DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

WATER-SUPPLY PAPER 423

GEOLOGY AND WATER RESOURCES OF BIG SMOKY, CLAYTON, AND ALKALI SPRING VALLEYS, NEVADA

BY

OSCAR E. MEINZER

WASHINGTON
GOVERNMENT PRINTING OFFICE
1917

DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

Water-Supply Paper 423

GEOLOGY AND WATER RESOURCES OF BIG SMOKY, CLAYTON, AND ALKALI SPRING VALLEYS, NEVADA

BY

OSCAR E. MEINZER

WASHINGTON
GOVERNMENT PRINTING OFFICE
1917

CONTENTS.

ILLUSTRATIONS.

GEOLOGY AND WATER RESOURCES OF BIG SMOKY, CLAYTON, AND ALKALI SPRING VALLEYS, NEVADA.

By Oscar E. Meinzer.

BIG SMOKY VALLEY.

INTRODUCTION.

GEOGRAPHIC SKETCH.

Big Smoky Valley is a typical Nevada desert valley—a plain hemmed in by mountain ranges and underlain by porous rock waste eroded from these ranges and saturated with water discharged from them. Like most of the valleys of the State, it has a general north-south elongation and an interior drainage. The valley itself comprises somewhat more than 1,300 square miles (exclusive of Ione Valley), and the entire drainage basin includes 3,250 square miles, being 130 miles long and extending from a point near the geographic center of the State to a point less than 20 miles from the California line. The valley lies in parts of Lander, Nye, and Esmeralda counties and is crossed by the thirty-eighth and thirty-ninth parallels and by the one hundred and seventeenth meridian (fig. 1).

A low, gentle, alluvial swell west of Manhattan divides the area draining to Big Smoky Valley into a north basin, which contains the upper valley, and a south basin, which contains the lower valley. Each of these basins held a lake in the Pleistocene epoch and now contains an alkali flat. Ione Valley, which lies west of Big Smoky Valley proper and has a drainage basin including about 500 square miles, discharges into the lower valley from the northwest and hence forms a part of the south basin. The lowest point in the north basin is 5,443 feet and the lowest point in the south basin is about 4,720 feet above sea level. Arc Dome, in the Toyabe Range, is 11,775 feet above sea level and is the culminating point of the mountain rim that incloses Big Smoky Valley.

The climate exhibits the features characteristic of aridity. At one station in the northern part of the valley the average annual precipitation during a period of six years was found to be 6.55 inches. In the southern part the precipitation is still less, and only on a few of

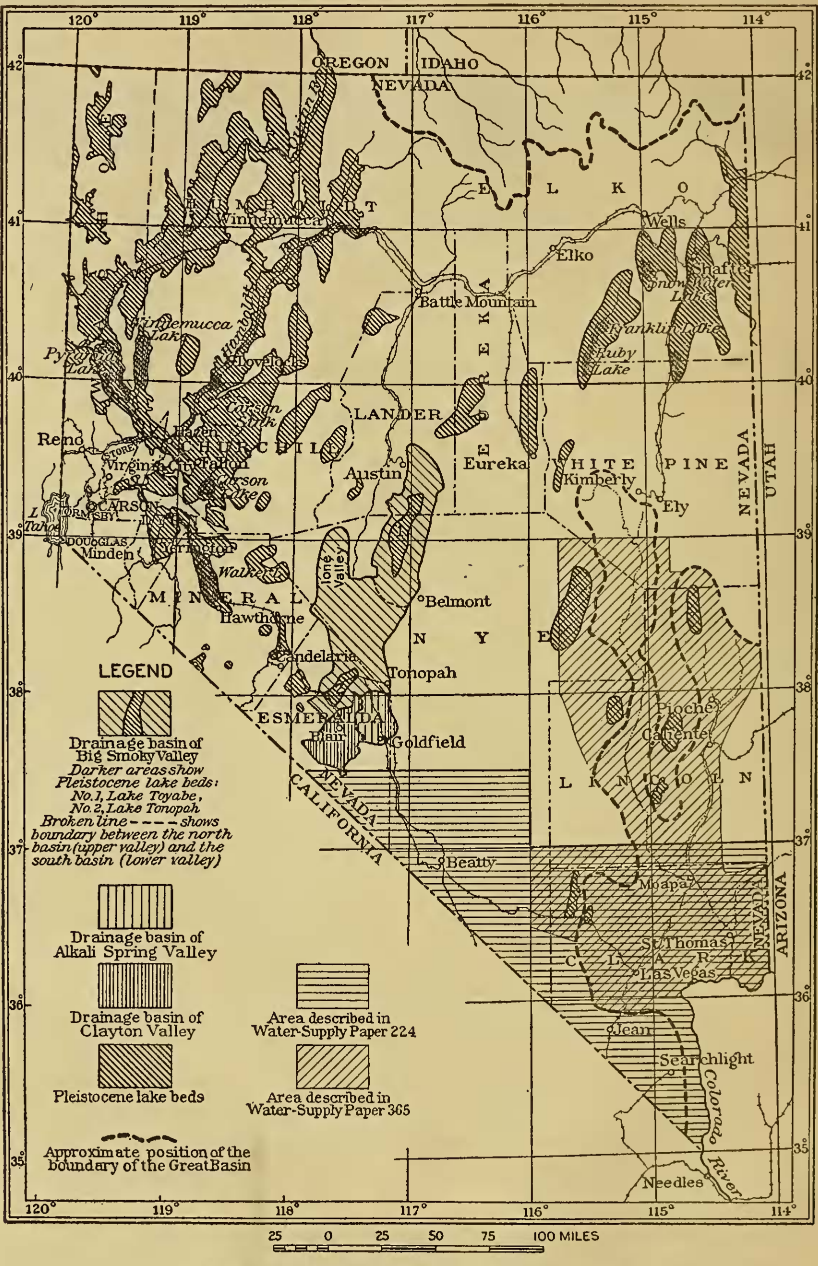


FIGURE 1.—Map of Nevada showing boundary of Great Basin, Pleistocene lake beds (so far as known), areas covered by ground-water surveys, and drainage basins described in this paper.

the highest mountains is it considerably more. Owing to differences in both latitude and altitude there are appreciable differences in temperature within the region, the climate being distinctly more rigorous in the northern than in the southern part of the valley.

The drainage basin of Big Smoky Valley is sparsely populated. Tonopah, near its southeast corner, contains most of the inhabitants. In 1913 it was said to have a population of 7,000 and was probably the largest mining town in the State. Most of the rest of the inhabitants of the basin are in the mining and milling towns of Manhattan, Round Mountain, and Millers, and at a number of ranches along the west side of the northern part of the valley.

Big Smoky Valley is most conveniently reached over branch lines connecting with the main line of the Southern Pacific Railroad between Oakland and Ogden. A branch of the Southern Pacific leads from the main line at Hazen to Rhodes, where it connects with the Tonopah & Goldfield Railroad, which leads to Tonopah and Goldfield. In 1913 Pullman cars were operated daily between Oakland and Goldfield by way of Tonopah. The Tonopah & Goldfield Railroad also connects at Rhodes with a branch of the Southern Pacific leading to southern California by way of Owens Valley, and at Goldfield with the Las Vegas & Tonopah Railroad and the Tonopah & Tidewater Railroad. The Las Vegas & Tonopah line leads to Las Vegas, which is on the San Pedro, Los Angeles & Salt Lake Railroad. Automobile stages connect Tonopah with Manhattan and Round Mountain. The northern part of Big Smoky Valley can be reached over the Nevada Central Railroad, which connects Battle Mountain, on the main line of the Southern Pacific, with Austin, situated a few miles northwest of this valley.

HISTORICAL SKETCH.

The old Overland stage route crossed Big Smoky Valley near its north end.[1] Little appears, however, to have been known of the region by white men until 1862, when a vein of rich silver ore was discovered in Reese River valley, near the present site of Austin, by William M. Talcott, who had been a pony-express rider. In the same year Lander County was organized, and Jacobsville, at the Overland stage station, was made the county seat. In 1863 Austin was settled and became the principal town of the Reese River mining district.[2]

The mountain areas adjacent to Big Smoky Valley in many localities contain rich ores of the precious metals, and the history of the region since 1862 is primarily a history of mining operations. During the last half century the region has had an ever-changing population

[1] Map showing detailed topography of the country traversed by the reconnaissance expedition through southern and southeastern Nevada in charge of Lieut. George M. Wheeler, U. S. engineer, assisted by Lieut. O. W. Lockwood (P. W. Hamel, chief topographer and draftsman), 1869.

[2] Bancroft, H. H., History of Nevada, Colorado, and Wyoming, pp. 264-267, San Francisco, The History Publishing Co., 1890.

of prospectors, who have scrutinized every hillside and canyon of its interminable labyrinth of desert ranges. Occasionally some one has come on a deposit of high-grade ore, and with meteoric suddenness and brilliancy a new mining camp has sprung into fame. After having had a productive period of great prosperity the typical camp has declined and finally, perhaps, gone to ruin, while attention was attracted to a new camp, which in turn had its period of prosperity and decline.

In 1864 ore was discovered 60 miles south of Austin in the Shoshone Range, as a result of which Nye County was organized, with the newly established town of Ione as its county seat. In 1865 the town of Belmont was founded on the east side of the Toquima Range. In 1867 or thereabout this town became the county seat of Nye County, and for many years it was a well-known mining center.[1] Rich ore was discovered in Ophir Canyon, on the east side of the Toyabe Range, and in 1866 a mill was erected in this locality. Other well-known camps in the early days of mining development were Jefferson, in Jefferson Canyon, on the west side of the Toquima Range, and Grantsville, about 8 miles south of Ione.

The principal base of supplies for this region before the railroad was built was Sacramento, Cal., situated on the navigable Sacramento River, about 350 miles from Austin. The very high freight rates made the cost of supplies excessive, and consequently only ore with high values could be profitably mined. Bancroft[2] gives the following information on freight and passenger rates and on the cost of living:

> In 1862 freight from Sacramento to Virginia City was $120 per ton, and the total freight money amounted to nearly $5,000,000. * * * Being directly upon the overland route, Austin had stage communication with the east and west, besides which special lines were established. The passenger traffic for 1865 was estimated at 6,000 fares between Virginia City and Austin, at $40 a fare. The freight carried over the road cost $1,381,800 for transportation from this direction alone, besides what came from Salt Lake. Lumber transported from the mills of the Sierra cost $250 per thousand feet, and that sawed out of the native piñon $125 per thousand. Brick manufactured at Reese River cost $12 to $18 per thousand, and other things in proportion. The treasure carried by the express company that year aggregated $6,000,000.

In May, 1868, the Central Pacific Railroad was completed to Reno, and the next year the transcontinental line was finished. The Nevada Central Railroad, a narrow-gage line from the main line to Austin, was completed in 1880. Soon after this the Carson & Colorado Railroad, also a narrow-gage line, was built southward through Sodaville, which later became the supply station for the southern part of the valley.[3]

After the first decade or two of activity the mining industry of the region gradually declined until 1900, when a new epoch of mining activity was opened as a result of the discovery of rich silver and gold

---

[1] Bancroft, H. H., op. cit., pp. 264–267.
[2] Idem, pp. 235, 268.
[3] Idem, pp. 232–240.

deposits by James L. Butler, at the present site of Tonopah. The town of Tonopah sprang into existence the next year and at once became a large producer. At first the ore was hauled in wagons to Austin by way of Belmont, but later it was hauled to Sodaville, a distance of about 60 miles, and shipped by rail to the smelters at Salt Lake City. Gold was found in 1902 near the present site of Goldfield, and by 1904 that town was in a flourishing condition. In 1904 a narrow-gage railroad was built to Tonopah, and in 1905 it was converted into a standard-gage road and extended to Goldfield. In 1905 the electric transmission lines of the Nevada-California Power Co. reached Tonopah from Bishop Creek, Cal., a distance of about 90 miles. The next year a 100-stamp mill and cyanide plant of the Desert Power & Mill Co. began operating at Millers, and the year following a 60-stamp mill of the Tonopah-Belmont Development Co. was completed at the same place.[1]

Manhattan, on the west slope of the Toquima Range, a short distance up the canyon from Central, was started in 1905 when high-grade ore was discovered in that vicinity. The latest developments at this place have been in placer mining in Manhattan Canyon.[2] The camp at Round Mountain, a short distance southwest of the old town of Jefferson, came into existence in 1906, when gold was discovered there.[3]

In addition to the towns that have been mentioned the region contains a number of smaller mining centers in various stages of development or decay.

In 1913 Tonopah was very prosperous and the mills at Millers were in full operation, Goldfield was still active although not so prosperous as a few years earlier, Manhattan and Round Mountain were both active, and the little town of Blair, at the terminus of a 19-mile branch railroad extending southeast from Blair Junction on the Tonopah & Goldfield Railroad, was the busy center of the Silver Peak mining district and the site of a 120-stamp mill and cyanide plant at which the ore of the district—chiefly rather low grade gold ore—was concentrated. The latest producer was Republic, a small camp on the west side of the valley, from which a little ore was hauled to Millers. At Austin there was almost no mining activity but the town retained considerable importance as a trade center for a large area.

In an arid region, such as this, water for mining and milling and for domestic uses at the mining camps is frequently very difficult to procure. At Tonopah water was at first brought on the backs of

---

[1] This paragraph is abstracted from an address by A. T. Johnson entitled "Mining in the Tonopah district": Am. Min. Cong. Twelfth Ann. Sess. Proc., pp. 412–417, 1909.

See also Spurr, J. E., Geology of the Tonopah mining district, Nev.: U. S. Geol. Survey Prof. Paper 42, pp. 25–29, 1905; and Ransome, F. L., The geology and ore deposits of Goldfield, Nev.: U. S. Geol. Survey Prof. Paper 66, pp. 16–23, 1909.

[2] Evans, C. R., Manhattan: Am. Min. Cong. Twelfth Ann. Sess. Proc., pp. 398–400, 1909.

[3] Loftus, J. P., Round Mountain—Its mines and its history: Idem, pp. 445–448.

burros from wells in the valley to the east. Later wells in the hills about four miles north of town provided a small supply, which was led to the town through a pipe line. Still later a larger and better supply was procured for the community at rather heavy cost by pumping from wells in Ralston Valley, 11 miles from Tonopah, through a pipe line to a reservoir on the summit of the range north of town.[1] At Manhattan water for domestic use was found by sinking wells above the town, and small supplies for placer mining are pumped from the shafts through which the pay gravels are recovered. At Round Mountain water for domestic use is obtained from Shoshone Creek and for hydraulic mining from Shoshone and Jefferson creeks, the mining supply having been provided at considerable cost. In 1914 a project was undertaken to lead the water of Jett Creek, in the Toyabe Range, to Round Mountain, for use in mining. At both Manhattan and Round Mountain the rate of production, in so far as placer and hydraulic mining are concerned, is controlled largely by the quantity of water available. In locating the mills at Millers advantage was taken of the relative abundance of ground water underlying Big Smoky Valley.

Most of the ranches of this region have been in existence a long time and their history is related to that of the mining camps. As a rule they were established where small supplies for irrigation could be obtained from springs or mountain streams and where, consequently, agriculture could be combined with cattle ranching. The principal crops are alfalfa and wild hay, but vegetables, fruits, and other foodstuffs are produced for the local markets. The revival of mining since the discovery of ore at Tonopah in 1900 has created new markets for farm produce and has accordingly made the ranchers more prosperous.

Most of the ranches are on the west side of the upper valley, where water from the canyons of the Toyabe Range and from scores of springs that issue from the valley fill is available. The main wagon and automobile road from Austin to Manhattan and thence to Tonopah runs along the west side of the upper valley and in this part of its course passes a dozen inhabited ranch houses. There are several other inhabited ranches on the west side of the upper valley but very few on the east side, and there are none in the lower valley except the Cloverdale ranch and two or three ranches along Peavine Creek. A number of these ranches, as well as some that are now abandoned, have been well known as stage stations or watering and camping places for freighters and other travelers. Birch Creek (Spencer ranch), Minium station (Bowman's ranch), Millett, Darrough Hot Springs, San Antonio, Midway station, and Montezuma wells have all at some time been stage stations.

---

[1] Spurr, J. E., Geology of the Tonopah mining district, Nev.: U. S. Geol. Survey Prof. Paper 42, p. 28, 1905.

PREVIOUS INVESTIGATIONS AND LITERATURE.

The Toyabe, Shoshone, and Toquima ranges attracted the attention of geologists in the decade following the discovery of ore at Austin, when rich mines were opened in various parts of these ranges. The most important geologic work done within the drainage basin of Big Smoky Valley in the early days was that of Emmons, who, in 1869 (?), in connection with the King Survey, studied the Toyabe range and also made observations in the Shoshone and Toquima ranges. Arnold Hague, of the same survey, also visited the mountains adjacent to the upper valley. In 1871 Gilbert, who was connected with the Wheeler Survey, made an expedition from Battle Mountain to Ophir Canyon by way of Austin and thence crossed the upper valley on his way to Belmont.

Little attention was given to the region by geologists during the years of mining decadence. In 1899 Turner and Weeks worked in the Silver Peak and Lone Mountain ranges, and Spurr, in his reconnaissance of Nevada south of the fortieth parallel, crossed Big Smoky Valley over the road leading from Belmont to Ione by way of Cloverdale. After the discovery of ore at Tonopah, in the following year, the region again became attractive to mining geologists and has been visited by many of them. In 1904 Spurr made an intensive study of the Tonopah district.

The valley itself has received very little attention by geologists. The following note on the upper valley is given by Emmons in his paper on the Toyabe Range:[1]

> Smoky Valley, on the east, is both deeper and wider than Reese River Valley, and forms an independent basin; the waters flowing into it from this range all drain toward a large mud or alkali flat, opposite Park Cañon, which is about 18 miles long by 6 miles wide; a low divide, opposite the Hot Springs, forms the southern limit of this basin, though the valley extends over a hundred miles farther south without any considerable change of level. Such alkali flats as this form a very characteristic feature in the scenery of the great plateau; partially covered by water from the melting of the snows in spring and early summer, its surface, destitute of all vegetation, is left, by the evaporation of these waters, incrusted with a thin, white coating of mineral salts. At its northern extremity is the so-called salt marsh, where these incrustations are so considerable that large quantities of the salts (here containing from 50 to 60 per cent of chloride of sodium) are collected for use in the reduction works in the vicinity. It is probable that saline springs exist under this portion of the flat, as the salts which have been removed are constantly replaced by fresh incrustations.

The following description of the upper valley is given in King's report on the systematic geology of the region of the Fortieth Parallel Survey:[2]

> East of Toyabe Range, in Smoky Valley, there is a prominent depression, formed of Lower Quaternary stratified clays, which receives the drainage of the mountains on both sides, and is a wet, marshy clay bed during winter and a hard, smooth, alkali flat

[1] Emmons, S. F., Geology of Toyabe Range: U. S. Geol. Expl. 40th Par. Rept., vol. 3, pp. 322 and 323, 1870.

[2] King, Clarence, U. S. Geol. Expl. 40th Par. Rept., vol. 1, Systematic geology, p. 503, 1878.

during summer. At the northern or lowest portion of this alkaline plain there is a region of reasonably pure chloride of sodium, which is derived from the evaporation of saline springs that pour their water into the valley. The salt proves to have 90 per cent of chloride of sodium and a little over 9 per cent of sulphate of potash.

The existence of a Pleistocene lake in the upper valley is shown on the large map accompanying Russell's paper on Lake Lahontan,[1] but nothing about the beaches in the lower valley has been found in the literature except a bare mention of them by Free [2] in a recent paper.

The following list includes the titles of the principal papers dealing with the geology of the drainage basin of Big Smoky Valley:

Evans, C. R., Manhattan mining district: Am. Mining Cong. Twelfth Ann. Sess. Proc., pp. 398–400, 1909.

Emmons, S. F., Geology of the Toyabe Range: U. S. Geol. Expl. 40th Par. Rept., vol. 3, pp. 320–348, 1870.

Emmons, W. H., and Garrey, G. H., Notes on the Manhattan district: U. S. Geol. Survey Bull. 303, pp. 84–93, 1907.

Free, E. E., The topographic features of the desert basins of the United States with reference to the possible occurrence of potash: U. S. Dept. Agr. Bull. 54, 1914.

Gilbert, G. K., The geology of portions of Nevada, Utah, California, and Arizona examined in 1871 and 1872: U. S. Geol. Surveys W. 100th Mer. Rept., vol. 3, pp. 25, 36, 87, 121, and 184, 1875.

Hague, Arnold, Mining and milling at Reese River: U. S. Geol. Expl. 40th Par. Rept., vol. 3, pp. 349–405, 1870.

——— Region east of Reese River: U. S. Geol. Expl. 40th Par. Rept., vol. 2, pp. 627–641, 1877.

Hill, J. M., Some mining districts in northeastern California and northwestern Nevada: U. S. Geol. Survey Bull. 594, 1915.

Johnson, A. T., Mining in the Tonopah district: Am. Mining Cong. Twelfth Ann. Sess. Proc., pp. 412–417, 1909.

King, Clarence, Systematic geology: U. S. Geol. Expl. 40th Par. Rept., vol. 1, 1878.

Loftus, J. P., Round Mountain, its mines and its history: Am. Mining Cong. Twelfth Ann. Sess. Proc., pp. 45–448, 1909.

Russell, I. C., Geological history of Lake Lahontan, a Quaternary lake of northwestern Nevada: U. S. Geol. Survey Mon. 11, 1885.

Spurr, J. E., Descriptive geology of Nevada south of the 40th parallel and adjacent portions of California: U. S. Geol. Survey Bull. 208, 1903.

——— Coal deposits between Silver Peak and Candelaria, Esmeralda County, Nev.: U. S. Geol. Survey Bull. 225, pp. 289–292, 1904.

——— Preliminary report on the ore deposits of Tonopah: U. S. Geol. Survey Bull. 225, pp. 89–111, 1904.

——— Geology of the Tonopah mining district, Nev.: U. S. Geol. Survey Prof. Paper 42, 1905.

——— Ore deposits of the Silver Peak quadrangle, Nev.: U. S. Geol. Survey Prof. Paper 55, 1906.

Turner, H. W., The Esmeralda formation: Am. Geologist, vol. 25, p. 168, 1900.

——— The Esmeralda formation, a fresh-water lake deposit, with a description of the fossil plants by F. H. Knowlton and of a fossil fish by F. A. Lucas: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pp. 192–244, 1900.

[1] Russell, I. C., Geological history of Lake Lahontan, a Quaternary lake of northwestern Nevada: U. S. Geol. Survey Mon. 11, 1885.

[2] Free, E. E., The topographic features of the desert basins of the United States with reference to the possible occurrence of potash: U. S. Dept. Agr. Bull. 54, p. 33, 1914.

PHYSIOGRAPHY.

GENERAL FEATURES.

The trend of the main trough of Big Smoky Valley is in general northeast and southwest. The northern part of the basin trends nearly north and south, but southward it curves gradually toward the west, and near the south end of the basin the trend is more nearly east and west than north and south. The borders of this trough are formed by several mountain ranges and intervening saddles. A very gentle swell in the surface of the valley between Manhattan and Round Mountain forms the divide that separates the basin into two distinct parts. (See Pls. I and II, in pocket.)

The upper valley is bordered on the east by the Toquima Range and on the west by the Toyabe Range, the largest and highest mountain range in the basin. At their north ends these two ranges are more or less united by low hills and ridges that inclose the valley; southward their divergence gives the valley a width of 10 to 14 miles, but near their south ends they are less than 5 miles apart and hold between them the swell that separates the upper and lower valleys.

The lower valley is bordered on the east by the San Antonio Range, on the south by Lone Mountain, on the southwest by the Silver Peak Range, on the west by the Monte Cristo Range and associated ridges, and on the north by the ends of the Toyabe and Shoshone ranges. Between the detached ranges the boundry of the basin is formed by broad low saddles.

The Shoshone Mountains form a comparatively high range lying west of the Toyabe Range and parallel with it. West of the Shoshone Mountains is the large Ione Valley, and west of that valley are the Paradise Range and several low indefinite ridges. Ione Valley is drained through what is practically a rock gap into the lower division of Big Smoky Valley. The Toyabe and Shoshone ranges coalesce at their south ends, forming a massive mountain area. Farther north, however, the Reese River valley, which is drained northward into Humboldt River, intervenes between the two ranges and thus bifurcates the basin of Big Smoky Valley.

This basin, like most other desert basins, comprises two strongly contrasted types of topography, one in the mountains and the other in the valley. The mountains have a relief of several thousand feet and their surface has been eroded or carved by streams; the valley has a relief of only a few hundred feet and most of its surface is formed of deposits laid down by streams. The mountains are steep sided and almost infinitely varied in topographic detail; the valley consists of smooth, gentle slopes and nearly level plains. In comparison with the mountains the valley appears to a casual observer to be flat and monotonous.

