composed of angular material of various shapes and sizes jumbled together in a confused mass without definite stratification. Near the axes of the basins, farther from the mountains, the materials are waterworn, sorted, and distinctly stratified. As is to be expected in deposits of this type, however, cross-bedding is common, and the individual beds lack persistency and grade from sand into gravel within short distances.

The Gila conglomerate crops out in a belt skirting the southern flanks of the Gila Range, in a similar belt adjacent to the northern

[1] Gilbert, G. K., U. S. Geog. and Geol. Surveys W. 100th Mer. Rept., vol. 3, pp. 540-541, 1875.

edge of the Turnbull Range, and along the east side of the Pinal Range. (See Pl. II.) It is carved into a great number of rounded ridges that are separated from one another by deep gorges, forming a foothill belt that contrasts sharply with the rugged ranges above and also with the intricately dissected but generally even surface of the long, sweeping slopes that extend from the lower limit of the foothills to the edges of the river valleys.

The conglomerate belt that skirts the Gila Range on the north side of the basin extends across the east boundary of the reservation. Within the reservation it has an average width of about 3 miles and stretches from the east boundary northward about 15 miles and disappears beneath the lava flows centering about the Triplets.

The conglomerate belt adjacent to the Turnbull Range is 2 to 3 miles wide and extends westward from a locality 4 miles southwest of the box canyon to a point south of Bylas. Beyond this point it was not traced, but it was seen to narrow considerably and to sweep southward along the eastern flanks of Mount Turnbull. At the upper margin it laps up against the range at an average altitude of about 4,200 feet. Its general surface slopes at the rate of about 450 feet to the mile, and its lower limit corresponds approximately to the 3,300-foot contour.

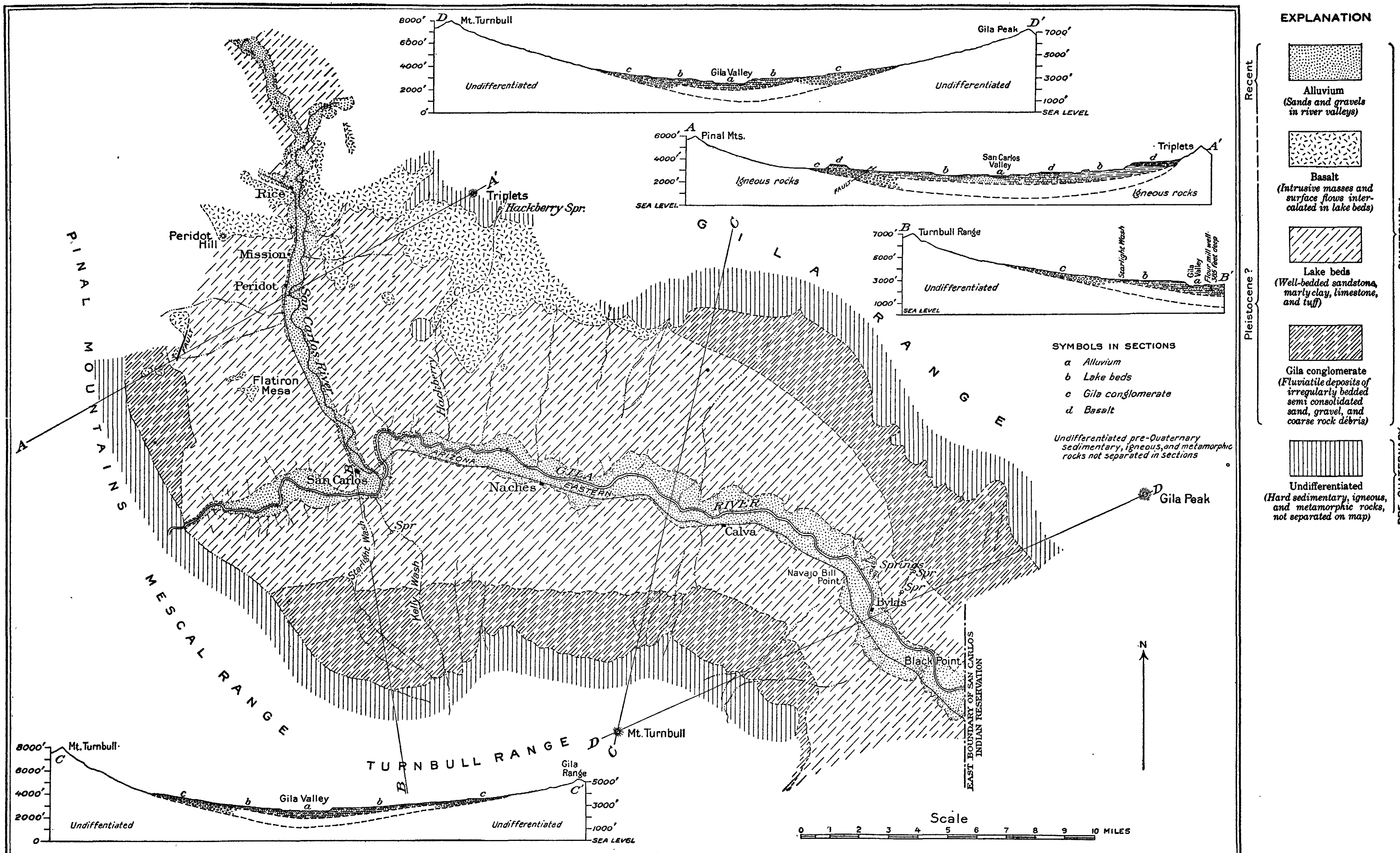
The conglomerate area on the west side of the San Carlos Basin extends northward from the box canyon along the flanks of the eastern ridges of the Pinal Mountains. From the box canyon the conglomerate is easily traced northward for 5 miles by its characteristic topography. Farther north the topographic distinction becomes less marked, and the contact between the conglomerate and the overlapping sandstone is not easily traced.

As no complete sections were exposed the thickness of the formation could not be determined, but on the basis of the position and slope of the rock floor as determined in some of the canyons, and of the position and slope of the original upper surface of the formation as determined by the ridges of conglomerate, the maximum thickness of the Gila conglomerate in the middle of the Gila Basin is estimated to be not less than 1,000 feet. (See sections, Pl. II.)

LAKE BEDS.

Upon the eroded surface of the Gila conglomerate was deposited a series of sandstones, tuffs, limestones, and marly clays which will be referred to collectively as the lake beds, for they were evidently deposited in a body of standing water. This formation underlies the central and intermediate parts of the Gila and San Carlos basins, where it is at the surface except in the river valleys. (See Pl. II.)

The sandstone member of this formation is a soft, fine-grained, well-stratified buff sandstone, interbedded with thin layers or partings of a hard indurated sandstone of similar composition but usually



GEOLOGIC MAP OF GILA BASIN AND PARTS OF SAN CARLOS BASIN, SAN CARLOS INDIAN RESERVATION, ARIZ.

Base from plane-table maps by A. T. Schwennesen, U. S. Geological Survey topographic map of Christmas quadrangle, and railroad alinement maps.

of a somewhat coarser texture. Good sections are exposed in the bluffs that border the valley of Gila River and in the numerous canyons that open into the valley.

The other members of the formation consist of interbedded light-colored tuffs, buff marly clays, and light-gray limestones, all of which are found principally in the region extending from the Triplets northward to San Carlos River and southward to the Gila. These rocks are prominently displayed in the bluffs on the east side of the San Carlos Valley between San Carlos and Rice and on both sides of the valley above Rice.

The maximum thickness of the lake beds within the reservation is not known, as no complete sections are exposed. In the construction of the geologic sections (Pl. II) an estimate of the thickness of these beds was made which is believed to be reasonable. A surface passing through the crests of the ridges formed by the Gila conglomerate was assumed to represent the original surface of the Gila conglomerate. By projecting this surface beneath the lake beds and allowing for a gradual decrease in slope toward the axis of the basin the writer determined the approximate position of the surface upon which the lake beds would have been deposited if there had been no previous erosion of the conglomerate. In section D–D′, Plate II, for instance, the general slope of the surface of the Gila conglomerate where it crops out on the south side of the basin is shown as between 4½° and 5°, or about 450 feet to the mile. This surface projected beneath the lake beds, with allowances for decrease of slope northward, gives an elevation of approximately 2,000 feet above sea level at the axis of the basin, or about 600 feet below the surface of the river valley. Similarly, section C–C′, which crosses the valley of Gila River between Calva and Dewey Flat, shows the bottom of the lake beds to be about 600 feet below the surface at the axis of the basin. The lake beds at San Carlos (section B–B′), are estimated to be about 800 feet thick, and those at Peridot (section A–A′), in the valley of San Carlos River, about 700 feet. If the conglomerate was deeply dissected before deposition began the maximum thickness of the lake beds may be greater.

The lake beds generally have a slight dip toward the river valleys. On the south side of the Gila the dip is from 1½° to 2° N. West of San Carlos River the beds have a slight dip toward the east. North of the Gila and east of the San Carlos they appear to be nearly horizontal.

The formation seems to have undergone little folding or faulting. Slight folding and minor faulting were noted in the limestone beds exposed in the bluffs of Gila River just east of its junction with the San Carlos. An east-west fault was also noted in the vicinity of a lava flow 2 miles west of Flatiron Mesa, on the west side of the San

Carlos Basin. Faulting has probably occurred in connection with the disturbances that accompanied the outpouring of the lava at other places.

ALLUVIUM.

The youngest sedimentary deposit in the area is the alluvium of the Gila and San Carlos valleys. It consists of sand and gravel laid down in troughs channeled out of the lake beds. Most of the fine material has been deposited by the rivers and resembles the material that forms the bottoms of the present channels. The gravel has for the most part been brought down through the arroyos opening into the valleys from the sides.

QUATERNARY HISTORY.

The Quaternary history of the region can be outlined as follows:

1. Aggradation in the rock troughs, resulting in the deposition of about 1,000 feet of gravelly alluvium and the construction of large, steep alluvial slopes.

2. Erosion of the alluvial slopes.

3. Submergence of the lower parts of the alluvial slopes by a lake. Deposition of sand, tuff, and other sediments in the lake to a maximum depth of probably 800 feet. Continued erosion of the parts of the slopes that were not submerged.

Volcanism, resulting in the outpouring of basalt, the deposition of tuff, and minor faulting and folding, at least chiefly, in the later part of the period covered by epochs Nos. 1, 2, and 3, but may not have been confined to No. 3.

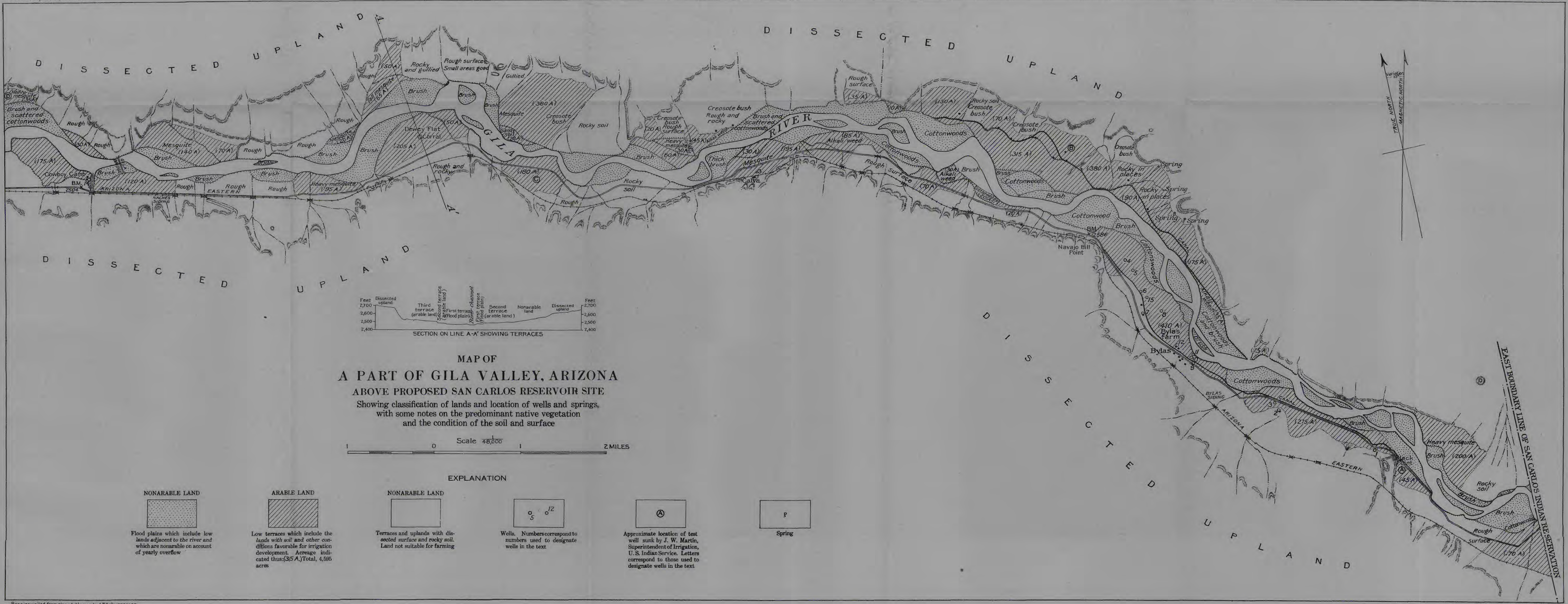
4. Disappearance of the lake. The cause of the formation of this lake and that of its disappearance are not known. Excavation of the valleys by Gila and San Carlos rivers in the old lake bottom, and intricate dissection of the lake bottom near the river valleys.

5. Partial refilling of the river valleys through deposition by the streams, followed by slight changes in stream grade that resulted in the formation of a series of low terraces. Continued erosion of the lake bottom.

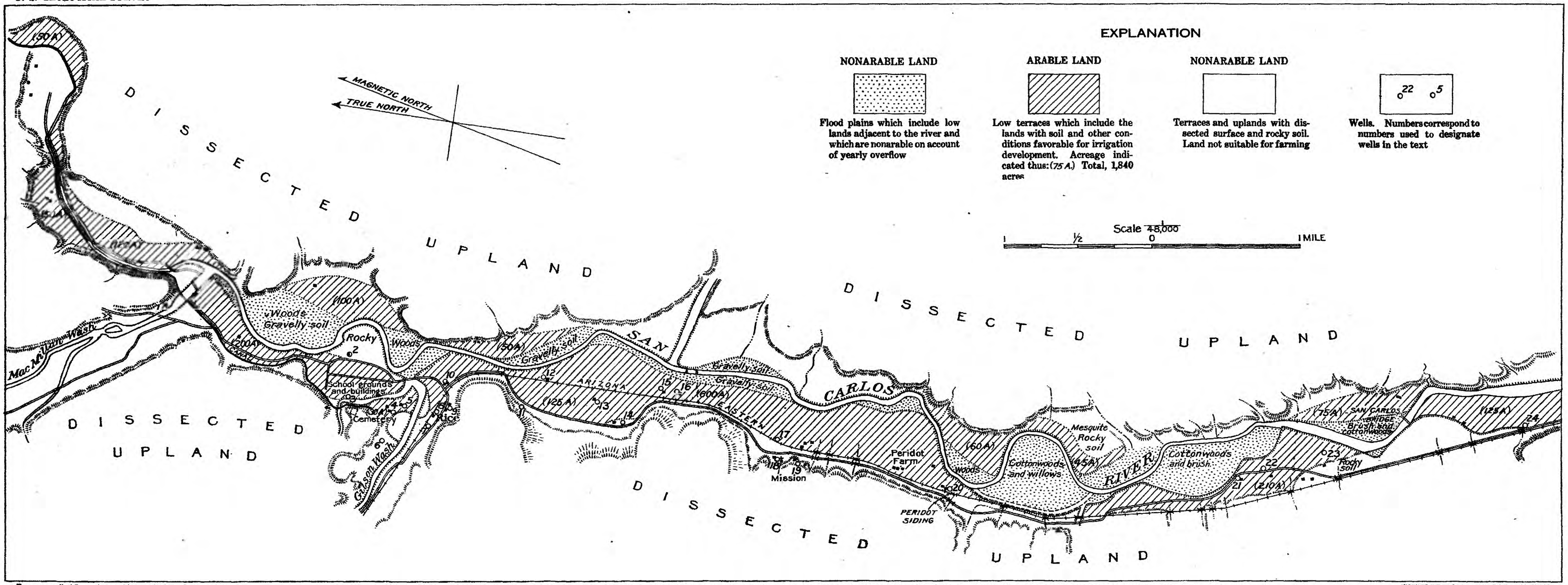
Erosion of the older alluvial slopes was practically continuous after epoch No. 1; the erosion of the mountain ranges continued throughout the period, and the erosion of the lava beds began immediately after their extrusion and continued without interruption.

CLASSIFICATION OF LANDS.

The lands of the Gila and San Carlos valleys may be classed as arable or nonarable on the basis of their suitability for farming and irrigation if a water supply is provided. Their suitability for this purpose depends in part on their topography and the quality of their soil.



Base compiled from plane-table map by A. T. Schwennesen and railroad alinement maps



Base compiled from plane-table map by A.T. Schwennesen and railroad alinement maps

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

MAP OF A PART OF SAN CARLOS VALLEY, ARIZONA, ABOVE PROPOSED SAN CARLOS RESERVOIR SITE
Showing classification of lands and location of wells, with some notes on the predominant native vegetation and the condition of the soil and surface

All the lands that lie at a sufficient elevation above the rivers to be out of reach of floods, whose soil is satisfactory, and whose surface can be prepared for cultivation and the application of irrigating water with a reasonable amount of labor and expense have been classified as arable lands. These lands are for the most part on the low terraces. The soils are light and well drained. Among the native plants growing on the uncleared tracts mesquite and cat-claw predominate, but cottonwood trees are also common.

In the valley of Gila River above the proposed San Carlos reservoir site there is, as nearly as could be determined, 4,595 acres of land which may be classed as arable. This area includes 421 acres irrigated and farmed in the Bylas district in 1913. (See Pl. III.)

In the main valley of San Carlos River above the proposed reservoir site the amount of arable land, including that irrigated under the present system, is approximately 1,840 acres. (See Pl. IV.)

The nonarable lands consist of the river channels, the flood plains, or river bottoms, and the terrace lands near the edges of the valley where the surface is too uneven or the soil is too gravelly for farming. Cottonwoods, willows, and certain unidentified water-loving shrubs grow as thickets on the flood plains. The higher gravelly tracts near the bluffs are the favorite habitat of the creosote brush and members of the cactus family.

Along Gilson Wash, which enters the valley of San Carlos River at Rice, and MacMillan Wash, which enters it 1½ miles above Rice, are numerous small tracts of land that could probably be successfully farmed if water were available, but these lands have not been included with the area classed as arable.

SURFACE WATER SUPPLY.

The only streams in the area under discussion that offer a possible source of water supply in sufficient quantities for irrigation are Gila River and San Carlos River. Both streams head in areas where melting snow furnishes considerable flow during the early spring months, but about the last of April the snow disappears and the streams fall rapidly, reaching a minimum about the first of July, when the summer rains ordinarily begin. The most severe droughts, however, occur during July and August in years when the summer rains fail or are not of sufficient intensity to swell the streams.

The total annual run-off of Gila River, even during the lowest years, is undoubtedly more than sufficient to irrigate all the arable land in the reservation, but without storage it is of little value, because it passes during the months when it is least needed or in floods so intense that it can not be conducted to the land without unduly expensive diversion dams.

San Carlos River is ordinarily dry for a considerable part of each year, but if the total run-off during normal years could be economically stored it would probably be sufficient to irrigate several thousand acres of land. It is doubtful, however, if feasible storage sites exist on this stream.

The following tables give the essential results of measurements of stream flow on Gila River in the vicinity of San Carlos and on San Carlos River that have been made by the United States Geological Survey. The records of flow on Gila River at San Carlos from 1899 to 1905 are of exceptional value and interest, in that they cover a period of the most severe drought that has been experienced in the history of modern agricultural development in Arizona.

GILA RIVER AT SAN CARLOS, ARIZ.

LOCATION.—Half a mile south of San Carlos Indian Agency at San Carlos, Gila County, half a mile below San Carlos River, and about 7 miles above dam site in box canyon.

RECORDS AVAILABLE.—July 11, 1899, to November 27, 1905 (incomplete). From August 17, 1910, to February 5, 1911, a station was maintained just below the Arizona Eastern Railroad bridge and half a mile above San Carlos River. Because of insufficient data discharges have not been computed for this station. For discharge measurements and gage heights see Water-Supply Papers 289 and 309.

GAGE.—Inclined staff on right bank.

DISCHARGE MEASUREMENTS.—Made from cable a short distance above gage.

CHANNEL AND CONTROL.—Sandy and badly shifting.

EXTREMES OF DISCHARGE.—Discharge varies from zero flow to enormous floods, probably exceeding 100,000 second-feet. No accurate measurements of extreme floods have been made.

DIVERSIONS.—Water for irrigating several thousand acres was diverted above the station for use in the Solomonville and Duncan valleys. A small amount of water (probably not exceeding 5 second-feet at any time) was also diverted just above the gage for irrigating lands within the reservation.

ACCURACY.—Results liable to considerable error, particularly during low stages, on account of shifting channel and control.

Monthly discharge of Gila River at San Carlos, Ariz., for 1899–1905.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1899.				
July 11-31	11,000	195	1,760	73,300
August	2,740	90	408	25,100
September	6,860	75	416	24,800
October 1-18	300	75	143	5,110
The period				128,000
1900.				
April 4-30	75	3.5	5.7	305
May	4.5	.9	2.4	148
June	.8	.3	.6	36
July	.5	.1	.3	18
August	2,750	1.0	198	12,200
September	6,900	25	937	55,800
October	102	36	60.0	3,690
November	2,900	10	177	10,500
December	118	66	102	6,270
The period				89,000
1901.				
January	1,150	36	141	8,670
February	2,110	420	1,110	61,600
March	1,080	155	426	26,200
April	155	6	59.3	3,530
May	8	4	5.5	338
June	6	.3	2.6	155
July	3,600	0	377	23,200
August	1,870	67	482	29,600
September	1,700	18	212	12,600
October	460	10	67.5	4,150
November	630	133	223	13,300
December	155	94	110	6,760
The year	3,600	0	262	190,000
1902.				
January	94	50	79.1	4,860
February	57	26	45.9	2,550
March	26	8	13.5	830
April	2	0	.1	4
May	0	0	.0	0
June	0	0	.0	0
July	400	0	28.2	1,730
August	1,820	0	407	25,000
September	340	40	114	6,780
October	4	0	.1	8
November	30	0	1.2	71
December	2,750	0	583	35,800
The year	2,750	0	107	77,600
1903.				
January	360	79	169	10,400
February	73	43	53.3	2,960
March	110	10	35.7	2,200
April	147	9	50.6	3,010
May	8	.6	2.2	135
June	670	.4	107	6,370
July	575	.2	53.3	3,280
August	3,570	1	963	59,200
September	2,150	16	223	13,300
October	405	38	106	6,520
November	78	42	55.4	3,300
December	43	22	35.5	2,180
The year	3,750	.2	156	113,000

Monthly discharge of Gila River at San Carlos, Ariz., for 1899–1905—Continued.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1904.				
January	36	27	31.7	1,950
February	48	17	32.6	1,880
March	15	9	11.0	676
April	12	2	5.3	315
May	115	0	8.7	535
June	0	0	0	0
July	1,580	0	143	8,790
August	3,200	240	952	58,500
September	1,300	20	232	13,800
October	5,870	20	825	50,700
November	210	42	112	6,660
December	660	31	306	18,800
The year	5,870	0	224	163,000
1905.				
January 1–11	7,000	120	1,290	28,100
May 14–31	1,400	440	949	33,900
June	675	30	255	15,200
July	740	5	99.6	6,120
August	1,090	110	441	27,100
September	1,650	68	544	32,400
October	705	28	149	9,160
November 1–27	6,150	58	1,100	58,900

NOTE.—No record for the periods Oct. 19, 1899, to Apr. 3, 1900, and Jan. 12 to May 13, 1905.

GILA RIVER NEAR SAN CARLOS, ARIZ.

LOCATION.—One mile above dam site in box canyon, in San Carlos Indian Reservation, about 6 miles below San Carlos Indian Agency, Gila County.

RECORDS AVAILABLE.—April 29, 1914, to September 30, 1917.

GAGE.—Stevens water-stage recorder on left bank about 1 mile above dam site.

DISCHARGE MEASUREMENTS.—Made by wading near gage or from cable about 1 mile above gage.

CHANNEL AND CONTROL.—Channel composed of sand, gravel, and boulders. A semipermanent control is formed by rapids over heavy boulders just below gage. Control shifts somewhat because of sand filling in and washing out from crevices between the boulders.

EXTREMES OF DISCHARGE.—1914–1917: Maximum stage 25.5 feet January 20, 1916 (approximate discharge, determined from extension of rating curve, 92,000 second-feet); minimum stage 0.15 foot, July 1, 1914 (discharge, 1 second-foot).

DIVERSIONS.—Water for irrigating about 30,000 acres is diverted from river in valley just above station. At times this diversion reduces the low flow practically to zero at the station. About 7,000 acres is irrigated from this stream above the station at Guthrie.

ACCURACY.—Results fair except for extremely high or low stages or for estimated periods. (See footnote to monthly discharge table.)

Monthly discharge of Gila River near San Carlos, Ariz., for years ending Sept. 30, 1914–1917.

