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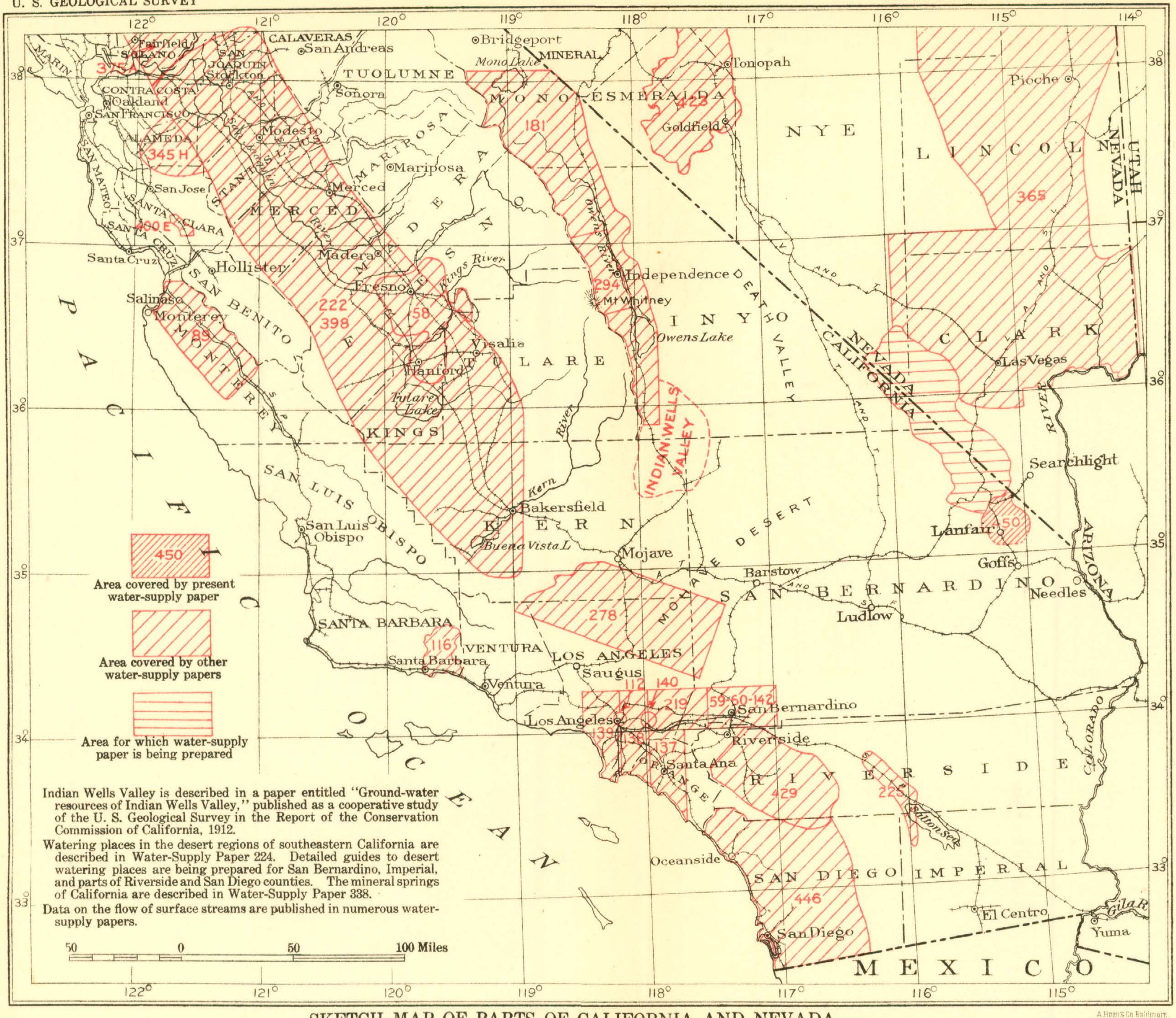
[1] Thompson, D. G., Routes to desert watering places in San Bernardino County, Calif., and adjoining areas: U. S. Geol. Survey Water-Supply Paper — (in preparation).