More careful study, however, shows that the valley contains many interesting physiographic features; that its form is an expression of delicate adjustments between various physical forces operating in the basin and a record of the physical changes that occurred in at least the later part of the basin's existence. In general the relation of the mountains to the valley is that of cause and effect, and a study of the physiography of the basin therefore consists largely in correlating the land forms in the valley with the causal conditions in the mountains.

The greater part of the valley surface consists of coalescing alluvial fans, or slopes built of the rock waste discharged from the canyons. At their bases the slopes become very gentle and merge, in many places imperceptibly, into large playas, or alkali flats, that occupy the lowest parts of the upper and lower valleys. Superimposed on these main features are numerous scarps produced by recent faulting large ridges built by ancient lakes, hills and ridges of sand heaped up by the wind, and in a few places mounds and terraces built by springs. The alluvial fans have also been modified by large, deep streamways carved into them.

MOUNTAINS.

TOYABE RANGE.

MAIN FEATURES.

The Toyabe Range, which is the largest range in this basin, extends along the west side of the valley from its north end to beyond the Peavine ranch. The entire length of the range is about 100 miles, and its extent within this basin is about 80 miles. It is a lofty and persistent mountain mass, its crest in many places being more than 10,000 feet above sea level, or about a mile above the alkali flat of the upper valley. Arc Dome, the highest peak, rises 11,775 feet above sea level, or more than 6,300 feet above the flat; Bunker Hill Peak, a conspicuous mountain farther north, rises 11,477 feet above sea level. The crest of the range is in general near the east edge, but near Bunker Hill Peak and Arc Dome the mountain areas draining eastward widen to about 7 miles, and farther south, where Peavine Creek heads, it is still wider. The steep east face of the range is rugged and is cut by deep precipitous walled canyons, but farther back the mountains, although having great relief, appear notably less rugged and more undulating (Pls. III and IV). Pine trees, large enough to be sawed into lumber, formerly grew on the mountains, but the timber now consists chiefly of a sparse growth of piñon, juniper, and mountain mahogany, with birch and willow in the cañyons.

TOYABE RANGE AND ADJACENT PART OF VALLEY.

Showing two types of topography in the mountains and features produced by faulting in the valley.

UPPER VALLEY OF BIRCH CREEK.

Showing mature topography of the upper part of the Toyabe Range and water-bearing detritus.

The following excellent description of the range by Emmons[1] is based on field work which he did about 1869:

The name Toyabe, which signifies in the Indian language "mountains," has been appropriately applied to this great range, whose sharp, serrated ridge rises several thousand feet above the neighboring ranges which rib the surface of the great Nevada plateau. The view from its summits extends over more than 4° of longitude and is limited only by the White Pine and East Humboldt Mountains on the east and the Sierra Nevadas on the west, whose forms and outlines can be traced with the utmost distinctness in the dry, thin air of these elevated regions. Snow rests upon its higher points until late in the summer and, with the verdure which accompanies it, forms a most pleasing contrast to the somber hues that prevail over the mountains of this arid region. Rising nearly 6,000 feet above the broad valleys which border it on either side, its height is rendered still more imposing by its limited lateral extent, its average width from foot to foot being scarcely 8 miles in a horizontal line; contrasted with the steep slopes of its sides, the valleys, although very considerably inclined toward their center, seem almost level ground.

* * * * * * *

This portion of the range has a trend of about N. 23° E. and in general outline forms a high single ridge, characterized by a short, steep declivity on the east and a longer and more gentle slope to the west; but a closer examination of its topography discloses a double-ridge system, which prevails through the greater part of its extent, giving rise to a series of interior longitudinal basins; hence the line of the main watershed is extremely sinuous, although that of N. 23° E. would pass through all the principal summits of the range. To the north the range consists of two low and somewhat broken diverging ridges, inclosing between them the Park basin, which opens out farther north into the large meridional depression called Grass Valley. These ridges rise gradually to the south, preserving a certain parallelism, though broken through at various points by the waters of the high, narrow valleys which they inclose, until they reach their culminating points, respectively, in Bunker Hill and Big Creek peaks. In this extent, although the eastern ridge is generally over a thousand feet higher than the western, the greater part of their surface is drained into Smoky Valley through Park Creek, Birch Creek, and Kingston Creek, which break through the eastern ridge, while only Big Creek flows to the west. For a few miles south of Big Creek Peak the western ridge forms the main divide of the range, which bends round the head of Kingston Creek, but to the south of it forms a continuation of the main eastern ridge. For a distance of 25 miles south the range consists of a single and, in general direction, straight ridge, with steep, craggy slopes to the east, and long smooth western spurs. By the bend in this ridge to the westward at Summit Canyon the western summit again becomes the main divide, its continuation to the north being indicated by the widening of the spurs toward the west, which inclose the small basins at the heads of Cross and Washington canyons. This ridge grows higher toward the south, till in the sharp peak of Mount Poston [Arc Dome] it forms the highest crest of the range. The eastern ridge, meanwhile, finds its continuation in the shoulders of the eastern spurs, which, rising into high peaks at the Twin Rivers, inclose the large interior basins of these canyons, around whose head the main divide makes another bend to the eastward. These numerous mountain valleys afford most excellent summer grazing ground, their slopes being covered with bunch grass, which remains green and nutritious long after that of the plains is parched and worthless; they form, moreover, natural inclosures, where cattle can be left comparatively unwatched without danger of their straying.

---

[1] Emmons, S. F., Geology of the Toyabe Range: U. S. Geol. Expl. 40th Par. Rept., vol. 3, pp. 320–322, 1870.

The steep sheltered sides of many of the canyons of the range support a growth of piñon and juniper trees, with some yellow pine, fir, and mountain mahogany, which, though somewhat sparse, is abundant compared to the average mountain range of this region and sufficient to afford several years' supply of mining timber and fuel to mines that are likely to be opened.

GLACIATION THEORY.

As this range is crossed by the thirty-ninth parallel of latitude, as its altitude is in many places between 10,000 and 12,000 feet above sea level, and as its present climate is sufficiently cold and humid to allow small quantities of snow occasionally to pass from one winter to the next, the conditions within it in the Pleistocene epoch, when the valley contained a large lake and when glaciers formed on many of the ranges of western United States, must have favored glaciation. It would, therefore, not be surprising to find evidence of incipient glaciation, although comparison with other ranges makes it seem improbable that large glaciers were formed or that any glaciers extended into the valley.

The following statements are made by Emmons in regard to evidences of glaciation which he believed existed in the Toyabe Range:

On the lower face of the foothills, just north of the mouth of Santa Fe Canyon, are the remarkable glacier polishings already mentioned. A thin seam of gray quartz, striking N. 15° E., with a dip of 59° E., here forms the face of the spur; its somewhat undulating surface has, on the salient parts, over a tolerably continuous extent of several hundred feet, received a mirror-like polish equal to the finest produced by artificial means, so that when the sun's rays strike upon it at the proper angle their reflection is visible as a bright point from a distance of many miles. The lines of striation, which are only visible on a close examination, are parallel to the line of greatest inclination. The surrounding rock, which is a somewhat metamorphosed and slaty limestone, has not been of sufficient hardness to retain any other traces of glaciers, though it is evident that to this agency must be attributed these polishings. Their position is indeed singular at the foot of such a steep slope and entirely on the outside of the canyon basin; the head of this canyon, which extends up to the northeastern crest of Bunker Hill, must have been filled by a glacier, whose lower end overlapped this spur, which closes up, in a measure, the mouth of the canyon, and the descending mass of ice and gravel has worn away the less resisting rocks, while this sheet of quartz received its present high polish. As far as known, this is the only instance of such ice polishings in the range, though, as elsewhere remarked, the shape of the interior valleys seems to indicate that they were once filled by glaciers.[1]

To what extent the present configuration of the range is due to glacial action is not easy to determine, since the decomposable nature of some of the rocks, and the position of the strata of others, are not adapted to preserve the traces of such action.

From the fact, however, of glacier polishings having been found on the face of a spur, at the mouth of Santa Fe Canyon, in such a position as to necessitate the supposition of the existence of a glacier in that canyon, whose lower extremity, covering the end of this spur, extended out into Smoky Valley, it may be inferred that the basin-shaped heads of most of the large canyons were formerly filled by glaciers, which, flowing over the inclosing ridges at their lowest points, by their abrasion, followed the

[1] Emmons, S. F., Geology of the Toyabe Range: U. S. Geol. Expl. 40th Par. Rept., vol. 3, p. 335, 1870.

course of the present canyons; the subsequent action of water having cut the narrow gorges which now exist in their lower portions.

The great accumulations of débris at the mouths of the larger canyons, whose slope is frequently more than 6°, through which the waters have cut channels from 50 to 100 feet deep and of more than double the width, favor this supposition, while the narrowness and steepness of the range, and the probable existence of lakes which filled the adjoining valleys, might account for the absence of any well-defined moraines.[1]

Although the opinion of so thorough a geologist as Emmons must be given much weight, it appears necessary to question his conclusions both as to glacial polishing and as to glacial topography.

The highly polished surface is in all respects as described by Emmons, except that it is somewhat more extensive. The surface also bears evidence, in the details of its configuration, that the abrasive agent moved downward over it. There appears, however, to be nothing to distinguish this polished surface from the polished surfaces ordinarily produced by faulting or from the polished surfaces observed in another part of the range, near Peavine ranch, where slickensiding is definitely proved by two such polished surfaces that are still in contact on opposite walls of a fault. Indeed the precise parallelism in the grooves of the surface described by Emmons suggests slickensides rather than glacial scour.

The position of this polished surface is such as to render the theory of glaciation apparently untenable. Its position is comparable to that of the escarpment at the foot of the mountains shown in Plate IX, *B* (p. 44). To account for this polishing by glaciation it is necessary to postulate a huge ice sheet that overrode the entire side of the mountain, including the rugged front which is now so deeply and extensively dissected, that scoured the edge of the mountain at an angle of more than 45° with the horizontal, and that pushed into the valley to a level 6,000 feet or less above the sea. As the steep, jagged walls of the canyon of Santa Fe Creek were obviously not glaciated (see Pl. V, *A*) it is necessary on this theory to assume that the canyon is postglacial.

The undulating surface of the upper parts of the range is indeed in sharp contrast with the extremely rugged mountain front, but its topography exhibits mature erosion features rather than the cirques characteristic of mountain glaciation. Moreover, a contrast in topography would be produced by the existence of small glaciers that did not extend to the mouths of the canyon, not by the general glaciation that is required to account for the polished surface below the rugged zone.

No cirques, moraines, glacial drift, or glacial striae were observed in the present investigation, but the mountains were not examined in sufficient detail to make this negative evidence conclusive, and it is possible that incipient glaciers formed in a few localities where

[1] Emmons, S. F., op. cit., p. 328.

conditions were specially favorable. The evidence appears, however, to be adequate to prove that large glaciers did not exist. Both the polished surface and the contrast in topography can be satisfactorily explained by faulting, of which there is abundant evidence.

FAULTING THEORY.

The two types of topography that characterize the Toyabe Range can best be explained, in the opinion of the writer of this paper, by assuming two cycles of erosion. After the region had been extensively deformed, as explained by Emmons, it appears to have been subjected to stream erosion until it reached a stage of maturity, when its relief was still a few thousand feet but its surface was undulating rather than rugged and its stream courses occupied open valleys rather than narrow canyons. Then—probably late in the Tertiary period—the mountain mass was lifted with reference to the area occupied by Big Smoky Valley and may have been tilted away from the valley area. The resulting escarpment was vigorously attacked by the streams, and thus the present youthful and precipitous topography has been developed on the front of the mountains, while the mature topography farther back has remained without much change.

General faulting along the east side of the Toyabe Range is indicated by observed faults, as in the vicinity of Peavine ranch, by polished surfaces, such as that near Santa Fe Creek, and by an extensive system of escarpments at the foot of the mountains (Pl. IX, *B*, p. 44) and on the adjacent alluvial slope (Pl. I, in pocket, and Pl. III, p. 18), bearing evidences of a fault origin as explained on pages 44–45. The fact that scarps attributable to faulting were found only on the alluvial slopes adjacent to the two notably precipitous mountain fronts—those of the Toyabe Range and of Lone Mountain—is itself a strong indication that these fronts were produced by faulting.

TOQUIMA RANGE.

The Toquima Range, which is about 80 miles long, lies on the east side of Big Smoky Valley, opposite the Toyabe Mountains, with which it merges at the north. Monitor Valley, east of this range, and Ralston Valley, southeast of it, are separated by a spur of the Toquima Range in the vicinity of Belmont. In the north the range is low and indefinite and bears only a little scattered timber, but toward the south it increases in height and becomes a prominent range, although not so large as the Toyabe. A high mountain area culminating in Jefferson Peak lies back of Round Mountain and gives rise to Jefferson and Shoshone creeks. Bald Mountain, north of Manhattan, is 9,275 feet in altitude.

The upper parts of this range have undulating topography, somewhat similar to that of the upper areas of the Toyabe Mountains, but the range does not have a steep front and no evidence was found of general faulting, either in the bedrocks or in the valley fill.

SAN ANTONIO RANGE.

The San Antonio Range is an irregular mountain mass, about 30 miles long, which lies south of the Toquima Range, from which it is separated by an open gap several miles wide. It separates Ralston Valley on the east from Big Smoky and Alkali Spring valleys on the west. It is somewhat lower, smaller, and more arid than the Toquima Range, and it decreases in general altitude toward the south. The highest point, which is near the north end, is about 8,500 feet above sea level. In the vicinity of Tonopah and farther south the range includes numerous more or less isolated and barren conical peaks.

LONE MOUNTAIN.

Lone Mountain constitutes a compact mountain mass at the south end of Big Smoky Valley. It has very precipitous slopes, especially on its north side, and, rising abruptly to an altitude of 9,114 feet above sea level, or about 4,400 feet above the alkali flat, it forms a conspicuous mountain. A spur of lower hills and ridges extends northward to Millers, and a large irregular mountain mass lies to the south, forming the divide between Clayton and Alkali Spring valleys, and for some miles constituting the south boundary of the basin of Big Smoky Valley. Lone Mountain and the associated mountains are separated from the southern part of the San Antonio range by a low, open gap several miles wide, similar to the gap between the San Antonio and Toquima ranges.

The Recent scarps at the north base of the mountain (Pl. IX, *B*, p. 44) and on the adjacent alluvial slope (Pls. I and X, and pp. 44–45) suggest that the steep north-facing front of this mountain has, like the front of the Toyabe Range, been produced by uplift in late geologic time.

SILVER PEAK RANGE.

The Silver Peak Range is a wide and rather high mountain mass except near its north end, where it becomes a low, narrow ridge. It terminates Big Smoky Valley on the southwest and separates this valley from Fish Lake Valley, farther west. It also lies between Clayton and Fish Lake valleys. Only a narrow belt on the east side of the low northern part of the range drains into Big Smoky Valley.

MONTE CRISTO RANGE.

The Monte Cristo Range is an irregular mountain mass that lies northwest of the southern part of Big Smoky Valley and culminates in the southeast in a conspicuous peak 7,950 feet above sea level.

The range presents an arid appearance and supports but little timber. North of the main range is an extensive arid upland area containing many low ridges and hills and several wide and very dry débris-filled basins that were not examined. This upland extends northward almost to the south end of the Shoshone Range, the intervening gap forming the outlet of Ione Valley.

SHOSHONE RANGE.

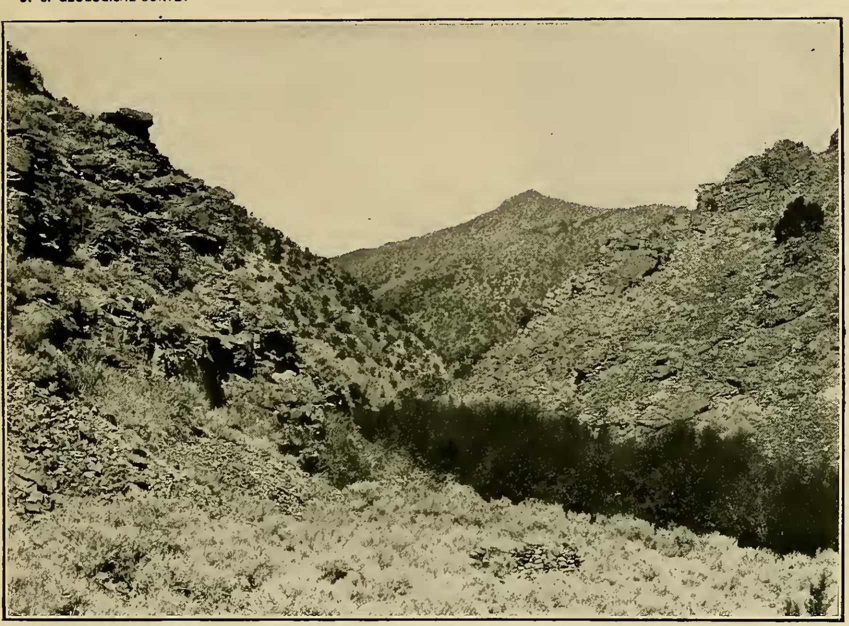
The Shoshone Range lies on the east side of Ione Valley but extends far beyond the north end of this valley. It is a narrow but relatively lofty range, a considerable part of the crest line being more than 9,000 feet above sea level. The west slope is only about 3 miles wide and is cut by many short canyons that are normally dry but discharge their flood waters into Ione Valley. Near its south end this range coalesces with the Toyabe Range, forming a mountainous area that is more than 20 miles wide. About 210 square miles of this area drains into the lower valley, exclusive of the belt that drains into Ione Valley. North of the divide the Reese River valley intervenes between the Shoshone and Toyabe ranges. The lowest point in the divide is at the gap between the head of Cloverdale Creek and the depression known as Indian Valley, where Reese River rises.

ALLUVIAL FANS.

RELATION OF FANS TO CANYONS.

The valley is nearly surrounded by a mountain wall in which are cut innumerable notches of various sizes. Each notch is the mouth of a canyon—the portal through which a certain part of the mountain area makes its contributions to the valley, not only of the water that falls upon it as rain or snow but of the very substance of the mountains themselves. The water that is discharged at the surface or as underflow is the vehicle by means of which the transportation of this rock material is effected, the soluble matter being carried in solution, the fine particles of sand and clay held in suspension, and the pebbles and boulders rolled over the surface by the impact of the water. Only from the larger canyons are these contributions made continuously, most of the canyons being dormant the greater part of the time and becoming active contributors only at long intervals when freshets occur. The character and quantity of the contributions that the valley receives through these notches determine almost exclusively the shape of its surface, the distribution and capacity of its water-bearing beds, the quantity, quality, and level of its ground water, the character of its soil and native vegetation, and the agricultural possibilities of its lands.

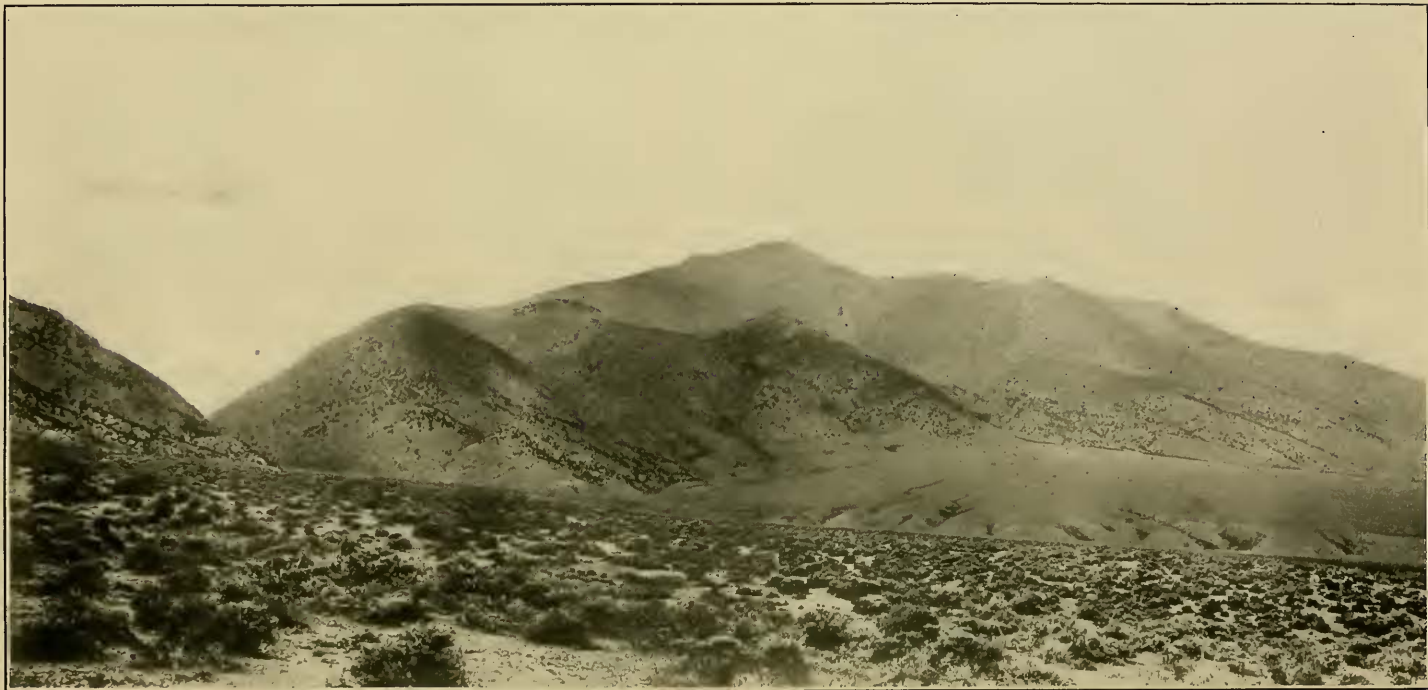
At the mouth of each canyon is an alluvial fan, or débris cone, built of the materials contributed by the canyon. Each of these fans



A. MOUTH OF SANTA FE CANYON.

Showing absence of glacial features and presence of birch trees, which indicate water.

B. TRANSPORTED GRANITE BOWLDER.



SHORT, STEEP ALLUVIAL FAN CUT BY THE STREAM FROM KINGSTON CANYON.

is or has been the greatly expanded streamway or flood plain of the stream that periodically flows from the canyon. The floor of the canyon and surface of the fan form parts of a single stream profile and are as closely adjusted to each other by the laws of stream gradation as the upper and lower courses of more ordinary streams. All the fans have the same general form because they are produced under the same general conditions. Each has an apex at the mouth of the canyon, from which it extends downward in all directions except as it is limited by other land forms. In each the grade diminishes with distance from the apex, thus giving the fan a concave profile along a line drawn from the apex in any direction in which the fan extends. In their size and in the shape of their concave profiles, however, the fans differ as widely as the canyons from which they are supplied. These differences are never haphazard but are determined by the sizes and gradients of the canyons, the volume and character of the floods which they discharge, and the quantity and nature of rock waste which the floods have to handle.

As the canyons are not far apart their fans are crowded together and modified by each other. Many small fans are superimposed on the larger ones (see Pl. VI), and fans of nearly equal size merge with each other in their middle and lower parts, forming a single smooth slope, a given point of which may receive sediments from two or more canyons.

Where the contributing area is low and narrow the resulting fans are inconspicuous and are definitely terminated by the burial of their bases under the alluvium of large fans or under lake or playa deposits. This condition is well illustrated at Millers, where the outwash from a small area of low hills at the end of the spur extending northward from Lone Mountain has formed an insignificant débris slope extending from a short distance south of the railroad to the vicinity of the pumping plants. The base of the slope is a definite line, and beyond it extends a wide plain produced by the flood waters of large canyons to the north.

Where the contributing area is narrow but steep and high, the fans are steep but short (Pl. VI). The steep gradients of the canyons make the floods of such an area torrential and give them great carrying power, but owing to the shortness of the canyons the floods are of brief duration, and they lack sufficient volume to transport far into the valley the coarse rock waste which they bring to the mouths of the canyons. Like the fans of the type first mentioned, their bases are generally overlapped by alluvium from larger fans or by lake or playa deposits. A fan of this kind is impressive to anyone ascending it but appears insignificant when represented on a topographic map. A good example of a slope composed of such fans may be seen at the north base of the prominent ridge that extends northwest from Lone Mountain. Here the mountain rises 2,000 to 3,000 feet in about the same horizontal distance, and although the mouths of the canyons are high above the valley the débris slopes are so precipitous that the alkali flat approaches within less than a quarter of a mile of the edge of the mountain. An almost equally good example of this type is in the vicinity of Seyler Peak, where the mountain rises 2,000 feet in about half a mile, and where a steep débris slope occupies a narrow belt between the mountain and a mud flat. In the vicinity of Moore's ranch there is a larger débris slope of the same type. Here the mountain rises a mile in a horizontal distance of a little more than 2 miles, and the resulting débris slope, though wider than at Lone Mountain and Seyler Peak, is equally steep and more impressive. The fan shown in Plate VI is also of this character. It is supplied from a steep, short canyon that drains a part of the outer flank of Bunker Hill Peak.