Month.	Discharge in second-feet.			Run-off (in acre-feet).
	Maximum.	Minimum.	Mean.	
May			8	492
June	405	3	725	4,310
July	2,380	1	968	59,500
August	3,220	291	1,080	66,400
September	2,430	120	612	36,400
The period				167,000
1915.				
October	6,150	116	1,170	71,900
November	3,220	250	781	46,500
December		490	6,180	380,000
January			2,420	149,000
February			3,950	219,000
March			3,570	220,000
April			3,870	230,000
May			1,130	69,500
June			193	11,500
July			907	55,800
August			500	30,700
September			267	15,900
The year			2,100	1,500,000
1916.				
October	164	26	66.7	4,100
November	134	26	71.5	4,250
December	387	130	222	13,600
January		387	12,800	787,000
February			3,290	189,000
March			2,890	178,000
April	2,410	533	1,080	64,300
May	968	127	403	24,800
June	121	17	57.3	3,410
July	190	12	87.6	5,390
August	1,770	144	788	48,500
September	2,670	128	720	42,800
The year		12	1,890	1,370,000
1917.				
October	33,500	103	3,240	199,000
November	822	330	442	26,300
December	444	316	347	21,300
January	14,400	328	1,850	114,000
February	1,550	514	964	53,500
March	1,910	418	774	47,600
April	938	190	482	28,700
May		72	152	9,350
June	66	15	34.8	2,070
July	1,050	14	187	11,500
August	827	57	221	13,600
September			48.2	2,870
The year	33,500	14	732	530,000

NOTE.—Mean discharge for May and December, 1914; January to September, and December, 1915; January to March, and December, 1916; and May and September, 1917 estimated or partly estimated by comparison with records at other stations on this stream.

SAN CARLOS RIVER AT SAN CARLOS, ARIZ.

LOCATION.—Opposite railroad station at Sán Carlos, Graham County, in San Carlos Indian Reservation, about half a mile above junction with Gila River.

DRAINAGE AREA.—Not measured.

RECORDS AVAILABLE.—August 17, 1910, to January 12, 1911,[1] and April 1, 1914, to September 30, 1915, when station was discontinued.

[1] Discharge not computed from Aug. 17, 1910, to Jan. 12, 1911. For discharge measurements and gage heights see Water-Supply Papers 289 and 309.

GAGE.—Stevens water-stage recorder on left bank. The original gage, which was used from August 17, 1910, to January 12, 1911, was a vertical staff fastened to right pier of railroad bridge, downstream end.

DISCHARGE MEASUREMENTS.—Made by wading or from cable at gage.

CHANNEL AND CONTROL.—Sand, badly shifting at all stages. Section flat and nonsensitive.

EXTREMES OF DISCHARGE.—Stream dry a part of each year. July 26, 1915, a heavy flood occurred, covering the surrounding lowlands. Discharge not determined.

DIVERSIONS.—No record of any diversions, although a small amount was probably diverted above the gage for irrigation.

ACCURACY.—Results poor because of shifting control and insufficient discharge measurements.

Monthly discharge of San Carlos River at San Carlos, Ariz., from Apr. 1, 1914, to Sept. 30, 1915.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1914.				
April	0	0	0	0
May	0	0	0	0
June	21	0	2.1	125
July	165	0	12.8	762
August	145	0	47	2,800
September	90	10	32.3	1,920
October	375	10	59	3,630
November	290	25	60	3,570
December 1-18	150	40	63	2,250
The period	375	0	292	15,100
1915.				
January 1-28	145	40	79	4,390
February 1-19	210	5	128	4,820
March	160	7	97	5,960
April	190	6	46	2,740
May	132	2	36	2,210
June	155	0	2.6	155
July 1-25	0	0	0	0
August			[a] 15	920
September			[a] 5	300

[a] Estimated.

NOTE.—Floods above the limit covered by the rating curve occurred during the period Dec. 19-30, 1914, Jan. 29-31, Feb. 20-22, and July 26-31, 1915. Discharge Dec. 31, 1914, 150 second-feet. Mean discharge Feb. 23-28, 1915, 15.7 second-feet.

PRESENT IRRIGATION.

All irrigation on the reservation in 1914 was done with water from the Gila and San Carlos rivers, diverted into the main canals by brush and earth dams thrown across the channels. These dams are temporary affairs that wash out at each flood and must be rebuilt at the beginning of each irrigating season and perhaps several times during the season. They are necessarily low and are too frail to impound the water and raise it much above its natural level, so that the intake of the ditch can be little higher than the bottom of the channel. This condition allows little opportunity for the silt to settle before the water is taken into the canals. Consequently the canals, especially those on the Gila, become choked with silt and must frequently be dug out. Flood waters discharging into the canals through gullies from the sides of the valley also deposit much silt and often destroy sections of the canals by cutting across them.

Permanent dams that could withstand the floods would save much expense and also relieve the present water shortage to some extent, for much water is now lost by seepage through the temporary dams, even when the rivers are low. On account of the unstable character of the bottom and sides of the channels, however, permanent dams may not be practicable on Gila River. On the upper San Carlos a suitable site for a permanent dam could probably be found, but whether the additional land that could be irrigated with the water saved by a permanent dam would warrant its construction is not certain.

The enlargement of the present irrigation system on Gila River to include more of the arable lands in the valley would require the construction of canals at higher levels than those now in use. If permanent dams are not practicable the construction of high-level canals would necessitate either carrying the ditch head much farther up the river and outside of the reservation, or else pumping from the river into the high-level canals.

The most serious drawback to the present irrigation system is the inadequacy of the water supply during certain months of the year. Gila and San Carlos rivers are usually lowest in May, June, and July, the months during which water is most needed. It is not unusual for these streams to dry up entirely at times during these months, so that it becomes necessary to scrape out holes in the sand and gravel of the channels to provide water for stock. According to the stream-gaging records of the United States Geological Survey for 1914 no water passed the gaging station on San Carlos River at San Carlos during April and May, but in June 125 acre-feet and in July 762 acre-feet passed the station. At the gaging station above the box canyon on the Gila the average flow for the first 22 days after the automatic gage was in operation, from May 27 to June 17, was 18 acre-feet per day. As these records were obtained below the irrigated districts of the reservation they do not show the amount of water taken out by ditches.

The yearly cost of keeping up the ditches and diversion dams on the reservation is from $1,800 to $2,000. In 1913 the expenditure in preparation for the season's irrigation was $1,908, according to the statement of the superintendent, A. L. Lawshe. The total area irrigated, according to Mr. Lawshe, was 1,428 acres, of which 421 acres was in the Bylas district, 469 acres in the San Carlos district, and 538 acres in the Peridot district. The cost per acre was therefore $1.34.

SHALLOW GROUND WATER.

OCCURRENCE AND QUANTITY.

Water is found at shallow depths in the Recent alluvial fill of the Gila and San Carlos valleys. Most of the wells are on the low terraces above the stream channels. Most wells dug by the Indians for domestic water supplies are not more than 15 or 20 feet deep, but several constructed by white settlers on higher ground are deeper. The Rice school well, at the base of the bluffs on the north side of San Carlos Valley (No. 3, Pl. IV), is 36 feet deep and has a depth to water of 32 feet. Two large dug wells at the flour mill at San Carlos are 30 and 32 feet deep. The well at the railroad station at Calva, near the foot of the bluffs on the south side of Gila Valley (No. 13, Pl. III), is 75 feet deep, and the water table here is 45 feet below the surface.

The shallow wells on the level arable terraces end in sand and fine gravel similar to the material in the present stream channels. The general correspondence of the water level in the wells with the level of the water in the streams indicates that the alluvium is saturated about to the stream level.

The water is supplied by percolation from the rivers, by water discharged into the valleys through tributary arroyos, and by direct rainfall on the valleys. The principal contributions are probably made by percolation of stream water into the bottoms and sides of the river channels. Second in importance are contributions made by tributary arroyos, a part of whose water sinks into the gravel near the edges of the valleys. The amount of water contributed by direct rainfall is relatively small. The rapidity with which water withdrawn from wells is replenished depends on the porosity and continuity of the water-bearing beds and the location of the wells with respect to the streams. Wells close to the stream channels will probably yield more freely than wells farther back, at a greater distance from the principal source of supply. Where large quantities of water are required it is therefore generally not advisable to sink wells at very great distances from the streams.

The lake beds, which underlie the Recent alluvium, yield some water but do not constitute good water-bearing material. The large dug wells at the San Carlos flour mill, on the gently sloping ground above the San Carlos bottoms, penetrate about 15 feet of coarse sand and gravel and then pass into the lake beds. The upper sands and gravels are above the water level and are therefore dry, and the water is said to come out of thin "clay" seams in soft fine-grained sandstone. The wells are about 30 feet deep and have an aggregate cross-sectional area of about 1,400 square feet. In summer about 50,000 gallons of water is pumped from them during a 10-hour day.

At this rate these large wells are soon pumped down, and in order to continue pumping it is necessary to put into operation a syphon connecting the large wells with a well on the terrace of San Carlos River. When pumping is continuous this well, which is only 10 feet deep and 8 by 8 feet in cross section and which ends in Recent alluvium, furnishes most of the water.

A number of years ago two wells were drilled from the bottom of the larger of the two wells at the flour mill in the hope of getting an increased supply from a deeper stratum. One of these wells reached a depth of about 115 feet, and the other was sunk to a depth of 385 feet below the surface. Both wells were failures, although in the 385-foot well a small supply of water was obtained at 85 feet. All the way down these wells were in the same fine-grained sandstone—probably belonging to the lake beds—found in the lower parts of the dug wells.

QUALITY.

The mineral character of waters from wells and from Gila River is shown in Tables 1 and 2. The samples whose analyses are given in Table 1 were collected by the writer in the course of the field investigation. Table 2 gives the results of analyses of waters from a number of shallow test wells put down in the Gila Valley several years ago under the direction of James W. Martin, superintendent of irrigation for the Indian Office.

In samples 1, 9, 12, 13, and 14 (Table 1), which represent waters from shallow wells in the Gila Valley above the proposed San Carlos reservoir site, the amount of total solids ranges from 1,330 to 2,412 parts per million. Samples 9, 12, 13, and 14 are very high in their content of chlorine, one of the constituents of sodium chloride or common salt, ordinarily referred to as one of the "white alkalies." These waters are practically worthless for irrigation under ordinary conditions. Sample 1 contains less sodium chloride but contains a prohibitive amount of sodium carbonate or "black alkali," which is even more harmful than white alkali. The sample of water from Gila River at the canal intake is representative of the water now used for irrigation on the reservation. Comparison with the well waters shows that it contains less than half as much white alkali. The fact that it has been used successfully for many years for the irrigation of crops in the Gila Valley is sufficient proof of its value as an irrigating water. The effects of its continued use, however, are shown by the alkali spots that appear in the alfalfa fields, and it is questionable whether the crops could endure a much greater amount of these salts. A doubling of the amount of alkali, which would result from the use of well waters such as the analyses represent, would probably prove fatal to most crops, even under the most favorable conditions of soil and drainage.

The sample from the pumping plant at San Carlos (Table 1) is a mixed water from wells at the flour mill and a well about 500 feet northeast of the flour mill, on the San Carlos River bottoms. This water contains less soluble salts than any of the other well waters that were analyzed. It contains a moderate amount of white alkali and a small amount of the more injurious black alkali. As an irrigating water it may be classed as fair, and in its probable effects on crops it is comparable to the water from Gila River.

Unfortunately no analyses of well waters from the San Carlos Valley are available. A sample thought to be fairly representative of well waters in the San Carlos Valley was obtained from a driven well near the river at the new steel bridge across the San Carlos. The sample was too small for a complete analysis, however, and therefore no report on this water was obtained.

TABLE 1.—*Chemical composition of water from wells and from Gila River in San Carlos Indian Reservation, Ariz.*

[Samples collected by A. T. Schwennesen; analyzed by A. E. Vinson at the laboratories of the Arizona Agricultural Experiment Station.]

No. of well.[a]	Designation and location.	Kind of well.	Depth of well.	Depth to water level.	Composition (parts per million).							Alkali coefficient.[b]	Classification for irrigation.[b]
					Total solids.	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chloride radicle (Cl).	Permanent hardness stated as $CaSO_4$.	Black alkali stated as Na_2CO_3.		
			Feet.	*Feet.*									
1	Domingo's well, one-fourth mile west of Black Point.	Dug	16.3	13.5	1,330	12	480	152	354	....	263	2.8	Poor.
9	Indian well, 400 feet southeast of new Bylas well at Bylas.	....do	17	16	1,852	....	403	236	660	337	....	3.1	Do.
12	Domestic well on agency farm at Bylas (old well).	....do	15.6	14.2	2,376	....	385	303	876	544	....	2.4	Do.
13	Railroad well at Calva siding.	Dug and drilled.	45	75	2,412	....	536	306	880	190	....	2.2	Do.
14	Well at Cowboy Camp, 1 mile west of Naches siding on Gila River.	Dug	....	....	1,864	....	415	257	658	239	....	3.0	Do.
	Wells at agency pumping plant at San Carlos.	....do	[c] 30, [c] 32, [d] 10	....	816	....	409	68	204	....	93	6.0	Fair.
	Gila River at intake of canal, three-fourths mile southeast of Black Point.	....	....	....	1,008	....	291	152	307	141	....	6.5	Do.

[a] Numbers refer to numbers used to designate wells on map (Pl. III).

[b] Calculated according to Stabler's formulas (Stabler, Herman, Some stream waters of the western United States: U. S. Geol. Survey Water-Supply Paper 274, pp. 177-179. 1911), modified as follows: If black alkali is reported, use Stabler's formula 13*c* and compute sodium as follows: $Na=0.4339\ Na_2CO_3+0.6486\ Cl+0.4789\ SO_4$. If permanent hardness is reported and SO_4 equals or is less than $0.7056\ CaSO_4$, use Stabler's formula 13*a*. If permanent hardness is reported and SO_4 is more than $0.7056\ CaSO_4$, use Stabler's formula 13*b*. If formula 13*a* or 13*b* is required, compute sodium as follows: $Na=0.6486\ Cl+0.4789\ (SO_4-0.7056\ CaSO_4)$.

[c] At flour mill.

[d] About 500 feet east of flour mill on San Carlos River bottoms.

TABLE 2.—*Chemical composition of water from test wells in Gila Valley in the San Carlos Indian Reservation.*

[Analyses made at laboratories of Arizona Agricultural Experiment Station under direction of R. H. Forbes. Results of analyses taken from report of J. W. Martin, superintendent of irrigation, United States Indian Office, furnished by C. H. Southworth, engineer, United States Indian Office.]

Designation.[a]	Source.	Quantitative analysis (parts per million).			Qualitative analysis.				Classification for irrigation.[b]
		Total solids at 110° C.	Chlorides in terms of NaCl.	Alkalinity in terms of Na_2CO_3.	Sulphate.	Magnesia.	Lime.	Bicarbonates.	
A	Dug test well southeast of Black Point.	884	343	97	Moderate	Very slight	Moderate	Moderate	Objectionable on account of black alkali.
B	Dug test well on north side of river opposite Navajo Bill Point.	11,774	10,180	762	Very strong	Strong	Very strong	Very strong	Objectionable on account of extreme amounts of total soluble solids.
C	Dug test well 1,500 feet south of river bank, 1½ miles east of Dewey Flat.	1,584	970	359	Moderate	Moderate	Strong	Strong	Not desirable on account of large amount of total soluble solids.
D	Dug test well on north side of Gila River 1½ miles northwest of Cowboy Camp.	2,380	1,590	212	Strong	do	do	do	Not desirable on account of high sodium chloride content.

[a] Approximate location shown on map (Pl. III).

[b] Comments by R. H. Forbes in report to J. W. Martin.

USE FOR IRRIGATION.

Although no definite tests have been made there is reason to believe that the recent alluvium would yield enough water, if pumped from shallow wells, to irrigate all the arable lands. As the principal contributions to the ground-water supply are received from seepage of the streams into the bottoms and sides of the stream channels, wells should be located as near the channels as possible if large yields are desired. Wells and pumping plants should, however, be placed where there is no danger that they will be washed out, for the streams are continually changing their courses and wearing away the lands adjacent to their channels.

Irrigation with water pumped from wells would have an important advantage over irrigation with surface water in that the supply would be nearly uniform throughout the year, whereas surface supplies are most abundant when irrigation is not needed and least abundant in the dry season. Its cost would be considerably higher than the present cost of irrigating with surface water, but this higher cost would be compensated to a large extent by an increased crop yield made possible by an assured water supply in the dry season, during which the crops often suffer.

The principal objection to the use of water from wells is the poor quality of the water. The waters of the Gila Valley are so heavily impregnated with mineral matter as to require extraordinary precautions to prevent the accumulation of an injurious amount of alkali in the soil, and it is doubtful whether they could be successfully used for any length of time even under the most favorable conditions of soil and drainage. The data as to the quality of the ground waters of the San Carlos Valley are meager, but there is reason to believe that these waters are better than those of the Gila Valley.

Final judgment as to the availability of the shallow ground waters may well be deferred until practical tests have been made and their effects on crops noted under actual working conditions. Experiments of this kind should be carried on at the Bylas farm, in the Gila Valley, where a small pumping plant has lately been installed, and similar experiments should be made in the San Carlos Valley.

To the extent that the shallow ground water is found to be good enough for irrigation, it can be used advantageously on the tracts now under cultivation to supplement the inadequate surface water supply, and also on the arable tracts that lie above the present ditch system.

ARTESIAN WATER.

The principles upon which artesian flows from sedimentary rocks depend are explained in textbooks on geology and in many of the publications of the United States Geological Survey. The necessary conditions are concisely stated by T. C. Chamberlin[1] as follows: (1) A pervious stratum to permit the entrance and the passage of the water; (2) a water-tight bed below to prevent the downward escape of the water; (3) a like impervious bed above to prevent escape upward, for the water, being under pressure from the fountain head, would otherwise find relief in that direction; (4) an inclination of these beds so that the edge at which the waters enter will be higher than the surface at the well; (5) a suitable exposure of the edge of the pervious stratum, so that it may take in a sufficient supply of water; (6) rainfall adequate to furnish this supply; (7) absence of any means of escape for the water at a lower level than the surface at the well.

In the Gila Basin and in the lower part of the San Carlos Basin the essential conditions for an artesian flow as stated above are believed to be fulfilled, the Gila conglomerate serving as the pervious stratum for the entrance and passage of the water, the rock floor upon which it rests serving as the lower impervious stratum, and the lake beds serving as the upper impervious stratum. (See section D–D^{1}, Pl. II.)

Wherever the Gila conglomerate is exposed it has the appearance of a good water-bearing material. Its outcrops along the flanks of the ranges, several hundred feet above the river valleys, provide a large intake area for the absorption of direct rainfall and run-off from the mountains above. If the conglomerate extends to the axes of the basins and is of the same character as at the outcrops, it fulfills the first requisite given above. Its character near the axes of the basins, where it is hidden beneath the overlying formations, can only be conjectured. It probably contains less coarse material there than where it crops out, but there is no reason to believe that it is entirely devoid of water-bearing gravels.

The rock basins in which the Gila conglomerate lies appear to be sufficiently tight to prevent the escape of ground water. At their lower ends the Gila and San Carlos basins are closed by mountains that allow the escape of surface water through a narrow gorge (the box canyon), but are believed to hold back effectively the deep ground waters. The rock floor of the basins is likewise believed to be sufficiently impervious to prevent the escape of ground water downward and out of the basins.

The lake beds occupy the middle parts of the basins and extend far up on the sides, blanketing the Gila conglomerate to elevations several hundred feet above the river valleys. On the whole they seem to be an effective artesian cover, comparatively free from fractures and sufficiently impervious in themselves to prevent, at

[1] U. S. Geol. Survey Fifth Ann. Rept., pp. 134–135, 1885.

least in part, the upward escape of water imprisoned beneath them. Along the north side of the Gila Valley, opposite Navajo Bill Point and at several other places farther east, small springs issue near the base of the bluffs. A group of springs occurs in the large arroyo which enters the Gila from the north opposite Bylas siding. There is another spring in Kelly Wash, on the south side of the basin, 2 miles southeast of San Carlos. (See Pl. II.) If these springs represent leakage from the artesian reservoir, as seems probable, the lake beds are not perfectly water-tight, but apparently the amount of water lost in this way is not great. At a number of places there are also evidences of a possible disturbance of the artesian cover, as indicated by lava intrusions and slight folding and faulting.

In the Gila Basin favorable artesian conditions exist along the north side of the basin for 15 miles from the east boundary of the reservation to a point 8 miles east of the Triplets. Farther west the Gila conglomerate is not exposed and consequently the artesian prospects are not so good. On the south side of the Gila Basin favorable artesian conditions are found for a distance of 20 miles below Bylas and a point 4 miles east of the box canyon.

In the San Carlos Basin artesian structure exists along the west side for 5 miles northward from the box canyon. Beyond that point the structure may be less favorable on account of possible serious disarrangements of the strata as a result of volcanic disturbances, which are indicated by numerous lava flows. On the east side the absence of outcrops of the Gila conglomerate makes conditions unfavorable.

As the structure is favorable to artesian conditions on one or both sides of the Gila Basin between the east boundary of the reservation and San Carlos, there are prospects that artesian water can be obtained in the river valley between these points by drilling through the recent alluvium and lake beds into the Gila conglomerate.

As the structure is favorable to artesian conditions on the west side of the San Carlos Basin for 5 miles north from the box canyon, there are also prospects that artesian water can be obtained in the river valley from San Carlos north to the new San Carlos steel bridge. All this part of the valley, however, is inside the proposed reservoir site. In the part of the San Carlos Valley above the steel bridge conditions do not appear to be favorable for obtaining an artesian supply.

According to the writer's estimates, based entirely on the probable relative positions of the formations as represented graphically in the cross sections in Plate II, the average thickness of the lake beds near the middle parts of the basins does not exceed 700 feet. However, as no complete sections are exposed, this estimate may be much too low. As the lake beds were laid down on an eroded and somewhat hilly surface, their thickness probably varies from place to place. In some places it may be necessary to drill 1,000 or even 1,500 feet to reach the Gila conglomerate, and as much as 2,000 feet to penetrate the conglomerate deep enough to make a conclusive test.

It is impossible from data obtained in a geologic investigation to predict definitely the presence or absence of artesian water, for the reason that unfavorable conditions may exist underground which do not appear at the surface. However, the investigation that has been made shows that the conditions, in so far as they can be observed, are sufficiently favorable to warrant the drilling of a test well.

As no wells have been drilled into the Gila conglomerate, the quality of the water which it contains is not known. The source of the water is the rain on the outcrop and the run-off from the hard igneous and sedimentary rocks of the mountains above. The water as it enters the Gila conglomerate is therefore probably only moderately mineralized. In passing downward to lower levels through the conglomerate it dissolves more or less mineral matter, but, to judge from the character of the materials in this formation as revealed in its outcrops, the amount of soluble matter is not large. There may, however, be buried saline beds along the axes of the valleys. In view of the source of the water contained in the Gila conglomerate and the character of the formation, there is reason to believe that the water is good enough for use.

SUMMARY AND CONCLUSIONS.

1. The part of the Gila Valley within the reservation and outside of the proposed reservoir site contains about 4,595 acres of arable land. In 1913 only 421 acres, or less than 10 per cent of this arable land, was irrigated and farmed.

2. The San Carlos Valley, all of which lies within the reservation, contains 1,840 acres of arable land above the proposed reservoir site. In 1913, 538 acres, or a little more than 30 per cent, of this arable land was irrigated and farmed.

3. On account of the lack of sufficient water in Gila and San Carlos rivers during a certain period in summer when irrigation is most needed and on account of the difficulty of maintaining diversion dams and canals, the system of irrigation in 1914 was inadequate.

4. In the river valleys water in sufficient quantities for irrigation can probably be obtained by pumping from shallow wells in the alluvium.

5. The principal source of the water in the valley alluvium is believed to be seepage from the rivers. Consequently the largest yields may be expected from wells near the river channels.

6. In 1913 the cost of irrigating under the present system was $1.34 an acre. The cost of pumped well water would probably be higher.

7. The waters from shallow wells in the Gila Valley are heavily mineralized. They are so high in chlorine, which is one of the constituents of common salt, that they are of doubtful value for irrigation, and if used continuously they would require extraordinary precautions to prevent an excessive accumulation of alkali in the soil.

8. The shallow ground waters in the San Carlos Valley are believed to be better than those of the Gila Valley and comparable to the water from Gila River, which is now successfully used for irrigation.

9. Final judgment on the suitability of the shallow ground waters for irrigation should be deferred until their effect on crops has been determined by actual experiment.

10. To the extent that the shallow ground waters are found to be good enough for irrigation they can be advantageously used on the tracts already under cultivation to supplement the surface-water supply and on arable tracts that lie above the ditches.

11. In the Gila Basin structure favorable to artesian conditions exists on one or both sides of the valley between the east boundary of the reservation and San Carlos, and it is believed that artesian water can be obtained in the river valley between these points.

12. In the San Carlos Basin structure favorable to artesian conditions exists only on the west side adjacent to that part of the valley included within the proposed reservoir.

13. To test the water-bearing possibilities of the Gila conglomerate it will be necessary to drill through the Recent alluvium and the lake beds, which, according to the writer's estimates, have an average thickness below the river valleys of not more than 700 feet. In some places it may be necessary to drill 1,000 to 2,000 feet to test the existence of water-bearing beds.

14. The structure appears most favorable on the south side of the Gila Basin, west of Bylas. A good location for a test well would be on Dewey Flat or on the 180-acre tract of arable land 1 mile east of Dewey Flat.

15. There is no direct information as to the quality of the water in the Gila conglomerate, but it is probably good enough to be used for irrigation.

16. Unfavorable conditions may exist underground that will make it impossible to obtain artesian wells, but the conditions as observed at the surface are sufficiently favorable to warrant the drilling of a test well.

GROUND WATER IN LANFAIR VALLEY, CALIFORNIA.