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

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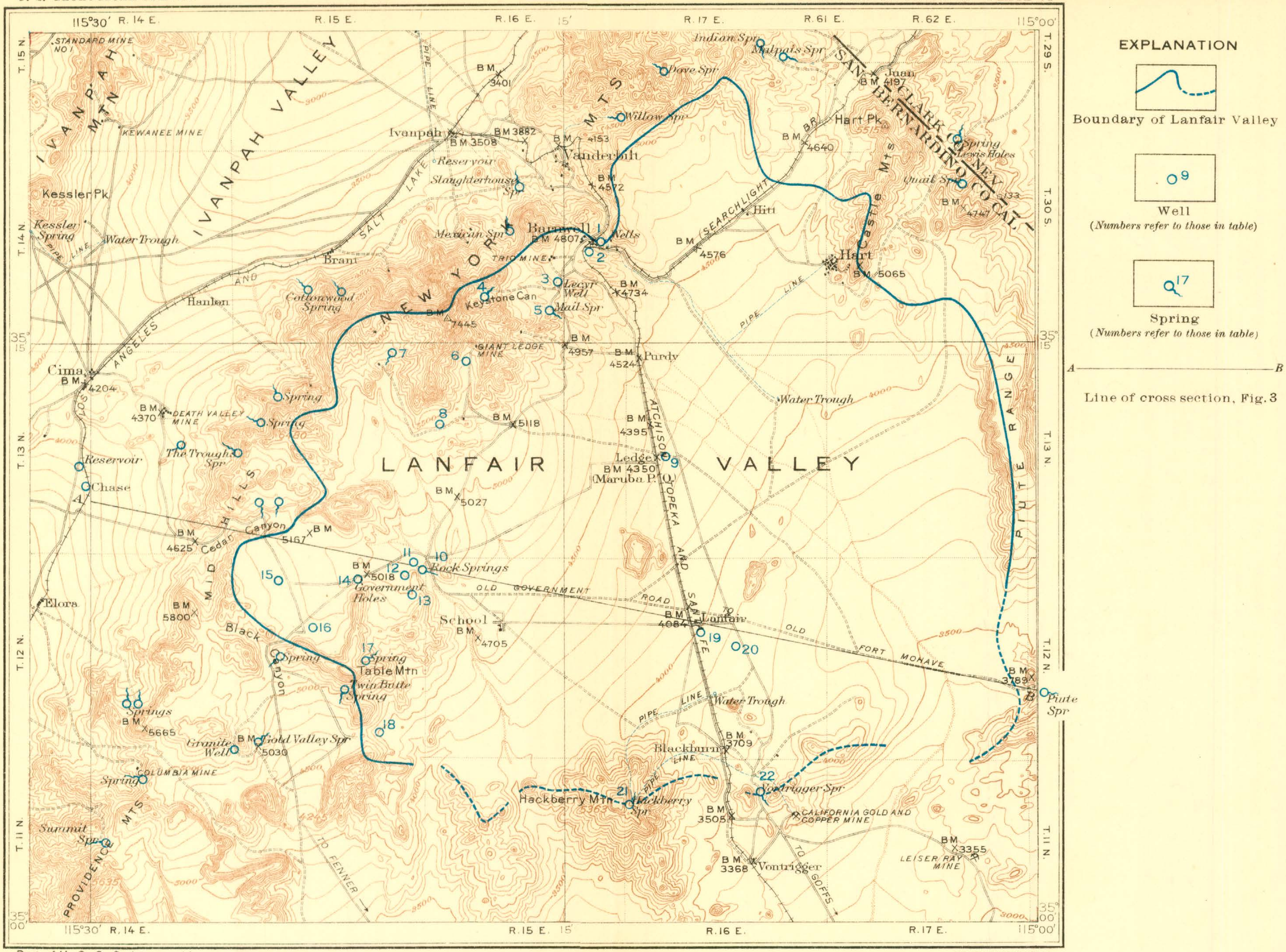
[1] Hill, J. M., The mining districts of the western United States: U. S. Geol. Survey Bull. 507, p. 128, 1912.

[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.



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

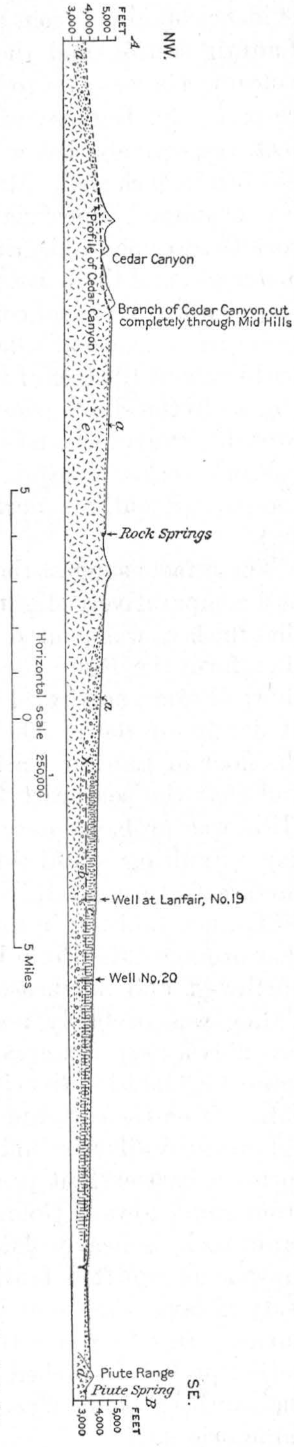


FIGURE 3.—Profile and hypothetical cross section of Lanfair Valley, Calif. *a*, Recent alluvial gravel, grading into *b*; *b*, older alluvial gravel of Pleistocene or Tertiary age; *c*, extrusives (lava, ash, etc.), Pleistocene or Tertiary, resting on *b*; *d*, volcanic rocks of Piute Range, probably 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 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	c2.98	(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 [illegible] 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, [illegible].

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).

[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-

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[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 1½ miles southwest of Barnwell; equipped with galvanized iron tank, concrete water trough, and windmill. Pumps at least 12 gallons a minute. See analysis, p. 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. T.	Location. R.	Location. Sec.[a]	Owner of well or name of spring.	Depth of well.	Depth to water level in well, Nov., 1917.	Remarks.
					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; volcanic 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.