Very different are the large fans of gentle gradient produced at the mouths of the long canyons that head far back in the high mountains and, receiving the drainage of innumerable tributary canyons, form the outlets of extensive areas of high altitude and heavy precipitation. These canyons are much gentler in gradient but discharge floods of much greater volume and duration. The detritus brought out of the mountains through one of these canyons is not heaped about the mouth of the canyon but is spread widely, some of it being carried many miles into the valley. The result is a flattened and expanded fan over which one may travel for miles before realizing that he is on such a feature at all, which nevertheless required a vast amount of sediment for its construction, as is indicated by the topographic map, and which appears sufficiently impressive when viewed from its apex. Of this type are the fans of Twin Rivers and Kingston Canyon, as is clearly shown on the large map (Pl. I). Each of these fans receives the contribution of about 35 square miles of mountain area, parts of which are more than 10,000 feet above sea level, and each radiates from its apex a distance of about 5 miles and would extend farther were it not interrupted by the ancient lake bed. Another fan of nearly equal magnitude is that of Jefferson and Shoshone creeks.

Ranking between these large fans and the narrow steep débris slopes are a great number of fans of intermediate sizes and gradients which are generally built together to form continuous alluvial slopes of intermediate width and grade. North of Jefferson Creek are the fans of Willow, Barker, Moore, Charnock, and Northumberland canyons, each rather large and built of the rock waste supplied by mountain areas of considerable extent. These fans coalesce with each other or are so united by smaller intermediate fans that they form a single smooth, continuous slope rather than a series of distinct physiographic features. The slope bordering the Toquima Range south of Jefferson and Shoshone creeks and the slope adjoining the San Antonio Range also afford examples of the intermediate coalescing types of fans. Another slope of the same kind is adjacent to the Toyabe Range south of the Twin Rivers fan. Thus between Twin Rivers and Seyler Peak are found alluvial slopes of three distinct types. The characteristics of each type and of their contributing mountain areas are shown on the map (Pl. I).

The largest fan in the valley is that of Peavine Creek, but the area available for it is so restricted that it could not develop symmetrically, like the Twin Rivers and Kingston fans. The contributing area of this great, misshapen fan includes more than 100 square miles of mountains with high average altitude, and it is therefore not surprising that it is the controlling feature for 20 miles south from the point where Peavine Creek leaves the mountains, and that its influence on the topography can apparently be traced beyond Millers.

Another expanded alluvial slope is that formed by Willow, Blackbird, Birch, and other canyons near the north end of the valley. This slope extends nearly to the east side of the valley and southward indefinitely.

RELATION OF VALLEY AXIS TO FANS.

As in most localities the contributing mountain areas on opposite sides of the valley differ in size, the corresponding fans are likewise unequal, and the axis, or line of lowest depression, is not in the middle of the valley but relatively far from the side on which the mountains are large and near the side on which the mountains are small. The largest mountains are not, however, all on the same side, but are here on one side and there on the other. Consequently the line of lowest depression is a sinuous line that keeps far away from the large mountains.

Near the north end of the valley the axis, as shown by the medial draw, is close to the east side, because here the Toquima Range is low and has produced a low and narrow though steep alluvial slope which does not balance the extensive slope at the mouths of Willow, Blackbird, Birch, Santa Fe, and Kingston canyons.

South of the Kingston fan the medial line of depression expands into a wide flat which for about 12 miles holds a position slightly nearer the west than the east side, this balance in favor of the east side being due to the increased prominence of the Toquima Range and the fact that the divide of the lofty Toyabe Range approaches within about 2 miles of the east margin of the range.

For a distance of about 10 miles, from the vicinity of the Jones ranch to that of the Logan ranch, the Twin Rivers fan dominates the west side and crowds the medial flat about 6 miles from the Toyabe

Range. This segment of the valley, however, also receives heavy contributions from the east, especially from Moore Creek. The valley has here about the same width as in the segment to the north, but its débris slopes are so much larger that its medial flat is notably contracted.

Southward from the Twin Rivers fan the line of lowest depression is carried first near the west side, on account of the heavy discharge of Barker, Willow, Jefferson, and Shoshone creeks and the narrow contributing area back of the Darrough and Moore ranches; then near the middle, on account of the approximate balance between the contributing mountain areas on the two sides, as shown on the map (Pl. I); then gradually westward again as the contributing area on the west side becomes narrower, until, in the vicinity of Seyler Peak, the contributing area is only one-half mile wide and the asymmetry becomes pronounced.

Peavine Creek emerges from the mountains at a level so much lower than the smaller streamways that in the first 5 or 10 miles of its course through the valley it follows largely the line of depression established by the small, steep fans on the opposite sides of the valley, which is here relatively narrow. Farther south, where it comes in competition with Cloverdale Creek and the drainage from Ione Valley, its real importance as a contributor of rock waste becomes manifest. Ione Valley occupies a basin of its own and has its own series of alluvial fans on the opposite sides of its medial line of depression. The greater part of the rock waste supplied to it by its bordering mountain areas no doubt underlies these fans, but the broad drainage channel which leads through the gap at Black Spring shows that some of this rock waste has been carried into Big Smoky Valley. The contributions of Peavine Creek are, however, so much greater than the combined contributions of Cloverdale Creek and Ione Valley that the channel which conducts the drainage from these two is not only crowded near the west side of Big Smoky Valley, but is to some extent impounded, as is shown by the existence of small flats northwest of Midway station. (See Pl. I.)

South of Midway station the storm waters of Peavine Creek and Ione Valley mingle to some extent and follow the same general course along the broad indefinite medial depression. Still farther south the medial depression expands into a large flat which in most places is at a considerable distance from the mountain borders but comes close to parts of Lone Mountain that have very narrow contributing areas and also to the spur of the Monte Cristo Range at the Desert Well.

The dominating influence in the lower valley of the material brought in by its northern tributaries—Peavine and Cloverdale creeks and

Ione Valley—is shown by the position of the large flat that occupies the lowest depression in the valley. This flat has been crowded into the southwest corner of the lower valley by the great quantity of rock waste poured into the valley from the north.

ALLUVIAL DIVIDES.

If the axis, or medial line of depression, is regarded as passing through the flats that occupy the lowest levels of the upper and lower valleys, respectively, and as extending without interruption from the north to the south end of Big Smoky Valley, it will be seen that the vertical projection of this line consists in general of two sections that are concave upward, between which there is a section that is convex. The convex section is in the narrow segment of the valley that lies between the southern parts of the Toyabe and Toquima ranges, and is, of course, at the parting of the waters between the upper and the lower valley. This alluvial divide apparently owes its existence primarily to the fact that the two ranges come close together in a region where both are large and high. The divide is not on the fan of Peavine Creek and probably that creek has never discharged into the upper valley. It may, however, have had an influence in holding back the rock waste in the vicinity of the divide by aggrading the valley farther south. The Tertiary sediments in the vicinity of San Antonio may have had a similar effect. The well-developed shore features (Pl. I, in pocket) that are found at lower levels in the upper valley show that this divide is older than the lakes of the Pleistocene period.

The most important departure from concavity in either of the two end sections is in the vicinity of the Charnock and Rogers beaches (Pl. I), where the heavy gravel embankments extending across the axis of the valley form a divide that separates the drainage south of these beaches from the drainage north of them. The Daniels beach was not examined at every point but apparently it also forms a divide which debars the northern surface waters from the main flat.

The alluvial divide between Big Smoky Valley and Alkali Spring Valley is of the same nature as the one between the two parts of Big Smoky Valley. Several of the other low gaps are of the same general character except that the Tertiary sedimentary beds are more largely involved.

SHORE FEATURES.

THE TWO ANCIENT LAKES.

Big Smoky Valley once contained two large lakes, of which one occupied the lowest parts of the upper valley and the other the lowest parts of the lower valley (Pl. I, in pocket). For convenience in referring to these lakes it is desirable that they should be given names. The ancient lake in the upper valley may appropriately be called Lake Toyabe, and the one in the lower valley, Lake Tonopah. The surface of both lakes fluctuated and stood at various levels. There is no evidence that either lake had an outlet, even at its highest level, and it is therefore inferred that the water of both was salty.

Lake Toyabe, when at its highest level, was about 40 miles long, 9 miles in maximum width, and covered an area of approximately 225 square miles, or 18 per cent of the drainage basin in which it lay. Its maximum depth was about 170 feet, and its shore line, which, so far as was determined, is still horizontal, stood a short distance above the present 5,600-foot contour and measured about 85 miles in length. The maximum depth of the part of this lake that lay south of the present road to Charnock Pass was only about 70 feet. When the surface of the water went down the lake divided into two parts which were completely separated by an isthmus just south of the Charnock Pass road, the relatively large northern water body covering the large flat east of Millett and the smaller body occupying the depression which now holds Moore Lake (Pl. I).

Lake Tonopah, when at its highest level, was about 22 miles long, 5½ miles in maximum width, and approximately 85 square miles in area, or only about two-fifths the area of Lake Toyabe. This area was only 4.2 per cent of the total drainage basin tributary to the lake—a percentage less than one-fourth as great as that of Lake Toyabe. The maximum depth of Lake Tonopah was about 70 feet, and its highest shore line stood a little below the present 4,800-foot contour, or about 825 feet below that of Lake Toyabe. The total length of the Lake Tonopah shore line is estimated at 53 miles.

The existence of these ancient lakes and the dimensions given in the foregoing paragraphs are deduced from the shore features which were formed by the waves and currents of the lakes and which are still in existence. These shore features consist almost entirely of gravelly beaches and beach ridges, or embankments, many of which are very definite structures that can be followed for a number of miles, the largest attaining heights of nearly 50 feet (Pl. I and fig. 2, profiles A to G). To facilitate the description and discussion of these features the principal ones have been named the Schmidtlein, Minium, Vigus, Daniels, Spaulding, Charnock, Rogers, Gendron, Millett, and Logan beach systems being recognized on the bed of Lake Toyabe, and the Railroad, Alpine, Desert Well, and French Well beach systems on the bed of Lake Tonopah (Pl. I). These names do not apply to specific lake stages but to the most conspicuous beach structures, some of which are composites of beaches that were functional at several different water levels.

The existence of Lake Toyabe is indicated on the large map in Russell's monograph on Lake Lahontan, [1] but no mention is made of it in that monograph, nor in any other literature that was searched in the preparation of the present paper. No mention of beaches in

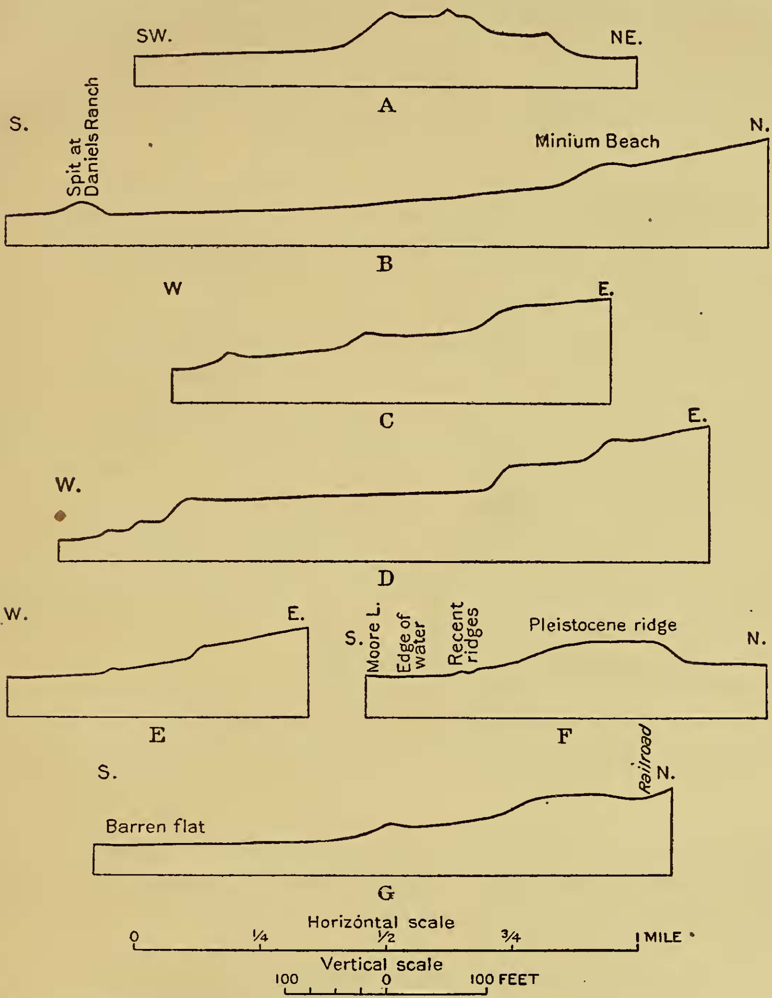


FIGURE 2.—Profiles across beaches and beach ridges in Big Smoky Valley. A, Spaulding beach system near the southeast corner of sec. 8, T. 14 N., R. 44 E.; B, Minium beach system and the spit at the Daniels ranch along road between Daniels and Schmidtlein ranches; C, Charnock beach system along road between Charnock Springs and Charnock Pass; D, Charnock beach system in the locality of its greatest development—south of Charnock Springs; E, Charnock beach system along Moore Creek road, on or near NE. ¼ sec. 18, T. 12 N., R. 44 E.; F, Rogers beach system in its middle part and the Recent beaches at the north end of Moore Lake; G, Railroad beach system 2 miles west of McLeans.

the lower valley was found in any of the literature except by Free (p. 16), although a part of the area containing conspicuous and well-formed beach ridges is covered by a detailed geologic map.[2]

[1] Russell, I. C., Geological history of Lake Lahontan, a Quaternary lake of northwestern Nevada: U. S. Geol. Survey Mon. 11, pl. 46, 1885.

[2] Spurr, J. E., Ore deposits of the Silver Peak quadrangle, Nev.: U. S. Geol. Survey Prof. Paper 55, 1906.

SHORE FEATURES OF LAKE TOYABE.

Spaulding beaches.—The main feature of the Spaulding beach system is a gravelly ridge that extends from near the middle of the east shore line of Lake Toyabe, in a north-northwest direction for a distance of about 7 miles, and ends as a spit at a point north of the Spaulding salt marsh, not far from the west shore of the ancient lake (Pl. I). This ridge extends boldly across the lake bed but should perhaps be regarded as the outermost of a series of beaches at the north end of the ancient lake. It is most prominent in its middle part. On sec. 8, T. 14 N., R. 44 E., where it was measured, it is more than three-fourths mile wide and about 45 feet high and has the rather complex form shown in figure 2, A. Southeast of the locality at which this profile was made the ridge first widens and then becomes smaller and less distinct, gradually assuming the character of an expanded gravelly beach surface that extends with a gentle slope from the highest shore line nearly to the flat. A short distance northwest of the locality represented in figure 2 the ridge diminishes to a width of about one-fourth mile and a height of only about 5 feet. Thence it extends northwestward for nearly 3 miles, as a low but distinct feature, to the north side of the salt marsh, where it ends.

The crest of this ridge does not maintain a uniform altitude. At the locality represented in figure 2 it is approximately level with the top of the beach ridge at the Daniels ranch but distinctly lower than the highest shore line; farther northwest it drops to a level considerably below that of the Daniels ranch.

Daniels beaches.—The Daniels beach system consists of three limbs that form a sort of zigzag (Pl. I). The main part is a prominent gravelly ridge that trends west-northwest and belongs to the series of beaches at the north end of the lake, being next in succession to the Spaulding beach. This ridge becomes indefinite at both ends where it approaches the shore, but throughout most of its extent it is a very distinct feature and holds a nearly straight course. South of the Daniels ranch it is nearly a quarter of a mile wide and about 15 feet high.

Near its east end the ridge splits; the north prong continues a short distance in approximately the same direction as that of the main ridge, and ends in an area of sand dunes; the south prong extends almost due south a distance of about 1½ miles to the mainland, where a steep, gravelly beach surface slopes from the highest shore line down to the flat, through a vertical range of more than 50 feet. About a mile farther northeast a small but distinct beach was observed at the highest shore line, about 50 feet above the main ridge of the Daniels beach system.

From a point near the west end of the main ridge another gravelly ridge zigzags back with an east-northeast trend parallel to that of the west shore line (Pl. I). This ridge forms a distinct, symmetrical spit, at the abrupt, rounded end of which is situated the Daniels ranch.

Vigus beach.—The Vigus beach is in sec. 7, T. 15 N., R. 45 E., and sec. 12, T. 15 N., R. 44 E. (Pl. I), and is next in the series to the Daniels beaches. It stands at a somewhat higher level than the main Daniels beach, its top being not much below the level of the highest shore line. It is a gravelly ridge, slightly arched in ground plan, about 2 miles long, one-tenth mile wide, and 10 feet high. At its east end it is interrupted by a streamway cut by flood waters from the north.

Minium beaches.—Next in the series to the Vigus beach is the Minium beach system, which is separated from the Vigus beach by a flat only a little more than one-fourth mile wide (Pl. I). Its trend is in general east-northwest, with a slight S-shaped flexure, and it can be traced as a distinct feature through a distance of somewhat more than 4 miles. It is best developed in its middle part, where it forms a gravelly ridge from one-fourth to one-half mile wide and 20 to 25 feet high. Toward the southwest it loses its character as a ridge and becomes a gravelly beach extending lakeward from the highest shore line. Farther southwest this beach diminishes in prominence. At its intersection with the road leading from the Daniels ranch to Schmidtlein's ranch it is a conspicuous feature, its top being about 40 feet higher than the top of the ridge at the Daniels ranch, as is shown in figure 2, B; at its intersection with the Kingston road it is smaller but still distinct; and at its intersection with the Bowman road it is too indistinct to be definitely located. The Minium beach extends as a definite but gradually diminishing ridge northeastward from the locality of maximum development to a point nearly one-half mile north of the middle of the Vigus beach, where it ends as a spit.

Schmidtlein beaches.—The Schmidtlein beach system begins about 4 miles northeast of the Minium spit and extends northward about 2½ miles. It is crossed near its south end by the road leading from the Daniels ranch to the Spencer Hot Springs (Pl. I). In its southern part its character is that of an inner beach and it has no definite southward limit, but toward the north it bifurcates, forming two ridges 10 to 15 feet high, both of which end abruptly as spits. The eastern ridge, which is the larger, extends nearly due north approximately parallel with the shore; the somewhat smaller western limb takes a more northwesterly course and extends into the lake.

One and one-half miles north of Schmidtlein's ranch, along the main road on the west side of the valley, there are several small low ridges that appear to be shore features at the head of the Gillman Spring embayment of the ancient lake.

Charnock beaches.—The Charnock, like the other large systems, is not a single beach representing one water level, but a composite of several strands at different stages of the lake. It is in a sense the counterpart of the Spaulding beach system, for it lies on the southeast side of the main flat just as the Spaulding system lies on the northeast side, and its distal part, ending as a spit, may be regarded as the outermost of the south-end beach ridges, just as the Spaulding embankment is regarded as the outermost of the north-end beach ridges. As in the Spaulding system, the ridge or ridges are attached to the east shore, where they become parts of a gravelly beach surface that slopes downward from the highest shore line (Pl. I).

A feeble high-level strand practically connects the Spaulding with the Charnock system. In the vicinity of Charnock Springs the shore eatures gradually strengthen and increase in complexity toward the south. Opposite the northernmost springs there is only a single, small, built terrace somewhat more than 150 feet above the flat, but along the road between the springs and Charnock Pass there is the more complex profile shown in figure 2, C. A heavy inner beach which marks the highest water level is here associated with two parallel ridges at levels about 30 and 50 feet lower, respectively. Farther south the belt of shore features widens and consists of a series of terraces with slight ridges at their outer edges. A composite and not quite accurate profile of this series of terraces is shown in figure 2, D.

The innermost beach, which marks the highest water level of the ancient lake, and a parallel beach 25 feet lower swing southward, and where they cross the Moore Creek road they have the profile shown in figure 2, E. South of the road they are interrupted, probably by recent deposition of sediments on the fan of Moore Creek, and farther south (in sec. 19) the shore line is represented by a single small beach that fades out toward the south. This beach is about 70 feet above the level of Moore Lake and presumably represents the highest water level.

The lower terraces maintain a southwest trend, and after diverging from the shore line they form a broad low ridge that ends in the middle of the lake bed as a spit with a blunt, rounded end (Pl. I).

Rogers beaches.—A short distance south of the spit formed by the Charnock beaches and separated from it by alkali flat and sand dunes is the Rogers beach system.

It extends with a nearly east-west course across the lake bed in the locality where the latter is constricted between the Twin River and Moore Creek fans, but is deflected northward at both ends. At one time it formed an isthmus that connected the two fans and separated the waters of Lake Toyabe into two disconnected lakes. It was functional as a beach on both sides, but its chief development seems to have been as a beach at the north end of the southern lake, now represented by the small intermittent body of water designated on the map as Moore Lake.

In its middle part, shown in figure 2, F, it consists of a ridge more than one-fourth mile wide, standing about 35 feet above the level of Moore Lake and, as nearly as could be determined, about 35 feet below the highest shore line. Toward the east it is flanked by sand dunes but appears to end as a spit; toward the west it increases in size and height and then disintegrates into several small ridges, somewhat as is shown in Plate I.

Gendron and Millett beaches.—The large Spaulding and Charnock beaches flank the lowest depression of the ancient lake bed on the northeast and southeast sides but no beaches of corresponding magnitude were formed on the west side. Small ridges are, however, found along a considerable part of the western shore line, some of them indistinct but others very definite.

Three of the best developed beach ridges on the west side are west of Mrs. Alice Gendron's ranch and are parallel, or concentric, with each other (Pl. I). The outermost, or lakeward ridge, which lies one-fourth mile west of the ranch, is about 75 feet above the level of the flat due east. The middle ridge, which lies three-tenths mile nearer the shore, is longer and larger, and its crest is about 25 feet higher. Where the road leading west from Mrs. Gendron's ranch crosses this ridge it is about 50 feet wide at the top, and stands 10 to 15 feet above the general surface on the east side and 5 to 10 feet above the general surface on the west side. The inner ridge is one-fourth mile farther west and is also well developed.

Small or indistinct shore features are found on the steep slope west of Millett and the Jones ranch and between the latter and the Rogers ranch. They probably connect with the fingers of the Rogers beach system. Deposition on the Twin River fan has to some extent obliterated the shore features built upon it.

Logan beach.—The name Logan beach is applied to a poorly developed beach that extends along the west shore line for several miles but becomes unrecognizable south of the Darrough Hot Springs. From the elevation of the observed shore features it is inferred that the ancient lake at its highest stage extended southward nearly to Wood's ranch, but no shore features were found near the south end.

SHORE FEATURES OF LAKE TONOPAH.

Railroad beaches.—A series of concentric beaches and beach-ridges encircles the west end of Lake Tonopah. It extends without interruption along the main railroad from McLeans nearly to Blair Junction; thence, with a great, graceful curve, it crosses the branch railroad and swings southward to the "salt well," and thence, turning eastward, it recrosses the branch line, and extends to a locality about 5 miles east of this railroad, where it fades out. Thus this beach system persists as a distinct and conspicuous feature through a distance of about 18 miles. Because the railroads run close to it through most of its course and for want of a better name, the name Railroad beach is applied to this dominant shore feature of Lake Tonopah.

South of Blair Junction the beach system includes one conspicuous gravelly ridge. A short distance east of the branch railroad this ridge was found to be 10 to 15 feet high on the inner side and 25 feet or more on its outer side. From the ridge, which in this locality is more than one-fourth mile wide, a gravelly beach slopes downward an indefinite distance toward the flat.

In the vicinity of the "salt well" the ridge splits into two distinct but smaller, concentric ridges, the outer or lakeward ridge being tied to the rock butte that is a short distance northeast of the "salt well." These ridges are about one-tenth mile wide and 10 feet high where they cross the railroad but diminish in size farther east. At several points they are broken by postlacustrine stream channels. Plate XI, *A* (p. 60), shows the exposed section on the banks of a stream channel cut through the outer beach, as indicated by the interruption shown on the map (Pl. I) a short distance southwest of bench mark 4,766. The ridge is here only 5 feet high and about 250 feet wide, and exhibits the gentle outer slope and a comparatively steep inner slope characteristic of beach ridges.

From a locality a short distance east of the branch railroad to McLeans the shore features are well developed, but differ somewhat in character from those on the west and southwest sides of the lake bed. The shore zone, which is nearly a mile in average width, has a range in altitude of fully 50 feet. It is strewn throughout with beach gravel but includes several nearly parallel ridges that were functional at different stages of the lake. Three or four of these ridges were distinguished, but their relations were not fully determined.

At milepost 33, two miles west of McLeans, the gravelly shore zone is about three-fourths mile wide, and its profile is approximately that shown in figure 2, G. The outermost beach is here a small ridge one-half mile south of the railroad and only a short distance above the level of the flat. Between it and the railroad there is a more prominent ridge that stands at a higher level and is about one-fifth mile wide. The inner beach is not well defined in this locality but appears to lie a short distance north of the railroad. Farther west two ridges seem to intervene between the highest shore line and the prominent ridge at milepost 33. One of these crosses the wagon road one-tenth mile north of the railroad at a point one-third mile east of milepost 29, or about 2 miles east of Blair Junction. The other passes a little more than one-eighth mile south of Blair Junction and crosses the main railroad at an acute angle just west of milepost 28, or about one-half mile east of Blair Junction.