By David G. Thompson.

LOCATION AND GENERAL FEATURES OF THE VALLEY.

The area described in this paper lies in the east-central part of San Bernardino County, Calif. (See Pl. V.) It is mostly a large alluvial plain, which slopes southeastward with a nearly uniform grade of about 100 feet to the mile, though its continuity is at several places broken by small buttes of lava or by granite knobs. This plain is bordered on the west and north by the Mid Hills and the New York Mountains, and on the south and east by several more or less detached mountain masses, composed principally of volcanic rocks. The largest of these detached mountains are the Piute Range, on the east, and Hackberry Mountain, on the south. The plain and the adjacent mountain slopes form a nearly inclosed drainage basin, which is outlined on Plate VI. This drainage basin includes about 325 square miles. The alluvial slopes cover about 260 square miles, or 80 per cent of the basin; the mountains cover about 65 square miles. The grade of the alluvial slopes is generally so slight as not to interfere with agriculture. The basin includes no lowland tract of nearly flat land, such as is found in the Ivanpah, Mesquite, and Pahrump valleys, to the north.

This drainage basin has been called the Barnwell Sink,[1] but this name is not appropriate, because Barnwell lies on its extreme outer edge, and it is not a "sink," for that term is commonly used in the desert region of California to designate the bottom of a closed basin in which a stream disappears either because its water is evaporated or because it sinks into the ground. It is suggested that this area be called Lanfair Valley, as most of the settlements in it are near Lanfair and as that town is not far from its center.

During the last two or three years many settlers have taken up homesteads in this valley, most of them near Lanfair, and have been

[1] Tait, C. E., Irrigation resources of southern California: Conservation Comm. California Rept., p. 324, 1912.

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attempting to raise crops by dry farming. In the fall of 1917 more than 130 registered voters were living here. The writer visited the valley in November, 1917, while he was gathering data for a guide to desert watering places,[1] and obtained information about the water supply. Although very few wells have been drilled in the valley and very little data were available concerning the water supply, it has been decided to publish this brief report because a large number of settlers have already taken up land in the valley or are planning to settle there.

ROADS AND SETTLEMENTS.

Lanfair Valley is traversed from north to south by the Barnwell and Searchlight branch of the Atchison, Topeka & Santa Fe Railway, which connects with the main transcontinental line at Goffs, 9 miles southeast of Vontrigger. In 1917 there was train service from Goffs to Searchlight six days a week, and on Sunday a train ran from Goffs to Ivanpah. There were small settlements at Lanfair, Ledge (Maruba post office), and Barnwell, and post offices at the first two places. There was a small store at Lanfair, at which groceries, gasoline, and oil could be obtained. Purdy, Blackburn, and Vontrigger are merely railroad sidings, not settlements. Fair automobile roads connect the valley with the surrounding country. The Ivanpah and adjoining valleys may be reached by way of Barnwell. From Lanfair a road leads to Cima and the Valley Wells mining region, by way of Rock Springs, Government Holes, and Cedar Canyon. A road leads southward, parallel to the railroad for part of the distance, to the much-traveled National Old Trails Road at Goffs. Another road leads southwestward and then southward from Government Holes to the Santa Fe Railway and the National Old Trails Road at Fenner.

ELEVATION AND DRAINAGE.

Lanfair Valley stands at a high altitude, most of it 3,500 to 5,000 feet above sea level, and two extensions of the valley west and northwest of Rock Springs rise nearly 5,500 feet above sea level. These two branch valleys reach almost to the summit of the Mid Hills, which form a small range in the rim between the Providence Mountains and the New York Mountains. At one place the almost flat surface of the southern branch valley has been slightly dissected by drainage lines that lead to Cedar Canyon. This canyon, which drains westward, has cut entirely through the former divide of the Mid Hills and is tapping the drainage of the eastern side of the mountains.

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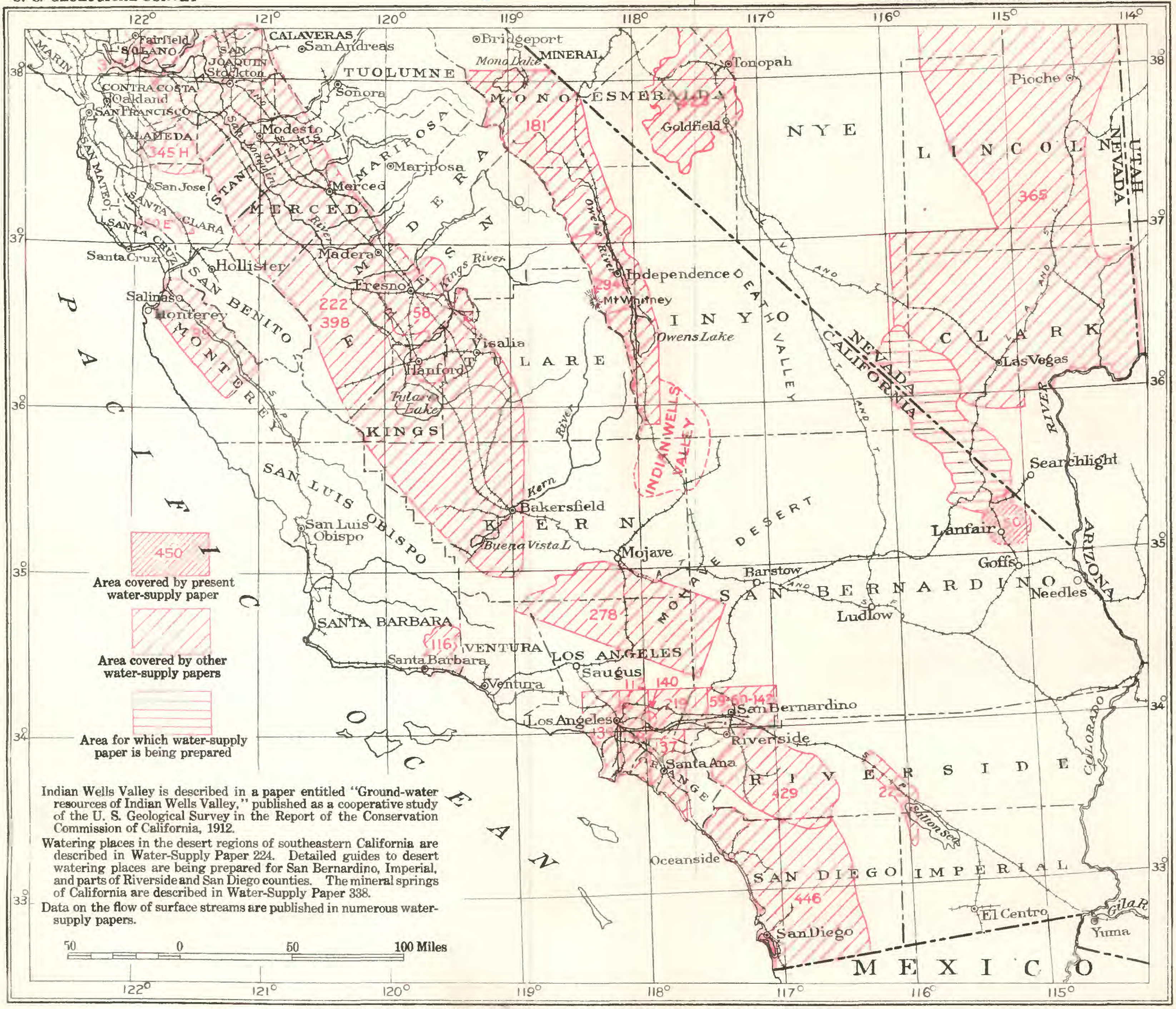
[1] Thompson, D. G., Routes to desert watering places in San Bernardino County, Calif., and adjoining areas: U. S. Geol. Survey Water-Supply Paper — (in preparation).



SKETCH MAP OF PARTS OF CALIFORNIA AND NEVADA

Showing areas treated in the present report and in other water-supply papers of the U. S. Geological Survey relating to ground water

The surface of Lanfair Valley has a gentle and nearly uniform southeastern slope from the head of these elevated valleys, above which the mountains, except one or two peaks, rise not more than 1,000 feet.

The valley is drained at several places, principally through a wide pass 6 miles east of Blackburn, but partly through two narrow passes on the east and west sides of Hackberry Mountain. Nearly all the drainage moves southward to a large valley that extends from Goffs southwestward to a closed basin several miles south of Cadiz (see Pl. V), the bottom of which is about 600 feet above sea level. A drainage line extends continuously from a point near Barnwell to a point several miles south of Cadiz, a distance of more than 75 miles.[1] This is one of the longest drainage lines in any closed basin in the desert region of southern California. A very small part of the drainage of the valley goes toward Colorado River by way of two canyons at its extreme eastern edge (see map, Pl. VI), where the old Government road to old Fort Mohave passes south of a small hill (marked B M 3789) 10 miles east of Lanfair. These canyons drain through Piute Wash into Colorado River a few miles north of Needles, a distance of about 30 miles. As the climate of the valley is arid and the soil is porous the rain that falls in it seldom if ever reaches the basin south of Cadiz or Colorado River as surface run-off.

GEOLOGY.

The geology of the region has not been studied in detail. The main mass of the New York Mountains and the Mid Hills is composed of granite, which is flanked on the north and northeast by metamorphosed limestone, quartzite, gneiss, and schist, into which it is intruded. The sedimentary rocks are shown on the geologic map of the State of California as of Cambrian age,[2] but Larsen has found one or two fossils in them which he believes to be Carboniferous.[3] At the south end of the Providence Mountains, near the edge of the area shown on Plate VI, the granite is intruded into limestone, which has been determined as Carboniferous.[4] The granite is part of a large intrusive mass that covers many square miles, extending at least as far as Marl Spring and Kessler Spring, west and northwest of Cima. In some of the low hills east of Blackburn and Vontrigger, granite, diorite, and altered limestone are found.[5]

[1] Darton, N. H., Guidebook of the western United States, Part C, The Santa Fe Route: U. S. Geol. Survey Bull. 613, maps 21 and 22, 1916.

[2] Geologic map of the State of California, State Mining Bureau, 1916.

[3] Larsen, E. S., U. S. Geol. Survey, personal communication.

[4] Mines and mineral resources of San Bernardino County, p. 53, California State Min. Bur., 1917.

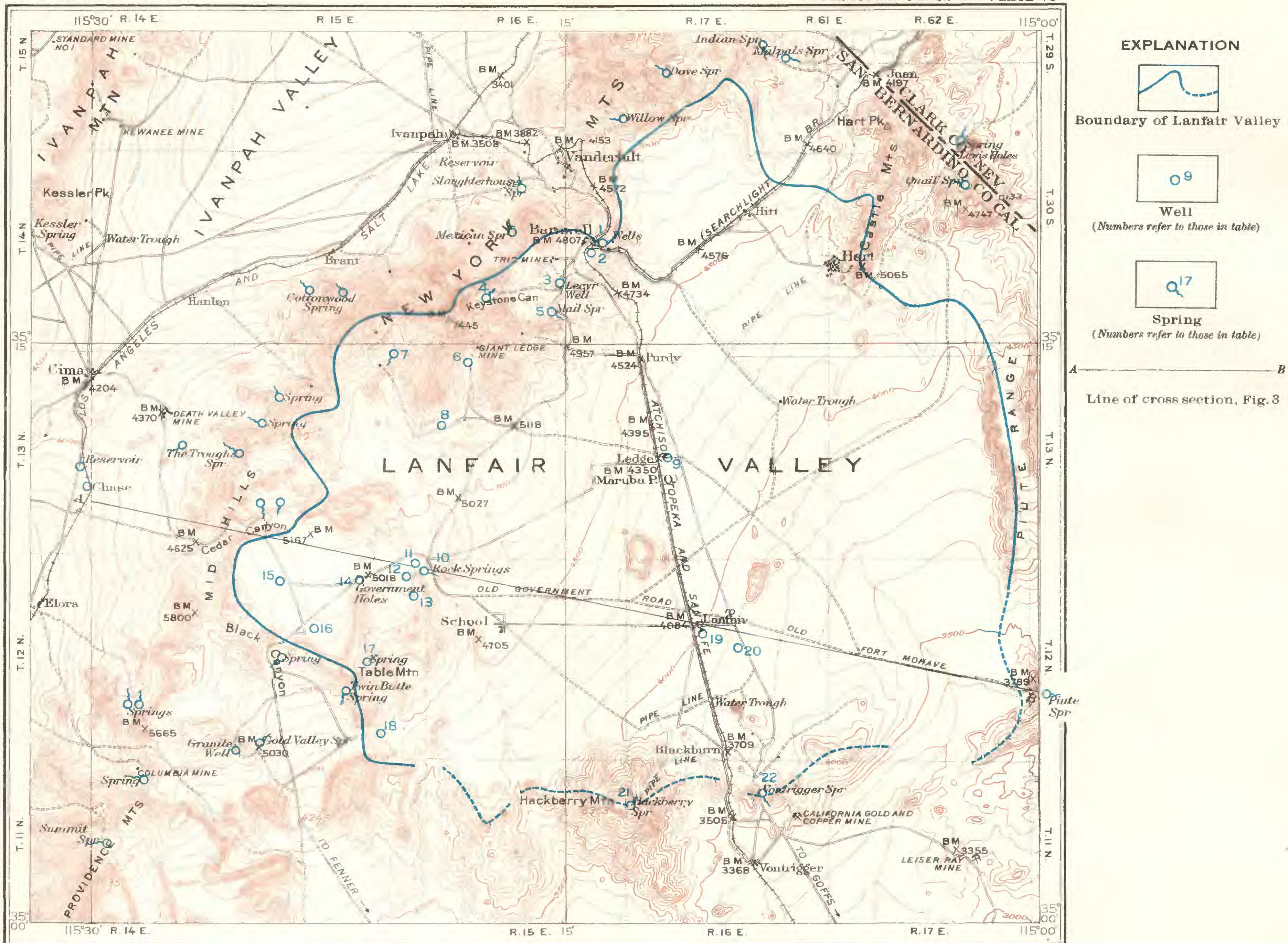
[5] Idem, pp. 11, 69–72. Darton, N. H., op. cit., pp. 147–148, footnote, and maps 21 and 22.

Volcanic rocks, mostly of Tertiary age, are abundant around the edges of the valley. Purplish extrusives, probably rhyolite, occur on the road between Ivanpah and Barnwell, but their full extent there is not known. Rhyolite is found in the Castle Mountains, in the Hart mining district.[1] The Piute Range, forming an imposing steep-sided mountain on the east border of the valley, is composed of volcanic rocks, as are Hackberry Mountain and the low hills west of it. The flat-topped mesas at the east foot of the Providence Mountains are composed of similar extrusives. A prominent butte 2 miles north of Government Holes appears from a distance to be composed of the same series of light-colored rhyolites, latites, and tuffs as those seen in Table Mountain and the hills south of this mountain, which have been described by Darton as of Tertiary age.[2] The extrusive rocks of Table Mountain obviously lie on the old erosion surface of the granite which forms the main mass of the New York Mountains and Mid Hills. The volcanic rocks near Barnwell and in the Castle Mountains are perhaps of the same age as those along the east and south sides of the basin, but their erosion and weathering suggest that they are somewhat older. Buttes a short distance northwest and northeast of Lanfair were not examined but are believed to be composed of rhyolite. Part of Lanfair Valley is underlain at no great depth by lava of Tertiary or Pleistocene age, which rests on older gravel, and this lava may have covered a large area. Extrusive rocks of Pleistocene age are found elsewhere in San Bernardino County at places not far distant.

The greater part of Lanfair Valley is covered with detrital materials—sand, gravel, and boulders—washed down from the mountains on the west side of the valley. The depth of the alluvial material in the center of the valley is not definitely known, but well records indicate that in places it is not very thick and that it is underlain by volcanic material, below which at no great depth there are still other beds of gravel. Moreover, the hills of granite and lava that outcrop at many places in the valley indicate that in some places at least igneous bedrock lies at no great depth beneath the gravel floor. The gravel which has been penetrated at depths of 400 to 500 feet is older than the overlying igneous rocks, and is no doubt of late Tertiary or early Pleistocene age. This gravel may possibly be correlated with the red sandstone and conglomerate that outcrop on the Santa Fe Railway near Klinefelter and at other localities between that place and Colorado River. The sandstone and

[1] Hill, J. M., The mining districts of the western United States: U. S. Geol. Survey Bull. 507, p. 128, 1912.

[2] Darton, N. H., Guidebook of the western United States, Part C, The Santa Fe Route: U. S. Geol. Survey Bull. 613, pp. 147–148, footnote, and maps 21 and 22, 1916.



Part of U. S. G. S. topographic map of Ivanpah quadrangle

A. HOEN & CO. LITH. BALTIMORE

TOPOGRAPHIC MAP OF LANFAIR VALLEY AND VICINITY, SAN BERNARDINO COUNTY, CALIFORNIA.

Showing location of wells and springs

Scale $\frac{1}{250,000}$

2 1 0 2 4 6 8 10 Miles

Contour interval 100 feet.

Datum is mean sea level.

conglomerate are believed by Darton[1] to be Pleistocene. One or two miles south of Barnwell several tongues of very coarse alluvial conglomerate, the boulders of which are mainly blue quartzite, extend out from the foot of the mountains. These tongues rise 15 to 50 feet above the general level of the slope. They are apparently older than the present alluvial deposits and have been exposed by faulting along the east edge of the mountains. They are probably of Pleistocene age, and may perhaps be correlated with the gravel that underlies the volcanic materials penetrated in the wells at Lanfair.

The northwestern slopes of the New York Mountains, the Mid Hills, and the Providence Mountains are much steeper than their southeastern slopes, and their rocky walls extend 1,000 to 2,000 feet lower on their northwestern than on their southeastern side. (See fig. 3.) These differences in slope might be explained by assuming that the mountain mass on the northwest side of Lanfair Valley is a large fault block that has been uplifted on its northwest edge and tilted down on its southeast edge, but not enough is known of the geology to permit this assumption.

Another explanation of the difference in the slope of the northwest and southeast sides of the mountains is based on meager

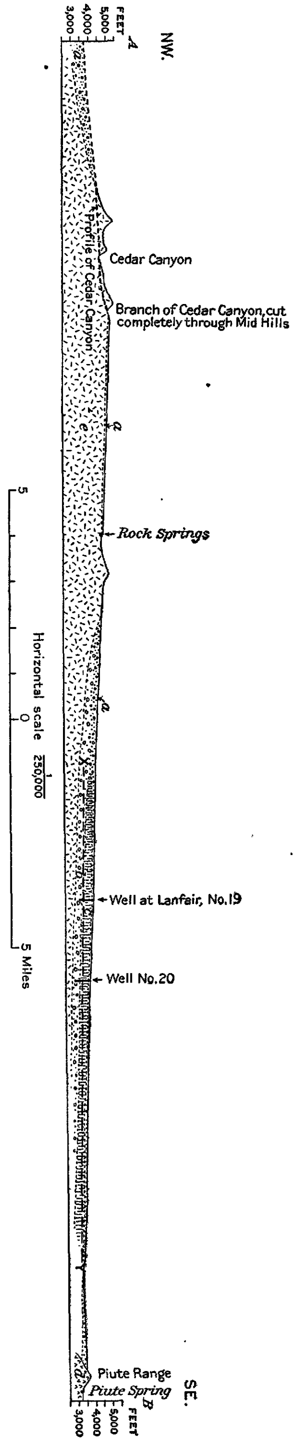


FIGURE 3.—Profile and hypothetical cross section of Lanfair Valley, Calif. *a*, Recent alluvial gravel, grading into *b*; *b*, olde ralluvial gravel of Pleistocene or Tertiary age; *c*, extrusives (lava, ash, etc.), Pleistocene or Tertiary, resting on *b*; *d*, volcanic rocks of Piute Range, probably Tertiary; *e*, granite of Mid Hills and New York Mountains. The volcanic rocks of the Piute Range act as a dam, west of which ground water is held under pressure. For the area east of Lanfair the dashed line X–Y marks the level to which water will probably rise in wells; for the area west of Lanfair it marks the probable depth to the water table.

[1] Darton, N. H., op. cit., pp. 146–147 and map 21.

evidence obtained from wells in Lanfair Valley. In two wells, one at Lanfair station and the other about a mile southeast of Lanfair, volcanic ash was said to have been reached at depths of 52 and 4 feet, respectively. In these wells the ash continued to depths of 520 and 410 feet, respectively, below which gravel was penetrated to a depth of 550 feet in each well. Material taken from the well at Lanfair, which was examined superficially by the writer, contained fragments of a rock that seemed to be rhyolite, although they were mixed with other materials, and there was no indication as to the depth from which the fragments of lava had come. In a well at Ledge (Maruba post office) water was reached at a depth of 365 feet and rose in the well to a point within about 100 feet of the surface. Though no information is available as to the strata penetrated in this well, the water-bearing bed is probably gravel which is overlain by a more impervious bed, perhaps volcanic rock. Volcanic rocks are abundant around the valley and form small outliers northwest and northeast of Lanfair. (See p. 32.)

These facts suggest that a thick bed of lava may occupy the valley at a comparatively slight depth below a cover of alluvial gravel, and that the lava was poured out at the time of the extrusion of the masses that form the Piute Range, Hackberry Mountain, and the buttes a short distance northwest and northeast of Lanfair. The gravel found at depths of 400 to 500 feet in the wells at Lanfair indicates that the floor of Lanfair Valley at one time stood at a much lower level, and that the southeast face of the New York Mountains and Mid Hills was probably once as precipitous as the northwest face is today. Faulting would thus not be involved in the explanation of the surface features of this large, high valley, but there has probably been much faulting in the mountains. Before the volcanic eruptions that produced the Piute Range, Hackberry Mountains, and the buttes northwest and northeast of Lanfair the area that is now Lanfair Valley was probably not so nearly inclosed as it is now. It was probably a part of a great alluvial slope that extended southeastward toward Colorado River, unbroken by the volcanic rocks that now border it on the east and south.

Lanfair Valley is limited on the east by the Piute Range, which forms a barrier that prevents the drainage from its northern part from going toward Colorado River. This range is composed of volcanic rock, is nearly flat-topped, and has almost vertical sides. It may be an uplifted fault block, or it may be a remnant of a large body of lava which was poured out on old gravel that is now deeply buried. In either case the drainage from the valley at some earlier period probably reached Colorado River. The mountains that form the southern boundary of the valley are also in large part of volcanic origin.

MINERAL RESOURCES.

A number of mines in the mountains around Lanfair Valley have been active at one time or another, but in 1917 very little mining was being done. Gold is found in the Castle Mountains, near Hart, where a shaft 900 feet deep had been sunk in 1917, and about 20 men were employed. The ore is said to be rich in spots. A mill had been built, but it was not being operated in the later part of 1917. Deposits of tungsten are found on the southeast side of the New York Mountains, but they have not yet been much developed.[1] Gold, copper, tungsten, and some vanadium, are found in the hills east and northeast of Vontrigger station, and considerable mining has been done in this district.[2]

CLIMATE.

In 1917 practically all the large number of homesteaders in Lanfair Valley were trying to raise crops by dry farming. The degree of success attained in dry farming is determined largely by natural and uncontrollable conditions of climate and soil, especially of climate. The main features of climate to be considered by the dry farmer are the average annual precipitation, the distribution of precipitation through the year, the character of the precipitation, the evaporation, and the temperature.

Unfortunately, no reliable records are available for Lanfair Valley. The United States Weather Bureau has published observations made at Jean, Nev., about 45 miles north of Lanfair; at Searchlight, Nev., 50 miles northeast of Lanfair; at Needles, Calif., about 40 miles southeast of Lanfair; and at Bagdad, Calif., about 50 miles southwest of Lanfair.[3] In addition, Mr. E. L. Lanfair kindly furnished the writer with incomplete records of precipitation at Lanfair for the period from March, 1912, to March, 1915. These records are given on page 36.

The great variation in climate within comparatively short distances in the arid regions of the Southwest, due in large measure to the influence of surface features, prevents close comparison between the climate at Lanfair and at the points mentioned above, but the records at these places afford some information of value. The average annual precipitation at these places is given in the accompanying table:

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[1] Mines and mineral resources of San Bernardino County, p. 68, California State Min. Bur., 1917.

[2] Idem, pp. 11, 69–78.

[3] Climatological data for the United States, by sections; U. S. Dept. Agr. Weather Bur.

Average annual precipitation at stations in Nevada and California.[a]

Station.	Altitude above sea level in feet.	Length of record in years.	Average annual precipitation in inches.
Jean, Nev	2,864	7	[b]3.81
Searchlight, Nev	3,445	4	[b]7.90
Needles, Calif	477	26	3.52
Bagdad, Calif	784	14	3.08
Lanfair, Calif	4,040	3	[b]9.77

[a] Based on data given in Climatological data for the United States by sections, 1914, to 1917, U. S. Dept. Agr. Weather Bur., and records for Lanfair given below.
[b] No record for one or more months in certain years. The average given is therefore probably slightly below the true facts.

A record of the precipitation at Lanfair from March, 1912, to March, 1915, furnished by Mr. Lanfair, is given in the following table:

Monthly precipitation, in inches, at Lanfair, Calif.

[Elevation about 4,040 feet.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1912	(a)	(a)	3.60	0.68	0.13	0.00	0.60	0.25	(b)	1.28	(b)	0.10	[e] 6.64
1913	0.39	[c]2.98	(d)	(d)	(d)	(d)	1.29	1.43	0.63	(b)	1.56	(b)	[e] 8.28
1914	2.32	3.39	.53	1.01	(b)	.46	1.05	.19	2.29	3.16	(b)	(b)	[e] 14.40
1915	.30	5.70	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	......

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

As the record for Lanfair is not complete for any single year, it furnishes no ground for definite conclusions, but the information it gives, scant as it is, if studied in connection with the records at the Weather Bureau stations mentioned above, brings out the fact that the precipitation in Lanfair Valley is similar to that in other parts of the desert region in the following respects: (1) Most of the precipitation comes late in the fall, in the winter, and early in the spring; (2) there is great variation both in the average precipitation for any given month during a period of years and for the average annual precipitation; (3) the precipitation varies considerably from place to place on a given date. The precipitation in summer very often comes in the form of violent thunderstorms, and in one of these storms the rainfall in a few hours may be so abundant as to make up what would otherwise be a deficiency for the year, or to produce an excess of several inches above the normal annual rainfall. At another point a few miles away the storm may produce little or no precipitation. On the other hand a larger proportion of the rain seems to fall in summer at Lanfair than at the other observation stations, but this apparent difference may be due only to the fact that the record at Lanfair covers a period so short that it does not accurately represent the normal rainfall. The average annual precipitation at Lanfair, as shown by the very incomplete records given, also seems to be somewhat greater than at other observation stations within 50 miles of it.

The first table shows that in general the precipitation is greatest where the altitude is highest, and that it decreases with the decrease in altitude, a fact that accords with observations made in other parts of the United States. The moisture-laden winds, in moving across the land, rise to high altitudes in passing over mountains and other elevated regions, such as Lanfair Valley, and as the temperature of the air is decreased as it rises and its moisture-bearing capacity is therefore also decreased, its moisture is condensed and precipitated. As the winds again descend to lower levels on the leeward side of the mountains they become warmer and can absorb more moisture, so that evaporation rather than precipitation occurs. As Lanfair Valley stands at a high altitude the precipitation in it should be somewhat greater than that at the other places mentioned. Similarly, because of their greater altitude the precipitation in the New York Mountains and Mid Hills would be greater than at Lanfair, especially as the prevailing winds in the valley are from the west and as Lanfair is on the leeward side of the mountains. Settlers in the valley state that the precipitation at Lanfair is actually less than at points farther west, on the eastern slope of the mountains. In winter, especially, several inches of snow will fall in the mountains while practically no rain or snow falls at Lanfair.

Evaporation is an important element in the climate of the desert region of California, of which Lanfair Valley is a part, because of the high temperature and resulting low relative humidity and because of the frequent winds, which aid greatly in drawing moisture into the atmosphere.[1] The evaporation is very great during the summer, and is considerable even in winter. Much of the rain that falls in Lanfair Valley is doubtless evaporated within a few hours and is not available for use for agriculture.

No records of temperature at Lanfair are available, but the conditions there are probably somewhat similar to those in other parts of the desert. High temperature occurs during the day in summer, but the daily range is considerable, and the nights are cool. Because

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[1] For a detailed discussion of factors involved in evaporation and the results of experiments on evaporation from water and soil surfaces, see Lee, C. H., An intensive study of the water resources of a part of Owens Valley, Calif.: U. S. Geol. Survey Water-Supply Paper 294, pp. 48–60, and accompanying diagrams, 1912.

of the high altitude, the maximum summer temperatures are probably not so high as those at lower levels. At Searchlight, 50 miles northeast of Lanfair, for instance, at an altitude of 3,445 feet, the maximum temperature during the years 1914 to 1917 was 104°, but at Needles, 40 miles southeast of Lanfair, at an altitude of only 447 feet, the temperature in each of the same four years reached 111° or more. The winters are comparatively mild, there being many days without frost, but low temperatures, from 10° to 20° above zero, occur occasionally. The winters at Lanfair are probably slightly colder, and frosts are probably more common than at lower levels.

The influence of the climate on the prospects of agricultural development of Lanfair Valley is considered on pages 46–48.

VEGETATION.

The vegetation of Lanfair Valley is very different from that of the Ivanpah and other valleys to the north and of the region to the south and southwest. It is characterized by an abundance of spine-bearing forms, such as the cactus commonly called cholla, which grows profusely, the yucca, known as the Spanish dagger, and the Joshua tree, or giant yucca. Arid-land grasses are also found, such as "galleta" and a form known as "grama grass." In the branch valley that lies west of Government Holes, more than 5,000 feet above sea level, there is a flourishing growth of sage brush (*Artemisia tridentata*) [1] and piñon, and probably some juniper. The creosote bush, *Covillea* (*Larrea*) *tridentata*, which is the prevailing species in most of the adjoining region, is very rare; it was noticed by the writer only on the north side of Hackberry Mountains near Blackburn and in one small tract near Ledge. Catsclaw was seen in washes just west and south of Blackburn. None of the forms indicating ground water at slight depth, such as mesquite and salt grass, were seen.

SOURCE OF GROUND WATER.

There are no permanent streams in Lanfair Valley, nor any which flow except immediately after storms. The water supply of the region is derived entirely from the rain and snow that fall in the valley and from the ground water, which is derived from precipitation. As this valley lies higher than any of the surrounding valleys it evidently receives no ground water from outside areas. The quantity of water now beneath the surface or that is now or will be available for domestic use for irrigation is limited by the amount of precipitation. No definite figures can be given to show the quantity

[1] Specimens of sagebrush collected in the field were identified by Miss Alice Eastwood, California Academy of Science, San Francisco.

of water available for use, but some significant facts may be considered.

Evaporation disposes of a large part of the rain in desert regions, such as Lanfair Valley, where much of it falls a little at a time, a few hundredths to a few tenths of an inch. The soil is usually so dry that it is seldom moistened to depths of more than an inch or two. Much of the rain evaporates soon after it falls, and only when rain falls steadily for a number of hours or when a large amount falls in a short time, as during a heavy thunderstorm, does any of it percolate deep enough to replenish the ground water.

It is only during the occasional heavy rains that some of the water becomes surface run-off. In the mountains, where there is little soil to absorb the rain and the rocks are nearly impervious, the run-off may then be considerable. On alluvial slopes, such as compose a large part of Lanfair Valley, the rather porous detrital material absorbs large amounts of water, and the run-off is relatively small. Most of the run-off from the mountains is absorbed on the alluvial slopes and even a large part of the run-off that is concentrated into definite streams eventually sinks into the alluvial material.

Only about one-fifth of Lanfair Valley is occupied by mountains. Some of the precipitation that falls on the north slope of Hackberry Mountain and the adjoining hills and the west slope of the Piute Range during heavy rains is immediately carried out of the basin as surface run-off. A number of springs in the New York Mountains and Mid Hills indicates that some of the water that is absorbed by the rocks and soil in the mountains is returned to the surface and removed by evaporation. Water is obtained at moderate depths in a number of wells in the mountains or in the wide valleys west and north of Rock Spring. Some of the precipitation in the mountains obviously does not enter the porous detrital material of the alluvial slopes but is held in pockets in the rock beneath the soil. Furthermore, water percolates into the alluvial material only when rain falls for a long time or in heavy storms, so that much of the annual rainfall does not replenish the ground-water supply.

GROUND WATER IN UPPER PART OF VALLEY.

Water is found at a number of places in the New York Mountains and Mid Hills at comparatively slight depths. At Barnwell the Rock Springs Cattle Co. has dug a well (No. 1),[1] 62 feet deep, in which water stands 48 feet from the surface. On the west side of the railroad at Barnwell there are two wells, one about 60 feet deep and the other about 90 feet deep, but the depth to water in them is not

[1] The numbers given in the text correspond to those given on the map, Pl. VI, and in the table on pp. 48–49.

known. At this station the Atchison, Topeka & Santa Fe Railway Co. in 1905 drilled a well 457 feet deep (No. 2), which is now abandoned. The depth to water in this well was 73 feet, and the supply was ample. During a pumping test of 24 hours the well furnished 20 gallons a minute. The well was probably abandoned because the water was unsuitable for use in locomotive boilers. The Lecyr well (No. 3) is dug in a sandy wash. When visited by the writer it was tightly covered and could not be measured, but the pumping equipment indicates that the depth to water is probably not great. Two miles west of Government Holes, about 200 feet northwest of the junction of the road from this place with a road leading to Cima, by way of Cedar Canyon, is a well dug in granite (No. 15). In the later part of November, 1917, the water stood 4 feet from the top of this well. A few feet west of the well was a slight depression in granite, about 15 feet in diameter, containing water about a foot deep. A mile south of this well, at the ranch of A. E. Moore, is a dug well (No. 16), 12.7 feet deep, in which the depth to water is 7.2 feet. Government Holes (No. 14) is a well 32 feet deep, dug at the foot of a granite hill. The depth to water is 15 feet. There are three shallow wells near Rock Springs, but they were not visited by the writer. The most northerly of these is the Beaty well (No. 11), which is said to be about 30 feet deep and in January, 1918, was reported to contain only 18 inches of water. The middle one of the three, called the Emdee well (No. 12), is said to be 18 feet deep and to contain 8 feet of water. The third well (No. 13) is near the shaft of the Barnett Mining Co. The depth to water is reported to be about 8 feet. The depth of the well is not definitely known but is probably about 20 feet.

The quantity of water available in any of these wells is apparently not great. The well of Mr. Moore (No. 16) yields 11 gallons a minute, and if the pumping is increased the well is pumped dry. The largest quantities pumped from the Emdee and Barnett wells are about 1,000 gallons a day each. Although the actual capacity of these wells is not known they could probably be pumped dry easily with power pumps. All the wells mentioned above that are west and southwest of Rock Springs are near the foot of granite hills, where solid rock lies close to the surface. They are apparently supplied from rain water, which percolates downward to the surface of the solid rock, along which it moves toward lower levels. If the wells mentioned were pumped heavily the water level would probably be lowered considerably, as the small tracts in which the wells are dug do not contain a sufficient supply to withstand heavy drafts.

During years of normal precipitation the water in the ground is sufficient to keep the water table rather near the surface, and in some places it returns to the surface in springs, such as Rock Springs, which are in a small canyon that heads in the wide valley west of the springs. During a series of unusually dry years the supply of ground water would probably be rapidly diminished. At the end of the dry fall of 1917, Rock Springs were practically dry, and other springs in the New York Mountains and Mid Hills were also reported to be dry.

GROUND WATER IN MAIN PART OF VALLEY.

In the main part of Lanfair Valley the depth to the water table is apparently much greater than in the marginal parts, where rock lies close to the surface and prevents the rain water from sinking to great depths. Information is available concerning only three wells drilled on the alluvial slopes that compose the surface of the greater part of the valley. As far as is known, no other wells have been drilled on these slopes. At Ledge (Maruba post office) Mrs. E. J. Jacoby has drilled a well (No. 9) 879 feet deep. Water was struck at a depth of 365 feet and rose within about 100 feet of the surface. The well furnishes about 20 gallons a minute. No log of the strata penetrated is available. At Lanfair Mr. E. L. Lanfair has drilled a well (No. 19) 550 feet deep. Gravel was penetrated to a depth of 52 feet, below which the materials encountered to a depth of 520 feet were described as volcanic ash. Fragments of the drill cuttings examined by the writer seemed to be a rhyolitic rock. A bed of water-bearing gravel was entered at a depth of 520 feet and extends to the bottom of the well. The water rose within 500 feet of the top. Mr. Lanfair has drilled another well (No. 20), also 550 feet deep, about a mile southeast of the one just described. In this well volcanic ash was struck at a depth of only 4 feet and extended to a depth of 410 feet, where gravel was found, which reached to the bottom of the well. Water was found in the gravel at 410 feet and rose 10 feet in the well.

Though the data afforded by the wells in the valley are meager they disclose three important facts:

First, the depth to water is great.

Second, the water is confined in deeply covered gravel under sufficient pressure to rise somewhat in wells when the overlying beds are penetrated, but not under sufficient pressure to rise near the surface. Unfortunately, the data available are too incomplete to suggest the heights to which the water might rise in wells drilled at different points in the valley. The conditions mentioned above, together with the occurrence of large masses of volcanic rock on the borders of the valley, indicate that a large part of the alluvial slope is underlain at a slight depth by volcanic material. (See fig. 3, p. 33.) In both of Mr. Lanfair's wells this material was reported as volcanic ash, but it may include ash, tuff, rhyolite, or other extrusive rocks.

Third, the fact that the water rose higher in the well at Ledge than in the well at Lanfair indicates that the underground conditions are not uniform throughout the valley—that some underground structure affects the ground-water level. Low hills 3½ miles northeast of Lanfair and a low ridge that extends from the Castle Mountains to a point about 4½ miles south of Hart indicate that a rock barrier may cross the deeply buried gravel in such a way as to dam the water west of these hills, so that it is held under greater pressure than the water on the lower side of the barrier.

The great depth to water in Lanfair Valley is due chiefly to the high elevation of the valley above the bottom of the basin into which it drains—the basin south of Cadiz—and to the steepness of the alluvial slope. The water in the detrital material is drained toward Goffs and thence to the basin near Cadiz. Data furnished by the Atchison, Topeka & Santa Fe Railway Co. in regard to the level of water in its wells shows that the water table in the valley both southwest and east of Goffs lies at a considerable depth. At Goffs the depth to water in 1917 was 606 feet; at Homer, in 1902, it was 608 feet; at Fenner, in 1906, it was 460 feet; and at Danby, in 1903, it was 268 feet. Thus, the conditions facilitate the draining away of any large quantity of water that might pass into the upper gravel in Lanfair Valley.

Not only is some ground water being lost by percolation toward Goffs, but some may be coming to the surface in springs. As nearly as could be ascertained Piute Spring (No. 23) is just outside of the eastern border of the area shown on the map (Pl. VI), in a canyon south of the hill marked "B. M. 3789," about 11 miles from Lanfair. This canyon has been cut back so far that it receives some drainage from Lanfair Valley. The spring was not visited by the writer, but it is said to be one of the strongest in San Bernardino County, the water flowing down the canyon for nearly a mile. This spring is below the level to which water rises in the wells at Lanfair, and the strong flow may come from the gravel, which is deeply buried at that place.

In November, 1917, several persons planned to drill wells in the near future, but as late as June, 1918, none of them had done any drilling. A number were confident that wells drilled about 3 miles west of Lanfair would find water at depths of less than 200 feet, because the surface drainage here goes southward, toward Hackberry Mountain, which, they believed, holds the ground water at a somewhat higher level than at Lanfair, it being assumed that the ground water moves in the same direction as the surface flow. The land on which these wells would be drilled lies 200 to 400 feet above the base of Hackberry Mountain, so that even if the water table on the north side of the mountain is near the surface the depth to water in the wells would still be great. Moreover, there are no indications that the water table at the foot of the mountain is close to the surface. Water does not come to the surface in the short canyon between Blackburn and Vontrigger, through which much of the surface run-off goes, nor is there any vegetation in this canyon—such as running mesquite and arrow weed—to indicate that water lies near the surface. Although the depth to the water table is doubtless much less in this canyon than at Lanfair, it is probably at least 50 feet, and at points farther northwest, up the alluvial slope, it increases. Unless some concealed structure causes the water level to stand higher here than at Lanfair, and there are no surface indications of any such barrier, the depth to water at places 3 or 4 miles west of that town will probably be fully as great as it is in the wells described.

At Lanfair the water-bearing bed slopes less steeply than the surface. If it bears the same relation to the surface in areas near the south and southeast borders of the valley, where the low mountains may tend to hold the water back, it will probably lie not so deep in these areas as at Lanfair, a probability indicated by Piute Spring, but as only a little information is available, and as that indicates that the depth to water on the alluvial slopes is great, no one should begin to drill a well unless he is prepared to go to a depth of 300 to 500 feet.

QUALITY OF WATER.

Samples of water from three wells (Nos. 3, 9, and 16 on Pl. VI) in Lanfair Valley were collected by the writer and were analyzed in the water-resources laboratory of the United States Geological Survey. An analysis of water from a well (No. 2) drilled at Barnwell by the Atchison, Topeka & Santa Fe Railway Co. but now abandoned was furnished by that company. The results of the analyses are given in tables on page 50, where the waters are classified according to their quality for domestic, boiler, and irrigation use.[1]

The suitability of a water for domestic use depends on its acceptability for drinking, washing, and cooking. Hard waters can be used for drinking but are unsatisfactory for cooking and especially for washing. Waters whose hardness exceeds 200 parts per million (in terms of $CaCO_3$) are not satisfactory for washing. Waters whose hardness exceeds 1,500 parts per million are undesirable for cooking. The presence of approximately 200 parts per million of the normal

[1] See Mendenhall, W. C., Dole, R. B., and Stabler, Herman, Ground water in San Joaquin Valley, Calif.: U. S. Geol. Survey Water-Supply Paper 398, pp. 56–58, 65–69, 73–82, 1916, for a detailed discussion of the classification of waters for different uses.

carbonate radicle, 250 parts of the chloride radicle, or 300 parts of the sulphate radicle, can be detected by taste. Waters that contain considerably more of these constituents can be tolerated by a human being, but those that contain more than 300 parts per million of the carbonate radicle, 1,500 parts of the chloride radicle, or 2,000 parts of the sulphate radicle are intolerable to most people. Local conditions and individual preference, however, largely determine the significance of the terms "good" or "bad" as applied to the mineral quality of water for domestic use. In a desert region a water having 240 parts per million of hardness (expressed as $CaCO_3$) might be classed as fair; in a region where the supply is abundant and the general quality is much better, as in the New England States, the same water would by most users be classed as bad. It should be borne in mind that in this report the classification of a water for domestic use is based only on its mineral content; it does not indicate the sanitary quality of the water. A water may contain only 100 parts per million of total solids in solution and yet be so badly polluted as to be unfit for drinking.

With respect to their quality for use in boilers, waters are classified according to the amounts of their scale-forming (incrusting) and foaming constituents and the probability of corrosion. The following rating of boiler waters is adapted from that suggested by the American Railway Engineering and Maintenance of Way Association, but the amounts are recomputed to parts per million.

Ratings of waters for boiler use according to proportions of incrusting and corroding constituents and according to foaming constituents.

Incrusting and corroding constituents.		Foaming constituents.	
Parts per million.	Classification.[a]	Parts per million.	Classification.[b]
Less than 90	Good	Less than 150	Good.
91 to 200	Fair	151 to 250	Fair.
201 to 430	Poor	251 to 400	Bad.
More than 430	Bad	More than 400	Very bad.

[a] Am. Ry. Eng. and Maintenance of Way Assoc. Proc., vol. 5, p. 595, 1904.
[b] Idem, vol. 9, p. 134, 1908.

With respect to their value for irrigation, waters are classified according to their content of alkaline salts. Water containing large quantities of alkaline salts is injurious to vegetation because, through evaporation, the alkali[1] collects in the few inches of top soil in quantities so large as to interfere greatly with the growth of plants. The value of a water for irrigation as determined by the

[1] The term "alkali" is used to designate the common soluble salts formed on the evaporation of natural waters. Sodium carbonate (sal soda), or "black alkali," and sodium sulphate (Glauber's salt) and sodium chloride (table salt), or "white alkalies," are the principal alkaline salts.

amount of alkali it contains is expressed by its "alkali coefficient,"[1] which is defined as the depth of water in inches which, on evaporation, would yield sufficient alkali to render the soil to a depth of 4 feet injurious to the most sensitive crops. The alkali coefficient affords a purely arbitrary means of comparing waters used for irrigation. It does not take account of the methods of irrigation and of drainage, the character of the soil, and the kind of crop, but it indicates very well the general suitability of any water for irrigation. The waters in the areas here discussed have been classified as to quality for irrigation in accordance with the following rating:

Classification of water for irrigation.[a]

Alkali coefficient (inches).	Class.	Remarks.
More than 18	Good	Waters have been used successfully for many years without special care to prevent accumulation of alkali.
18 to 6	Fair	Special care to prevent gradual accumulation of alkali has generally been found necessary except on loose soils with free drainage.
5.9 to 1.2	Poor	Care in selecting soils has been imperative and artificial drainage has frequently been found necessary.
Less than 1.2	Bad	Waters practically valueless for irrigation.

[a] Stabler, Herman, Some stream waters of the western United States, with chapters on sediment carried by the Rio Grande and the industrial application of water analyses: U. S. Geol. Survey Water-Supply Paper 274, p. 179, 1911. See also U. S. Geol. Survey Water-Supply Paper 398, p. 57, 1916.

The waters analyzed range in total content of solids from 229 to 1,992 parts per million, but three of them contain less than one-half as much mineral matter as the fourth. The most highly mineralized water, that from the Lecyr well (No. 3), is used only for cattle. The classification shows that the water from the Lecyr well is bad for domestic use because of its extreme hardness and its high content of sulphate. It would be considered unfit for use in boilers on account of its tendency to form scale and to foam, and it could not be improved economically by chemical treatment. It has, however, been classed as fair for irrigation. It is essentially a calcium-sulphate water, such as is found near gypsum deposits, although no such deposits are known to exist in the region.

The water from the well of Mrs. E. J. Jacoby, at Ledge (No. 9), is good for domestic use and for irrigation but is of only fair quality for use in boilers because of its rather large content of scale-forming constituents. This water comes from a depth of about 365 feet. The water from the deep wells at Lanfair is probably somewhat similar to it.

The water from the well of A. E. Moore (No. 16), the only other water used for domestic purposes, is of fair quality for drinking and

[1] Stabler, Herman, Some stream waters of the western United States, with chapters on sediment carried by the Rio Grande and the industrial application of water analyses: U. S. Geol. Survey Water-Supply Paper 274, pp. 177–179, 1911.

cooking but will cause trouble in washing because of its hardness. It is poor for boiler use because of its high content of scale-forming and foaming constituents, and it might possibly corrode boilers. This sample probably represents the water obtained from shallow wells in the high valleys on the western edge of Lanfair Valley.

The water from the abandoned well of the Atchison, Topeka & Santa Fe Railway at Barnwell (No. 2) is of fair quality for drinking and cooking, but because of its hardness it is not very satisfactory for washing. It is bad for boiler use because of its large amount of scale-forming constituents and its tendency to corrode boilers. The well was probably abandoned because its water was of poor quality for use in locomotive boilers.

The results of the four available analyses of water from wells in this valley appear to show that the ground water is satisfactory for use in irrigation.

WATER SUPPLY FOR AGRICULTURE.

Although many homesteaders were living about Lanfair in 1917, only three of them possesed their own domestic water supplies. The others were forced to haul water for all purposes, often having to pay for it. A number of them hauled water from the wells west of Rock Springs and from springs in the mountains. Some of the springs are controlled by a large cattle company and there has been friction between the ranchers and the cattlemen over the water.

Most of the settlers have attempted dry farming. The crops that have been tried include milo maize, varieties of field corn, and beans. The small grains have been sown in the fall, and the corn and beans in the spring. Some fair crops have been obtained, the most successful of which were grown well up on the alluvial slope, a short distance east of Rock Springs—that is, in that part of the valley where the rainfall is usually greatest because of the influence of the mountains. None of the crops have proved as successful as had been hoped.

Success in dry farming depends upon the knowledge and skill that may be called technique [1] and upon climatic conditions—such as the average annual precipitation, the seasonal distribution of precipitation, the nature of the precipitation (that is, in heavy showers or in small amounts), and the evaporation—and on the soil, the nature of which determines the quantity of water that enters the ground. These have already been considered (pp. 35–39).

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[1] Clothier, R. W., Dry farming in the arid Southwest: Univ. Arizona Agr. Exper. Sta. Bull. 70, 1913. This paper discusses the methods of dry farming and gives the results of experiments in Arizona. It contains much valuable information for the prospective dry farmer.

Incomplete records at Lanfair for short periods give an average annual precipitation of less than 10 inches, and longer records for the region around Lanfair Valley show that the average annual precipitation is probably not more than this amount. Dry farming has generally been considered impracticable where the precipitation is as low as 10 inches and where the evaporation is as great as it doubtless is in Lanfair Valley.[1] The rainfall at Lanfair, as shown in the table on page 36, is not confined principally to any season but is distributed through the year, some of it coming when it can do no appreciable good. The record for the years 1912, 1913, and 1914 shows that from 17 to 33 per cent of the annual precipitation came in amounts of less than half an inch in 24 hours. These light showers add very little water to the soil, although they may help plants that are growing.[2] On the other hand, some of the rain falls in heavy thundershowers, when it may do more damage than good.

Unfortunately, the climatic observations in Lanfair Valley are very imperfect and are not strictly reliable. They cover a period so short that they are not of much value to any one who is trying to reach conclusions as to the possibility of carrying on successful dry farming. The prospects of the dry farmer in the valley do not seem to be very good. At the best, he will be laboring precariously in that borderland which separates success from failure. Fair crops may be raised in the wettest years, and possibly in years of normal precipitation, but it is certain there will be years when the rainfall is so deficient that crops will fail. Those who attempt to develop this valley by dry farming should have sufficient financial backing to carry them over a number of years, and until they can prove that crops can be raised without irrigation they should consider their work an experiment.

Only a little irrigation has been attempted in Lanfair Valley. Mrs. E. J. Jacoby has used water from her well at Ledge to irrigate about an acre of melons and garden truck. Mr. A. E. Moore has irrigated a few fruit trees at his ranch, 2 miles southwest of Government Holes (well No. 16, Pl. VI), but he states that the climate is too uncertain early in the spring to allow the trees to thrive. Mr. Moore used water from a shallow dug well, which yields about 11 gallons a minute. In the high valleys west and northwest of Rock Springs the supply from the shallow wells is doubtless sufficient for household use and for the irrigation of small tracts, but it would be insufficient to irrigate a large tract. In this part of the region, however, because of the high altitude, the precipitation is probably con-

[1] Briggs, L. J., and Beltz, J. O., Dry farming in relation to rainfall and evaporation: U. S. Dept. Agr. Bur. Plant Industry Bull. 188, p. 8, 1911. This bulletin deals with the conditions affecting dry farming that are not within the control of the farmer and that should be understood by him.