Near McLeans the beach shows a slight tendency to protrude as a spit that forms the counterpart of the Alpine spit on the opposite side of the lake bed. This spit is, however, a double feature. One prong projects directly south of the station; the other is a mile farther west. Between the two prongs is a broad streamway that apparently existed at the time the ridges were being built. Its waters seem to have been effective in modifying the work of the waves by merging the ridges and deflecting them outward, as shown on the map (Pl. I). In the angle formed by the main ridge and the embankment that borders the streamway is a depressed area which has no drainage outlet and which must have formed a small lagoon at the time the lake existed.

Alpine beaches.—The Alpine beach system comprises a group of short but conspicuous ridges on the south side of the lake bed, opposite McLeans (Pl. I). The outer beach consists of a V-shaped embankment, from the point of which a spit extends lakeward. At the junction of the two limbs the feature is nearly one-fourth mile wide and approximately 35 feet high on the north side. The southern limb is a gracefully curving ridge about 25 feet in maximum height, but diminishing in size toward the shore until, in the course of less than a mile, it disappears entirely. The inner ridge is a distinct feature for about a mile. Where it has its maximum development it is about one-tenth mile wide, 10 feet high on the inner side, and 25 feet high on the outer side. It stands considerably higher than the V-shaped embankment and apparently a little higher than McLeans.

The south limb of the V-shaped embankment and the south side of the spit constituted a beach that bordered the deepest part of the lake at a stage when the shallower part farther east was much smaller than is shown in Plate I. The east limb and the north side of the spit were at the same time functional as a beach bordering the shallower eastern water body. The two parts of the lake were at this time connected by a strait 1½ miles wide. The protruding character of this feature is perhaps due partly to the great amount of gravel carried into the lake by large arroyos on both sides of the spit.

Desert Well beach.—The Desert Well beach is in some degree a continuation of the railroad beach system. The main beach contours the shore a short distance north of the well and just north of the little black butte situated one-fourth mile west of the well. This butte was in a position where it was exposed to the full force of the waves, and although it is composed of hard rock, the rugged escarpment on its south side was apparently formed by wave cutting. The butte is tied to the main beach by a heavy accumulation of beach gravel, as shown in Plate I.

French Well beaches.—About 2½ miles north of the French Well, near the northern shore line of the ancient lake, at its highest level, are two well-defined gravelly ridges. The outer ridge is about a mile long, nearly one-tenth mile wide, and 5 to 10 feet high; the inner lies about one-half mile farther north and is approximately 250 feet wide and 5 feet high. These are the only distinct shore features that were observed east of the Alpine and Desert Well beaches. As at the two ends of Lake Toyabe, the very gentle slope of the lake bottom and the shallowness of the water were apparently not favorable for the development of beaches. Such small beaches as were formed have been covered with sediments deposited by postlacustrine floods.

ORIGIN OF SHORE FEATURES.

The principal factors that influenced the size, shape, and position of the shore features on the two ancient lake beds of Big Smoky Valley are the slope of the lake bottom, the depth of water in the different parts of the lakes, the fluctuations in water level, the sources of the beach material, the prevailing direction of the winds, especially the storm winds, and the resulting direction of lake currents.

The type of ancient shore features found in a desert valley depends largely on the height to which the valley was filled with water. The lakes of this valley, even at their highest stages, did not extend far up the alluvial slopes. Hence the water was shallow for considerable distances out from the shore, and the energy of the waves and shore currents was spent in transporting and arranging the rock waste, with which the shores were abundantly supplied, rather than in cutting back into the land. Wave cutting apparently took place on the exposed rock of the black butte just west of the Desert Well and on the valley fill in several localities, especially on the east side of Lake Toyabe, but it was unimportant as compared with the constructional work represented in the large embankments that have been described.

Where the water was shallow shore features did not develop to any important extent, probably because the waves did not attain sufficient size and force. Thus at the two ends of Lake Toyabe and in the shallow water of the northwest end of Lake Tonopah shore features were not observed. The deepest parts of both Lake Toyabe and Lake Tonopah were, however, partly inclosed by large beaches and beach ridges. The extensive bodies of shallow water back of these beaches were in the nature of lagoons, and they contain only a few small shore features.

The beaches and beach ridges that follow the highest shore line or run parallel to it were formed by the combined action of the waves and shore currents at various stages of the lake. The broad sloping beach surfaces, in some places extending through a vertical range of more than 50 feet, were not formed at any single water level but developed at different horizons as the surface of the lake slowly rose and fell. The ridges were the outer, or barrier, beaches, and those at distinctly different levels were formed at different stages of the lake.

A few of the largest ridges were, however, not formed parallel to the shore but extended boldly across the lake and attained heights of 20 to 50 feet. The most conspicuous example of this type is the Spaulding Ridge. These great embankments were evidently built by currents that diverged from the shore, as explained by Gilbert [1] and Russell.[2] They were probably built at different times by currents set in motion by storm winds from different directions.

The following tables show the prevailing directions of the wind at Millett (Jones ranch) and at Tonopah, respectively, and give some clue as to the direction of prevailing storm winds that swept the ancient lakes:

Prevailing direction of wind at Millett.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1910	S.	N.	S.	S.	W.	W.	W.	W.	S.	S.	S.	N.
1911	S.	S.	S.	W.	S.	S.	W.	S.	S.	S.	S.	N.
1912	S.	W.	S.	S.	W.	....	S.	W.	S.	S.	W.	N.
1913	S.	....	W.	S.	W.	S.	S.	S.	....	W.	S.	S.

Prevailing direction of wind at Tonopah.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1910	SE.	NW.	SE.	SE.	NW.	W.	SE.	W.	SE.	SE.	SE.	W.
1911	SE.	SE.	SE.	NW.	SE.	SE.	W.	SE.	SE.	SE.	W.	W.
1912	SE.	W.	SE.	SE.	NW.	SE.	W.	SE.	SE.	SE.	SE.	W.
1913	SE.	SE.	W.	SE.	NW.	W.	SE.	SE.	SE.	W.	SE.	SE.

The Minium and Vigus ridges and a part of the Daniels beach system were apparently built by currents that moved northward along the west shore of the lake but eventually set out across the lake, the divergence from the shore probably having been caused by the angle in the shore line and the shallowing of the water opposite the Kingston fan. The materials of which these ridges were constructed were supplied from Kingston Canyon and several canyons farther south. The Vigus Ridge may also have received contributions from the east side. The Rogers beach ridge appears to have been constructed in large part by a current that likewise moved northward along the west shore but that was deflected across the lake in the vicinity of the Twin River fan. It is built out of the

[1] Gilbert, G. K., The topographic features of lake shores: U. S. Geol. Survey Fifth Ann. Rept., pp. 85–101, 1885.

[2] Russell, I. C., Geological history of Lake Lahontan, a Quaternary lake of northwestern Nevada: U. S. Geol. Survey Mon. 11, pp. 87–124, 1885.

abundant sediments furnished by the Twin Rivers. Like the northern embankments, its principal functional beach was on the south side.

The Charnock, Spaulding, and Schmidtlein beach ridges and a part at least of the Daniels beach system are attached to the east shore and were evidently built by a different set of currents. A strong west wind acting without obstruction across the main part of Lake Toyabe, 9 miles wide and 170 feet deep, was no doubt effective in thrusting large waves against the east shore and also in producing a slow eastward motion in the water. When this slow, general current reached the east shore it was presumably deflected to the right or to the left, according as the wind was northwesterly or southwesterly, and continued as a more restricted and, therefore, swifter shore current. Where these currents reached projecting angles in the shore line or shallow water they were apparently deflected from the shore and built the projecting part of the Charnock beach system, the eastern limb of the Daniels beach system, and the long, large embankment of the Spaulding beach system.

The ridges of Lake Tonopah were produced chiefly by shore currents, but the spits at McLeans and on the opposite side of the lake were developed by currents that diverged from the shore. These currents probably came from opposite directions at different times and their deflection was probably due chiefly to the large quantities of sediment furnished by the arroyos on both sides and the resulting angles in the shore line. The embankment extending westward from the butte near the Desert Well indicates that the east winds were most effective in that locality.

LAKE STAGES.

The complex profiles of the larger beach systems, as shown in figure 2, A to G, are the result of fluctuations in the water level of the ancient lakes, the ridges and terraces at distinctly different levels having been formed at different lake stages. Several levels at which the lake stood long enough to construct definite shore features were recognized, but the elevations of the various features were not instrumentally determined. The whole subject of lake stages is rendered obscure by the fact that the lake stood at all intermediate levels and did a certain amount of work at these intermediate levels; also by the fact that there are no exposures in the shore structures that give a clue to the order of events.

Some of the largest features of Lake Toyabe are 35 to 50 feet below the highest strand and seem to represent a somewhat persistent water level. To this class belong the main parts of the Daniels and Spaulding beach systems, a prominent terrace of the Charnock system, and a part of the Rogers system. Minor fluctuations at this general level are indicated by the small ridges superimposed on the main part of the Spaulding embankment (fig. 2, A). A strand intermediate in altitude between this general level and the highest shore line is indicated by the terraces in the vicinity of the Charnock Springs (fig. 2, C, D, and E), and perhaps by the Vigus beach and other features a short distance below the level of the highest strand. Lower stages of the lake are indicated by the two lowest terraces south of Charnock Springs (fig. 2, D), the terrace on the north flank of the Spaulding embankment (fig. 2, A), and the low spit that extends beyond the main part of this embankment. In Lake Tonopah at least two or three lake levels can be identified.

The tiny strand that surrounds the small modern lake, shown on the map as Moore Lake, shows in a striking manner the radical difference between the large lakes of the Pleistocene epoch and their insignificant modern remnants. The contrast is shown in figure 2, F, which represents a locality where the modern strand is superimposed on the edge of one of the large, ancient features. The strand of Moore Lake consists at its north end of an inner beach, which, at the time the lake was examined, stood 600 feet from the water's edge and 9 feet above the water level, and an outer beach, consisting of a ridge 1 or 2 feet high, 125 feet nearer the water and at a level about 4 or 5 feet lower. This double shore feature can be traced around the east and west sides of the lake bed but is indistinct on the south side. The beach on the lakeward side of the ridge is extended to accommodate the lake at different levels but practically disappears some distance out, where levels are reached that represent a very small and shallow body of water. Although this pond is not generally filled to the level of the encircling ridge, it has, nevertheless, built a definite and relatively permanent structure at this level, and has formed no shore feature at a lower level except a uniformly sloping beach. The larger lakes of the Pleistocene epoch apparently had the same habit of forming definite features at certain levels, although they were constantly fluctuating. The inner strand of Moore Lake, which is 4 or 5 feet higher than the ridge, is probably functional under only exceptional conditions.

POSTLACUSTRINE CHANGES.

The shore features have not been much changed since the ancient lakes disappeared. In many places the gravelly ridges seem to be almost without modification. In only a few places have the shore features been cut by gullies. The principal changes have been produced by aggradation on the large fans, where the shore features have been, to a great extent, buried under sediments deposited by the streams. Small beaches at both ends of Lake Toyabe and at the northeast end of Lake Tonopah have no doubt been thus buried, and the lower parts of even some of the large ridges may be buried beneath considerable recently deposited material.

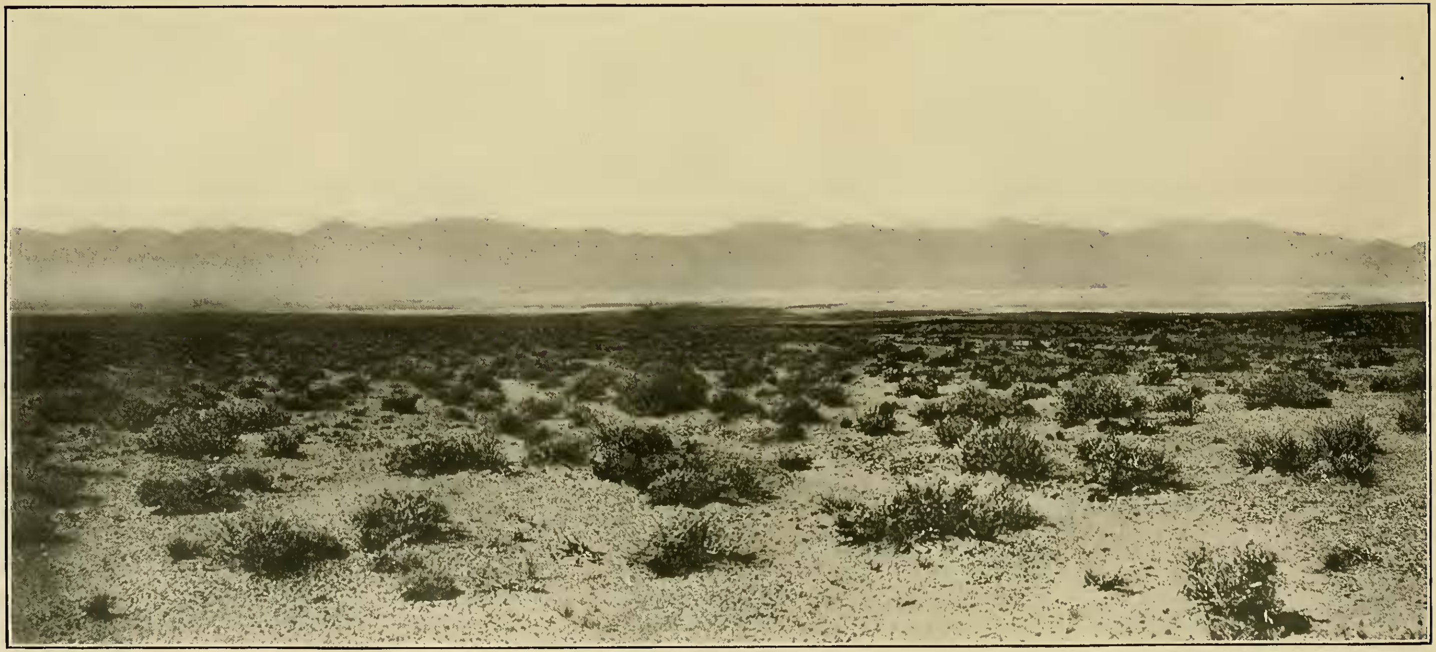
PLAYAS.

GENERAL FEATURES.

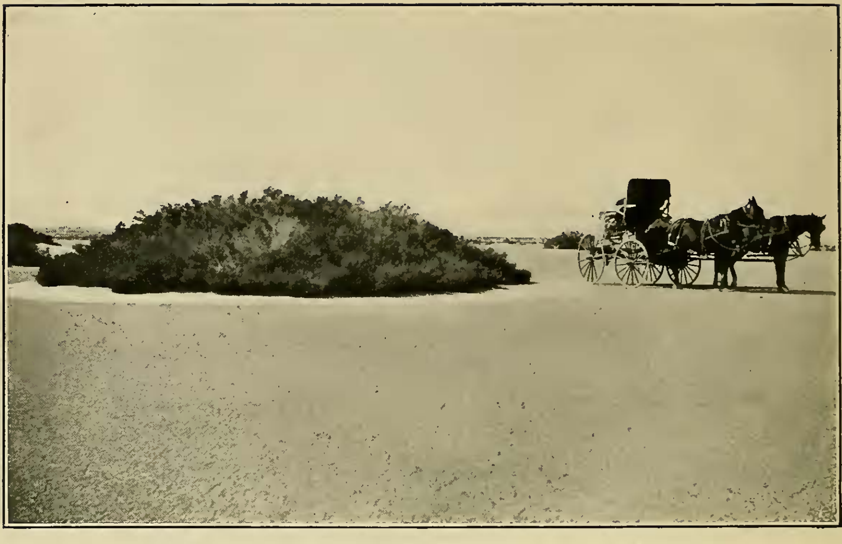
Many of the desert valleys have no drainage outlets, either because their surface waters have not accumulated in sufficient quantities to overflow and cut through the barriers produced by deformation of the rock formations or because these waters have themselves built barriers by depositing alluvium. In such valleys the flood waters that are not lost in their descent over the fans are impounded in the lowest parts of the valleys, from which they are removed almost exclusively by evaporation. Even in the valleys that have outlets the drainage may be partly or temporarily obstructed.

The impounded flood waters are always roily and on evaporation deposit fine sediments. This process of aggradation is as characteristic of the desert valleys as the aggradation on alluvial fans through deposition by running waters, and it produces as distinct a type of land surface. The running waters form surfaces with grades, whereas the impounded waters form surfaces that approximate horizontal planes. (See Pl. VII.)

These constructional flats, often called playas, are formed in part by thin temporary sheets of water such as are occasionally spread over the lowest parts of Big Smoky Valley at the present time and in part by permanent lakes such as occupied these low tracts in the Pleistocene epoch. The flatness of the lake bottoms is no doubt in a measure due to the deposition by thin sheets before and after the lakes existed. The margins of the flats differ according to the existence or nonexistence of an ancient lake. Where there has been no lake of appreciable depth the alluvial fans extend to the flat, the grade commonly becoming so gentle in the lower parts of the fans that the limits of the flat can not be sharply drawn and the casual observer may think he is still on the flat when in fact he is ascending the lower part of a fan. It is only where the bases of short, steep fans are buried under sediments derived from larger fans that there is a sharp line of demarcation between the fan and the flat of this origin. Where a lake of considerable depth existed a shore zone borders the flat, occupying the parts of the fans that were submerged. Locally the surface of this zone has been formed by wave erosion, but more commonly on the lake bottoms of the desert valleys it is a zone of exceptional aggradation because the streams of flood water were suddenly checked when they reached the lake and therefore deposited near the shore their entire load of rock waste except the fine sediments that remained long in suspension. Even where definite deltas and beach ridges were not formed the shore zone generally shows a convexity in profile, and a new cycle of erosion can often be seen starting on the relatively steep lakeward slope.



PART OF UPPER BIG SMOKY VALLEY, SHOWING ALLUVIAL SLOPE AND PLAYA.



A. PLAYA AND MOUNDS IN LOWER BIG SMOKY VALLEY.

B. SAME WHEN FLOODED.

The flats of the desert valleys are typically barren, as is the large playa east of Millett, the intermittent submergence of the dense and generally alkaline soil being a condition to which no plant species is able fully to adapt itself; but in many places they support considerable vegetation, commonly in isolated clumps, as on a large part of the playa of the lower valley both east and west of McLeans. Many of the flats are kept moist by capillary rise of ground water, as the Millett and McLeans playas, but others lie far above the water table, as the playa in Alkali Spring Valley. In some places they are covered with incrustations of salt, as at the Spaulding Salt Marsh, but they may contain no unusual amounts of soluble matter. The essential characteristic of the playas is one of topography—they are flat surfaces produced by deposition from impounded waters. They are not, however, absolutely level, and in some places they are interrupted by dunes or wind-formed mounds, by mounds built by springs, or by gullies cut by exceptional floods.

PLAYAS IN THE UPPER VALLEY.

The principal flats in Big Smoky Valley are found in the depressions occupied by the two ancient lakes. The largest is the Millett flat, which lies between the Daniels and Charnock beaches and occupies the central part of the ancient lake bed. It is nearly 15 miles long, and in the vicinity of Millett and the Jones ranch it is fully 6 miles wide. Over a large part of this area it is moist, alkaline, barren of vegetation, and monotonous and desolate in aspect. South of the Rogers beach ridge and extending toward Wood's ranch is another large flat that is in general covered with vegetation except at the north end, where its waters accumulate in the rather definite depression of Moore Lake. Like the Millett flat it is wet and alkaline. North of the Daniels beach system a flat, interrupted by the Vigus and Minium ridges, extends for many miles as a moist, alkaline surface supporting an irregular growth of vegetation. Northward it gradually merges into the gentle slope of the large fans at the north end of the valley.

The following information was furnished by F. J. Jones: On July 17, 1915, when the streams were near their highest stages, about 1,000 acres of the Millett flat was submerged, but in some years when there is heavier snowfall the submerged area expands to several thousand acres, reaching its maximum from June 15 to July 1. Moore Lake has not been dry for eight years, but earlier it was dry for a long time. A wet summer was the cause of its filling up eight years ago. The area of the lake in June, 1915, was estimated at 1,000 acres.

PLAYAS IN THE LOWER VALLEY.

The main flat in the lower valley occupies the depression extending from the vicinity of the French well southwestward to the Silver

Peak Railroad. It is interrupted by sand dunes and by numerous mounds covered by greasewood and other bushes (Pl. VIII, *A* and *B*). Throughout considerable areas it is entirely barren and in some places it is very wet and alkaline. Northeastward it merges insensibly with the long, gentle alluvial slope over which the waters from the north are discharged. In the vicinity of Millers and farther north the gradient of this slope is so slight that there are small areas of partial impounding which are flat and barren but not alkaline nor wet except after floods. Similar small flats, conspicuous for long distances because of their smooth, bare surfaces, are found along the axis of the valley between Cloverdale and Midway station (Pl. I). North of Peavine Creek is an area whose flood waters are partly impounded by the deposits of this creek, although a definite streamway skirting the eastern margin of the Peavine fan allows some of the water to escape southward. This area has to some extent the character of a playa, though it does not show indications of alkali or of shallow ground water (see Pl. I).

FAULT SCARPS.

East of the Toyabe Range and north and northwest of Lone Mountain there are numerous conspicuous escarpments which face the valley and are believed to be due to recent faulting. Some of these escarpments are at the edges of the mountains and appear to have been produced by the valley fill slipping down from its contact with the rock formation (see Pl. IX, *A* and *B*), but most of them extend across the alluvial fans approximately parallel with the edges of the mountains (see Pls. III and X). In some localities there is only a single escarpment, but in others there are two or three parallel to each other. The maximum height is more than 200 feet, but in most places it is much less. The escarpments west of Bowman's, Mrs. Gendron's, and McLeod's ranches are made conspicuous by green bands of buffalo-berry bushes, greasewood, rabbit brush, wild roses, sagebrush, and salt grass supported by springs and seeps that issue from the escarpments. The large, distinct escarpments are shown on the map, Plate I (in pocket). That these features were produced by faulting is indicated by several lines of evidence:

1. They lack the distinctive characteristics of shore features and they are found far above the levels at which there is any evidence or reasonable presumption of ancient strands. Neither do they have the characteristics of stream-cut or stream-built features or of features that could well have been formed by any known agency except faulting. They have, however, the broken profile that characterizes fault scarps, and they appear to be similar to the features in various parts of the Great Basin that have been described by Gilbert [1] and others as fault scarps.

[1] Gilbert, G. K., Lake Bonneville: U. S. Geol. Survey Mon. 1, pp. 340-362, 1890.

A. FAULT SCARP AT FOOT OF LONE MOUNTAIN.

B. FAULT SCARP AT FOOT OF TOYABE RANGE.

FAULT SCARP ON ALLUVIAL SLOPE ADJACENT TO LONE MOUNTAIN.

2. They are not found in all parts of the valley but only on the alluvial slopes adjacent to the two ranges which present especially steep fronts such as are commonly attributed in the Great Basin to block faulting. In the Toyabe Range some direct evidence of faulting was also found.

3. The springs to which some of the escarpments give rise, though not furnishing conclusive evidence, suggest a fault origin, for it has been demonstrated that faults displacing valley fill may produce underground barriers that raise the water level.[1]

4. The exposed parts of the blocks that form a few of the escarpments, particularly between Carsley and Blue Spring creeks and south of Black Bird Canyon, consist of bedrock overlain with valley fill which has a graded surface similar to that of the alluvial slopes below the escarpments. This is a condition that indicates displacement and is difficult to explain on any other theory.

A few of the escarpments at the lowest levels, as the one west of Mrs. Gendron's ranch, are near the highest shore features and may at one time have formed a part of the shore line. No conclusive evidence was found as to the relative ages of the fault scarps and the shore features, but the great difference in the amount of stream erosion by which these two groups of features are affected indicates that the fault scarps are in general older than the shore features.

STREAMWAYS.

The lower parts of the alluvial fans are still generally in process of being built up by stream deposition but the upper parts of most of the large fans are trenched by deep and broad stream valleys. These trenched surfaces, like the shore features, are no longer in process of construction, as are the flats and the undissected parts of the fans.

There is evidence that the stream trenching is caused to only a moderate extent by the normal development of the gradation cycle and is due more largely to faulting and climatic changes and to other agencies not well understood.