[2] Idem, p. 15.

siderable, so that if proper methods are used a large amount of water would not be required. The water from Vontrigger Spring (No. 22) was used in 1917 by Mrs. M. L. White to irrigate about 140 peach, apple, and other fruit trees, and some grapes on her ranch half a mile south of the spring. The spring fills in about 60 hours a concrete reservoir having a capacity of about 20,000 gallons. In November, 1917, the trees had been planted 2½ years and had produced good fruit. Mr. Lanfair, who owns the well at Lanfair and the well about a mile southeast of it, expected to irrigate a few acres in 1918 with water from a spring in the mountains 8 miles west of his ranch. The water is piped to a concrete reservoir near the railroad, having a capacity of about 15,000 gallons. The spring furnishes about 1,000 gallons a day.

The ground water in the valley seems to be satisfactory for irrigation, but the supply is apparently nowhere sufficient, and the cost of the high lift required to bring the water to the surface in the main part of the valley prohibits its use for irrigation, except possibly for especially valuable crops, such as garden produce or fruit trees. The conditions are not favorable for the development of practical irrigation. Wells for domestic supply and for watering stock can probably be obtained throughout the valley, but because of the great depth to which they must be drilled their cost will be rather great.

WELL DATA AND ANALYSES.

Data in regard to the wells in Lanfair Valley and the results of analyses of water from four wells, with a classification of the waters for domestic, boiler, and irrigation use, are given in the following pages:

Record of wells and springs in Lanfair Valley, Calif.

Number on Pl. VI.	Location.			Owner of well or name of spring.	Depth of well.	Depth to water level in well, Nov., 1917.	Remarks.
	T.	R.	Sec.[a]				
					Feet.	Feet.	
1	14 N.	16 E.	[b] 13 (?)	Rock Springs Cattle Co.	62	48	At Barnwell; equipped with windmill.
2	14 N.	16 E.	[b] 13 (?)	Atchison, Topeka & Santa Fe Ry.	[c] 457	[c] 73	At Barnwell; drilled in 1903. Abandoned. See analysis on p. 50.
3	14 N.	16 E.	[b] 23 (?)	Lecyr well (controlled by Rock Springs Cattle Co.)	....	....	Dug well, located in a wash, about 1⅓ miles southwest of Barnwell; equipped with galvanized iron tank, concrete water trough, and windmill. Pumps at least 12 gallons a minute. See analysis, p. 50.

[a] Field investigations of the United States General Land Office show that great errors have been made in the location of the township lines in Lanfair Valley. The lines shown on Plate II are probably not accurate, but as the true positions of the lines are not known, the locations are referred to the lines shown on the map.

[b] On unsurveyed land. The location given is only approximate, according to imaginary lines continued from the township and range lines in the vicinity of Lanfair.

[c] Depth to water and depth of well not measured.

Record of wells and springs in Lanfair Valley, Calif.—Continued.

Number on Pl. VI.	Location.			Owner of well or name of spring.	Depth of well.	Depth to water level in well, Nov., 1917.	Remarks.
	T.	R.	Sec.[a]				
					Feet.	*Feet.*	
4	14 N.	16 E.	[b] 29 (?)	Spring			
5	14 N.	16 E.	[b] 27 (?)	Mail Spring			
6	13 N.	16 E.	[b] 5 (?)	Spring			
7	13 N.	15 E.	[b] 2 (?)	do			
8	13 N.	16 E.	[b] 18 (?)	do			
9	13 N.	17 E.	S. ½ 18 [c]	Mrs. E. J Jacoby	[d] 879	[d] 100	12-inch drilled well at Ledge. Water reached at 365 feet; rose in well to 100 feet from surface. No solid rock encountered. Capacity, 11,000 gallons in 10 hours. See analysis, p. 50.
10	12 N.	15 E.	[b] 1 (?)	Rock Springs, controlled by Rock Springs Cattle Co.			Water comes from between granite boulders in a wash. Probably supplied by shallow ground-water flow. Nearly dry in January, 1918.
11	12 N.	15 E.	[b] 1 (?)	Beaty well	[d] 30 (?)	[d] 29 (?)	Dug.
12	12 N.	15 E.	[b] 1 (?)	Emdee well	[d] 18 (?)	[d] 8 (?)	Dug. Reported to supply 25 barrels a day.
13	12 N.	15 E.	[b] 12 (?)	Barnett Mining Co.	[d] 20 (?)	[d] 8 (?)	Do.
14	12 N.	15 E.	[b] 3 (?)	Government Holes, owned by Rock Springs Cattle Co.	32	15	Dug well. Equipped with small engine.
15	12 N.	15 E.	[b] 5 (?)			4	Shallow dug well at foot of low granite knob. A small pond stands near it.
16	12 N.	15 E.	[b] 16 (?)	A. E. Moore	13	7	Dug. Supplies 11 gallons a minute. See analysis, p. 50.
17	12 N.	15 E.	[b] 23 (?)	Spring			
18	12 N.	15 E.	[b] 25 (?)	do			
19	12 N.	17 E.	SW. ¼ 8[c]	E. L. Lanfair	[d] 550	[d] 500	6-inch drilled well. Water struck at 520 feet; rose to 500 feet. Gravel, 0 to 52 feet; volcanic ash, 52 to 520 feet; gravel, 520 to 550 feet. Supplies 16 gallons a minute.
20	12 N.	17 E.	SW. ¼ 16[c]	do	[d] 550	[d] 400	10-inch drilled well. Gravel, 0 to 4 feet; volcanio ash, 4 to 410 feet; gravel, 410 to 550 feet. Supplies about 35 gallons a minute.
21	11 N.	17 E.	7 (?)	Hackberry Spring, controlled by Rock Springs Cattle Co.			Water is diverted into two pipe lines. A pipe at a cattle trough 1½ miles northwest of Blackburn flowed 3½ gallons a minute from a 1½-inch pipe in November, 1917, probably not maximum flow of spring.
22	11 N.	17 E.	3 (?)	Vontrigger Spring, owned by Mrs. M. L. White.			Flows about 5 gallons a minute. Used for irrigating fruit trees.
23	12 N.	19 E.	19 (?)	Piute Spring			Said to be a strong spring.

[a] Field investigations of the United States General Land Office show that great errors have been made in the location of the township lines in Lanfair Valley. The lines shown on Plate II are probably not accurate, but as the true positions of the lines are not known, the locations are referred to the lines shown on the map.
[b] On unsurveyed land. The location is only approximate, according to imaginary lines continued from the township and range lines in the vicinity of Lanfair.
[c] Location given by the owner.
[d] Depth to water and depth of well not measured.

Mineral analyses and classification of ground waters in Lanfair Valley.

[Parts per million except as otherwise designated. Numbers at heads of columns refer to corresponding well numbers on Plate VI, and in table on pages 4z–49.]

	2	3	9	16
Quantities determined:				
Silica (SiO_2)	14	32	32	36
Iron (Fe)	....	.59	.29	.19
Calcium (Ca)	134	308	35	86
Magnesium (Mg)	50	74	7.0	33
Sodium and potassium (Na+K)	71	[a] 172	[a] 35	[a] 126
Carbonate radicle (CO_3)	.0	.0	.0	.0
Bicarbonate radicle (HCO_3)	382	186	173	422
Sulphate radicle (SO_4)	208	1,006	23	152
Chloride radicle (Cl)	117	175	19	84
Nitrate radicle (NO_3)	....	.08	.08	.31
Total dissolved solids at 180° C.[b]	782	1,992	229	731
Quantities computed: [c]				
Total hardness as $CaCO_3$	540	1,070	116	350
Scale-forming constituents	490	1,100	150	340
Foaming constituents	190	460	94	340
Alkali coefficient (inches)	17	11	35	19
Classification: [c]				
Mineral content	High.	High.	Moderate.	High.
Chemical character	Ca-CO_3	Ca-SO_4	Ca-CO_3	Na-CO_3
Probability of corrosion [d]	(?)	C	N	(?)
Quality for boiler use	Bad.	Unfit.	Fair.	Poor.
Quality for domestic use	[e] Poor.	[e] Bad.	[e] Good.	[e] Poor.
Quality for irrigation	Fair.	Fair.	Good.	Good.
Date of collection	Mar. 23, 1903.	Nov. 5, 1917.	Nov. 5, 1917.	Nov. 22, 1917.
Analyst	(f)	C. H. Kidwell.	F. E. Keating.	F. E. Keating.

[a] Computed.
[b] By summation.
[c] See pages 43–46.
[d] C=corrosive; N=noncorrosive; (?)=corrosion uncertain or doubtful.
[e] Classification for domestic use based on mineral composition only; sanitary quality not determined. See p. 43.
[f] Analysis furnished by Atchison, Topeka & Santa Fe Railway Co., Arizona division, water analysis No. 4560; recalculated from hypothetical combination in grains per U. S. gallon. This water contains 5.1 parts per million of free CO_2.

GROUND WATER IN PAHRUMP, MESQUITE, AND IVANPAH VALLEYS, NEVADA AND CALIFORNIA.

By Gerald A. Waring.

INTRODUCTION.

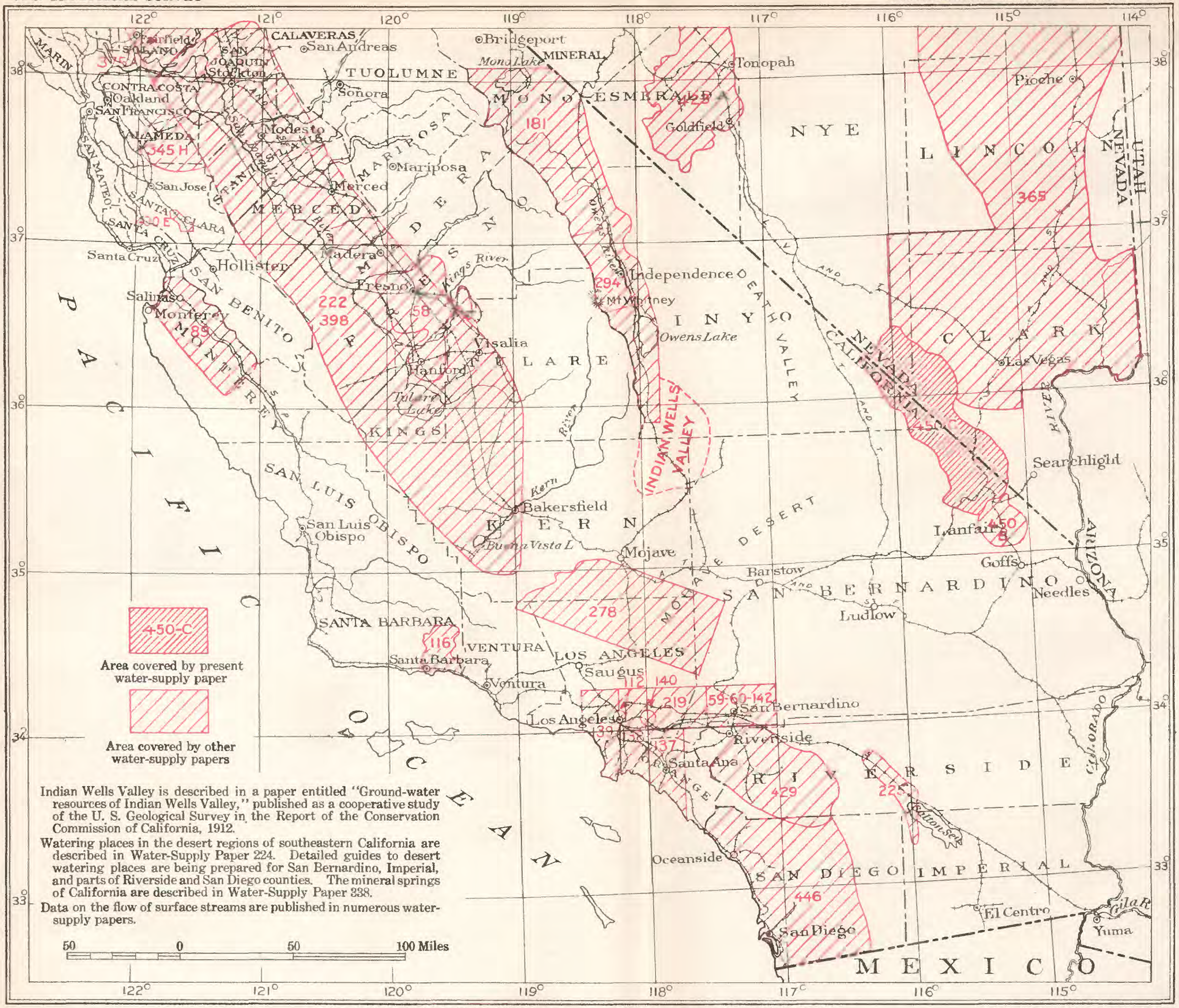
In eastern California and southern Nevada there are numerous detached drainage basins that have no outlets for their surface water. The lowest parts of these basins are occupied by clay flats which may be covered with water during wet seasons but which are dry during the greater part of the year. These flats are known as playas or "dry lakes." Pahrump, Mesquite, and Ivanpah valleys occupy three such inclosed basins, partly in Nevada and partly in California. (See Pls. VII and VIII.)

The drainage basin of Pahrump Valley is mainly in Nye and Clark counties, Nev.; a small portion of it lies in Inyo and San Bernardino counties, Calif. (See Pl. VIII.) Somewhat less than half of the drainage basin of Mesquite Valley lies in Clark County, Nev., and the remainder is in California, chiefly in San Bernardino County but partly in Inyo County. About 57 per cent of the drainage basin of Ivanpah Valley is in San Bernardino County, Calif., but the lowland as well as the bordering slopes extends northward into Clark County, Nev. The areas of the drainage basins of Pahrump, Mesquite, and Ivanpah valleys, by planimetric measurement on the topographic maps of the region, are, respectively, 1,040, 395, and 770 square miles.

There are no perennial streams of consequence in any of the basins, but numerous small springs furnish water supplies for prospectors and for range stock, and at two places in Pahrump Valley there are large springs used for irrigation. Within the last few years attempts have been made in each valley to develop supplies of water for irrigation by sinking wells. Although the preliminary tests did not result in agricultural settlement of the valley lands, attempts to develop ground water for irrigation have been continued, and the writer was assigned to make a short examination of the region, in order to determine, if possible, the relative amount of ground water available and its adaptability to successful farming. A short time in August, 1916, was spent by the writer in the examination of the valleys, in company with Ernest L. Neill, of Stanford University, who rendered able assistance in gathering information. The collection of well records and other data during the short time that could be spent in the region was greatly facilitated in Pahrump Valley by Messrs. T. G. Darrough, J. M. Raycroft, Albert Quill, Hoffman & Vetter, and T. J. Donovan; in Mesquite Valley by Mr. J. B. Cryor; and in Ivanpah Valley by Mr. Ruben Fuchner. Some additional data were collected in 1917 by D. G. Thompson, of the United States Geological Survey.

Ivanpah Valley is traversed by the Los Angeles & Salt Lake Railroad. At Cima, Ivanpah, and Nipton there are small stores and limited accommodations for travelers. Roach, a settlement of half a dozen houses, is a shipping point for ore and affords meals and accommodations for the night. Jean, the principal settlement in the valley, is a mining supply and shipping point, with a large general store, warehouse, post office, hotel, saloon, and a dozen dwelling houses. From Jean a narrow-gage railroad extends northwestward to the mining settlement of Good Springs, which in 1916 had a population of perhaps 200, and to the Yellow Pine or Bybee mine, 4 miles farther west. From Good Springs and Roach well-graded wagon roads extend to Platina, in Mesquite Valley. This town, which was started in 1914 during local excitement over the discovery of platinum in the adjacent hills, consisted in 1916 of a general store and post office and seven other houses along streets laid out about a quarter of a mile north of the former Ripley post office and an equal distance southeast of the abandoned mill of Sandy. The store and post office were discontinued, and the town was practically abandoned. At the Milford mine and other mines in the mountains east of Platina there were small groups of tents and cabins of those engaged in getting out ore. From Platina roads lead northwestward to Manse and Pahrump ranches, the principal settlements in Pahrump Valley. In 1916 Pahrump post office had mail service three times a week with Shoshone, a station 27½ miles to the southwest, on the Tonopah & Tidewater Railroad. The small mining settlement of Johnnie is near the north border of the Pahrump Valley.

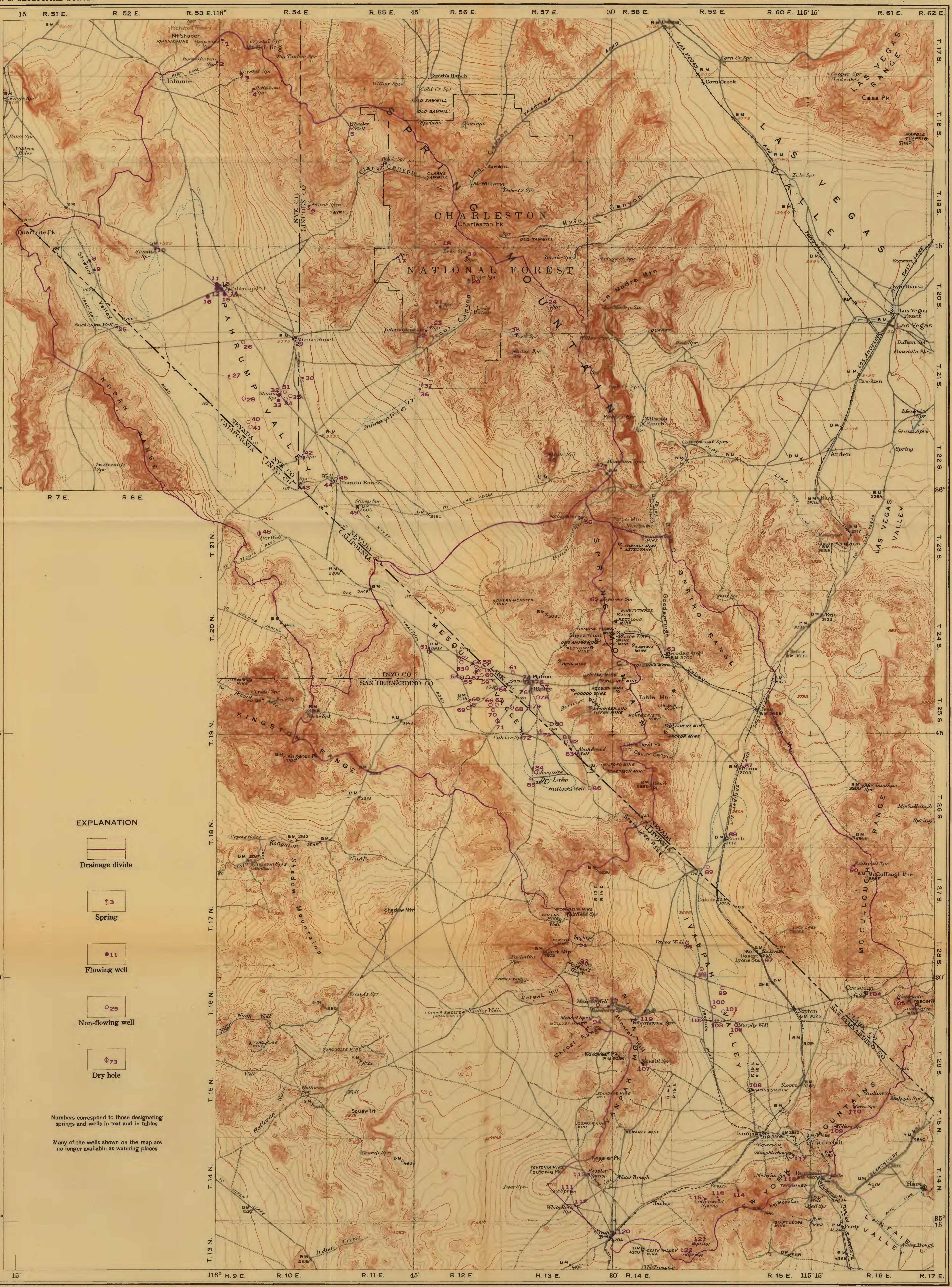
The old copper smelter at Valley Wells, 20 miles northwest of Cima, was rebuilt by the Ivanpah Copper Co. late in 1917, and was in operation as late as February, 1918, when about 50 men were working there. The smelter was later reported to have been closed down. Because of fluctuations of the metal market and other conditions the future of many mining camps is very uncertain, and a traveler who is going into a region for the first time should make inquiries regarding the presence of settlers and not depend on finding people at places where settlements have flourished in the past.



SKETCH MAP OF PARTS OF CALIFORNIA AND NEVADA

Showing areas treated in the present report and in other water-supply papers of the U. S. Geological Survey relating to ground water

ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY



Base from U. S. Geological Survey topographic maps, with minor corrections by Gerald A. Waring

MAP OF THE DRAINAGE BASINS OF PAHRUMP, MESQUITE, AND IVANPAH VALLEYS, NEVADA AND CALIFORNIA SHOWING LOCATION OF WELLS AND SPRINGS

Locations by Gerald A. Waring

Scale 1/250000

Contour interval 100 feet.
Datum is mean sea level.

1920

GEOGRAPHIC SKETCH.

TOPOGRAPHY.

Spring Mountain, a range that culminates in Charleston Peak, at an elevation of 11,910 feet above sea level, is the dominant topographic feature of the region. The east side of the range is characterized by great cliffs. The west side, which is in the Pahrump drainage basin, is somewhat less precipitous and is bordered by extensive alluvial slopes. (See Pl. IX, *A*.) The lowest part of the Pahrump basin is in the northwest, in a reentrant known as Stewart Valley (Pl. IX, *B*), at an elevation of about 2,450 feet. The southwest border of the Pahrump basin is formed by the steep slopes of the Nopah Range, which rises 2,000 feet above the valley, and by subsidiary ranges to the north and south. The drainage divide between the Pahrump basin and that of Ash Meadows, to the northwest, follows the crests of several semidetached, unnamed mountains that attain elevations of 4,000 to 5,000 feet above sea level. On the southeast the Pahrump basin is separated from the Mesquite basin by a drainage divide that extends from the crest of Spring Mountain down the alluvial slopes and across the lowland as an indefinite divide, to the base of a northeastern spur of the Kingston Range.

The Mesquite drainage basin, which is rudely triangular, has its northern, southern, and western corners, respectively, near Potosi Mountain, Clark Mountain, and Kingston Peak. The highest point in the basin is Potosi Mountain, at an elevation of 8,500 feet above sea level; the lowest land is in the dry Mesquite Lake, at an elevation of about 2,535 feet. The divide on the east is formed by a southward extension of Spring Mountain; on the southwest by lower mountains. Between spurs of these mountain ranges on the east and the southwest, wide alluvial slopes extend down to the lower land at grades of 100 to 400 feet to the mile.

The western border of the Ivanpah drainage basin, which lies south of Mesquite basin, is formed by Clark Mountain (elevation, 7,903 feet) and adjacent ranges, and by Ivanpah Mountain, whose main peaks are more than 5,500 feet above sea level. On the east the limit of the drainage basin is formed in part by the crest of the Bird Spring Range, Sheep Mountain, and the McCullough Range. From the south end of the McCullough Range the divide swings southwestward along the crest of the New York Mountains. The extreme northern limit of the Ivanpah basin is definitely marked by the summit of Potosi Mountain. The extreme southwestern limit is less definitely determined by alluvial slopes on each side of the railroad pass at Cima. The lowest portion of the basin is occupied by the dry Ivanpah Lake, at an elevation of 2,595 feet, separated by a slight divide from the dry lake near Roach, whose surface is 13 feet higher.

The surface in each basin may be divided into three parts—lowland, alluvial slopes, and mountains. The approximate areas and percentages of each class are shown in the following table:

Area of land of different classes in Pahrump, Mesquite, and Ivanpah basins.

	Lowlands.		Alluvial slopes.		Mountains.		Total area of basin (square miles).
	Area (square miles).	Per cent of total area.	Area (square miles).	Per cent of total area.	Area (square miles).	Per cent of total area.	
Pahrump basin	250	24	330	32	460	44	1,040
Mesquite basin	90	23	115	29	190	48	395
Ivanpah basin	85	11	375	49	310	40	770

It will be noted that the proportion of lowland, alluvial slopes, and mountains are approximately the same in the Pahrump and Mesquite basins, but that the Ivanpah basin contains a much larger percentage of alluvial slopes than either of the other two basins, and less than half as large a percentage of lowland.

CLIMATE.

Most of the precipitation is in the winter. More than half of it falls during the four months December to March, inclusive. On the mountains much of the precipitation is in the form of snow. Occasional thunderstorms during the summer locally furnish considerable water, but they are so irregular in occurrence and are likely to be so severe that they are of relatively small value to growing crops. The following record of precipitation at Jean, in Ivanpah Valley, and at Pahrump, in Pahrump Valley, indicate the approximate monthly distribution of the precipitation in the valleys. The precipitation increases rapidly with increase of elevation.

Monthly and annual precipitation, in inches, at Jean, Nev.

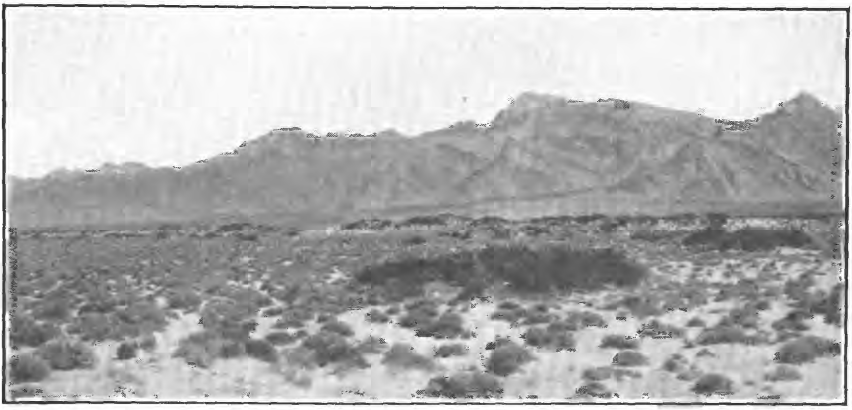
[Elevation 2,864 feet.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1908	1.30	0.10	0.20	0	Tr.	0	0.10	0.06	2.71	1.00	0	0	5.47
1909	.09	......	1.32	0.30	0	0	.03	.12	2.03	0	0.67	1.59	[a] 6.15
1910	0	0	0	0	0	0	2.05	1.13	.40	.60	.90	......	[a] 5.08
1911	.44	.75	1.00	0	0	......	Tr.	0	0	......	0	Tr.	[a] 2.19
1912	0	0	......	.27	.10	Tr.	.46	.20	0	.30	0	0	[a] 1.33
1913	.30	.40	......	.25	0	Tr.	......	.52	.23	Tr.	1.25	0	[a] 2.95
1914	1.50	.05	Tr.	1.25	0	Tr.	.03	0	.65	......	......	......	[a] 3.48
1915	1.25	1.00	.20	Tr.	Tr.	Tr.	.29	Tr.	......	......	......	......	......
1916	......	......	......	......	......	......	......	......	......	......	......	......	......

[a] Approximate.

A. ALLUVIAL SLOPE ON EAST SIDE OF PAHRUMP VALLEY, NEV., LOOKING NORTH.

B. STEWART VALLEY, NEV.-CALIF., LOOKING NORTH.



A. SAND RIDGES ON SOUTHEAST SIDE OF MESQUITE LAKE, CALIF., AND ALLUVIAL FANS ALONG EAST BORDER OF MESQUITE VALLEY.

B. CLAY HUMMOCKS IN SOUTHEASTERN PART OF MESQUITE LAKE.

C. CLAY BEDS AND ESCARPMENT AT J. B. YOUNT'S RANCH, PAHRUMP VALLEY, NEV.-CALIF.

Monthly precipitation, in inches, at Pahrump, Nev.

[Elevation 2,608 feet.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1914	......	......	0.14	1.56	Tr.	0.09	......	0.02	0.42	0.05	0	1.01
1915	1.20	1.40	......	......	......	......	......	......	......	......	......	......
1916	......	......	......	......	......	......	0.64	0.42	0	......	0	0.58

The extremes in temperature are great. In the valleys there are usually frosts during November to March, and in the mountains temperatures near zero are common during these months. Snow does not lie on the mountains very long in the spring, however.

VEGETATION.

The higher mountains are sparsely clothed with junipers, which in some portions are sufficiently numerous to form wooded areas. (See Pl. VIII.) The higher part of Spring Mountain also supports yellow pine and piñon, which have been to a large extent cut for lumber for the neighboring mines. The lower parts of the mountains and the extensive alluvial slopes are covered chiefly by creosote bush (*Covillea tridentata*), several species of greasewood (*Sarcobatus*), rabbit brush or rayless golden rod (*Chrysothamnus graveolens*), cactus, and yucca. Sagebrush (*Artemisia tridentata*) was not observed by the writer in any of the basins, but it is found in the elevated valleys east and north of Government Holes, 10 miles southeast of Cima.

In the southwestern part of the Ivanpah basin the giant yucca or Joshua tree (*Yucca* or *Clistoyucca arborescens*) is abundant on the slopes north of Cima, with an undergrowth of creosote bush and greasewood. On the southeast side of the basin the yucca is less common, and it does not descend much below an elevation of 3,000 feet above sea level. In the northern part of the basin, on the slopes of State Line Pass and west of Borax and Jean, a smaller yucca, either a stunted form of the Joshua tree or a related form, is fairly plentiful. The slopes below 2,800 feet are dominated by creosote bush and greasewood down to the flatland bordering the dry lakes. The larger of the two "dry lakes" in Ivanpah Valley is bordered by a zone 200 to 400 yards wide that is occupied by greasewood almost to the exclusion of creosote bush. The smaller lake bed near Roach is bordered by a zone of rabbit brush and stunted greasewood, extending to the base of the alluvial slopes, where the creosote bush becomes dominant. The lake beds themselves are barren of vegetation and during most of the year have hard, level clay surfaces. During storms they may be covered by water to a depth of several inches.

Mesquite Lake is surrounded by a belt of mesquite trees in some places 100 yards or more in width. Sand ridges on the east side of the lake bed (Pl. X, *A*) are also in part covered by mesquite. The lake bed is largely crusted with alkaline deposits that are barren of vegetation, and a part of the east side consists of a barren clay flat, dotted with clay hummocks (Pl. X, *B*), some of which are more than 15 feet high, but in some portions of the lake bed there are sparse growths of salt grass and other alkali-resistant plants.

In the Pahrump basin mesquite grows along the east side of Stewart Valley, and there are groups of the mesquite trees near Sixmile, Mound, Stump, and other springs. On the lower slopes a yucca, smaller than the average Joshua tree but resembling it, is the most prominent plant, though scattered clumps of stunted greasewood and creosote bush form the principal growth. Along the upper borders of the alluvial slopes an occasional barrel cactus is found. The lake bed southwest of Mound Spring is a barren clay flat, but that of Stewart Valley is covered by salt grass.

ANIMAL LIFE.

Wild animals are not plentiful in this region. Occasionally a coyote or a jack rabbit may be seen, and during the evening or early morning a small variety of swift or fox is abroad, hunting for desert rats. These rats and the lizards are the most common forms of wild life. On the higher slopes, especially in the wooded portions of the mountains, a few birds may be found, but the region as a whole does not furnish much food for animal life. The smaller animals are by no means so common in this region as they are farther west, where in some of the recently homesteaded valleys they are so numerous that rabbit-tight fences are almost essential to the production of crops.

MINERAL RESOURCES.

Mining has been carried on in the mountains of the region for many years. Probably the first production came from the Potosi mine, near the north border of the Mesquite basin, where lead was obtained by the Mormons about 1860. Later ores of gold, silver, copper, and lead were discovered; and in 1906 a material that accompanies some of the lead ores and had been considered to be country rock was recognized by a mining engineer to be an ore of zinc.[1]

In 1914 platinum and palladium were recognized in a gold ore from the Boss mine (3 miles northeast of Ripley), which was an old property, originally developed for copper.[2] One result of the mining rush that followed was the establishment of the town of Platina.

[1] Hill, J. M., The Yellow Pine mining district, Clark County, Nev.: U. S. Geol. Survey Bull. 540, pp. 225–226, 1913.

[2] Knopf, Adolph, A gold-platinum-palladium lode in southern Nevada: U. S. Geol. Survey Bull. 620, pp. 1–2, 1916.

In 1916 ore from mines in the Mesquite basin was being hauled by auto trucks and by teams to Roach, for rail shipment to smelters, and ore from mines near Good Springs was being brought down by the narrow-gage railroad to the main line at Jean. The prevailing high prices of copper, lead, and zinc had caused the reopening of several properties that had been idle for some time.

In the New York Mountains, south of Ivanpah, tungsten minerals (wolframite and ferberite) were discovered in May, 1916, in old copper and gold-silver prospects. When the region was visited in August, 1916, many claims had been staked and several leases had been taken, but a recent drop in the price of tungsten had caused suspension of work. The prospects are on quartz ledges that cut the coarse gray granite country rock. In some places the quartz carries small amounts of blue and green copper carbonates and black manganese oxide. The Garvanza mill, erected about 1910 2 miles southeast of Brant, for the chlorination of the gold ore, was not successfully used, but small amounts of gold and copper ores from the mines were concentrated and shipped.

About 10 or 15 years ago salt was produced in Mesquite Lake by the evaporation, in iron pans heated by mesquite wood, of brine obtained from shallow pits, and the product was taken to San Bernardino and sold. In the pits at the old workings (locality 84, Pl. VIII) crusts of salt form. A sample collected by the writer in August, 1916, was analyzed in the United States Geological Survey laboratory by W. B. Hicks and reported to be nearly pure sodium chloride. It contains small amounts of sulphate, calcium, and magnesium and a trace of potassium.

About half a mile northwest of the old salt works the surface over several acres is strewn with large crystals of gypsum, which develop in the mud and seem to work their way up to the surface, where they disintegrate and cover the ground with shining flakes. It is said that a number of years ago about 1,200 acres on the west side of the dry lake was staked as placer gypsum claims, but in 1916 no assessment work appeared ever to have been done.

GEOLOGIC SKETCH.

STRUCTURE.

The dominant structural feature of the region is the Spring Mountain, a mass of irregular shape which has a general northwesterly trend and culminates in Charleston Peak, on the east side of the Pahrump basin. The range was studied by members of the Wheeler Survey[1] and in 1900–1901 by the late R. B. Howe, whose

[1] U. S. Geol. Surveys W. 100th Mer. Rept., vol. 3, pp. 124, 166, 179, 180, 1875.

notes were incorporated by Spurr[1] in a report on the region. These studies show that the mountains have been uplifted by extensive folding and faulting. Spurr[2] says that the range "shows more complex folding than any of the ranges north or east, and to this folding the irregular shape of the range is probably due. * * * In an east-west section the general structure of the range seems to be a broad syncline, with a number of minor folds of little importance. * * * In a north-south section the structure * * * appears to be anticlinal." Hill[3] visited the south end of the range in 1912 and found that "in this region the general structure seems to be monoclinal, but it is complicated by numerous faults and some folding. * * * The ridges extending westward into Mesquite Valley are faulted in a very complicated manner."

The Kingston and Nopah ranges, which together form the western border of the Pahrump and Mesquite basins, have steep fronts, especially on the west side of the Nopah Range. According to R. B. Rowe[4] the general structure of these ranges seems to be monoclinal, the dip being eastward, but there are many faults. At Kingston Peak the rocks are somewhat folded but have a general northward dip.

No detailed studies of the mountains bordering the southern part of the Ivanpah basin have been made. Clark and Ivanpah mountains, on the west, and the New York Mountains and their northern extensions in the McCullough Range, on the south and southeast, are all believed to be greatly faulted, with minor folding, and to have a complex structure, much like that of Spring Mountain, to which both the eastern and western limiting mountains of Ivanpah basin are structurally related.

CLASSES OF ROCKS.

Granite and gneiss, presumably of Archean age, are found in the southwestern part of the New York Mountains. A belt of granite forms the central part of Clark Mountain,[5] and granite also forms the core of the mass that culminates in Kingston Peak.[4] The greater part of the mountains in the region, however, are composed of ancient sedimentary rocks. Quartzite, considered to be of Cambrian age, overlies the granite of Kingston Peak, and Cambrian lime-

[1] Spurr, J. E., Descriptive geology of Nevada south of the 40th parallel and adjacent portions of California: U. S. Geol. Survey Bull. 208, pp. 164–180, 1903.

[2] Idem, p. 175.

[3] Hill, J. M., The Yellow Pine mining district, Clark County Nev.. U. S. Geol. Survey Bull. 540, p. 233, 1914.

[4] Spurr, J. E., op. cit., p. 199.

[5] U. S. Geog. and Geol. Surveys W. 100th Mer. Rept., vol. 3, p. 32, 1875.

stones and other sedimentary rocks have been mapped by Spurr[1] as constituting the Nopah and adjacent ranges, the ranges near Clark Mountain, the McCullough Range, and the northern part of the New York Mountains. Spring Mountain and its offshoot, the Bird Spring Range, are composed chiefly of massive limestones and conglomerates of Carboniferous age.[2] Small areas of sandstone and shale of Triassic and Jurassic age are present north of Good Springs. No consolidated sedimentary materials of later age than the Jurassic have been recognized in the region, but there are a few small areas of lava, probably of Tertiary age, notably on Table Mountain, between Platina and Jean.

Each of the three valleys is underlain by deep deposits of alluvium. Great alluvial slopes extend from the bases of the mountains down to the lowlands. In their upper portions these slopes consist chiefly of angular gravel and cobbles, but in their lower portions the material is chiefly sand, silt, and clay. The greater part of the lowland in Pahrump Valley is underlain by calcareous sandy soil. In the northern part of Mesquite Valley numerous wells that were dug a few years ago show that the material is almost entirely silt and clay down to the ground-water level. In most of these wells only light-colored, nearly white calcareous clay and silt are exposed; but the northernmost well (No. 52, Pl. VIII) exposes about 50 feet of red-brown calcareous sandy silt, overlying the more common white material.

Along the east side of Pahrump Valley, from Pahrump to a point some distance south of Stump Spring, there are beds of light brown to cream-colored clay from only 2 or 3 feet thick to a maximum thickness, near Stump Spring, of about 50 feet. (See fig. 4.) The clay beds along the north side of the road between Manse and Pahrump contain layers and lenses of limestone gravel and in some places the clay is calcareous and cemented into a very hard material. A test well on the north side of the road halfway between Manse and Pahrump is said to have reached gravel underlying the clay at a depth of 41 feet. The western front of the beds form low but conspicuous bluffs at several places, notably at J. B. Yount's ranch (see Pl. X, *C*), suggesting a fault scarp. At no place were any of the clay beds observed to pass beneath the gravelly alluvium. Where the upper border was seen, east of Stump Spring and also east of Pahrump, the clay immediately overlies the alluvial wash, and its eastern limit is marked by a declivity several feet high. In the vicinity of Yount's ranch, where the formation covers the widest area, its surface rises with a uniform slope of about 100 feet to the mile north-

[1] Spurr, J. E., op. cit., pl. 1.
[2] Hill, J. M., The Yellow Pine mining district, Clark County, Nev.: U. S. Geol. Survey Bull. 540, pl. 4, 1914.

eastward to the lower border of the gravelly alluvial wash. In the southeast the clay extends up to an elevation of about 3,000 feet above sea level; but at its northwest end, near Pahrump, it is only 2,700 feet above sea level. These clay beds were presumably laid down in a lake or playa that formerly occupied that part of Pahrump Valley and were later elevated, probably with tilting and faulting.

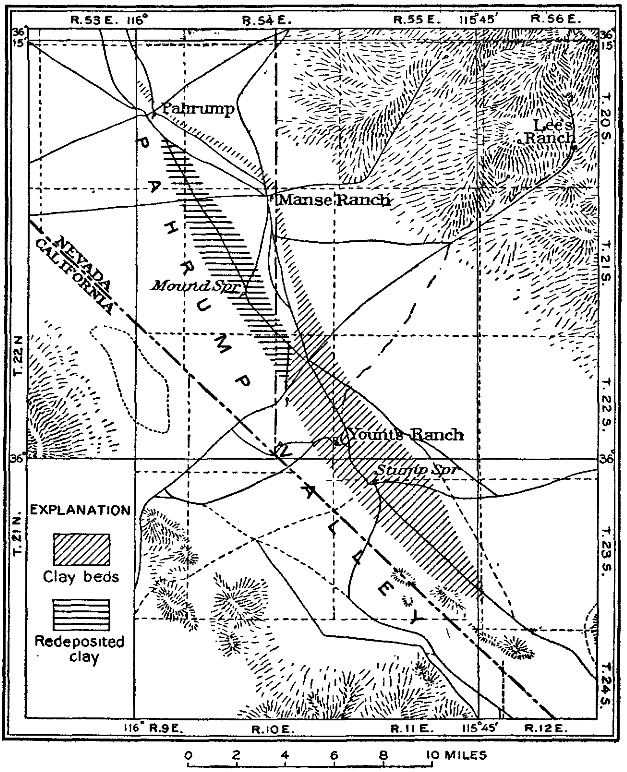


FIGURE 4.—Sketch map showing approximate extent of elevated clay beds in Pahrump Valley, Nev.

Between Mound Spring and Pahrump there is a belt of soft, fine-grained calcareous soil, standing 3 or 4 feet above the mean level of the valley floor, which seems to consist of clay redeposited by storm waters that have brought it from the main bed of clay to the east.

No evidence of clay beds appreciably above the levels of the playas and adjacent low slopes was observed in Mesquite and Ivanpah valleys. The drainage basins of these two valleys are smaller than that of Pahrump Valley, and they are surrounded in general by lower mountains, upon which less rain and snow fall, so that it is improbable that they formerly contained extensive lakes.

GROUND WATER.

PAHRUMP VALLEY.

SPRINGS.

Several large springs and many small ones are found in the mountains on the east side of Pahrump Valley and along the base of the mountains. A few large springs also occur farther down in the valley.

Lee's Spring and Trout Spring, up in the mountains, and Intermittent Spring and the Pahrump Valley springs, at the base of the mountains, yield large flows. The records of flow of these streams, as measured by the United States Geological Survey, are given in the following tables:

Daily discharge, in second-feet,[a] of Lee's Spring near its source, 18 miles east of Pahrump, Nev., for the period Apr. 1 to Sept. 30, 1916.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Day.	Apr.	May	June.	July.	Aug.	Sept.
1	9.0	12	4.9	2.4	1.5	0.9	16	10	7.1	3.8	3.7	1.2	0.7
2	8.9	11	4.7	2.4	1.7	.9	17	12	6.6	3.7	2.9	1.1	.7
3	9.7	12	4.7	2.3	1.6	.9	18	12	6.2	3.5	2.6	1.1	.6
4	8.0	14	4.7	2.3	1.5	.9	19	12	6.4	3.5	2.3	1.0	.6
5	7.3	15	4.5	2.2	1.5	.9	20	12	6.0	3.2	2.0	1.0	.6
6	6.8	13	4.5	2.2	1.4	.8	21	13	6.0	3.0	1.9	1.0	.6
7	6.8	12	4.5	1.7	1.4	.8	22	14	6.2	2.7	1.9	1.0	.6
8	8.0	12	4.4	1.6	1.4	.8	23	16	6.2	2.7	1.9	1.0	.6
9	9.9	11	4.4	1.6	1.4	.8	24	18	5.8	2.8	1.7	1.0	.6
10	12	10	4.4	1.6	1.3	.8	25	18	5.5	2.8	1.6	1.0	.6
11	11	9.6	4.4	1.6	1.3	.7	26	20	5.1	2.7	1.6	1.0	.5
12	8.9	9.2	4.2	1.6	1.3	.7	27	20	5.3	2.6	1.6	1.0	.5
13	7.8	8.4	4.0	1.6	1.3	.7	28	20	5.3	2.4	1.5	1.0	.5
14	7.3	8.0	4.0	2.0	1.2	.7	29	19	5.3	2.4	1.5	.9	.5
15	8.4	7.5	4.0	12	1.2	.7	30	16	5.3	2.4	1.5	.9	.5
							31	......	5.1	......	1.5	.9	......

[a] A second-foot is equal to about 448 gallons per minute.

Monthly discharge of Lee's Spring near its source, 18 miles east of Pahrump, Nev., for the period Apr. 1 to Sept. 30, 1916.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
April	20	6.8	12.0	714
May	15	5.1	8.32	512
June	4.9	2.4	3.68	219
July	12	1.5	2.28	140
August	1.7	.9	1.20	74
September	.9	.5	.69	41
The period	....	....	....	1,700

Discharge measurements of Trout Creek about 5 miles below Trout Spring, or 16 miles east of Pahrump, Nev.

[Made by Albert Quill.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1916.	*Feet.*	*Sec.-ft.*	1916.	*Feet.*	*Sec.-ft.*	1916.	*Feet.*	*Sec.-ft.*
Apr. 6	0.60	1.75	June 15	0.40	1.70	Aug. 17	0.32	1.22
20	.65	2.16	22	.40	1.70	24	.32	1.22
27	.70	2.69	30	.35	1.39	31	.33	1.28
May 8	.44	1.96	July 6	.34	1.33	Sept. 7	.31	1.16
11	.45	2.03	13	.34	1.33	14	.29	1.05
17	.45	2.03	20	.33	1.28	21	.28	1.00
24	.43	1.90	27	.33	1.28	28	.27	.94
June 1	.43	1.90	Aug. 3	.33	1.28	Oct. 5	.28	1.00
8	.42	1.83	10	.33	1.28			

Daily discharge, in second-feet, of Intermittent Spring 50 yards below its head, 16 miles east of Pahrump, Nev., for the period Apr. 1 to Sept. 30, 1916.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Day.	Apr.	May.	June.	July.	Aug.	Sept.
1	23	36	16	9.4	5.0	2.2	16	20	24	17	13	4.0	1.2
2	22	33	16	9.1	5.7	2.2	17	23	23	16	10	3.7	1.1
3	22	32	16	8.6	5.7	2.0	18	24	22	16	9.1	3.5	1.1
4	21	33	16	8.1	5.2	2.0	19	24	22	15	8.3	3.3	1.0
5	20	34	16	7.8	5.0	1.9	20	24	21	14	7.8	3.1	.9
6	18	35	17	7.8	5.0	1.8	21	25	20	14	7.6	3.0	.8
7	18	34	17	7.3	4.8	1.6	22	26	19	13	7.3	3.0	.8
8	18	33	18	7.1	4.8	1.5	23	28	19	12	6.6	3.0	.8
9	19	33	18	6.8	4.8	1.5	24	31	19	12	6.4	2.8	.6
10	22	33	18	6.4	4.6	1.4	25	32	18	12	6.4	2.6	.6
11	24	33	18	6.4	4.6	1.4	26	33	17	11	6.2	2.4	6
12	22	33	18	6.2	4.4	1.3	27	36	16	11	5.9	2.5	.5
13	21	31	17	5.9	4.2	1.3	28	38	16	10	5.7	2.6	.5
14	20	29	17	5.9	4.2	1.3	29	39	16	9.9	5.2	2.5	.4
15	20	26	17	15	4.0	1.3	30	38	16	9.6	5.0	2.4	.4
							31	......	16	......	5.0	2.2	......

Monthly discharge of Intermittent Spring 50 yards below its head, 16 miles east of Pahrump, Nev., for the period Apr. 1 to Sept. 30, 1916.

Month.	Discharge in second-feet.			Run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
April	39	18	25.0	1,490
May	36	16	25.5	1,570
June	18	9.6	14.9	887
July	15	5.0	7.53	463
August	5.7	2.2	3.83	236
September	2.2	.4	1.20	71
The period	....	....	....	4,720

Measurements of Pahrump Valley Creek (fed by the Pahrump Valley Springs) 15 miles southeast of Pahrump, Nev.

[Made by Albert Quill.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1916.	*Feet.*	*Sec.-ft.*	1916.	*Feet.*	*Sec.-ft.*	1916.	*Feet.*	*Sec.-ft.*
May 13	1.90	22.3	July 6	1.46	10.4	Aug. 24	1.14	4.53
18	1.90	22.4	13	1.40	9.19	31	1.06	3.36
24	1.86	21.6	20	1.44	9.61	Sept. 7	1.02	2.99
31	1.81	19.4	27	1.38	8.48	14	1.00	2.45
June 8	1.76	17.7	Aug. 3	1.36	8.25	21	....	1.91
15	1.71	16.6	10	1.22	5.73	28	.94	1.33
22	1.62	14.0	17	1.18	4.93	Oct. 5	....	.61
29	....	11.7						

Intermittent Spring issues in full volume in a bouldery wash. As is shown by the discharge record, although the flow is large in the spring months, it lessens until the stream becomes nearly dry in the later part of the summer. Pahrump Valley creek heads in a large spring (No. 37), and another spring, which had a flow of about 0.6 second-foot in August, 1916, joins the creek a few hundred yards below. These large springs, as well as the smaller ones, derive their water directly from the precipitation on the slopes above them, and consequently their flow decreases from a maximum in the spring months of rain and of melting snow to a minimum at the end of the dry season.

Horseshutem Spring (No. 2, Pl. VIII), near the north edge of the basin, has been estimated to yield 200 barrels a day. Its water has been piped down to the mining camp of Johnnie for domestic use.

Stump Spring (No. 49) is in a gully in the clay beds along the east side of the valley and apparently derives its water by seepage from these beds or from the gravel immediately underlying them. Its normal flow has been estimated at 20 barrels a day.

Large springs are found at the Pahrump and Manse ranches, and the water at each place has been used for many years for irrigation. At Manse there are two springs 75 yards apart. The temperature of the water in each is 75° F. The flow of the smaller spring is about 0.8 second-foot and the combined flow of the two springs, measured September 30, 1916, by Albert Quill, of the United States Geological Survey, was 3.23 second-feet.

At the Pahrump ranch there is a group of two large springs and one smaller one that are similar to those at Manse. The water rises principally in a pool 20 or 30 feet in diameter and 3 or 4 feet deep bordered by banks of partly cemented gravel a few feet high. The sandy bottom of the pool is kept in ebullition by the rising water, which has a temperature of 76½° F. The flow of the two larger springs, as measured by Albert Quill September 30, 1916, was 2.53 and 2.20 second-feet.

On J. M. Raycraft's ranch, half a mile northwest of Pahrump, there is a spring (near well location No. 12), which is probably similar in character to the large ones at Pahrump and Manse. It rises in a small marshy area and flows about 10 gallons a minute. A few hundred yards southeast of this spring there is a mass of calcareous tufa, apparently a spring deposit, forming a low mound 10 or 15 yards in diameter.

Mound Spring, 4 miles south of Manse, formerly had a small flow. It is at the base of a low mound composed of clay and fine sand. This mound was probably built, like many similar ones at desert springs, by the moistening and retention of material blown by the wind to the spring. The small spring at Mr. Raycraft's ranch issues at the base of a similar mound, and it is reported that there are also small springs at other mounds near by.