Trenched streamways are commonly found in the upper parts of the alluvial slopes of desert basins and may result from the normal processes of erosion and aggradation. The large canyons with relatively great and long-continued discharge have been cut deeper than the small canyons with meager discharge and hence they emerge from the mountains at lower levels. Consequently the floods from the large canyons can keep open an avenue of escape only by sweeping away the débris piled in their courses by the waters from the small canyons. This condition accounts in part for the trenching by Kingston Creek shown in Plate VI (p. 25). Moreover,

[1] Clark, W. O., Ground-water resources of the Niles cone and adjacent areas, California: U. S. Geol. Survey Water-Supply Paper 345, pp. 127-168, 1915.

as the mountains are worn down and the canyons are cut deeper the streams generally emerge from their rock canyons at lower levels and therefore sink their channels into the upper parts of the slopes which they themselves built at an earlier stage.

Where the profile of a fan is broken by faulting the stream grade is thrown out of adjustment, and dissection of the upthrow side is to be expected. On the alluvial slope adjacent to the Toyabe Range a very noticeable relation exists between faulting and stream trenching. This relation is especially well shown in the vicinity of Blue Spring Creek (see Pl. III, p. 18) and in the vicinity of Spanish, Lynch, and Tarr creeks. The alluvial fan of Santa Fe Creek is not crossed by any fault scarp, but there is evidence in this vicinity of comparatively recent displacement along the edge of the mountains whereby the mountain block was raised with reference to the valley (p. 22). The fan, which is below the fault, is not dissected, but the canyon above the fault has at its bottom a steep-walled notch about 15 feet deep and 15 feet wide that may have been cut as a result of the uplift (see fig. 3). It may also be significant that this canyon differs from most of the others in having so little rock waste that the stream flows over bedrock.

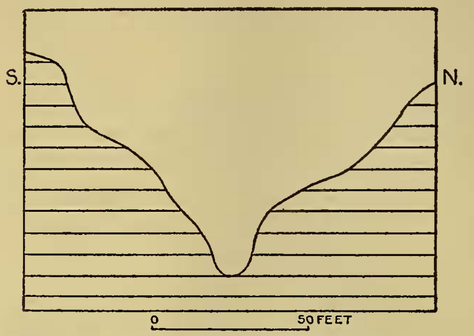


FIGURE 3.—Profile of Santa Fe Canyon near its mouth, showing recently cut notch (approximate).

Deposition is always taking place in some part of a closed basin, but the zone of deposition changes with the climate and with other conditions. In a humid epoch the floods from a given canyon are larger and of longer duration than in an arid epoch; hence the profile of the alluvial fan is longer and less steep, that is, the short steep fan built in the arid epoch is dissected in its upper part, and the eroded material, if not discharged into a lake, is deposited at the base of the old fan. The broad-bottomed arroyos that dissect the

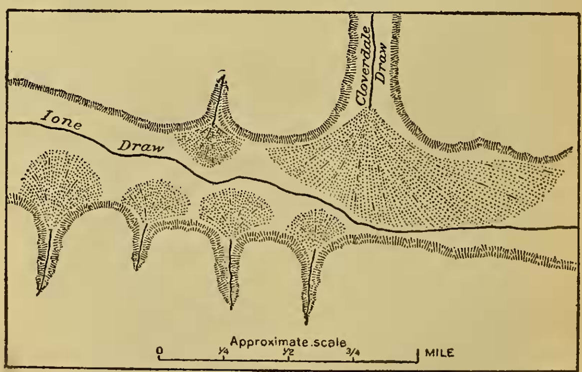


FIGURE 4.—Sketch map of axial part of valley 4½ miles south-southwest of Cloverdale, at junction of Ione and Cloverdale draws.

upper and middle parts of most of the large fans were probably formed in large part during the humid lake epoch. There does not appear to have been general erosion in these draws in recent times, although recently cut gullies can be found in many places, as on the Peavine fan from Peavine ranch nearly to Midway, and in the Ione Draw in the vicinity of Warm Spring. The accumulation of rock waste in the lower parts of most of the canyons may be due to the loss of transporting capacity by the streams in the present arid epoch.

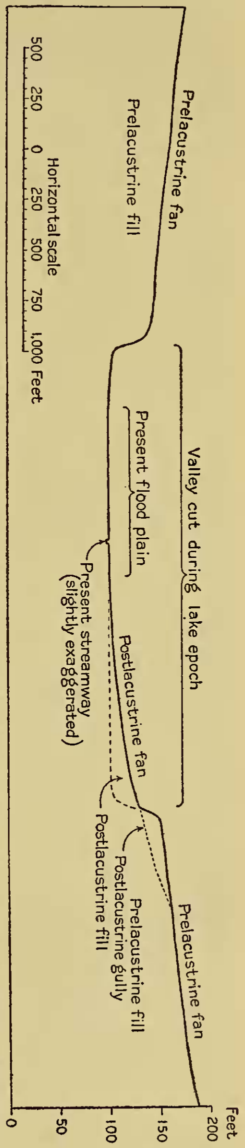


FIGURE 5.—Cross section of axial part of valley 4½ miles south-southwest of Cloverdale, showing channels cut by drainage from Ione Valley.

The draw through which the flood waters of Ione Valley are discharged is of especial interest because it is shown by its topography to be an ancient channel that was excavated at a time when more water had to be accommodated than at present. This ancient channel follows the axis of the wide, open valley that leads from Ione Valley to the main part of Big Smoky Valley (Pl. I), the axis here being crowded near the south side by the large Cloverdale fan. As shown by figures 4 and 5 this channel averages fully 50 feet in depth and nearly one-half mile in width. That it is larger than is required for the discharge of recent floods is shown by the small alluvial fans that have been built up on its floor by tributary gullies and draws. Although it disappears before reaching the bed of the ancient Lake Tonopah there can be no reasonable doubt that it was excavated to its large dimensions during the humid epoch when the lake existed, and that the little fans have been formed in postlacustrine times when the floods have been too small and infrequent to keep the entire channel open.

The canyons in the vicinity of Charnock Pass open into a stream valley which is nearly 200 feet deep but which diminishes rapidly in depth with the distance from the mountains and disappears entirely before it reaches the lower part of the alluvial slope. No escarpments were seen on this slope and the trenching is so much deeper than is usual under similar conditions that it can not well be explained as the result of normal development or climatic changes. However, no adequate explanation of the extensive stream cutting was found.

DUNES AND WIND-FORMED MOUNDS.

Sand dunes are found in several localities in both the upper and the lower valley (Pl. I, in pocket), but they are not so abundant as might be expected from the large amount of sandy soil that exists in the region.

In the upper valley dunes are found along the eastern margin of the ancient lake bottom. One group lies a short distance northeast of the Vigus beach ridge on the east side of the road leading from the Spencer Hot Springs to the Daniels ranch; another group lies at the east end of the Daniels beach system; and a few small dunes are found near the Vigus ranch. Dunes covering larger areas are found southwest of the Charnock Springs on both sides of the road leading from Rogers ranch to the Monitor Valley. Those south of this road border the eastern part of the Rogers beach ridge and extend southward on the east side of Moore Lake, forming a belt about 4 miles long and including the largest wind-built structures in the upper valley. Small sand hills are also found between the Barker and Crowell ranches.

In the lower valley dunes are found on or near the ancient lake bed and in a number of places farther north. A belt of large dunes lies on the south side of the playa and extends several miles in both directions from the road leading from McLeans to Alpine, and areas of smaller dunes are found on the north side of the playa west of this road and along the road leading from McLeans to the Desert Well. Large dunes are found in the vicinity of Millers Pond and along the margin of the playa farther south, and indefinite accumulations of wind-blown sand, imperfectly shown on the map (Pl. I) are scattered over an extensive area between McLeans and Millers. Only a few small dunes are found near the west end of the ancient lake bed. Farther north deposits of wind-borne material occur between Tonopah and Liberty, in the vicinity of San Antonio, and on the west side of the valley. The large dunes between Tonopah and Liberty were not seen at close range, but hills several hundred feet high appear from a distance to be entirely wind built. The dune areas in the vicinity of San Antonio comprise a belt of sand hills lying south of the springs and extending southwestward a distance of several miles and also groups of smaller sand hills extending along the axis of the valley from San Antonio to a point about 4 miles north.

Sand dunes have been formed on the shores of both modern and ancient lakes, generally to the leeward of the prevailing storm winds. The dunes in the northern part of Big Smoky Valley are on the east side of the lake bed, more or less closely associated with the east ends of the large transverse beach ridges, the largest being found northeast of what was once the southern water body of the ancient Lake Toyabe. The position of these dunes therefore indicates prevailing westerly or southwesterly winds, agreeing with the evidence furnished by the shore features and by the Weather Bureau records at Millett (p. 65). The dunes associated with the bed of Lake Tonopah are chiefly on the eastern and southern parts of the lake bed, suggesting prevailing westerly and northerly winds, but they are not confined to these parts, and, like the shore features of this lake, they do not give decisive evidence of any great predominance in the winds from any direction. No records of the direction of the wind in this part of the valley are at hand. At Tonopah the prevailing winds are from the southeast, but westerly and northwesterly winds are also reported. The dunes north of Tonopah and in the vicinity of San Antonio are not related to either of the ancient lakes.

On the bed of Lake Tonopah there are sand deposits of very different ages. Fresh dunes that support little vegetation and are actively migrating with the wind are superimposed on older ones that have been extensively eroded except where they are protected by vegetation. These striking differences probably do not indicate any definite sequence of events but rather illustrate the capricious activity of the wind. At present the wind is at work almost incessantly. Sand was seen drifting at 10 o'clock in the morning following a storm in the night in which at least an inch of rain fell and the flat was submerged.

In many places the playas, especially the large playa in the lower valley, contain mounds of sandy material overgrown with big greasewood (*Sarcobatus vermiculatus*) or other bushes (Pl. VIII, *A* and *B*). These mounds are generally rather symmetrical, and they may attain considerable size, as is shown by the illustrations. They owe their existence and growth to the combined action of wind and vegetation. The vegetation, by breaking the wind, induces deposition of wind-borne materials while it prevents erosion by the wind. In Big Smoky Valley there has not been much erosion of the flats by the wind, and the mounds appear to have been produced chiefly by deposition. A mound may have its origin in a single alkali-resistant bush which is able to establish itself on the flat. This bush, by acting as a windbreak, and accumulating a little wind-borne material, produces conditions that are favorable for plant growth in its immediate vicinity. It does this by providing a less dense, less alkaline, and better drained soil than that of the flat, and by providing some immunity from inundation. Thus the accumulation of soil induces plant growth, and plant growth induces further accumulation of soil, until mounds are developed that furnish a very different environment for plants than the flat furnishes.

The porous but moderately alkaline soil, with its immunity from inundation but close proximity to a perpetual water supply, furnishes conditions that are particularly agreeable to the big greasewood, and this bush has therefore won over all competitors on these island-like mounds, although hardier bushes may have been required to start the mounds.

SPRING TERRACES AND MOUNDS.

The largest topographic feature produced by springs in this valley is at the Spencer Hot Springs, which are 6 miles east of Spencer's ranch and a short distance north of the road leading from Austin to Potts (Pl. I). Here a terrace nearly a mile long and in some places half a mile wide borders the low mountain ridges at the edge of the valley (fig. 6). This terrace, composed largely of travertine, or calcareous tufa, is about 25 feet high at its outer margin, whence its surface ascends toward the mountain border. On this surface are several spring-built, tufaceous mounds and ridges (fig. 6) which are about 25 feet high and give the entire structure a relief of about 100 feet. The material forming the terrace and mounds was not, however, all deposited by the spring waters, some of it having been washed from the ridges and some blown from the desert.

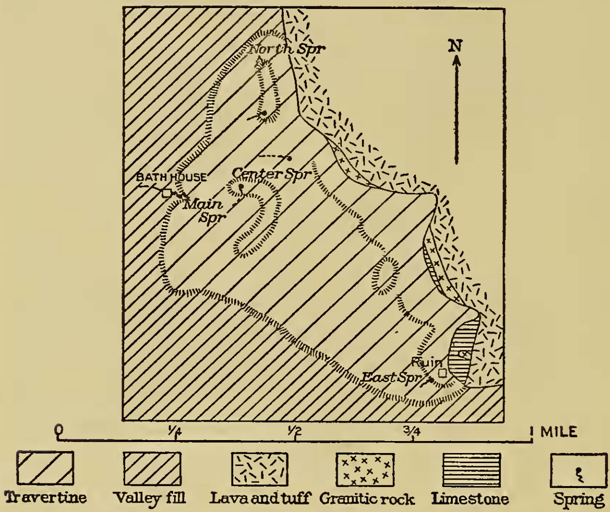


FIGURE 6.—Map of the vicinity of the Spencer Hot Springs.

Spring-built mounds are found also in a few places on the Millett flat, the most important locality being at the Charnock Springs, where a typical mound from which water was oozing and supporting a growth of grass measured 200 feet in length and 8 feet in height.

BUTTES.

In the lower valley the smooth surface produced by stream aggradation is in a number of places interrupted by hills or ridges of rock that project abruptly from the valley fill and form conspicuous landmarks. The character of these hills and ridges is determined largely by the kind of rock composing them. Many of the outcrops of the soft Tertiary strata form only low inconspicuous mounds or produce practically no modification of the topography of the alluvial fans.

In the upper valley no hills or ridges of bedrock project above the smooth surface formed by the valley fill.

GEOLOGY.

PALEOZOIC SEDIMENTARY AND METAMORPHIC ROCKS.

Limestone, slate, schist, and quartzite aggregating several thousand feet in thickness and ranging in age from lower Cambrian to Carboniferous, are the oldest rocks that have been found in this region. They have been studied chiefly by Emmons in the Toyabe Range and by Turner in the Silver Peak Range, but no detailed section of them has yet been made. They belong for the most part to the Cambrian and Carboniferous systems but are known to include rocks that contain Ordovician fossils and may include Silurian and Devonian strata. Although they have a wide range in age no unconformity has been discovered between successive formations. Since their deposition they have been extensively deformed, eroded, intruded by lavas, and largely covered by igneous bodies and sedimentary deposits. Originally they probably covered the entire region but at present they are found over extensive areas only in the Toyabe, Toquima, Silver Peak, and Lone Mountain ranges.

In the Toyabe Range the Paleozoic sedimentary rocks lie at the surface over most of the area between Birch Creek and Carsley Creek and outcrop in a part of the area farther south. They border the valley in the vicinity of Pablo and Wall creeks but are completely concealed under volcanic rocks near the south end of the range. Emmons has shown that they have a complex structure but in a broad way form large folds with a general north-south strike.

In the Toquima Range Paleozoic rocks, chiefly slate and limestone, are at the surface over an extensive area from a mile or two north of Central to and beyond Willow Spring. These rocks also outcrop extensively in the northern half of the range and appear in small outcrops in the central part. In the vicinity of Charnock Pass several thousand feet of slate is exposed; it dips northeast at angles ranging from almost vertical near the valley to less than 45° at the igneous contact 2 miles farther east.

In the San Antonio Mountains the Paleozoic strata appear in a few small outcrops, but are in most localities displaced or covered by igneous masses. At Tonopah Spurr reports fragments of limestone, quartzite, and granite in volcanic breccias.[1] Complexly folded and faulted limestone, slate, and quartzite of Cambrian and Ordovician age form the core of that part of the Silver Peak Range which borders Big Smoky Valley and also outcrops in parts of Lone Mountain that are tributary to this valley.[2]

---

[1] Spurr, J. E., Geology of the Tonopah mining district, Nev.: U. S. Geol. Survey Prof. Paper 42, p. 30, 1905.

[2] Spurr, J. E., Ore deposits of the Silver Peak quadrangle, Nev.: U. S. Geol. Survey Prof. Paper 55, pp. 17–19, pl. 1, 1906.

GRANITIC ROCKS.

Several great bodies of granitic rocks are found in this region. Wherever their relations have been determined they are intrusive in the Paleozoic strata but older than the Tertiary eruptive rocks. Five granite bodies were described by Emmons in the Toyabe Range, four of which lie partly in this drainage basin.[1] Granite is exposed over a large area north of Birch Creek and outcrops extensively from Bowman's ranch to beyond Wood's ranch. A large granite mass occupies the lofty central part of the Toquima Range, particularly in the region back of Round Mountain. Another large granite mass forms the main part of Lone Mountain, and granite also outcrops in the ridges farther southwest.

TERTIARY ERUPTIVE ROCKS.

Eruptive formations, consisting of rhyolite and minor amounts of basalt and rocks of intermediate composition with associated tuffs and breccias, are exposed over extensive areas in all of the ranges bordering Big Smoky Valley. They lie at the surface in all or nearly all of the Shoshone Range tributary to this valley, in the southern part of the Toyabe Range and in other localities in this range, in large parts of the Toquima Range from the north to the south end, in much the greater part of the San Antonio and Monte Cristo ranges and the hill country north of the Monte Cristo Range, and in considerable areas in the Silver Peak and Lone Mountain ranges.

These rocks comprise a series of extrusive sheets and connected dikes and necks. They differ widely in age but all were probably formed during the Tertiary period. In Clayton Valley, just south of Big Smoky Valley, there is Quaternary basalt, but, in so far as could be ascertained, the igneous rocks of the drainage basin of Big Smoky Valley are all pre-Quaternary. In the Tonopah district Spurr studied in detail a complicated series of volcanic formations, all of which, he concluded, were probably erupted between the early Miocene and some time in the first half of the Pliocene epoch. The oldest rocks in the Tonopah series are two bodies of andesite, above which are dacite, dacite breccia, and rhyolite-dacite. Above these are the Siebert tuffs, which consist mainly of lake beds composed of volcanic fragments, and above the Siebert tuffs there are sheets of basalt, rhyolite, dacite, and rhyolite-dacite.[2] Parts of this series were seen in various localities in the region under consideration. The tuff outcrops extensively in nearly all parts of the south basin but is generally absent in the north basin. It is well developed in the San Antonio and Monte Cristo ranges and near the south end

[1] Emmons, S. F., Geology of the Toyabe Range: U. S. Geol. Expl. 40th Par. Rept., vol. 3, pp. 320–348, 1870.
[2] Spurr, J. E., Geology of the Tonopah mining district, Nev.: U. S. Geol. Survey Prof. Paper 42, pp. 31–72, 1905.

of the Toyabe and Shoshone ranges. In some places it is overlain by heavy beds of rhyolite or allied rocks, in others by sheets of basalt.

North of Cloverdale about 500 feet of tuff is exposed and is intruded and overlain by a great mass of acidic lava, which shows near the contact the platy and glassy textures and other interesting characteristics observed by Spurr in the Tonopah district.[1] Other good exposures are found near the Peavine ranch, where the tuff lies between thick beds of acidic lavas that have been extensively faulted, producing beautifully fluted slickensides. In a number of places near these two ranches the tuff is overlain by basalt, and basalt is also abundant in the Monte Cristo Range. The extent of erosion on most of the basalt indicates that this rock is younger than the other lava beds of the region, but much older than the Quaternary basalt of Clayton Valley.

TERTIARY SEDIMENTARY ROCKS.

Tertiary sedimentary deposits are well developed in the southwest corner of the drainage basin of Big Smoky Valley and in adjacent areas draining into Columbus and Clayton valleys, where they have been studied in considerable detail by Turner, who named them the Esmeralda formation.[2] The following description by Spurr of these deposits in the Silver Peak quadrangle is based chiefly on Turner's work.[3]

The Tertiary deposits flank the edges of the mountains and underlie, in part at least, the Pleistocene veneer of the valleys. On account of folding and faulting since their deposition they arch upward along the sides of the mountains, although according to Mr. Turner they have not been found within 2,500 feet of the highest elevations. They consist of soft shales, sandstones, marls, tuffs, volcanic breccias, etc., with interbedded layers of andesitic and rhyolitic lava. The thickness of the whole accumulation is very likely several thousand feet. This mass has not yet been satisfactorily differentiated into separate members, but it undoubtedly contains materials deposited under widely varying conditions. Some of the beds are lake sediments; some appear to have been deposited in running water and were probably distributed by stream action. Others bear the marks of dry, subaerial origin. Also there is probably a great range in the period of deposition, as will be presently shown from a consideration of the fossil evidence. It is probable that practically the whole Tertiary, from the Eocene through the Pliocene, is represented. In short, it is probable that the beds are the record of the whole period of Tertiary sedimentation, beginning with the period when the Nevada land mass ceased to have free drainage to the ocean, at the close of the Cretaceous,[4] through the whole of the climatically changing but in general arid Tertiary period, when the material eroded from the mountains was accumulated in the valleys, in lakes, or in subaerial sheets, down through the Pliocene.

---

[1] Spurr, J. E., Geology of the Tonopah mining district, Nev.: U. S. Geol. Survey Prof. Paper 42, pp. 46, 47, 1905.

[2] Turner, H. W., The Esmeralda formation, a fresh-water lake deposit: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pp. 191-226, 1900.

[3] Spurr, J. E., Ore deposits of the Silver Peak quadrangle, Nev.: U. S. Geol. Survey Prof. Paper 55, p. 19, 1906.

[4] Spurr, J. E., Origin and structure of the Basin ranges: Geol. Soc. America Bull., vol. 12, p. 249, 1901.

A section of these deposits along the lines C–D, E–F, F–G, and H–I, shown on Plate I, was made by Turner, who makes the following explanation:[1]

No continuous section of the entire formation was found, but an attempt was made to estimate the approximate thickness of the beds. They dip nearly everywhere at angles varying from 5° to 60° from the horizontal and are broken by numerous small faults, so that often a layer followed along the strike is found to offset from 10 to 100 feet or more every few hundred feet. However, in the section at the coal mine (C–D, Pl. I) and in the zigzag section of the beds east of the south end of Big Smoky Valley (E–F, F–G, and H–I, Pl. I), all of the sections being run at approximately right angles to the strike of the beds, no evidence of repetition by faulting or folding was found, and the estimate may therefore be taken as having an approximate value, subject to later revision when better sections of the formation are found elsewhere.

The section thus obtained is given in condensed form, in downward succession, in the following table, and is shown graphically in figure 7, prepared by Turner. His comment on the section is as follows:[2]

The thickness of 14,800 feet of beds, as given in this estimate, seems incredible, although it may represent all of Miocene and Pliocene time, inasmuch as all the fossils that have any value in determining the age were found at the base of the formation. The field evidence of the occurrence of the basalt flows of the region, such as that capping the Monocline in Clayton Valley and supposed to represent the top of the section, certainly suggests for them a Pliocene age, for these basalt flows nearly everywhere cap mesas and seem to be the latest of the lavas, excepting only the basaltic eruptions, that built up the finely preserved crater in Clayton Valley, which is clearly of Pleistocene age. The depth below the surface of the basement complex on which the bed rests and the angle at which the lake beds rest on this complex are, of course, entirely unknown. In all probability the rocks underlying section C–D are vertical slates and cherts of the lower Silurian, since these beds outcrop not far to the west.

Section of the Esmeralda formation.[3]

[By H. W. Turner.]

	Feet.
Upper beds exposed in the Monocline:	
White pumice and basalt	150
Section I to H:	
Lacustral marls	1,300
Breccia beds	1,000
Sandstones and shales	800
Section G to F:	
Sandstones and shales	1,300
Breccia beds	1,300
Sandstones and shales	1,600
Section F to E:	
Breccia beds with intercalated layers of sandstone	900
Sandstone, shales, and lacustral marls; fossil fishes in middle and upper parts	4,200
Section D to C:	
Sandstone with some shale, containing abundant fossil leaves with some shells and fish bones	1,100
Sandstone and shales, with a layer containing abundant fossil gastropods	900
Coal seam with overlying shale bed containing leaves.	
Contorted sandstones and shales	250

[1] Turner, H. W., op. cit., 199. [2] Idem, p. 202. [3] Idem, pp. 200–202.

The Tertiary strata are best developed in the foothill region southwest of Lone Mountain, and in the region west and southwest of Blair Junction, in which regions Turner's sections were made. They are, however, found widely distributed in the ranges bordering the lower valley, and either outcrop or lie near the surface over extensive areas in the marginal parts of the lower valley and in Ione Valley.

They are found at the surface in various parts of the Monte Cristo Range, and at or near the surface in extensive valley areas adjacent to these mountains; they outcrop in the hills south of Millers, in the vicinity of Tonopah, and in the San Antonio Mountains north of Tonopah, and are below the surface in parts of the valley adjacent to the southern part of the San Antonio Mountains; they underlie the slope southeast of San Antonio and outcrop in some of the hills between San Antonio and Liberty; they outcrop extensively in the southern parts of the Toyabe and Shoshone ranges and in the detached hills south of these ranges; they constitute the surface formation in most of the constricted area where Ione Valley discharges into Big Smoky Valley; and they lie below a thin mantle of detrital material in a large part of Ione Valley and outcrop in several localities on the west side of that valley.

They do not habitually form conspicuous buttes or ridges in the valley, as do the harder rocks, but generally lie nearly at the valley surface and are exposed only in low gravelly mounds or on the side of gullies cut into the valley surface. In most places in the valley the exposures are so poor that the dip of the beds can not be ascertained, and in many places it is difficult to determine whether the outcrops are Tertiary strata or valley fill derived from these strata. For these reasons the boundaries of the rock outcrops are very unsatisfactorily shown on Plate I in the localities where Tertiary sediments are found. Some conspicuous buttes and ridges have, however, been formed where hard strata project above the general valley level; for example, the little butte on the south side of the road leading from Millers to Crow Spring, and some of the hills west and southwest of Blair Junction.