The springs along the border of the lowland seem to be supplied by water which rises from a considerable depth under artesian head produced in the extensive alluvial deposits to the east or possibly from deeper sources. The general character of the alluvial slope and the positions of the Manse and Pahrump ranches with respect to them are shown in Plate IX, *A*, a view looking northward along the east side of the valley. Evidence that the water comes from a deep source is furnished by the temperature of the springs—75° F. at Manse and 76½° F. at Pahrump, as compared with that of Intermittent Spring—57° F. The uniform flow of the Pahrump and Manse springs, contrasted with the varying flow of Intermittent Spring and the other mountain springs, also indicates that the mountain springs and the valley springs are supplied in different ways.

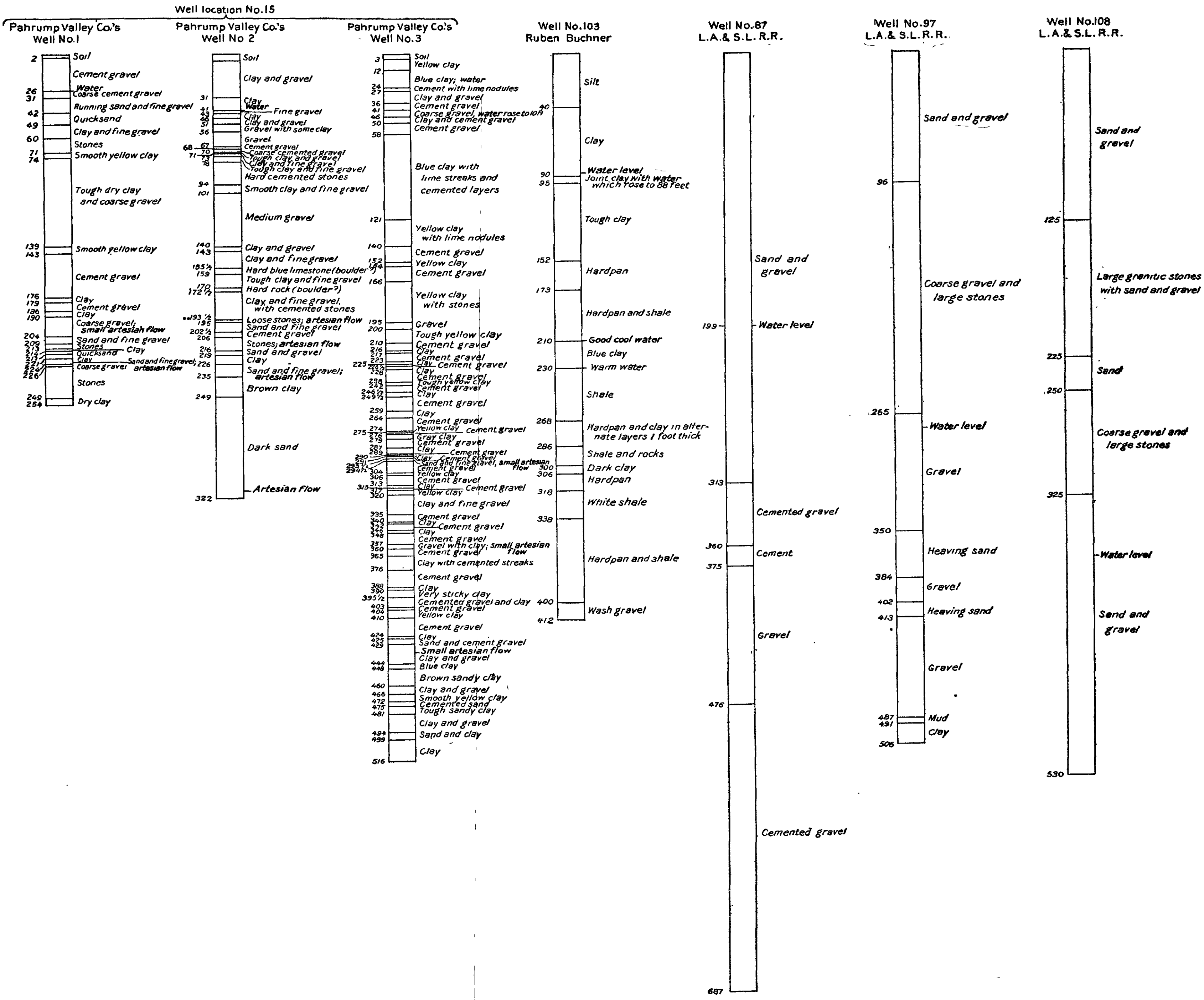
ARTESIAN WATER.

Besides the springs in Pahrump Valley that seem to give evidence of artesian conditions, there are several wells that yield artesian flows. (See table below.) Three wells on the Pahrump ranch have been drilled 200 or 300 yards apart, and the easternmost is 225 yards west of the main spring at this ranch. The records of these wells, presented through the courtesy of Mr. T. G. Darrough, manager of the ranch, are shown graphically in the left-hand portion of Plate XI. The artesian flows seem to have been obtained at several horizons below a depth of 200 feet, from layers of sand or gravel beneath relatively impervious beds of clay or cement gravel. The wells have the following flows, according to measurements with current meter made September 30, 1916, by Albert Quill, of the United States Geological Survey:

Flows of artesian wells on Pahrump ranch.

Well No.	Flow.		Temperature (°F.).
	Second-feet.	Gallons per minute.	
1	1.25	560	78½
2	.64	287	75
3	.62	278	74

J. M. Raycraft has three flowing wells, each 10 inches in diameter and about 175 feet deep, at his home (locality No. 12, Pl. VIII) on a low mound of wind-blown sand half a mile northwest of Pahrump. The wells flow about 35, 35, and 260 gallons a minute



SECTIONS OF WELLS IN PAHRUMP AND IVANPAH VALLEYS, NEV.-CALIF.

(according to measurements by the writer), and the water from each well has a temperature of 79° F. A quarter of a mile to the southeast a fourth well (No. 13) encountered flowing water at a depth of 285 feet; the discharge as measured by the writer was about 65 gallons a minute and the temperature 79° F. The following partial record of materials encountered in drilling this well was kindly furnished by Mr. Raycraft:

Record of J. M. Raycraft well (No. 13), Pahrump, Nev.

	Thickness.	Depth.
	Feet.	*Feet.*
Unrecorded	82	82
Hard limestone	3	85
Clay	5	90
Coarse cement gravel	3	93
Clay	43	136
Cement gravel	3	139
Unrecorded	147	286
Hard blue limestone (bedrock)	36	322

A fifth flowing well (No. 16), belonging to Mr. Raycraft, is said to have a somewhat larger flow than well No. 13.

F. A. Buol has also obtained flows near his house (at well locality No. 11) in five wells reported to be 150 to 520 feet deep, but detailed information concerning these wells was not obtained.

In the vicinity of Mound Spring several test wells were drilled during 1914–1916 by the Oasis Land Co. Water under artesian pressure was encountered in all of them, and in two (Nos. 32 and 33) small flows were obtained. Well No. 32 was sunk to a depth of 135 feet a few yards from Mound Spring, and in August, 1916, the water rose 15 feet above the surface. In well No. 33 flows were struck at depths of about 200 and 390 feet but were lost in gravel at 535 feet. After the well was filled to about 475 feet below the surface a slight flow was again developed. In August, 1916, the flow was about 1 gallon a minute, with a temperature of 72° F. It is said that in the Spanker wells (Nos. 40 and 41), 3 miles southwest of Mound Spring, water from the lower strata did not rise higher than 65 feet below the surface, and that the first water, struck at 23 feet, flowed down the well to the 65-foot level. J. B. Yount has sunk a well (No. 44) on his ranch, 7 miles southeast of Mound Spring, to a depth of 320 feet. A flow was not obtained, but at 225 feet water was struck in fine sand beneath clay under pressure that caused it to rise within 6 feet of the surface.

The great alluvial slopes that extend east and southeast of Yount's ranch probably contain water under considerable artesian head, and the lower portions of these slopes offer favorable conditions for obtaining artesian flow. It is possible that flows can also be developed in the lower part of Pahrump Valley, but the fact that the artesian springs and the artesian wells drilled up to August, 1916, are all more than 2,650 feet above sea level suggests that the artesian water may be shut off from the strata beneath the lower lands by the fine and relatively impervious sediments deposited in the lowest part of the valley.

WATER TABLE.

In Stewart Valley, which forms the lowest part of the Pahrump drainage basin, water is present at less than 10 feet beneath the surface and has caused the growth of salt grass. The water table around its borders fluctuates somewhat with the season and is highest in the spring, when the valley receives some surface water. The seasonal change is sufficient, so that shallow wells at localities 8 and 9 (Pl. VIII), which have at times served as watering places, were dry in August, 1916. At the south end of the valley, in well No. 25, dug close to the drainage channel leading to the central depression, the water stood 38 feet below the surface. Farther up the same drainage course water stood about 6 feet below the surface at Sixmile Spring in a pit in a low sandy mound. In the flowing wells drilled at and near Pahrump water was struck at 20 to 30 feet below the surface. In well No. 26, about 4 miles south of Pahrump, water was struck at 32 feet, and in wells Nos. 28, 40, and 41, 4 to 6 miles farther south, at 23 feet. In several wells near Mound Spring water was struck at 28 to 39 feet. The water, therefore, seems to be within 40 feet of the surface throughout a large part of Pahrump Valley. The quantity of ground water recoverable from shallow wells appears to be rather small, however, as the water is obtained in fine sand and silt that do not readily furnish a pumping supply.

A well dug about 5 miles southeast of Mound Spring is said to have struck water at a depth of 97 feet. No other information concerning the depth to water beneath the higher slopes was obtained. The reported depth in this single well, however, indicates that on the east side of the valley the water table slopes upward at a gradient that makes the increase in depth to water about 25 feet with each 100 feet of rise in the elevation of the surface.

The data obtained in regard to wells in this valley are tabulated on pages 76–79.

QUALITY OF WATER.

Samples of water for analysis were collected in the Pahrump basin from two springs (Nos. 22, 29, Pl. VIII), one flowing well (No. 15, 254-foot well on Pahrump ranch), and two shallow wells (Nos. 25, 45). (See table, p. 80.) The waters are on the whole better than those from the Mesquite or Ivanpah basins, the highest total solids being only 537 parts per million. The waters from the two springs are the best. Although the conditions governing the occurrence of these two springs are apparently different, the waters are of approximately the same mineralization, differing in total solids by only 17 parts per million, and both are of the same character. No. 22 contains only 4.3 parts per million of sodium and potassium, and No. 29 contains only a trace of these elements. The samples from wells Nos. 15 and 45 are similar to the spring waters in that they are calcium-carbonate in character, but they contain somewhat more mineral matter. The most highly mineralized water analyzed from the Pahrump basin (from the Buchanan well, No. 25) contains 537 parts per million of total solids and is of the sodium-carbonate type. The greater mineralization and high sodium content of this water are probably due to the location of the well, which is in almost the lowest part of the basin, close to a channel that carries the drainage from a playa south of Sixmile Spring into the lowest part of Stewart Valley.

All the waters are of fair quality for domestic use. They can be used without difficulty for cooking and drinking but are somewhat unsatisfactory for washing on account of their rather high hardness. All the waters except that from the Buchanan well (No. 25) are classed as fair for boiler use, although the scale-forming constituents are in excess of the amounts ordinarily considered to be allowable in a fair water, according to the rating in the table on page 80. Such a classification was made because the amounts of foaming constituents are so far within the limits for a good water. The waters could be improved by proper chemical treatment for the reduction of the scale-forming constituents. The water from the Buchanan well is of poor quality for boiler use because, in addition to the large amount of scale-forming constituents, the foaming ingredients are also high. All the waters except that from the Buchanan well are good for irrigation, and even that water can be used with good results if proper care is observed. This well is used very seldom, and it is possible that the quality of the water might be improved by regular pumping.

From the analyses it seems probable that waters fair for domestic and boiler use and good for irrigation can be obtained throughout most of Pahrump Valley. In the lowest parts of the valley, especially near the playas, there may be some highly mineralized waters.

IRRIGATION.

Within recent years farming has been attempted in each of the three valleys under consideration, but success has been obtained only where irrigation is practiced. Experiments have fully demonstrated that the rainfall is too slight and uncertain and the dry periods are too long and hot to allow the successful growing of crops by dry farming.

In Pahrump Valley farming has been carried on for many years at the Manse and Pahrump ranches by irrigation from the large springs at these places. In 1916 about 300 acres on the Manse ranch was under cultivation, 80 acres in alfalfa, 10 acres in vineyard and mixed orchard, and most of the remainder in grain. On the Pahrump ranch, by means of the spring water and that from three flowing wells, about 10 acres of orchard, 90 acres of alfalfa, and 125 acres of barley were irrigated, and in 1916 a considerable acreage of new land was being cleared and leveled, preparatory to planting to alfalfa. Northwest of the Pahrump ranch J. M. Raycraft and F. A. Buol had under cultivation lands that were irrigated by flowing wells. At Lee's ranch, in Trout Canyon, a few acres of alfalfa and vegetables were irrigated by the mountain stream, and at Yount's ranch a garden was supplied with water by windmills pumping from shallow wells. An attempt at farming in Stewart Valley had failed, probably because of the alkalinity of the soil as much as because of the lack of an irrigation supply. The Oasis Land Co. was preparing to develop a Carey Act project involving several thousand acres in the neighborhood of Mound Spring by irrigation water from Lee's Spring and Intermittent Spring, augmented by wells. The lands in the lowest part of the valley, from the "dry lake" west of Yount's ranch to Stewart Valley, are too poorly drained and too liable to become alkaline to be suitable for farming. The lower slopes along the east side of the valley, however, are probably capable of successful cultivation at those places where ground water can be developed for irrigation either in flowing wells or in wells with low pumping lift. The ground water obtained in the valley is generally of suitable quality for agriculture except in the lowest parts, near the "dry lakes."

MESQUITE VALLEY.

SPRINGS.

The only springs reported in the Mesquite drainage basin are Keystone Spring, near the northeast border, and a spring near the Potosi mine, in the north corner of the basin. Neither was visited by the writer, but J. E. Blackburn, who mapped the region in 1909–10, estimated their flow as, respectively, about 15 and 40 barrels a day. The spring near the Potosi mine has since been developed, so that in 1916 it supplied considerable water for the mining settlement.

WATER TABLE.

The depth to water in tne central part of Mesquite Valley was tested in 1910–1914 by a number of wells drilled or dug by entrymen on desert and homestead claims. The locations of the wells that were observed are shown on Plate VIII, and data as to their depth and the depth to water in them are tabulated on pages 76–79. In August, 1916, the depth to water in these wells ranged from 4 feet in pits in Mesquite Lake to 52 feet in Bullock's well, at the southeast border of the lowland; 52 feet at Sandy, in the northeast; and 67 feet in well No. 54, in the northwest. Well No. 51, drilled prior to 1910 in the northern part of the valley to furnish a water supply near the old traction road, extending from the borax deposits near Death Valley to the railroad, was dry at a total depth of 82 feet; but it is said to have formerly contained water at a depth of about 90 feet. The water table beneath the central and northern parts of the valley, along its axis, therefore seems to be fairly flat, as shown in figure 5, with a slope of only 5 or 6 feet to the mile. From northeast to southwest, across the valley, the slope of the

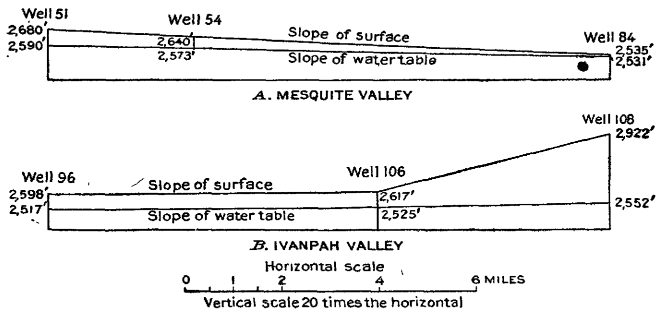


FIGURE 5.—Diagram showing slopes of surface and of water table in Mesquite and Ivanpah valleys, Calif. The Mesquite Valley section extends from northwest to southeast between wells 51 and 84 of Plate VIII; the Ivanpah Valley section extends from north-northwest to south-southeast between wells 96 and 108.

water table is somewhat greater, the available records of surface elevation and of depth to water indicating a rise of the water table toward the northwest of 10 or 12 feet to the mile.

QUALITY OF WATER.

Samples of water from six wells in Mesquite Valley (Nos. 58, 64, 72, 74, 76, and 86, Pl. VIII) were analyzed. (See table opposite p. 80.) All these waters are or have been used for domestic supply, although three of them contain more than 600 parts per million of solids in solution and have a distinctly mineralized taste. Only two of the six waters are better than the most highly mineralized water in the Pahrump basin. The character of the water apparently varies much more from place to place in Mesquite Valley than in Pahrump Valley.

The water from well No. 58, which is the least mineralized of those sampled in Mesquite Valley, is magnesium-carbonate in character. The waters from the Cryor well (No. 76) and the old Sandy

Mill well (No. 74) are like that from No. 58, in that they are carbonate waters, but in them calcium predominates over the magnesium. The Sandy Mill water, however, is more highly mineralized than the other two. These three waters are all classed as good for irrigation. They are so hard that they may be unsatisfactory for cooking and washing, but for drinking and other ordinary household purposes they are probably quite satisfactory. The waters from wells Nos. 58 and 76 are classed as only fair for boiler use because of the amount of scale-forming constituents present, and No. 74 is classed as poor because of its higher content of scale-forming constituents.

The water from the W. A. Tritt well (No. 64) is magnesium-sulphate in character. It is poor for domestic use because of its excessive hardness and bad for boiler use because of its tendency to corrode boilers—a condition, however, which could be corrected by the addition of the calculated amount of lime water. It is satisfactory for irrigation, although it contains more sodium than the waters previously described.

At locality No. 72 there were in 1916 two shallow dug wells a few yards apart, each of which was surmounted by a windmill that pumped to a cattle trough. One of these wells or a similar one was formerly known as Cub Lee Spring. The analysis shows that the water is sodium-carbonate in character. It is classed as fair for domestic use and irrigation but is bad for boiler use because of the large amount of scale-forming and foaming constituents. This water contains a greater amount of chloride than any of the waters described above. The water is probably contaminated to some extent by seepage from the mud trampled by cattle around the troughs, and the chloride content may for this reason be higher than is normal in ground water of this vicinity. An even higher chloride content, however, is found in Bullock's well (No. 86), sometimes known as Knight's well. This well was dug a number of years ago at the base of the desert wash slopes, at the southeast edge of the lowland. It has long furnished water for mines in the mountains to the northeast and for teams and autotrucks hauling ore to the railroad at Roach. The water is distinctly salty in taste, and the analysis shows that of its total content of 1,445 parts of mineral matter, 551 parts, or more than one-third, consists of the chloride radicle. The principal basic radicle is sodium. Although the water is of poor quality it is freely used for drinking and cooking because of the lack of a better supply. It is very bad for boiler use because of the high amount of foaming constituents. It is also poor for irrigation.

The two wells which have the highest chloride content are in the south end of the valley, not far from the salt-incrusted playa known as Mesquite Lake, suggesting that the ground water has become concentrated in this part of the valley by continual evaporation. On the other hand, the least mineralized waters in the basin, according to the analyses, are at the north end and on the sides of the valley some distance from Mesquite Lake.

IRRIGATION.

In 1910 to 1914 numerous homestead and desert entries were filed on land in the northern part of Mesquite Valley, and a number of wells were drilled and pumping plants established. Attempts to irrigate on an extensive scale proved unsuccessful, however, owing largely to the poor quality of the soil. In 1916 there were only two small irrigated tracts in the valley, those of W. A. Tritt and J. B. Cryor. At the Tritt ranch (locality No. 64, Pl. VIII) water was pumped from a dug well by a windmill and used to irrigate a small garden with indifferent success. As is shown by the analysis (opposite p. 80), the water is of good quality for irrigation. Any failure to produce crops was therefore due to the nature of the soil or other causes, rather than to the water. On the Cryor ranch, at Ripley, a few acres of alfalfa and garden were supplied by windmill, and the crops made a good growth under careful irrigation. The water here also is of good quality, as shown by the analysis of well No. 76. It is probable that other areas could be successfully irrigated along the eastern sandy slopes of the valley. The greater part of the shallow-water area in Mesquite Valley, however, is probably too alkaline or too clayey to permit its successful cultivation.

IVANPAH VALLEY.

WELLS, SPRINGS, AND INFILTRATION TUNNELS.

In the mountains that border the Ivanpah Valley there are a number of small but perennial springs that furnish reliable water supplies to prospectors and others. About 20 of these springs are shown on Plate VIII, and data furnished by S. G. Lunde, topographer, of the United States Geological Survey, concerning their yields, have been inserted in the records on pages 76–79. None of these springs yield much water, and some of them have no appreciable overflow during the dry months. Mescal Spring (No. 94) is said, however, to have furnished water for a small stamp mill at the Mollusk mine.

A small spring (No. 114) in the bed of a canyon has furnished water for prospectors in its immediate vicinity, and in 1916 water was also piped from it to the home of P. S. Banfield, three-quarters of a mile east of Brant, for domestic supply.

"Cut Spring" and "White Rock Spring" (Nos. 111 and 112) are small infiltration tunnels driven into the mountain side, and the seeping water collects in pools, from which it is hauled to Cima for domestic supply. At Kessler Spring (No. 113) water has been developed by a pit excavated about 10 feet deep in a dry wash and curbed and roofed with boards. From the bottom of the pit a pipe extends down the wash for several rods, so that a gravity flow is obtained at cattle troughs and at a faucet for domestic and travelers' supplies. Water supplies have been obtained at other places in washes at high levels in shallow wells like that of Kessler Spring, but so far as was learned gravity flows have not been developed elsewhere in this region by piping. The Mexican well (No. 93) is reported to be only 5 feet deep and usually to contain about 3 feet of water. When visited by D. G. Thompson late in 1917 it was tightly covered and equipped with a force pump. Water was hauled from the well to the Mohawk mining camp, 4½ miles west of the well, and was also used in considerable quantities by teams hauling ore from this camp to Roach. The supply is apparently very good. Water has been developed by somewhat deeper wells dug in the gravelly wash at Crescent (No. 104). The mining camp of Good Springs (No. 63) received its name from springs that formerly flowed in considerable volume, but it is said that of late years water is obtained chiefly from wells about 30 feet deep, dug in the gravel wash.

At Borax siding, 4 miles south of Jean, a well (No. 87, Pl. VIII) was drilled in 1905 by the Los Angeles & Salt Lake Railroad Co. to a depth of 687 feet. The record, kindly furnished by the company and reproduced graphically in Plate XI (p. 64), shows that only relatively coarse, unconsolidated materials were encountered. Water stood in the well 199 feet below the surface in 1905. The pumping station was dismantled in 1914, as the pumping station near Ivanpah served the railroad needs.

At Roach a test well, drilled by George Morgan, struck water at 91 feet. The water is said to be of fair quality, but the settlement is supplied with water brought by train from Las Vegas, as is also the town of Jean.

An abandoned dug well (No. 89) 2½ miles southwest of Roach and the Francis well (No. 102), dug more than 20 years ago on the west side of Ivanpah Valley, near the traction road, both contained water in August, 1916, at a depth of 90 feet below the surface.

The Yates well (No. 96) and the Murphy well (No. 106) were dug a number of years ago for cattle watering places. They are situated, respectively, at the west edge of Ivanpah Lake and at the south edge of the flat land bordering the "dry lake." They were abandoned some time prior to 1916, but the Murphy well was again used in 1917 for watering cattle. In August, 1916, the Yates well contained water at 81 feet and the Murphy well at 92 feet. Several wells drilled in 1914–1916 between the Murphy and Yates wells encountered water at practically the same level as in these wells. On the extensive alluvial slope in the southern part of the Ivanpah basin a well of the Los Angeles & Salt Lake Railroad supplies water to a reservoir near Ivanpah, for locomotive use. The reported depth to water in this well—370 feet—indicates that the water table beneath the valley is unusually flat, as is illustrated in figure 5 (p. 69). The rise of the water table southward from the Murphy well to the railroad well is only 5 feet to the mile, whereas the rise in elevation of the surface is 61 feet to the mile. From east to west across the valley the water table also seems to be nearly horizontal; for at Lyon station, 2,800 feet above sea level, the depth to water is reported to be 275 feet, the elevation of the water table therefore being 2,525 feet, or only 8 feet above the elevation of the water surface in the Yates well. The flatness of the water table indicates that the desert wash is fairly coarse and permeable throughout, so that water does not collect in porous sands and gravels between layers of relatively impermeable clay. In the wells that have been drilled, it is reported, water was encountered under little or no artesian pressure.

In many of the basins of the Southwest that have no outlets for surface water the supply of ground water received from precipitation is about balanced by losses through springs and evaporation from lakes or from the soil where the water is close to the surface. This condition is present in Pahrump and Mesquite valleys, where moist lands are found respectively in Stewart Valley and in Mesquite Lake. Beneath the lowest portions of Ivanpah Valley, however, the depth to water is about 80 feet, and it seems impossible that evaporation keeps the water table down to so great a depth below the surface. The water table from east to west across the valley is shown by the depth to water in wells Nos. 96 and 97 to be nearly horizontal. Toward the south the water table (see fig. 5) slopes gently upward. The elevation above sea level of the water table in Ivanpah Valley is about 2,515 feet and in Mesquite Lake about 2,531 feet, so that there would seem to be no underground escape northward. It is possible that leakage sufficient to balance the relatively small annual ground-water intake and keep the water table down to about 80 feet below the surface takes place along fault fractures extending northeastward toward Las Vegas Valley.

QUALITY OF WATER.

Samples of water from two springs (Nos. 111 and 113, Pl. VIII) and six wells (Nos. 89, 93, 96, 103, 106, and 108) in the Ivanpah basin were analyzed. (See table opposite p. 80.) One analysis furnished by the Los Angeles & Salt Lake Railroad (well No. 97) has been included in the table. The analyses show great extremes in the degree of mineralization of the waters in the valley, one sample (No. 108), which is the best water analyzed from the three valleys described in this report, having only 240 parts per million of total dissolved solids. Another water (No. 89) contains more than 100 times as much. Four of the nine waters are of good or fair quality for domestic, boiler, and irrigation use.

The waters from three wells in the southern part of the basin (Nos. 103, 106, and 108) are relatively low in total solids. Of these the water from the railroad well (No. 108) on the alluvial slope some distance above Ivanpah Lake contains only 240 parts per million, and the waters from the other two wells, which are much nearer the clay flat, are higher in total solids, containing 372 and 335 parts. The water from the railroad well is a sodium-sulphate water and the other two are sodium-carbonate waters. All three waters are classed as good for domestic use. The water from the railroad well, which is regularly used for locomotives, is classed as good for boilers. The other two are classed as only fair for boiler use on account of their content of foaming constituents. The water from the Murphy well (No. 106) will also form considerable scale. The waters from the railroad and Murphy wells are good for irrigation, but that from well No. 103 is only fair.

According to analyses of samples from wells Nos. 89 and 96, the water farther north, in the lowest part of the valley, is much poorer; in fact, it is practically unfit for any use. These wells are dug only a few feet below the ground-water level. It is said that they furnished water of fair quality when they were used regularly. They had been abandoned for some time prior to August, 1916, and at that time contained waters that were practically brines, one (No. 96) containing 7,702 parts per million of total solids and the other (No. 89) containing the unusually high amount of 27,501 parts per million. Both waters taste salty. It is said that in digging the Yates well (No. 96) salty water was first struck, but better water was obtained a few feet deeper. It is probable that in each well the water has become concentrated on standing unused. Both waters are sodium-chloride in character, and both are unfit for domestic, boiler, or irrigation use. A water from a well drilled by the Los Angeles & Salt Lake Railroad Co. at Lyons (Desert station) (No. 97), almost due east of Yates, according to an analysis furnished by the railroad company, is of much better quality, containing only 433 parts per million of total solids. It is sodium-chloride in character. This well is some distance up the alluvial slope away from the clay flat. The water is classed as good for domestic purposes, bad for boiler use, and fair for irrigation.

The remaining sources from which samples were analyzed, Nos. 93, 111, and 113, are all in the mountainous parts of the Ivanpah basin. Each of the three waters is a carbonate water. Two of them, from Cut Spring (No. 111) and Kessler Spring (No. 113), are calcium-carbonate waters. They are both classed as only fair for domestic use because of their hardness; they will probably require a considerable amount of soap in washing, but are good for drinking and other household purposes. The water from Cut Spring is hauled to Cima for domestic use. The waters from both Cut Spring and Kessler Spring are good for irrigation.

The water from Mexican well (No. 93) is sodium-carbonate in character and is considerably higher in total solids than the other two. It is good for irrigation but poor for boiler use because of its large amount of scale-forming and foaming constituents and poor for washing because of its high hardness. This water is used considerably by travelers, and despite its hardness it can probably be used for drinking and other ordinary household uses without any bad effects.

Although analysis shows two waters from the Ivanpah basin to be very highly mineralized, it is believed that throughout the greater part of the region water of good or fair quality for both domestic purposes and irrigation is available. The two saline waters were obtained from wells in the lowest part of the basin, at the edge of the playa. The high mineralization of these waters may be due to concentrated surface waters running into the wells or to salt derived from the clay of the playa. The water from wells on the alluvial slopes, some distance from the clay flat, is generally of good quality.

IRRIGATION.

During the three years prior to 1916 several wells were drilled in the lowlands south of Ivanpah Lake and a few attempts at irrigation were made, but these attempts proved unsuccessful on account of the clayey character of the soil. On the higher land, near Cima and Brant, gardens have been grown with water from springs, but the available supply from such sources is insignificant. Farming other than the cultivation of small gardens probably can not be successfully carried on in any part of Ivanpah Valley because of the lack of available water. Irrigation by means of wells is not feasible, because of the excessive pumping lift involved, and because water is not found in great enough quantity. In January, 1918, it was stated that the Murphy well (No. 106) could be pumped dry in about four hours at a rate of about 20 gallons a minute. This amount of water was derived from a 12-foot tunnel at the bottom of the well, which is in adobe. The water does not filter in rapidly enough to meet the ordinary requirements of irrigation. The soil in the lowest part of the valley, where the pumping lift is the least, is too clayey and too alkaline for successful cultivation. There is no stream water available, and apparently no suitable locations for storage reservoirs nor sufficient flood water to be of value if it could be stored.

In the later part of 1917 and the early part of 1918 no one was attempting farming in the Ivanpah Valley, and the valley had been practically abandoned as an agricultural project. The Rock Springs Cattle Co. had improved the Murphy well (No. 106) and was using it to water about 200 head of cattle. The number of cattle that may be kept in the valley is largely limited by the available supply of wild grass, as the conditions of water supply and soil will not permit the cultivation of grazing crops.

RECORDS OF WELLS AND SPRINGS.

Most of the wells and springs listed in the following pages have been mentioned in the text. The available data concerning all those whose locations are shown on Plate VIII are here brought together in tabular form for easy reference in connection with the map.

Records of wells and springs in Pahrump, Mesquite, and Ivanpah valleys, Nev.-Calif.

[For analyses of water see table opposite p. 80.]

No. on Plate VIII.	Location.[a]			Owner of well or name of spring.	Depth of well.	Depth to water in well August, 1916.	Remarks.
	Township.	Range.	Section.				
					Feet.	Feet.	
1	17 S.	53 E.	23	Spring			
2	17 S.	53 E.	27	Horseshutem Spring			Good water; yields 200 barrels a day.
3	17 S.	53 E.	36	Crystal Spring			
4	18 S.	54 E.	6	Rainbow Spring			Good water; yields 45 barrels a day.
5	18 S.	55 E.	19	Wheeler well			Yields several barrels a day.
6	19 S.	54 E.	14, 23	Horse Springs			Yields a few barrels a day.
7	19 S.	55 E.	3	Buck Spring			Do.
8	20 S.	52 E.	6	Formerly a spring	8	Dry.	
9	20 S.	52 E.	7	.....do	6	Dry.	
10	20 S.	52 E.	1	Sixmile Spring		6	
11	20 S.	53 E.	15	F. A. Buol	150 150 160 300 520	Flow.	Five wells reported.
12	20 S.	53 E.	15	J. M. Raycraft	170	Flow.	Three 10-inch wells; flow struck at 156 feet; flows of about 35, 35, and 260 gallons a minute. Also spring flowing about 10 gallons a minute.
13	20 S.	53 E.	14	.....do	322	Flow.	Drilled well; 30 feet to ground water; flow at 285 feet.
14	20 S.	53 E.	14	Pahrump Valley Co. (springs).			See discharge measurements (p. 63).
15	20 S.	53 E.	14	Pahrump Valley Co.	254 322 516	Flow.	Three wells. See records (fig. 5), discharge measurements (p. 64), and analysis of 254-foot well.
16	20 S.	53 E.	22	J. M. Raycraft	520	Flows.	
17	20 S.	55 E.	2	Spring			

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

Records of wells and springs in Pahrump, Mesquite, and Ivanpah valleys, Nev.-Calif.—Continued.

No. on Plate VIII.	Location. Town-ship.	Range.	Sec-tion.	Owner of well or name of spring.	Depth of well.	Depth to water in well August, 1916.	Remarks.
					Feet.	*Feet.*	
18	20 S.	56 E.	5	Lees Spring			Good water. See discharge measurements (p. 61).
19	20 S.	56 E.	3	Spring			
20	20 S.	56 E.	15	Trout Spring			Good water; flows 100 barrels a day. See discharge measurements (p. 62).
21	20 S.	56 E.	29	Spring			Slight flow.
22	20 S.	56 E.	31	Intermittent Spring			See discharge record (p. 62) and analysis.
23	20 S.	56 E.	31	Spring			Good water; yields 4 barrels a day.
24	20 S.	57 E.	27	....do			Yields 50 barrels a day.
25	24 N.	8 E.	28	B. P. Buchanan	40	38	See analysis.
26	21 S.	53 E.	1	Oasis Land Co	416	32	
27	21 S.	53 E.	23	Spring			Flow about 1 quart a minute to cattle trough.
28	21 S.	53 E.	25	Oasis Land Co	210	23	
29	21 S.	54 E.	3	Hoffman & Vetter (Manse Springs).			Discharge, 2¾ second-feet. See analysis (smaller spring).
30	21 S.	54 E.	22	Spring			Has summer flow of ½ gallon a minute at 69° F.; unused.
31	21 S.	54 E.	28	Oasis Land Co	163	23	Water struck at 39 feet, rose to 23 feet; drilling in August, 1916.
32	21 S.	54 E.	28	....do	135	Flows.	Ground water at 35 feet. At Mound Spring.
33	21 S.	54 E.	28	....do	535	Flows.	Ground water at 28 feet; flow 1 gallon a minute at 72° F.
34	21 S.	54 E.	28	....do	230	Nearly at surface.	Water struck at about 20 feet, rose nearly to surface.
35	21 S.	54 E.	28	....do	165	14	
36	21 S.	56 E.	19	Spring			Is source of Pahrump Valley creek.
37	21 S.	56 E.	19	....do			Flow in August, 1916, 0.63 second-feet.
38	21 S.	57 E.	5	Coal Spring			
39	21 S.	57 E.	7	Roses Spring			Reported flow of more than 10 miner's inches.
40	22 S.	54 E.	6	—— Spanker	165 165	23 23	Two drilled wells.
41	22 S.	54 E.	6	....do	35	23	Test well; pumping test of 15 miner's inches for 3 hours.
42	22 S.	54 E.	14	Spring			Fair water; yields 10 barrels a day.
43	22 S.	54 E.	27	....do			Fair water; yields 15 barrels a day.
44	22 S.	55 E.	30	J. B. Yount	320	6	Test well. All clay except quicksand at 225-230 feet, with water under pressure.
45	22 S.	55 E.	30	....do	10-15	7-10	Three wells and windmills. See Pl. X, *C*, and analysis of easternmost well.
46	22 S.	57 E.	15	Mule Spring			Good water; yields 15 barrels a day.
47	22 S.	58 E.	20	Mountain Spring			Good water; yields 20 barrels a day.
48	21 N.	10 E.	16	Dry well			
49	23 S.	55 E.	5	Stump Spring			Fair water; yields 20 barrels a day.
50	23 S.	57 E.	1	Potosi mine spring			Good water; yields 40 barrels a day.
51	20 N.	12 E.	30	R. M. Pettis	82	Dry.	
52	20 N.	12 E.	28	R. W. Barry	67	66	Dug; 0.50 foot, red-brown calcareous clay; 50-67 feet, white clay.
53	20 N.	12 E.	33	O. S. Erickson	57	Dry.	Dug in wash; clay.
54	20 N.	12 E.	33	Mike Ryman	71+	67	Centrifugal-pump pit, 71 feet deep; drilled well in bottom.
55	20 N.	12 E.	33	O. S. Erickson	[a]1,083	56	Water struck at 135 feet, rose to 56 feet; at oil-well rig.
56	20 N.	12 E.	34	G. W. Mitchell	41	40	Dug test well.
57	20 N.	12 E.	34	....do	37	Dry.	Do.

[a] Reported.

Records of wells and springs in Pahrump, Mesquite, and Ivanpah valleys, Nev.-Calif.—Continued.

No. on Plate VIII.	Location.			Owner of well or name of spring.	Depth of well.	Depth to water in well August, 1916.	Remarks.
	Town-ship.	Range.	Sec-tion.				
					Feet.	*Feet.*	
58	20 N.	12 E.	34	Charles Heidecke	41	38	Dug. See analysis.
59	20 N.	12 E.	34	....do	37	36	Dug; test well.
60	20 N.	12 E.	35	C. M. Gay	39	38	Do.
61	24 S.	57 E.	31		500	58	Two drilled wells, 12 feet apart; good supply reported at 135 feet.
62	24 S.	58 E.	6	Keystone Spring			Good water; yields 15 barrels a day.
63	24 S.	58 E.	25	Good springs	30±		Formerly flowing springs; now shallow wells.
64	19 N.	12 E.	2	W. A. Tritt	29	27	Dug; windmill; domestic use. See analysis.
65	19 N.	12 E.	10	J. H. Pate	43	Dry.	Dug.
66	19 N.	12 E.	11	J. H. Burke	30	29	Dug; test well.
67	19 N.	12 E.	11	....do	28	27	Dug; centrifugal pump.
68	19 N.	12 E.	12	C. M. Hill	18	Dry.	Dug; test well.
69	19 N.	12 E.	9		55	54	Dug.
70	19 N.	12 E.	14	C. A. Burke		28	12 inch, drilled.
71	19 N.	12 E.	13	H. A. Hoffman (Osborn well).	17	Dry.	Caved; 12-inch casing.
72	19 N.	13 E.	19	J. B. Yount	11	8	Two dug wells and windmills; cattle watering. See analysis (west well).
73	19 N.	13 E.	20	Roses well	6	Dry.	
74	25 S.	57 E.	5	Old Sandy Mill well	56	52	Dug; windmill, tank, and watering trough. See analysis.
75	25 S.	57 E.	5		50	48	Dug; small engine and pump in center of Platina.
76	25 S.	57 E.	5	J. B. Cryor	50	48	Dug; windmill. See analysis.
77	25 S.	57 E.	4	Boss mine	65	58	Dug; mine supply.
78	25 S.	57 E.	9		36	35	Dug; test well.
79	25 S.	57 E.	17		25	Dry.	Dug.
80	25 S.	57 E.	22		23	22	Dug; test well.
81	25 S.	57 E.	26		8	8	Do.
82	25 S.	57 E.	26			2	Pits dug by Indians at base of sand ridges.
83	25 S.	57 E.	36		42	Dry.	Dug.
84	18 N.	13 E.	5			4	Brine; in pits at old salt works.
85	18 N.	13 E.	8		15	12	Dug; at abandoned adobe house.
86	18 N.	13 E.	12	Bullock's well	56	52	Dug; hand pump; supply for prospectors and for Milford mine. See analysis.
87	26 S.	59 E.	2	Los Angeles & Salt Lake R. R.	687	199	At Borax siding. Abandoned, 14-inch well.
88	26 S.	59 E.	34	George Morgan	91	91	Drilled; test well; clay, to fine sand with fair water at bottom.
89	27 S.	59 E.	8	Old "Borax Team" well.	92	90	Dug; unused. See analysis.
90	27 S.	61 E.	7	Railroad Spring			Fair water; yields 20 barrels a day.
91	17 N?	13 E?	23, 24?, 25	Springs			Slight flows; in unsurveyed township.
92	17 N?	13 E?	35?	....do			Do.
93	16 N.	13 E.		Mexican well	5	2	In sandy wash; good supply. See analysis.
94	16 N?	13 E?	13?	Mescal Spring			Yields 200 barrels a day.
95	16 N.	14 E.	31	Roseberry Spring			Yields about 10 barrels a day.
96	16 N.	15 E.	6	S. E. Yates	91	81	Dug; unused. See analysis.
97	16 N.	15 E.	12	Los Angeles & Salt Lake R. R.	506	275	See record (fig. 5) and analysis.
98	16 N.	15 E.	17	Roy White	88	77	12-inch drilled well.
99	16 N.	15 E.	21	A. Dixon	120	79	Do.
100	16 N.	15 E.	33	A. E. Weaber	120	87	Do.
101	16 N.	15 E.	33	Chris. Mattly	120 120	82½ 84	Two wells; 12-inch, drilled.
102	16 N.	15 E.	32	San Francis	92	90	Dug; good water.
103	16 N.	15 E.	33	Ruben Buchner	412	88	See record (fig. 5) and analysis.

Records of wells and springs in Pahrump, Mesquite, and Ivanpah valleys, Nev.-Calif.—Continued.

No. on Plate VIII.	Location.			Owner of well or name of spring.	Depth of well.	Depth to water in well August, 1916.	Remarks.
	Town-ship.	Range.	Sec-tion.				
					Feet.	*Feet.*	
104	28 S.	61 E.	8	At Crescent, wells 30+			Shallow dug wells in wash.
105	28 S.	61 E.	10	Water hole			Fair water; yields 15 barrels a day.
106	15½ N.	15 E.	3	Murphy well	116	92	Dug; walled with 3-foot tile casing with 12-foot cross-cut at bottom; cement lined. Can be pumped dry in 4 hours at rate of 20 gallons a minute. On Oct. 26, 1917, the depth to water was 100 feet. See analysis.
107	15 N.	14 E.	2	Mineral Spring			Fair water.
108	15 N.	15 E.	13	Los Angeles & Salt Lake R. R.	530	370	See record (fig. 5) aud analysis.
109	15 N.	16 E.	36	Willow Spring			Good water; yields 50 barrels a day.
110	15 N.	17 E.	19	Dovė Spring			Do.
111	14 N.	13 E.	23	Cut Spring			Yields 50 barrels a day. See analysis.
112	14 N.	13 E.	25	White Rock Spring			Yields 40 barrels a day.
113	14 N.	14 E.	18	Kessler Spring			Yields 100 barrels a day See analysis.
114	14 N.	15 E.	23	Spring			
115	14 N.	15 E.	28	Cottonwood Spring			
116	14 N.	15 E.	27	Spring			
117	14 N.	16 E.	9	Slaughterhouse Spring			Good water; yields 75 barrels a day.
118	14 N.	16 E.	16	Mexican Spring			
119	16 N?	16 E.	33?	Wheaton Spring			Water piped from tunnel in granite 100 yards to galvanized-iron trough; flows about 100 barrels a day.
120	13 N.	14 E.	5	At Cima	135	Dry.	Dug; test well. No water struck.
121	13 N.	15 E.	8	Spring			
122	13 N.	15 E.	18	.....do			

QUALITY OF WATER.

CLASSIFICATION.

Samples of water from 12 wells and 3 springs in the three basins under consideration were collected by the writer and analyzed under contract by S. C. Dinsmore, Reno, Nev. Four additional samples, three from wells and one from a spring, were collected by David G. Thompson in the fall of 1917 and were analyzed in the laboratory of the water-resources branch of the United States Geological Survey. One analysis of water from a well owned by the Los Angeles & Salt Lake Railroad Co. was furnished by that company. The results of the analyses, together with a classification of the waters for domestic, boiler, and irrigation use, are given in the table opposite page 80.

The classification[1] of waters for domestic use, as given in the table, is based on the determinations of the dissolved mineral constituents and their chemical character. The suitability of a water for domestic use depends on its acceptability for drinking, washing,

[1] Mendenhall, W. C., Dole, R. B., and Stabler, Herman, Ground water in San Joaquin Valley, Calif.: U. S. Geol. Survey Water-Supply Paper 398, pp. 73–82, 1916.

and cooking, as determined chiefly by the amounts of iron, nitrate, and chloride in solution and by the hardness of the water. Waters high in hardening constituents can be used for drinking, but they are unsatisfactory for cooking and laundering. Hardness exceeding 1,500 parts per million makes water unfit for cooking. The hardness sufficient to cause prohibitive soap consumption in washing is much less than that which makes water undesirable for cooking.

The presence of approximately 200 parts per million of carbonate, 250 parts of chloride, or 300 parts of sulphate may give the water a slight taste. Waters containing considerably more of these constituents can be tolerated by human beings, but those which contain more than 300 parts per million of carbonate, 1,500 parts of chloride, or 2,000 parts of sulphate are intolerable to most people. Local conditions and individual preference, however, largely determine the significance of the terms "good" or "bad," as applied to the mineral quality of water for domestic use. For instance, in a desert region a water containing 240 parts per million of hardness might be classed as fair; in a region where the supply is abundant and the quality is in general much better, as in the New England States, the same water would be classed as bad by most users. It should be borne in mind in this report that the classification of a water for domestic use is based only on its mineral content, and although certain determinations afford indications of the sanitary quality of the water they may not permit a complete sanitary interpretation. A water may contain only small amounts of dissolved solids and yet be so badly polluted as to be unsafe for drinking.

With respect to their quality for use in boilers, waters are first classified according to their scale-forming and foaming constituents and the probability of corrosion, and from these data the advisability of their use is determined. Scale is formed in boilers by certain substances that go out of solution on heating and concentration of the water. Foaming, or the formation of masses of bubbles in the boiler, is caused by certain salts or by fine mud or other matter in the water. The corrosion or pitting of the walls and tubes of boilers is caused by electrolytic action, which may be accelerated or retarded by the presence of various substances in solution.

Rating of waters for boiler use according to proportions of incrusting and corroding constituents and according to foaming constituents.

Incrusting and corroding (scale-forming) constituents.		Foaming constituents.	
Parts per million.	Classification.[a]	Parts per million.	Classification.[b]
Not more than 90	Good	Not more than 150	Good.
91 to 200	Fair	151 to 250	Fair.
201 to 430	Poor	251 to 400	Bad.
More than 430	Bad	More than 400	Very bad.

[a] Am. Ry. Eng. and Maintenance of Way Assoc. Proc., vol. 5, p. 595, 1904.
[b] Idem, vol. 9, p. 134, 1908.

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No. on Plate VIII.[a]	Date of collection.	Silica (SiO_2).	Classification.[b]				
			Chemical character.	Probability of corrosion.[d]	Quality for boiler use.	Quality for domestic use.	Quality for irrigation.
	1916.						
15	Aug. 29	8.0	Ca-CO_3	(?)	Fair	Fair	Good.
22	Aug. 24	10	do	(?)	do	do	Do.
25	Aug. 26	36	Na-CO_3	N	Poor	do	Fair.
29	Aug. 27	18	Ca-CO_3	(?)	Fair	do	Good.
45	do	13	do	(?)	do	do	Do.
	1916.						
58	Aug. 26	23	Mg-CO_3	(?)	Fair	Poor	Good.
64	Aug. 27	26	Mg-SO_4	C	Bad	do	Do.
72	Aug. 25	53	Na-CO_3	(?)	do	Fair	Fair.
	1917.						
74[e]	Oct. 28	24	Ca-CO_3	(?)	Poor	Poor	Good.
	1916.						
76	Aug. 27	18	do	(?)	Fair	do	Do.
86	Aug. 25	35	Na-Cl	(?)	Very bad	do	Poor.
	1916.						
89	Aug. 25	23	Na-Cl	C	Unfit	Unfit	Bad.
	1917.						
93[e]	Oct. 27	45	Na-CO_3	(?)	Poor	Poor	Good.
	1916.						
96	Aug. 24	30	Na-Cl	C	Unfit	Unfit	Bad.
	1915.						
97[g]	Oct. 28	[h] 17	do	(?)	Bad	Good	Fair.
	1916.						
103	Aug. 24	41	Na-CO_3	N	Fair	do	Do.
	1917.						
106[e]	Oct. 26	59	do	N	do	do	Good.
	1916.						
108	Aug. 24	17	Na-SO_4	(?)	Good	do	Do.
	1917.						
111[k]	Nov. 6	45	Ca-CO_3	(?)	Poor	Fair	Do.
	1916.						
113	Aug. 23	36	do	(?)	Fair	do	Do.

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With respect to their value for irrigation, waters are classified according to their content of salts toxic to vegetation. Water containing considerable quantities of sodium salts or other alkali salts[1] is injurious to vegetation, because, through evaporation, the alkali collects in the few inches of top soil in such quantities as to interfere greatly with the growth of plants. The irrigating value of a water with respect to the amount of contained alkali is expressed by the term "alkali coefficient,"[2] which is defined as the depth of water in inches which on evaporation would yield sufficient alkali to render the soil to a depth of 4 feet injurious to the most sensitive crops. The coefficient affords a purely arbitrary means of comparing waters used for irrigation. It does not take account of certain important factors, such as the methods of irrigation and of drainage, the character of the soil, and the kind of crop, but it indicates very well the general suitability of the water for irrigation. The waters in the areas here discussed have been classified as to quality for irrigation in accordance with the following rating, which is based on ordinary irrigation practice in the United States and which indicates in a very general way the customary limitation in the use of waters having various alkali coefficients.

Classification of water for irrigation.[a]

Alkali coefficient (inches).	Class.	Remarks.
More than 18	Good	Have been used successfully for many years without special care to prevent alkali accumulation.
18 to 6.0	Fair	Special care to prevent gradual alkali accumulation has generally been found necessary except on loose soils with free drainage.
5.9 to 1.2	Poor	Care in selection of soils has been found to be imperative, and artificial drainage has frequently been found necessary.
Less than 1.2	Bad	Practically valueless for irrigation.

[a] Stabler, Herman, Some stream waters of the western United States, with chapters on sediment carried by the Rio Grande and the industrial application of water analyses: U. S. Geol. Survey Water-Supply Paper 274, p. 179, 1911. See also U. S. Geol. Survey Water-Supply Paper 398, p. 57, 1916.

ANALYSES.

The waters analyzed from the Pahrump, Mesquite, and Ivanpah basins vary in mineral content from moderate to very high. The lowest amount of total solids is 240 parts per million, from well No. 108, and the highest is 27,501, from well No. 89. Both of these waters come from the Ivanpah basin. The waters analyzed are mostly good or fair for irrigation, cooking, and drinking, but average somewhat poorer for washing and boiler use. A detailed discussion of the quality of the water from each basin will be found in the descriptions of the basins.

[1] The term "alkali" is used to designate the common salts formed on evaporation of natural waters. The principal alkali salts are sodium carbonate (sal soda), or black alkali, and sodium sulphate (Glauber's salt) and sodium chloride (table salt), or white alkalies.

[2] Stabler, Herman, Some stream waters of the western United States: U. S. Geol. Survey Water-Supply Paper 274, pp. 177–179, 1911.

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