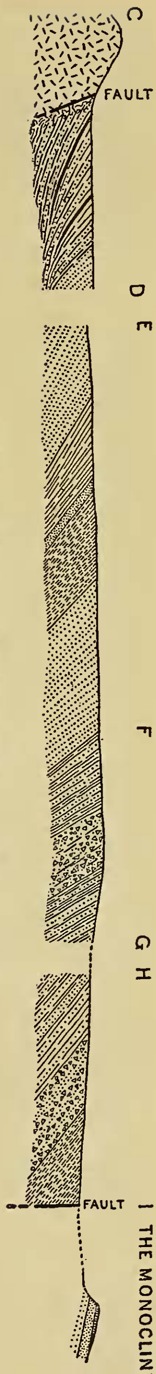


FIGURE 7.—Section of the Esmeralda formation. (After H. W. Turner.)

The sediments in Turner's section are largely of volcanic origin, and in many of the outcrops farther east and north they consist almost entirely of volcanic tuffs interbedded with thick sheets of lava. In the vicinity of Tonopah they are represented by lake beds, known as the Siebert tuff, composed chiefly of volcanic derivatives. In the southern part of the Toyabe and Shoshone ranges they are composed essentially of volcanic fragments which, in many places, are almost unstratified and grade into true volcanic rock.

In the vicinity of Tonopah the Siebert tuffs include a bed of white diatomaceous earth composed of fresh-water diatoms of Miocene or possibly later age. A bed of diatomaceous earth, with lenses of chert, also outcrops at a number of places at the base of a cliff of volcanic rock on the south side of the gulch southwest of Crow Spring, where it dips southeast. Parts of this bed contain very pure, white, fine-grained diatomaceous materials of low specific gravity, in places laminated and evidently waterlaid. In October, 1913, a number of prospect holes had been opened along the outcrop, but none of the material had been marketed.

The Tertiary strata have been faulted into blocks which were tilted in various directions. At Tonopah they dip in general westward at angles averaging about 20°.[1] Farther north in the San Antonio Range they dip in the opposite direction. Along the road from Peavine to Cloverdale, near the junction with the road from the east, they dip 30° S. In the hills west of Crow Spring and Kane's well they dip westward, but southwest of the spring they dip southeastward. In the vicinity of the coal mines (section C–D, fig. 7) they generally dip 20° to 45° in a direction east of north; in most of the hills west of the "salt well" they have only slight dips but locally they were seen to dip 60° SW. In the region between the Silver Peak Railroad and Lone Mountain they generally dip southeast at angles ranging from only a few degrees to about 60°.[2]

The Tertiary beds lie near the surface in much of the marginal part of the lower Big Smoky Valley but are apparently buried to considerable depths along the central axis. In some places there is a sharp structural unconformity between the Tertiary beds and the overlying Quaternary deposits, but generally the contact is not well shown. In Turner's section the younger beds are quite as much deformed as the older beds, but Spurr believes that under the valley the Pleistocene deposits form a direct continuation of the Tertiary beds.[3]

---

[1] Spurr, J. E., Geology of the Tonopah mining district, Nev.: U. S. Geol. Survey Prof. Paper 42, p. 55, 1905.

[2] Turner, H. W., The Esmeralda formation, a fresh-water lake deposit: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, p. 201, 1900.

[3] Spurr, J. E., Ore deposits of the Silver Peak quadrangle, Nev.: U. S. Geol. Survey Prof. Paper 55, p. 19, 1906.

QUATERNARY DEPOSITS.

GENERAL CONDITIONS.

The upper valley and the greater part of the lower valley are underlain by Quaternary deposits. As these deposits have been only slightly deformed and have suffered very little erosion except in the upper parts of the alluvial slopes they have few exposures, and as the deposits are relatively unconsolidated the existing exposures are generally poor. A number of shallow dug wells reveal the character of the upper beds, and the driller's logs of a few deeper wells give some information as to the lower beds.

As shown by the natural outcrops and by the exposures in dug wells, the Quaternary deposits consist chiefly of poorly assorted gravel, sand, and silt laid down by running water, but include also several other kinds of material. Silt and clay deposited by temporary sheets of water underlie the playas, and these fine sediments are generally impregnated or overlain by soluble salts. Under them no doubt lie stratified beds deposited by the Pleistocene lakes, but the lake beds are not exposed. Surrounding the principal playas and in some places extending across them are beach gravels deposited by the waves and currents of the Pleistocene lakes to maximum depths of at least 50 feet. In certain localities there are also irregular deposits of sand formed by the wind, and in a few places calcareous deposits, probably reaching a maximum thickness of 50 feet, have been formed by springs.

The lower deposits that fill the depression produced by the deformation of the recognized Tertiary and older formations are so completely concealed that their age and relation to the underlying formations remain matters of conjecture. As the exposed parts of the fill are, however, unquestionably Quaternary, all valley deposits that can not be identified as Tertiary or older may provisionally be regarded as Quaternary.

Although no very deep wells have been drilled in the upper valley, the steepness of the adjacent mountain sides, the distinctness of the boundary between the mountains and the valley, and the almost complete absence of rock outcrops in the valley indicate that the depth of the valley fill is considerable. Comparison with similar valleys in which deep wells have been sunk leads to the conclusion that except near the mountains it is probably at least several hundred feet deep. In the lower valley, on the other hand, the boundary between the mountains and the valley is less definite and rock outcrops are numerous in the valley areas. The fill is generally thin on the slope southeast of San Antonio, on the upper parts of the slopes adjacent to the San Antonio and Monte Cristo ranges, and in the southwestern corner of the valley. The absence of rock outcrops on the playa and on the lower parts of the alluvial slopes and the data obtained in regard to several wells, however, indicate that, except near the southwest end, the fill in the axial region of the lower valley is generally a few hundred feet thick. In the railroad well at Blair Junction Tertiary sandstone was struck at a depth of 110 feet; but in Kane's well, 700 feet deep, sand, gravel, and some clayey material were penetrated nearly to the bottom, where "limestone and quartzite" are reported; and in the well at Midway, 135 feet deep, and the well 2 miles northeast of Goldfield Junction (Pl. II) only gravelly fill was apparently penetrated. Some of the gravel, sand, and clay in Kane's well may, however, belong to Tertiary strata.

STREAM DEPOSITS.

The stream deposits consist essentially of trains of gravel that radiate from the mouths of the canyons and a more clayey matrix in which the gravel beds are incased. Both the gravelly and the clayey deposits increase in fineness with the distance from the canyons. Near the mouths of the canyons the matrix contains much embedded gravel and some large bowlders, but in the axial part of the valley it is composed chiefly of silt and clay and contains no very large particles.

The stream deposits are in general relatively unconsolidated, although they contain enough cement to stand in dug wells without casing. Near the bottom of the deeply incised draw east of the Charnock springs, however, a hard, firmly cemented valley fill outcrops, suggesting that in their lower parts the Quaternary stream deposits are considerably indurated and that there may be a sharp distinction between the older and younger valley fill.

In character the stream deposits are directly related to the rocks from which they are derived. The slates weather into hard, black angular fragments that are not readily rounded but yield clayey material when abraded. The limestones form abundant black pebbles that are rather resistant to weathering, but by abrasion and solution yield fine sediments and also calcium carbonate, by means of which the deposits become more or less cemented. The granitic rocks form arkosic gravel, sand composed chiefly of quartz grains, and only small amounts of clay. The rhyolites and associated volcanic rocks are disintegrated at the surface by temperature changes and frost and only to a small extent by chemical decomposition. The resulting detritus consists, therefore, of arkosic gravel and grit, with only small amounts of clay and true sand. The tuffs consist largely of minute volcanic fragments which are not firmly cemented and which therefore weather readily, producing much fine silt. These differences in the rock waste have a pronounced effect on the physical character of the soil and the water-bearing capacity of the valley fill.

The sediments derived from slate and limestone predominate on the Kingston fan and adjacent tracts and on the Manhattan fan and adjacent tracts and are abundant on the alluvial slope adjoining the northern half of the Toquima Range and on most of the slope adjoining the Toyabe Range south of the Kingston fan. They form only a small part of the fill in the lower valley.

Quartz sand derived from granite predominates in the axial part of the valley between Moore Lake and Round Mountain, and granitic gravel is abundant on the upper part of the alluvial slope in this region. A well at the Crowell ranch had been drilled to a depth of 87 feet in October, 1913, and had revealed practically nothing except coarse sand, which is composed chiefly of quartz grains, but includes also particles of granite, rhyolite, and slate. The greater abundance of dune sand in the southern than in the northern part of the bed of ancient Lake Toyabe is no doubt due to the greater abundance of granite in the adjacent mountains.

Granitic gravel and sand are also important on most of the slope south of Bowman's ranch. A well just west of Frank Gendron's ranch house was reported by the driller, E. J. Hyatt, to be 220 feet deep and to extend chiefly through sand similar to that encountered at the Crowell ranch. A flowing well a short distance southeast of this ranch house (Pl. II) was reported by Mr. Hyatt to have the following section, in which the abundance of sand and the scarcity of gravel is noteworthy.

Driller's log of flowing well at Frank Gendron's ranch.

	Thickness.	Approximate depth.
	Feet.	*Feet.*
Sand	50	50
Blue clay	25	75
Sand (flow)	25	100
Blue clay	21	121
Sand (flow)	}	
Blue clay	} 27	148
Sand (flow)	}	
Hardpan (cement gravel); entered some distance.		

Granitic waste occurs almost exclusively on the steep slope adjacent to Lone Mountain. The extensive sand deposits in the lower valley are derived partly from the granite of this mountain but more largely from the Tertiary strata.

Waste derived from the Tertiary lavas is the most abundant and the most widely distributed. It is supplied in great quantities by the southern part of the Toyabe and Shoshone ranges, the San Antonio Range, and the hills north of the Monte Cristo Range. Grit, consisting of irregular fragments of volcanic rock, mantles most of the surface of the northern part of the lower valley from Cloverdale and Peavine to Millers and Tonopah, and it no doubt comprises a large part of the fill underlying this area. Kane's well (see Pl. II) is reported to pass through large amounts of "sand and gravel."

Fine, light-colored silt that contains enough clay to bake hard when dry is a characteristic deposit of the axial parts of Big Smoky Valley and is especially abundant in the lower valley, where most of the tuff, from which it is chiefly derived, is found.

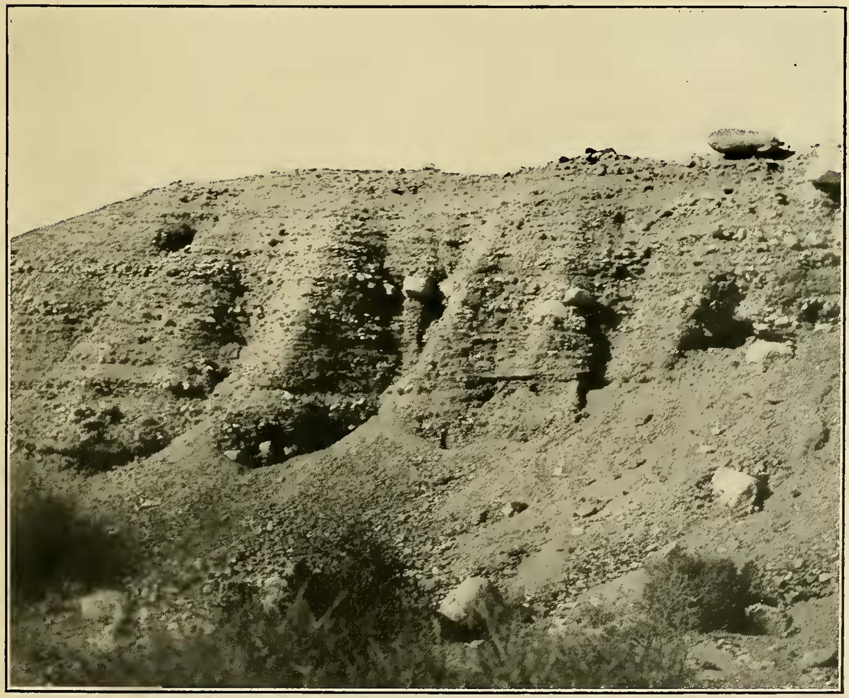
BEACH GRAVELS.

Gravels deposited by the waves and currents of the Pleistocene lakes are found in beaches along the margins of the lake beds and in large ridges that extend across these beds, as is shown on the map, Plate I, and described on pages 29–38. The maximum thickness of these gravel deposits, so far as known, is about 50 feet. They are more thoroughly assorted and less clayey than most of the stream deposits, and their pebbles are somewhat more waterworn and better rounded. (See Pl. XI, *A*.) The kind of pebbles that predominates in any beach or beach ridge depends, of course, on the source of the material, but this relation does not give any very reliable clues as to the direction of currents that produced the ridges, because the different kinds of rock are exposed in too many localities to make the source of the pebbles readily traceable. In most of the large beaches and beach ridges in the upper valley the black pebbles of slate and limestone predominate, but granitic materials are abundant in the southernmost beaches, and quartz sand, chiefly of granitic origin, predominates in the small modern beach of Moore Lake. The Alpine beaches are composed largely of granite pebbles, but the large beaches on the north side of the lake bed in the lower valley contain many black pebbles of volcanic origin. As the beaches do not support much vegetation, those in which limestone, slate, or basalt pebbles are abundant form conspicuous black bands that can be seen from the valley sides at distances of several miles.

PLAYA AND LAKE BEDS.

Underlying the flats are fine-grained sediments that have been deposited from thin temporary sheets of roily water which is for the most part derived from heavy floods. Before this water reaches the flats its velocity is reduced to such an extent that it deposits all of its load except fine sediments, which it holds in suspension. These sediments range from fine sand to dense clay and include large amounts of silt. The clay varies in color from light yellowish gray to dark brown, and the silt and sand are pale yellow or nearly white. Below the water level the sediments may have a bluish hue or may be quite black.

A. SECTION OF BEACH RIDGE.



B. OUTCROP OF VALLEY FILL IN UPPER PART OF ALLUVIAL SLOPE.

The sediments show a zonal arrangement, the densest clay generally being in the interior of the large flats and the sand and silt in the peripheral parts. Their distribution is affected also by the occurrence of the different kinds of rock, the relation of the abundant, light-colored, clayey silt to the derivative tuffs being the most evident. The large Millett flat was not examined in all parts, but east of Millett it is underlain by a plastic clay, and this material no doubt predominates in the interior. The large, nearly level region extending from the vicinity of the Daniels ranch to within a few miles of the Spencer hot springs is in most places underlain by a fine, gray, clayey silt. The flat extending southward from Moore Lake is underlain largely by sand and silt. The large flat in the interior of the lower valley has a core of dense clayey material extending from a locality south of the Desert Well nearly to the Silver Peak Railroad, but over a large area farther east it is underlain by more porous silt. In the dry seasons the more alkaline sediments form irregular crusts at the surface that are readily broken into granular or powdery material, but the dense clays bake hard and form huge sun cracks.

The playa deposits are nowhere exposed to depths of more than 10 feet and no deep excavations have been made in them. No doubt they are underlain by stratified lake beds of Pleistocene age, but these beds are not exposed.

DUNE SANDS.

Deposits formed by the wind and consisting chiefly of quartz sand occur in a number of localities shown in general outline on the map, Plate I. (See also pp. 48, 49.) As a rule they are considerably less than 100 feet thick, but in one locality on the east side of the lower valley they are apparently much thicker. They cover parts of the flat in the lower valley, forming not only dunes of the ordinary type but also the dome-shaped mounds described on page 50. The flat is inundated by freshets and receives the exceedingly fine sediments suspended in the water, but the mounds form islands which receive only the coarser, wind-borne sediments.

TRAVERTINE.

The terrace at the Spencer Hot Springs, which is nearly a mile long and half a mile in maximum width (see p. 50), is underlain by a mixture of calcareous spring deposit, wind-borne sediments, and vegetable matter, and supports calcareous mounds that were obviously built by springs although the largest are at present dry. The entire structure has a relief of about 100 feet, but the spring-formed deposits apparently rest on a small alluvial slope and are not more than 50 feet thick. The outcrops of limestone along the east edge of the terrace indicate that the water rises through solution channels in this rock and derives its calcareous material from it. The analysis given on page 154 indicates that the spring water contains 57 parts per million of calcium and a large amount of the bicarbonate radicle. As the water issues at temperatures ranging up to 144° F. it is probable that calcium carbonate is precipitated by the escape of carbon dioxide as soon as the water reaches the surface.

A small ledge of travertine was seen east of the Charnock ranch, a short distance below the highest shore line but well above the level of the present springs. It was no doubt formed by a spring that is now extinct and that may have existed in a more humid epoch, when the ground water had a higher head. The active spring mounds on the Charnock ranch (p. 50) are composed largely of wind-borne sediments and vegetable matter.

SALT DEPOSITS.

Soluble salts deposited by evaporation of surface and ground waters are found in considerable quantities in the lowest parts of both the upper and the lower valley and in other places where the surface water is impounded or the ground water comes to the surface. They are intermingled with the playa silts and clays or form thin crusts at the surface of the flats. The largest deposit known in the valley is at the Spaulding salt marsh, east of Frank Gendron's ranch and south of the west end of the Spaulding beach ridge, where comparatively pure sodium chloride, which was formerly used, exists as a thin, white, surface layer.

The analyses on page 161 show that sodium chloride and sodium carbonate are abundant and widely distributed and that calcium sulphate and sodium sulphate are also found and in some localities are abundant. No tests were made for borax, but it is probably present, at least in the lower valley. So far as known the potassium salts are present in only relatively small amounts. As is explained on pages 118–119, the distribution of the various salts is definitely related to the rocks from which they are derived.

GEOLOGIC HISTORY.

PALEOZOIC AND MESOZOIC EVENTS.

The region now occupied by the drainage basin of Big Smoky Valley was submerged by the sea during a great part of the Paleozoic era and received deposits of sand, clay, and the calcareous remains of marine organisms. These deposits accumulated, layer upon layer, until they aggregated many thousand feet in total thickness, as is shown by the formations that outcrop in the mountains. The sedimentation began early in the Cambrian period and was in progress in the Carboniferous, as is shown by fossils found in the rocks at different horizons. Whether the region was under water during all of the intervening time is not known but the fossils show that there was sedimentation in the Ordovician period and the apparent conformity of all the strata from the Lower Cambrian to the Carboniferous, inclusive, indicate that there was not much disturbance of the earth's crust in the region during all this time.

The era of sedimentation was followed by some notable geologic events. The Paleozoic strata were intruded by magmas that produced great bodies of granitic rock; they were extensively deformed, so that they are now found standing at all angles; and they were submitted to long-continued erosion, whereby the coarse-grained granites that must have been formed at great depths were exposed. There is no evidence that the region was under water at any time during the Mesozoic era.

TERTIARY EVENTS.

The Tertiary period was characterized by repeated volcanic outbursts of great magnitude and the extrusion of vast quantities of lava over the older formations in all parts of the region. During this period there was much deformation, probably caused by the volcanism, the rock formations being extensively broken and faulted. The volcanism and deformation together produced radical changes in the surface of the land. The uplifted areas were subjected to vigorous erosion while the depressed areas, especially in the southern part of the region, were filled with the eroded materials, partly by stream deposition, such as is taking place at present, but largely by accumulation in lakes that occupied the depressions.

The successive lava flows at Tonopah, the earliest of which were andesite and the later ones rhyolite and dacite with small amounts of basalt, are believed by Spurr to have been extruded in the Miocene and Pliocene epochs, and the tufaceous lake beds of that locality are believed by him to be Miocene. After the eruption of the first andesite at Tonopah the formation was fractured and veins rich in silver and gold were deposited by heated ascending waters.[1] In the southwestern part of the basin sedimentation continued during a longer time than at Tonopah, but even the oldest exposed strata are composed largely of volcanic fragments. The latest eruptions, probably of late Pliocene age, were flows of basalt. During at least a part of the Tertiary period the climate was more humid than it is now, as is indicated by coal seams and the fossil remains of large trees, and by lake beds that contain fossils of fresh-water organisms. It is believed that during a part of the time, as in the Pleistocene epoch, the region contained salt lakes. (See p. 119.)

[1] Spurr, J. E., Geology of the Tonopah mining district, Nev.: U. S. Geol. Survey Prof. Paper 42, p. 67, 1905.

QUATERNARY EVENTS.

At the beginning of the Quaternary period the basin of Big Smoky Valley had essentially its present dimensions and the mountain ranges occupied approximately their present positions. Slight disturbances, however, took place during the period, resulting in fault scarps on the valley sides. The characteristic process of the period has been the erosion of the mountains and the deposition of the resulting detritus in the valley. The climate was probably arid during most of the period, but in late Pleistocene time there was at least one relatively humid interval when large lakes were formed. There was also a time, apparently contemporaneous with the lake epoch, when deposition on the upper and middle parts of the alluvial fans generally ceased and valleys of considerable depth and width were cut.

Wind work, chiefly the handling of sandy sediments of the valley fill, was probably in progress throughout the period and is now going on, the present dunes having been deposited chiefly since the desiccation of the lakes. The great extent of postlacustrine wind work is indicated by the fact that dunes of very different ages occur on the lake bed in the lower valley. Considerable erosion of the tuff formations and a small amount of erosion on the flats has been accomplished by the wind, but except for the building of the dunes the wind has not been an important factor in the molding of the topography of the basin.

The existence of the two large lakes, exposing at their maximum stages respectively 85 and 225 square miles of water surface to continuous evaporation, indicates distinctly less aridity than exists at the present time, when there are no permanent lakes, when the surface waters that occasionally spread over the interior depressions are quickly disposed of by evaporation, and when the areas over which the slow evaporation of ground water takes place are considerably smaller than the ancient lake beds. On the other hand, these lakes do not indicate any great degree of humidity but only the moderate differences in precipitation and evaporation exhibited by the somewhat better watered and cooler basins that contain salt lakes at the present times. Both lakes show great fluctuations in water level in response to numerous climatic variations within the epoch of relative humidity. Even in the most humid times, however, Lake Toyabe occupied only about 18 per cent and Lake Tonopah about 4 per cent of their respective drainage basins. At no time did either lake overflow its basin nor did Lake Toyabe ever discharge into the lower valley.

In proportion to the size of their respective drainage basins Lake Toyabe was more than four times as extensive as Lake Tonopah. This difference was due to the higher altitude and consequently greater run-off of the northern than the southern mountains, to the lower altitude and latitude and consequently greater evaporation in the lower than the upper valley, to the relatively small contributions of water made by remotely connected areas tributary to the lower valley, such as Ione Valley and the basin discharging at Crow Spring, and perhaps also to the greater amount of underground leakage from the lower than from the upper valley.

PRECIPITATION.

RECORDS.

Careful and continuous observations of precipitation have been made at two places in the drainage basin of Big Smoky Valley in recent years—at Tonopah, where the record is complete since August, 1906, and where the United States Weather Bureau has for several years maintained a station; and at the Jones ranch, less than 3 miles south of Millett, where observations have been made by Fred J. Jones since September, 1907. The following tables give the summarized precipitation data for these two places and for several points in the surrounding country.

Monthly and annual precipitation (in inches) at Tonopah.

[Observations made at U. S. Weather Bureau station.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1906....	......	......	......	......	......	......	......	1.55	0.08	0.11	0.69	1.83	......
1907....	1.19	0.41	1.15	0.22	0.20	0.58	T.	T.	.04	1.23	.01	.21	5.24
1908....	1.10	1.04	.22	.38	.46	T.	0.92	.30	.74	.06	T.	.08	5.30
1909....	.45	.49	.34	.06	.01	.15	.20	.91	2.07	.26	2.39	.16	7.49
1910....	.55	.12	.20	.01	.18	.00	.52	.24	.94	.35	.36	.75	4.22
1911....	.31	.94	1.14	.63	T.	.10	.99	.00	.27	.40	.02	.13	4.93
1912....	.03	.02	.78	.58	.15	.02	1.34	.00	.01	1.03	.10	T.	4.06
1913....	.18	.76	.32	.49	1.11	.79	.16	1.16	.62	.07	.80	.29	6.75
Average	.54	.54	.59	.34	.30	.24	.59	.53	.60	.44	.55	.43	5.69
1914....	1.11	.59	.00	.50	.28	.58	.59	.02	.27	.00	.00	.21	4.15
1915....	.30	.50	.99	3.26	.35	T.	.21	.02	.00	......	T.	.68	6.58

Monthly and annual precipitation (in inches) at the Jones ranch, near Millett.[a]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1907....	......	......	......	......	......	......	......	......	0.07	1.20	0.00	0.75	......
1908....	0.82	1.14	0.05	0.12	0.38	0.00	1.42	0.60	.45	.07	T.	.13	5.18
1909....	1.00	.29	.51	.09	.14	.09	.38	1.02	2.38	.40	1.46	.75	8.51
1910....	1.50	.19	.34	.80	.33	.00	1.95	T.	1.82	.45	T.	.79	8.17
1911....	1.29	1.08	1.01	.61	.30	.17	.22	.00	.16	.15	.10	.28	5.37
1912....	.69	.05	.96	.59	.29	......	.88	.10	.20	1.29	.20	.00	[b] 5.45
1913....	.10	.48	.17	.56	1.72	.93	.38	1.11	.52	T.	.43	.20	6.60
Average	.90	.54	.51	.46	.53	.24	.87	.47	.80	.51	.31	.41	6.55
1914....	1.74	.87	.25	.42	.35	.72	1.21	.34	.85	.25	.00	.06	7.06
1915....	.25	.77	.15	2.12	.24	.00	.10	.32	T.	.00	.00	.50	4.45

[a] The observations were made for the U. S. Weather Bureau by Fred J. Jones at the ranch of Mr. Jones, nearly 3 miles south of Millett post office. (See Pl. I.)
[b] Estimated for June, 1912.

Annual precipitation (in inches) at stations in or near Big Smoky Valley, Nev.

[U. S. Weather Bureau.]

Year.	Austin.	Belmont.	Candelaria.	Hawthorne.	Millett.	Potts.	Tonopah.
1878	12.77						
1879	9.80						
1884				2.57			
1885				4.16			
1887				4.13			
1889				3.37			
1890	14.95		5.40	5.84			
1891	21.07	12.74		7.36			
1892	10.43	7.69		4.62			
1893	11.22	9.00	3.84	2.28			
1894	14.89	8.89		4.10			
1895	9.22	8.10		3.22		3.99	
1896	8.45		4.17	5.70		13.52	
1897	12.89		4.21	3.98			
1898	13.21		4.27	2.89			
1899				1.86		5.40	
1900		6.15	3.81			4.82	
1901	13.73	9.22		2.60			
1902							
1903	9.24	4.32	3.36	1.75		5.52	
1904		8.84	11.18	4.39		8.60	
1905						10.09	
1906						6.87	
1907						8.13	5.24
1908				2.10	5.18	3.34	5.30
1909				6.17	8.51	5.20	7.49
1910					8.17	4.08	4.22
1911					5.37	3.40	4.93
1912					[a] 5.45	4.54	4.06
1913					6.60	[b] 12.04	6.75
Average	11.72	8.67	4.98	3.56	6.55	6.93	5.69

[a] Estimated for June, 1912. [b] Estimated for January, 1913.

Average monthly and annual precipitation (in inches) at stations in or near Big Smoky Valley, Nev.

[U. S. Weather Bureau.]

	Length of record.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
	Years.													
Austin	23	1.21	1.33	1.50	1.50	1.56	0.63	0.39	0.55	0.51	0.62	0.68	1.24	11.72
Belmont	13	.85	1.10	.92	.68	.84	.46	.49	.94	.53	.46	.31	1.09	8.67
Candelaria	16	.47	.42	.37	.43	.66	.17	.28	.86	.35	.51	.17	.29	4.98
Hawthorne	25	.60	.35	.22	.24	.36	.25	.15	.24	.22	.22	.32	.39	3.56
Millett	6	.90	.54	.51	.46	.53	.24	.87	.47	.80	.51	.31	.41	6.55
Potts	22	.53	.66	.82	.71	1.11	.40	.65	.57	.30	.33	.39	.46	6.93
Tonopah	7	.54	.54	.59	.34	.30	.24	.59	.53	.60	.44	.55	.43	5.69

GEOGRAPHIC DISTRIBUTION.

The available precipitation data give reliable though general information as to the degree of aridity in the region, but they are too meager to show the range in precipitation which is suggested by the topography, vegetation, and other natural conditions in different parts of the basin. The data show that the valley must be regarded as arid rather than semiarid.

At the Jones ranch, situated on the west side of the upper valley, between 5,500 and 5,600 feet above sea level, the precipitation in 6 years averaged only 6.55 inches a year and in no year amounted to as much as 9 inches. In only 18 of the 99 months for which records are given at this station did the precipitation amount to 1 inch and in only 2 months did it reach 2 inches. These figures are believed to be fairly representative for the conditions in the upper valley.

At the Weather Bureau station in Tonopah, situated 6,090 feet above sea level, near the summit of the low group of hills forming the southern part of the San Antonio Range, the annual precipitation in seven years was between 4.06 inches and 7.49 inches and averaged only 5.69 inches. In the 113 months for which there are records, an entire inch of precipitation was recorded in only 18, and as much as 2 inches in only 3 months. These figures are probably fairly representative for the low mountainous areas in the southern part of the basin, and they corroborate the evidence of great aridity furnished by the vegetation, the topography, and the general lack of springs and streams in these areas.

The minimum precipitation probably occurs at the lower levels of the lower valley. No records are available for the valley area, but the aridity appears to be even more intense than in the upper valley or in the low ranges represented by the Tonopah record. At Candelaria, situated about 6,000 feet above sea level, the average annual precipitation in an interrupted record period of 16 years amounted to less than 5 inches, and at Hawthorne, situated about 4,500 feet above sea level, it amounted in an interrupted record period of 25 years to only a little over 3½ inches.

In the higher mountains the precipitation is appreciably greater, as is shown by the growth of trees and grass. At Austin the average annual precipitation is nearly 12 inches, according to the records, and in the loftiest parts of the Toyabe Range it is probably still more.

SEASONAL DISTRIBUTION.

The precipitation is irregularly distributed both in time and in space. Most of the rain for an entire year or even for several years may fall in a single storm of short duration, and while such a cloudburst is affecting a certain locality the sun may be shining only a few miles away. Consequently there are large differences in the monthly and even the annual precipitation of the different stations in the region, and the record of a station for any given month or year may not be representative of the general area in which it is located. In a period of years, however, the irregularities are largely compensated, and the monthly and annual averages are therefore fairly representative. The monthly averages for the different stations show that the heaviest precipitation is in winter and early spring and in midsummer, and the lightest in late spring and in autumn (fig. 8). They show, however, that the seasonal differences are not marked, aridity being characteristic of all seasons, whereas storms producing rain or snow may come in any month.

The summer precipitation generally comes in the form of violent local thunder storms in the afternoon or evening of hot days, giving rise to sudden floods. The precipitation of the winter and early spring more often accompanies the regional storms of longer duration. It forms a larger proportion of the total precipitation in the high mountains than in the valley, as is shown by the curves in figure 8. (Compare, for instance, Austin and Millett.) The winter precipitation in the higher mountains accumulates in the form of snow, which, melting gradually in the spring, either feeds the mountain streams directly or seeps into the rock waste and decomposed upper part of the bedrock, giving rise to springs that feed the streams during summer and autumn. These streams furnish most of the irrigation supplies and provide most of the ground water.

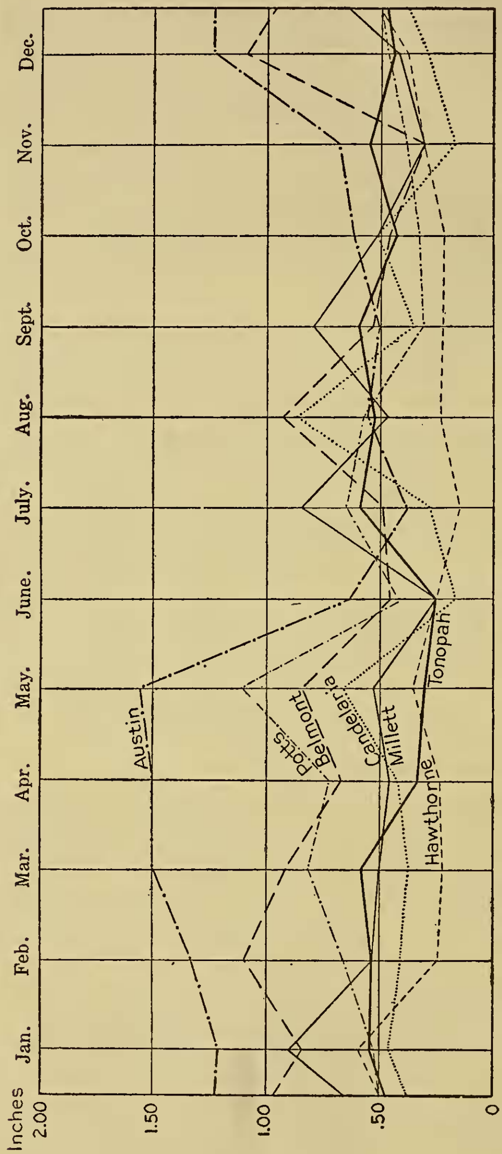


FIGURE 8.—Diagram showing average monthly precipitation at stations in or near Big Smoky Valley.

STREAMS.

GENERAL FEATURES.

As shown in Plates I and II (in pocket), about 50 of the canyons that drain into Big Smoky Valley contain small perennial streams. All of these discharge into the upper valley except Peavine, Cottonwood, and Cloverdale creeks, and all rise in the Toyabe Range except Cloverdale Creek, which is fed partly from the Shoshone Range, and North Moore, South Moore, North Barker, Barker, Willow, Jefferson, and Shoshone creeks, which rise in the Toquima Range. The largest streams are the Twin Rivers, Kingston Creek, and Peavine Creek, which fluctuates greatly in volume. North of Kingston Creek, in the Toyabe Range, are Santa Fe and Birch creeks and about 10 smaller streams; between Kingston Creek and the Twin Rivers there are about 18 small streams; and between the Twin Rivers and Peavine Creek there are about 8 small streams.

The perennial streams are fed partly by rain and melting snow and partly by springs supplied by seepage from the masses of rock waste in the undulating upper parts of the mountains and in the gulches farther down. The streams are largest in the spring of the year when the snow melts and when there is also considerable rain in the mountains. By the end of June most of the snow has disappeared and in the succeeding months the evaporation is great. Consequently the streams shrink very much. The heavy storms of midsummer occasionally swell the streams, but they do not contribute much to their permanent flow. In the spring many of the streams persist in their courses across the alluvial slopes and furnish water for the irrigation of considerable land at the ranches far down in the valley (Pl. II and p. 128), but in the fall most of them do not persist far beyond the mouths of the canyons and some of the smallest do not even reach the canyon mouths.

Three series of measurements of the flow of the principal streams were made at different seasons of the year. The first series was made by the writer September 27 to October 8, 1914; the second and third by A. B. Purton April 19 to 25, 1915, and June 30 to July 6, 1915, respectively. In the first series of measurements a current meter was used exclusively, in the second and third series a current meter was used chiefly, but a 1-foot Cippoletti weir was used in a few small streams. In measuring such small flows with a current meter the percentage of error was undoubtedly rather large. In many streams the rocky bed made it impossible to install the weir satisfactorily without spending more time than seemed warranted. In others it was impracticable to use the weir because it was necessary to go on foot 2 or 3 miles without knowing the amount of water that would be found and weir board and shovel could not be carried in addition to the current meter.

Considerable rain fell during the week of the April measurements and also earlier in the month. In the Nevada section of "Climatological data," published by the United States Weather Bureau, the following statement is made in regard to the weather in April: "Showery weather predominated. Considered as a whole, the month, with one exception (1900), was the wettest April on record. * * * At Tonopah all previous records were broken. The total precipitation at Jones's ranch near Millett amounted to 2.12 inches, and at Tonopah 3.26 inches. The month was appreciably warmer than usual for April."

As reported by the Weather Bureau, there was 0.24 inch of precipitation in May, 1915, at the Millett station and none in June, 1915. At Tonopah the May record was 0.35 inch and the June record "a trace." No rain fell while the measurements in June and July were being made except on July 4, when there were very light showers. The weather was hot and there was little wind. The snowfall during the previous winter was light, and by July 1 only a few small snow banks were visible on the highest mountains. From local information it appears that the streams in the southern part of the Toyabe Range were holding up better than those in the northern part. The streams on the east side of the valley, particularly the two Moore creeks and Barker Creek, were reported to be holding up remarkably well, although they had not reached stages as high as in 1914. The maximum in 1915 seems to have occurred on most of the creeks between May 25 and June 15 and to have been lower than the average. It was reported that some of the smaller creeks did not have the usual spring floods.

At the time of the visit in July considerable water was being used for irrigation, and some of the measurements made at different points on the same creek included this loss as well as that from percolation, evaporation, and transpiration. Examples of the loss of water flowing in the natural channels are afforded by Birch, Gilman, Blue Spring, Belcher, and Cove creeks, and Kingston Creek between the two lower measurements on July 1; examples of loss in channels that have been improved, by Decker Creek on July 2 and by the combination of Santa Fe and Shoshone creeks at Schmidtlein's ranch.

The discharge of the streams into Big Smoky Valley during the three periods in which series of measurements were made is summarized in the following table. The figures represent, as nearly as possible, the discharge at the mouths of the canyons. The detailed data are given on subsequent pages.

Measured and estimated discharge of streams into Big Smoky Valley, Nev., during three periods in 1914 and 1915.

	Sept. 27 to Oct. 7, 1914.		Apr. 19 to 26, 1915.		June 30 to July 6, 1915.	
	Number of streams.	Discharge.	Number of streams.	Discharge.	Number of streams.	Discharge.
MEASURED STREAMS.						
Upper valley:		*Sec.-ft.*		*Sec.-ft.*		*Sec.-ft.*
From Toyabe Range	13	19.04	23	86.34	23	83.13
From Toquima Range			7	23.38	7	16.02
	13	19.04	30	109.72	30	99.15
Lower valley			3	53.50	3	3.65
Grand total	13	19.04	33	163.22	33	102.80
ALL STREAMS (ESTIMATED).						
Upper valley:						
From Toyabe Range	44	27.0	44	94.0	44	88.0
From Toquima Range	7	4.0	7	23.0	7	16.0
	51	31.0	51	117	51	104
Lower valley	3	3.0	3	53.0	3	4.0
Grand total	54	34.0	54	170.0	54	108.0

STREAMS IN THE TOYABE RANGE.

Northern axial draw.—The draw which extends from the north end of Big Smoky Valley practically to the Daniels beach ridge was examined in October, 1914, nearly to the north end of T. 19 N., R. 45 E. Wherever it was seen it was found to be entirely dry, without indications of surface water except occasional freshets and without indications of ground water until it reaches the main shallow-water area a short distance south of the Spencer Hot Springs. (See Pls. I and II.)

Willow Creek.—A large but rather low area in the northeastern corner of the north basin of Big Smoky Valley is drained by Willow Creek. This creek was seen only in the vicinity of the Laxague ranch in October, 1914, and in the vicinity of the Moss ranch in the fall of 1913 and 1914. In both localities there were shallow wells, springs, and other indications of ground water but no stream that persisted more than a short distance. The map is probably not accurate in respect to the perennial and temporary parts of this creek.

Blackbird Creek.—Blackbird Canyon contains small springs and seeps in several localities but no permanent stream except the rills that flow short distances below the springs. On April 26, 1915, the flow above the ranch, about 2½ miles above the mouth of the canyon, as measured with the weir, was 0.20 second-foot. This flow was diverted for use on the ranch. The creek was dry at the mouth of the canyon.

Birch Creek.—The largest stream north of Kingston Creek is Birch Creek, which rises in the undulating upper part of the range, where in the fall it derives its entire supply from springs.

A gaging station was maintained by the United States Geological Survey on this stream at the mouth of the canyon (SW. ¼ sec. 35, T. 18 N., R. 44 E.) from June 13 to November 30, 1913, the daily gage heights being read by John H. Spencer. The following table shows the monthly discharge of the creek during this period according to the record, which, however, is of rather doubtful accuracy.

Monthly discharge of Birch Creek at the mouth of its canyon from June 13 to Nov. 30, 1913.[a]

Month.	Discharge in second-feet.			Total run-off in acre-feet.
	Maximum.	Minimum.	Average.	
June 13-30	12.0	3.3	4.96	177
July	4.1	2.3	3.07	189
August	4.1	1.5	2.89	178
September	11.0	3.3	3.97	236
October	3.3	.9	1.85	114
November[b]			.80	48

[a] Surface water supply of the Great Basin, 1913: U. S. Geol. Survey Water-Supply Paper 360, 1916: record subsequent to Oct. 1, 1913, unpublished.
[b] Estimated in part.

The flow at the gaging station was 1.12 second-feet September 27, 1914, 1.89 on April 26, 1915, and 2.79 on June 30, 1915. On September 27 the flow was 1.18 second-feet at a point 2.85 miles above the gaging station and a short distance below the meadow in the mountains. On the same day it was only 0.43 second-foot at a point 1.4 miles below the gaging station, and approximately 0.25 second-foot at the main road at Spencer's ranch. The heavy loss below the gaging station was due to diversion from the main ditch into a gravelly channel, where the water sank rapidly. On April 26 the flow was 1.65 second-feet at a point above the first diversion, a little more than a mile below the gaging station, and approximately 0.10 second-foot at the main road. On June 30 the flow was 2.68 second-feet at the point above the first diversion and approximately 0.10 second-foot at the main road, the water being used for irrigation above the road on the Spencer ranch.

Spanish, Lynch, and Tarr creeks.—South of Birch Creek there are several canyons that contain small streams. In September, 1914, Spanish Canyon contained no stream that reached the mouth of the canyon, but some underflow was indicated near the mouth by a clump of willows and a short distance farther down by a spring yielding about 10 gallons a minute and by birch trees and buffalo-berry bushes. The mouth of the canyon was dry also on June 30, 1915.

In September, 1914, Lynch Canyon contained a small stream which carried only about one-eighth of a second-foot at the mouth of the canyon and disappeared a short distance farther down. (See Pl. II and table, p. 80.) On June 30, 1915, it carried 0.32 second-foot at the mouth of the canyon, above the ditch, as measured with the weir, and this water was used on a small alfalfa field.

Tarr Creek is formed by two forks which come together less than a mile above the mouth of the canyon. The North Fork is reported to be a perennial stream for about a mile and the South Fork for $1\frac{1}{4}$ miles above the junction. In September, 1914, each fork was estimated to carry between 0.10 and 0.20 second-foot at points not far above the junction. Below the junction the water sank rapidly into accumulations of porous rock waste and disappeared in the course of about half a mile. A short distance farther down the canyon a part of the water was returned in springs, the flow of which, as determined with the current meter at a point one-eighth mile above the house at the mouth of the canyon, was 0.20 second-foot. When not used for irrigation the stream issuing from the springs extended in the fall only about one-fourth mile below the mouth of the canyon. The flow one-eighth mile above the house at the mouth of the canyon was determined to be 1.46 second-feet April 26, 1915, and 0.69 second-foot June 30, 1915. On April 26 the stream did not extend more than a mile below the house.

The water of Tarr, Lynch, and Spanish canyons is used by J. H. Cahill for the irrigation of small tracts near the canyon mouths.

Sheep, Rock, Crooked, Gillman, Globe, and Frenchman creeks.—Between Tarr Creek and Santa Fe Creek there are five short gorges with small streams known as Sheep, Rock, Crooked, Globe, and Frenchman creeks. In April and the first part of May these streams are at a maximum and flow down the alluvial slope to the Schmidtlein ranch, where they are in part used for irrigation. Early in the season, however, they shrink to small size and in the fall they do not generally reach the mouths of their canyons. A spring issues at the mouth of Rock Creek.

Gillman Creek rises from a spring at the edge of the mountains between Crooked and Globe canyons. On September 29 its flow was determined to be 0.38 second-foot just below the spring and 0.21 second-foot at the main road, 1.85 miles downstream. On April 26 its flow, measured by the weir, was 0.22 second-foot at the road; on June 30 it was 0.58 second-foot just below the spring and 0.45 at the road.

Santa Fe, Shoshone, and Blakey creeks.—Santa Fe and Shoshone creeks, which emerge from the mountains less than one-fourth mile apart, drain much of the north and east flanks of Bunker Hill Peak, where there is relatively heavy snowfall and where the snow is protected from the sun to such an extent that it contributes to the stream flow during practically the entire summer. On September 30, 1914, Santa Fe Creek was flowing 0.83 second-foot and Shoshone Creek 0.50 second-foot at the canyon mouths. At the same time Santa Fe Creek was flowing only 0.39 second-foot at a point below its junction with Shoshone Creek, 1.85 miles below the mouth of its canyon, and only about 0.20 second-foot at the main road. On April 25, 1915, Santa Fe and Shoshone creeks flowed 1.42 and 0.62 second-feet respectively at the mouths of their canyons and together flowed about 1.00 second-foot at the main road. On July 1, 1915, they flowed 2.33 and 1.07 second-feet respectively at the mouths of their canyons and together flowed 2.56 second-feet at a point above the first diversion.

Blakey Canyon, a short, steep gorge between Shoshone and Kingston canyons, carries a small stream which in the fall does not reach the valley.

Kingston Creek.—One of the largest streams in the basin is Kingston Creek, which drains not only the south and west flanks and a part of the north flank of Bunker Hill Peak but also an extensive area of the undulating upper part of the range. As in the Birch Creek basin, the autumn flow is derived almost entirely from springs in this upper part, the contributions in the steep, narrow part of the canyon below the lower Daniels ranch being nearly negligible. On October 1, 1914, the flow four-fifths mile below the upper Daniels ranch and about 3½ miles above the road crossing near the old mill was 6.68 second-feet and at the crossing near the old mill it was 7.21 second-feet. The flow, therefore, amounted to approximately one-fifth second-foot for each square mile that is drained. (See Pl. II and the table, p. 82.) The stream is said to be at its maximum in most years between the middle of May and the first part of July, when, according to certain records obtained by the State engineer from the commissioners of Lander County, it may carry 15 to 20 second-feet. On April 25, 1915, the flow at the old mill was only 3.41 second-feet, and no water was flowing at the lower end of the field, 1.8 miles below the old mill. On July 1, 1915, the flow was 10.0 second-feet at a point just below the field at the upper Daniels ranch, 14.9 second-feet near the old mill, 1.75 second-feet 1.8 miles below the old mill, and 1.11 second-feet at a point just above Schmidtlein's field, 4½ miles below the old mill. Most of the water is applied on the Kingston ranch, at the mouth of the canyon, but a part is used on the Daniels ranches, situated above the Kingston ranch, and a part reaches the Schmidtlein ranch in the valley. (See Pl. II, in pocket.) On July 1, 1915, water was being used on a small field on the lower Daniels ranch between the upper measurement point and that near the old mill, and on the Kingston ranch between the measurement point at the old mill and the next downstream, but no water was diverted between the lower two measurement points.

Clear and Carsley creeks.—Next south of Kingston Creek are Clear and Carsley creeks, which practically meet at the edge of the mountains. In the fall they were among the larger streams of the basin of Big Smoky Valley. At points a little above the house at the edge of the mountains (see table, p. 81) they flowed, respectively, 0.56 and 0.99 second-foot on October 2, 1914, 0.98 and 1.20 second-feet April 25, 1915, and 2.71 and 4.35 second-feet July 2, 1915. On April 25 the flow of the springs between the mouth of the canyon and the main road was estimated at 0.40 second-foot. The water is used for irrigating several fields belonging to the Rast and Bowman ranches. On each visit to the locality only a small amount of water, estimated at 0.05 to 0.08 second-foot, reached the Bowman ranch house on the main road, the rest being used for irrigation or sinking into the gravelly stream bed.

Needles and Decker creeks.—For about 15 miles between Carsley and Summit creeks the mountain area draining into Big Smoky Valley is exceptionally narrow and is cut by numerous short, steep canyons, about eleven of which contain small streams that shrink very much after the spring months.

Needles Creek, Decker Creek, and a small creek about half a mile south of Decker furnish irrigation water for Frank Gendron's ranch. On October 8, 1914, Decker Creek, probably with its south tributary flowed 0.64 second-foot at Gendron's ranch on the main road, the water being conveyed from the mountains in a more or less waterproofed ditch. (See p. 129.) Needles Creek flowed considerably less. On April 25, 1915, Decker Creek flowed 2.25 second-feet and the small south tributary 0.50 second-foot, both measured at the mouths of their canyons. Together they flowed only 0.58 second-foot at the main road, the stream presumably not being in the waterproofed ditch. On July 2, 1915, Needles Creek flowed 0.51 second-foot at the main road, and Decker Creek flowed 1.17 second-feet at the mouth of its canyon and 1.13 second-feet at the main road. On July 2 Decker Creek flowed in the waterproofed ditch, and Mr. Gendron stated that a few days earlier, when it was in its natural channel, it scarcely reached the road.

Blue Spring Creek.—On October 3, 1914, Blue Spring Creek flowed about 0.40 second-foot at the mouth of its canyon and only 0.10 second-foot just above Mrs. Alice Gendron's garden, west of the upper road, most of the water being lost by percolation. On April 25, 1915, it flowed 1.45 second-feet at the mouth of its canyon and 0.66 second-foot at the lower road. On July 2, 1915, it flowed 0.67 second-foot at the mouth of its canyon, 0.44 second-foot above Mrs. Gendron's garden, and 0.20 second-foot at the upper road, the last measurement being obtained with the weir. The water of this creek is used on Mrs. Gendron's ranch.

Decker Bob, Grinnell, Trail, Park, Wildcat, Clay, and Mose creeks.—Decker Bob and Grinnell creeks are very small streams that irrigate tiny fields near their respective canyon mouths. On April 25, 1915, Grinnell Creek flowed 0.45 second-foot at the upper road, 2½ to 3 miles below the mouth of its canyon, but in the fall of 1914 and on July 2, 1915, it was dry at this point. Trail Canyon also contains a very small stream. Park, Wildcat, and Clay canyons contain small streams, which in the spring are led to Millett. Mose Canyon carries little water.

Summit, Wisconsin, Ophir, Last Chance, and Hercules creeks.—In October, 1914, the aggregate discharge of Summit, Wisconsin, Ophir, and Last Chance creeks, across the road leading from Millett to Twin Rivers, was estimated at 0.75 second-foot. Earlier in the season their flow is, of course, larger. On April 23, 1915, the aggregate flow was 1.25 second-feet on the same road and on July 3, 1915, 3.98 second-feet about 1¼ miles below the mouths of the canyons, 1.19 second-feet being the flow on July 3 of Last Chance Creek alone. The combined flow of the four creeks at the main road on July 3 was 1.69 second-feet. The water of these four creeks is used on the Rogers ranch. The water from Hercules Canyon is used on a field near the mouth of the canyon.

Twin Rivers.—The Twin Rivers head in the lofty mountain mass that culminates in Aro Dome, and their combined drainage area is about equal to that of Kingston Creek. On October 7, 1914, North Twin River flowed 2.61 second-feet and South Twin River 3.48 second-feet at points about one-eighth mile below the mouths of their canyons. On April 23, 1915, North Twin River flowed 12.90 second-feet and South Twin River 8.54 second-feet at points about one-fourth mile below the mouths of their canyons. On July 3, 1915, North Twin River flowed 13.60 second-feet and South Twin River 14.40 second-feet at points about one-fourth mile below the mouths of their canyons. The water from both streams is used on A. B. Millett's Twin River ranch and on his ranch south of the Rogers ranch.

Belcher, Cove, and Broad creeks.—The steep slope south of Twin Rivers is drained by several perennial streams of great seasonal fluctuation. In the early part of the irrigation season they reach the ranches in the valley, but later they do not get far out of the mountains. On April 23, 1915, Belcher Creek flowed 6.25 second-feet at the mouth of its canyon and 4.75 second-feet at the upper road; on July 4, 1915, it flowed 5.20 second-feet at the mouth of its canyon and 3.01 second-feet at the upper road above the first diversion. On April 21 Cove Creek flowed 2.78 second-feet and Broad Creek 13.8, both measured at the mouths of the canyons. On July 4 Cove Creek flowed 3.43 second-feet at the mouth of its canyon and 2.21 second-feet at the road crossing. On the same day Broad Creek flowed 1.95 second-feet at the mouth of its canyon.

Jett Creek.—Among the larger streams of the basin is Jett Creek, the water of which was used on Wood's ranch until recently, when it was purchased for use in mining at Round Mountain. On April 20, 1915, it flowed 18.6 second-feet at the mouth of its canyon. On July 5, 1915, it flowed 5.83 second-feet 2 miles above the mouth of the canyon, at the intake to the 15-inch pipe line in which the water was conveyed to Round Mountain. On July 5 it flowed about 0.10 second-foot just below the intake and about 0.25 second-foot at the mouth of the canyon.

Pablo, Wall, Antelope, and Boyd creeks.—The canyons between Jett and Peavine creeks contain only small streams. The water of Pablo Creek is used for irrigation near the canyon mouth. In the fall it carries very little water, but on April 20, 1915, it flowed 6.58 second-feet and on July 6, 1915, it flowed 2.65 second-feet. On April 19, 1915, Wall, Antelope, and Boyd creeks were all dry at the mouths of their canyons, but Antelope Creek flowed about 0.01 second-foot, or 5 gallons per minute, at a point 300 feet above the mouth of its canyon.

Peavine Creek.—A mountainous area about 100 square miles in extent, at the south end of the Toyabe Range, is drained by Peavine Creek. This creek discharges large quantities of water in the aggregate, but it is subject to great fluctuations, and its normal low-water flow is much less than that of Kingston Creek or Twin Rivers. On October 2, 1913, the flow reaching the Peavine ranch, owned by E. E. Seyler, was estimated to be not more than 2 second-feet. The following measurements or estimates made by representatives of the State engineer show that at times the flow is much greater: May 5, 1911, at the crossing of the road to Manhattan, below the Peavine ranch, 100 second-feet; October 19, 1911, at the same point, 7 second-feet; July 4, 1911, 3 miles below San Antonio (middle of north margin of sec. 3, T. 6 N., R. 41 E.), 20 second-feet. The following measurements by the United States Geological Survey also show that the flow fluctuates between wide limits: April 19, 1915, one-half mile below Seyler's house, 41.70 second-feet; July 6, 1915, above Seyler's ranch, 3.50 second-feet; at the road leading from Cloverdale to Tonopah, about 0.30 second-foot. It was reported that on April 19 the stream reached the vicinity of Millers.

Cottonwood Creek.—On April 19, 1915, Cottonwood Creek flowed approximately 0.50 second-foot and on July 6, 1915, approximately 0.10 second-foot at the road that passes Mud Spring, but in the fall of 1913 it did not reach this road. It is said to be a perennial stream in its canyon.

Cloverdale Creek.—In the upper part of its canyon Cloverdale Creek is a small perennial stream, but in the fall of 1913 it did not reach the Cloverdale ranch. At the ranch a part of the underflow, amounting to perhaps a second-foot, was returned to the surface and used for irrigation. On April 19, 1915, the creek flowed 11.3 second-feet above the ranch, but on July 6, 1915, it became dry before reaching the ranch.

STREAMS IN THE TOQUIMA RANGE.

North and South Moore creeks.—On April 24, 1915, North Moore Creek flowed 0.94 second-foot above Jacob Urech's ranch and South Moore Creek flowed 0.24 second-foot opposite this ranch. On July 3, 1915, North Moore Creek flowed 4.63 second-feet at the mouth of its canyon and South Moore Creek flowed 2.61 second-feet at the mouth of the canyon, above the first diversion. In the fall of 1913 North Moore Creek nearly reached Moore Lake and less than a half mile above where it disappeared it flowed one-half second-foot. On April 24, 1915, it became dry about 2½ or 3 miles below its canyon; on July 3, 1915, it discharged water into Moore Lake. These streams are reported to be used chiefly on the Urech ranch.

Barker and North Barker creeks.—In the fall of 1913 Barker Creek did not reach the lower part of the valley, but, according to records of the State engineer, it had a flow on July 6, 1914, at the Barker ranch of about 1½ second-feet. On April 22, 1915, North Barker Creek had a flow of 1.00 second-foot opposite the small ranch in the mouth of Barker Canyon, and Barker Creek had a flow of 3.09 second-feet at the mouth of its canyon, above the cabin. On July 5, 1915, North Barker Creek had a flow of about 0.20 second-foot at a point one-fourth mile farther north and Barker Creek had a flow of 7.11 second-feet at the cabin and 2.77 second-feet at Cook's diversion, 4 or 5 miles downstream.

Willow Creek.—In the fall of 1913 Willow Creek did not reach the lower part of the valley. On April 22, 1915, it carried 1.21 second-feet at the foothill road, 1½ to 2 miles below the mouth of the canyon. On July 5, 1915, it carried only 0.31 second-foot at the same road.

Jefferson and Shoshone creeks.—The elevated parts of the Toquima Range that culminate in Jefferson Peak are drained by Jefferson and Shoshone creeks. Small patches of snow from the previous winter were still visible on the north side of this peak in October, 1914. These two streams supply water for mining at Round Mountain. It should be noted that the name "Shoshone" is used for two entirely distinct streams in the Big Smoky Valley basin. (See p. 73.) On April 21, 1915, Jefferson Creek flowed 16.80 second-feet about one-half mile above the forest ranger's station but below the mouth of North Jefferson Creek, and on July 4, 1915, it flowed 1.11 second-feet at a point about one-fourth mile farther upstream, but below the mouth of North Jefferson Creek, and 1.58 second-feet at the lower road. Shoshone Creek flowed about 0.10 second-foot at Shoshone village on April 22, 1915, and about 0.05 second-foot at the same place on July 4, 1915.

GROUND-WATER INTAKE.

SOURCES.

The bedrocks of the Big Smoky Valley drainage basin are relatively impervious and form a huge reservoir that is nearly water-tight. In this reservoir rests the great accumulation of porous rock waste called the valley fill, which is saturated with water up to a certain level known as the water table. The great body of water that is stored underground in this natural reservoir is derived from the rain and snow that fall upon the drainage basin.

Contributions to the underground supply are made at the localities where the following three conditions exist: (1) The formations lying between the surface and the water table are not water-tight; (2) the water from rain or snow is applied in sufficient quantity to percolate to the water table without being entirely absorbed by the capillary pores of the dry zone between the surface and the water table; and (3) the water table is not already at the surface. These three conditions are provided most fully on the upper parts of the alluvial fans, where water is poured from the mountains upon gravelly deposits through which it can percolate freely to the water table. They are largely wanting in the mountains, where nearly impervious bedrocks are near the surface, and in the lower parts of the valley, where the soil is too tight to admit water freely and where over large areas the water table is so near the surface that water is being discharged from the valley fill instead of being taken in.

Contributions to the water in the valley fill are made by (1) the perennial streams that flow out of the larger canyons; (2) the floods discharged at long intervals from the canyons which are normally dry; (3) the underflow of some of the canyons; (4) the rain that falls in the valley; and (5) water discharged underground from openings in the bedrocks. None of these contributions can be definitely measured, but an analysis of the conditions so far as known makes possible estimates which, though unsatisfactory, have some practical value.

CONTRIBUTIONS BY PERENNIAL STREAMS.

The valley fill is especially porous on the upper gravelly parts of the alluvial slope over which the streams of the Toyabe Range discharge and on the sandy parts of the slope over which the streams of the Toquima Range discharge. The data given in the following table show that the streams lose heavily as soon as they leave the mountains. That only a small part of this loss can be attributed to evaporation is shown by estimates based on two different kinds of observations. The area over which the water of a stream is discharged into the atmosphere by evaporation from the water surface, evaporation from the wetted ground bordering the stream, and transpiration from trees, bushes, and grass that grow along the stream and are fed by its water was rather definitely ascertained, and by estimating the rate of evaporation and transpiration the total discharge of the stream's water into the atmosphere was calculated. The distance between the highest point up the streamway to which a stream retreated during the day and the lowest point it reached at night was observed on several streams, and a rough estimate was made of the amount of water lost in this distance. This loss represents approximately the difference between maximum evaporation and transpiration in the day time and minimum evaporation and transpiration at night and thus affords a rough measure of the total loss that can be attributed to discharge into the atmosphere. With the most liberal estimates that could be made both methods gave comparatively small results for discharge into the atmosphere and compelled the conclusion that by far the greater part of the water that is lost sinks into the ground and eventually reaches the water table.

Flow of certain streams in Big Smoky Valley, Nev., and their estimated contributions to the ground-water supply.

September and October, 1914.

Stream.	Point of measurement.	Date, 1914.	Hour of day.	Temperature.		Flow.	Loss.	Estimated evaporation area.	Estimated evaporation and transpiration.[a]	Estimated percolation into the ground.		
				Water.	Air.					Second-feet.	Acre-feet a year.	Second-feet a mile of stream course.
				°F.	°F.	Sec.-ft.	Sec.-ft.	Acres.	Sec.-ft.			
Birch Creek	2.85 miles above gaging station; short distance below meadow.	Sept. 27	3.00 p. m.	56	62	1.18	0.06	7	0.06	....	....	....
Do	U. S. Geological Survey gaging station (at mouth of canyon); SW. ¼ sec. 35, T. 18 N., R. 44 E.	...do...	10.30 a. m.	49	71	1.12	.69	1	.02	0.67	485	0.41
Do	1.4 miles below gaging station; SW. ¼ sec. 1, T. 17 N., R. 44 E.	...do...	9.00 a. m.	56	....	.43	.18	1	.02	.16	116	.34
Do	Main road at Spencer's ranch; SE. ¼ sec. 1, T. 17 N., R. 44 E.	...do...	8.00 a. m.	....	....	[b].25						
Lynch Creek	Mouth of canyon; NW. ¼ sec. 9, T. 17 N., R. 44 E.	Sept. 28	1.00 p. m.	49	65	.12	.12	¼	.01	.11	80	.55
Do	One-fifth mile below mouth of canyon.	...do...	...do...	....	....	None.						
Tarr Creek	One-eighth mile above house at mouth of canyon; NE. ¼ sec. 17, T. 17 N., R. 44 E.	...do...	3.30 p. m.	47	65	.20	.20	½	.01	.19	137	.76
Do	One-fourth mile below house at mouth of canyon; NW. ¼ sec. 16, T. 17 N., R. 44 E.	...do...	...do...	....	....	None.						
Gillman Spring	Just below spring; W. ½ sec. 33, T. 17 N., R. 44 E.	Sept. 29	3.00 p. m.	54	69	.38	.17	1½	.03	.14	106	.08
Do	Main road; 1.85 miles below spring.	...do...	12.00 m.	68	70	.21						
Santa Fe Creek	Mouth of canyon; near center of sec. 18, T. 16 N., R. 44 E.	Sept. 30	3.00 p. m.	50	66	.83	.94	1½	.03	.91	659	.50
Shoshone Creek	Mouth of canyon; one-fifth mile south of mouth of Santa Fe Canyon.	...do...	2.00 p. m.	50	66	.50						
Santa Fe Creek below junction with Shoshone Creek.	1.85 miles below mouth of Santa Fe Canyon; SW. ¼ sec. 16.	...do...	4.00 p. m.	....	....	.39	.19	(?)	(?)	.10	72	.33
Do	Main road	...do...	8.00 a. m.	....	....	.20						

Kingston Creek	Road Crossing near old mill; NE. ¼ sec. 35, T. 16 N., R. 43 E.	Oct. 1	9.00 a. m.	46	64	7.21						
Do	Lower end of field, 1 mile below house; N. ½ sec. 31, T. 16 N., R. 44 E.	Sept. 30	6.00 p. m.			b .25	6.96	100	2.00(?)	4.96(?)	3,590(?)	
Clear Creek	Short distance above house at mouth of canyon; SW. ¼ sec. 12, T. 15 N., R. 43 E.	Oct. 2	12.00 m.		61	.56						
Carsley Creek	do	do	11.00 a. m.	47	61	.99	1.50	25	.50(?)	1.00(?)	724(?)	
Carsley and Clear creeks combined.	Main road	Oct. 8				b .05						
Blue Spring Creek	Mouth of canyon; NE. ¼ sec. 7, T. 14 N., R. 43 E.	Oct. 3	11.00 a. m.		65	.40						
Do	Near Alice Gendron's garden; NW. ¼ sec. 16.	do	3.00 p. m.			b .10	.40	2	.04	.36	261	.15
Do	150 feet east of upper road; sec. 16.	do	2.30 p. m.		62	c None.						
Do	Between lower road and Alice Gendron's ranch.	do				d None.						
			April, 1915.									
Birch Creek	U. S. Geological Survey gaging station.	Apr. 26	2.10 p. m.			1.89	0.24	1	0.02	0.22	159	0.20
Do	Just above Spencer's upper ditch	do	2.50 p. m.			1.65						
Decker Creek	Mouth of canyon	Apr. 25	7.20 a. m.			2.25						
Creek one-half mile south of Decker.	do	do	8.00 a. m.			.50						
Decker Creek below junction with creek one-half mile south.	Main road at Frank Gendron's ranch.	do	8.40 a. m.			.58	2.17		.05	2.12	1,525	1.08
Blue Spring Creek	Mouth of canyon	do	5.10 p. m.			1.45	.79	2	.04	.75	543	.31
Do	Lower road	do	6.10 p. m.			.66						
Belcher Creek	Mouth of canyon	Apr. 23	9.45 a. m.			6.25	1.52		.02	1.50	1,086	1.25
Do	Upper road	do	10.45 p. m.			4.73						
North Moore Creek	Above Urech's ranch	Apr. 24	9.30 a. m.			.94	.94		.04	.90	652	.33
Do	2½ or 3 miles below ranch	do	2.30 p. m.			None.						

a Roughly estimated on basis of (1) area of water surface, moist ground, and tree belt; (2) temperature and other climatic conditions; and (3) hour of day when measurements were made.

b Estimated.

c Farthest point reached by stream at 2.30 p. m.

d Farthest point reached by stream during preceding night.

Flow of certain streams in Big Smoky Valley, Nev., and their estimated contributions to the ground-water supply—Continued.

June and July, 1915.

Stream.	Point of measurement.	Date, 1914.	Hour of day.	Temperature.		Flow.	Loss.	Estimated evaporation area.	Estimated evaporation and transpiration.	Estimated percolation into the ground.		
				Water.	Air.					Second-feet.	Acre-feet a year.	Second-feet a mile of stream course.
				°*F.*	°*F.*	*Sec.-ft.*	*Sec.-ft.*	*Acres.*	*Sec.-ft.*			
Birch Creek	U. S. Geological Survey gaging station.	June 30	8.00 a. m.			2.79	0.11	1	0.03	0.08	58	0.07
Do	Just above Spencer's upper ditch	...do	9.15 a. m.			2.68						
Gilman Spring Creek	Just below the spring and seepy ground.	...do	5.00 p. m.			.58	.13	1½	.03	.10	72	.06
Do	Main road	...do	3.30 p. m.			.45						
Kingston Creek	Near the old mill	...do	4.15 p. m.			14.90	13.15		4.00(?)	9.15(?)	6,625(?)	
Do	Lower end of field; 1 mile below house.	...do	11.15 a. m.			1.75						
Do	Just above Schmidtlein's field	...do	10.45 a. m.			1.11	.64		.06	.58	420	.22
Blue Spring Creek	Mouth of Canyon	July 2	1.45 p. m.			.67	.23		.03	.20	145	.11
Do	Above Alice Gendron's garden	...do	2.45 p. m.			.44						
Summit, Wisconsin, and Ophir creeks, combined.	About 1¼ miles below mouths of canyons.	July 3	7.45 a. m.			2.79						
Last Chance Creek	.....do	...do	8.20 a. m.			1.19	2.29		.10	2.19	1,585	.68
Summit, Wisconsin, Ophir, and Last Chance creeks, combined.	Lower road	...do	11.40 a. m.			1.69						
Belcher Creek	Mouth of canyon	July 4	8.15 a. m.			5.20	2.19		.03	2.16	1,564	1.80
Do	Upper road	...do	9.30 a. m.			3.01						
Cove Creek	Mouth of canyon	July 6	11.20 a. m.			3.43	1.22		.03	1.19	862	1.19
Do	Main road	...do	12.30 p. m.			2.21						

According to the estimates given in the table, at the low-water stage in the fall of 1914 nine streams were yielding water to the underground supply, between the points where measurements were made, at the rate of 2,640 acre-feet a year, or 70 per cent of their total flow, or at the average rate of 0.39 second-foot for each mile of their courses; at the high-water stage of April, 1915, six streams were likewise yielding at the rate of 3,965 acre-feet, or 41 per cent of their total flow, or at the average rate of 0.63 second-foot a mile; and at the rather high stage about July 1, 1915, nine streams were likewise yielding at the rate of 4,286 acre-feet, or 36 per cent of their total flow, or at the average rate of 0.65 second-foot a mile. One of the heaviest contributions was from Belcher Creek, which on July 4, 1915, was losing more than 2 second-feet in the course of a little over a mile. In the fall of 1913, Moore Creek, flowing through its natural channel, lost its last one-half second-foot of water in a distance of about one-half mile, and Peavine Creek lost water at a rate also amounting to a considerable part of a second-foot per mile.

The contributions to the underground reservoir from Kingston Creek and the Twin Rivers can not be well estimated, because most of the water of these streams is used for irrigation near the mouths of the canyons, but there is evidence that the contributions are large. Only about 200 acres are irrigated on the Kingston ranch. Even if the annual evaporation and transpiration from the irrigated land amount to 5 feet the disposal of the creek's water through these processes will amount to only 1,000 acre-feet a year. No definite data are at hand to show how continuously the water is diverted for irrigation on the Kingston ranch, but each time the ranch was visited nearly the entire stream was thus diverted. On October 1, 1914, water was being applied to the ranch at an approximate rate of 5,039 acre-feet a year, and on June 30, 1915, it was being applied at an approximate rate of 9,520 acre-feet a year. It is safe to conclude that more than one-half of the water of Kingston Creek, amounting to several thousand acre-feet a year, goes into the underground reservoir.

From the data given above it is roughly estimated that the perennial streams of the Toyabe and Toquima ranges together contribute to the underground supply at an average rate of 15,000 to 30,000 acre-feet a year. Most of the water that percolates from the perennial streams goes to the supply of the upper valley, but the large contributions by Peavine Creek go to the lower valley.

CONTRIBUTIONS BY FLOODS FROM DRY CANYONS.

All the canyons occasionally carry water in large amounts, the evidences of which may remain long after the floods have passed, but the total quantity of water discharged into the valley by such floods is difficult to estimate. Some of the floods are very large and produce impressive results, but they occur so rarely that the average annual flood discharge is likely to be overestimated. These floods make heavy contributions to the underground supply where they flow over the gravelly upper parts of the alluvial slopes, but the largest are of such volume and velocity that they carry a great part of their water into the axial regions of the valley, where the soil is too dense to admit water readily or where the perpetual saturation of the ground prevents percolation. In the lower valley the floods that head in the mountains no doubt make larger contributions than the permanent streams, but in the upper valley the flood contributions are of less relative importance.

CONTRIBUTIONS BY UNDERFLOW.

Since the canyons were cut they have been partly filled with porous rock waste through which water can percolate freely. Hence not all the water discharged by a canyon flows at the surface; a part percolates underground and joins the main body of ground water without coming to view.

The existence of an underflow is demonstrated in many places where, owing to some underground obstruction, the water is compelled to return to the surface, producing swampy areas or sudden increases in the stream flow. Good examples of these conditions are found in Peavine and Cloverdale canyons, in certain sections of each of which the entire stream at low stages is below the surface. Many canyons contain small streams that disappear before they reach the valley, or merely springs or seeps at some places along their dry steam channels. These canyons generally have an underflow whose volume may be larger than is indicated at the surface. Willow and Blackbird canyons are good examples. In some of the canyons underflow is indicated only by certain kinds of trees, such as the birch.

That there is an underflow from Ione Valley into Big Smoky Valley is proved by the appearance of water at the surface in the constricted part of the valley at Warm Spring and Black Spring (Pl. II). As there is a considerable body of fill even in this constricted area it may be inferred that the water which appears at the surface is only a small part of the total underflow. If the constriction were a little less there would be no springs or other surface indications of water, although the underflow would be the same.

That a canyon which has no stream, spring, or indications of ground water may still carry an underflow has been shown by wells and shafts in Manhattan Canyon. Below the wide, flat floor of this dry canyon there is a deposit of gravelly rock waste ranging in depth from 30 or 40 feet near Manhattan to about 100 feet at the mouth of the canyon. This detrital deposit rests on slate bedrock and near the bottom contains gold in paying quantities. The many prospect holes that have been sunk to the rock floor in order to recover the auriferous gravels show that the lower few feet, as a rule, contains water which can be pumped in moderate quantities for sluicing. A part of this underflow may be derived from the pumpage out of the mines, but wells are also obtained above the mines.

Many of the smaller canyons have no permanent underflow, and wells sunk in them would find no water. But even these, if they contain detrital deposits, must at certain times conduct important amounts of rain and snow water underground. The rapidity with which the water of springs and streams sinks into the ground in many of the canyons shows the porosity of the detrital material, and indicates that the water from rain or melting snow will also be readily absorbed.

The quantity of water carried by the canyons as permanent or temporary underflow is certainly considerable, and this water is contributed to the main underground supply with almost no loss.

CONTRIBUTIONS BY PRECIPITATION IN THE VALLEY.

The precipitation of light showers in the valley is absorbed by the capillary pores of the soil and does not contribute to the underground supply, but the heavier rains produce streams or sheets of water that enter the earth wherever the soil is porous or fissured. The gravelly and sandy parts of the valley admit water readily, as is shown by the rapidity with which the streams from the mountains dwindle when they reach the valley. If 5 per cent of the precipitation in the valley joins the ground water the contribution from this source amounts to nearly 10,000 acre-feet a year in both the upper and the lower valley.

CONTRIBUTIONS FROM BEDROCK.

The rock formations in the mountains are so nearly impervious that they absorb only a small part of the water supplied by rain and snow. The limestone is compact but has some joints and solution channels that receive water and allow it to percolate far below the surface; the slate is likewise compact but admits small amounts of water along some of its joints and cleavage planes; the granite, rhyolite, and other eruptive rocks are somewhat porous near the surface, where they are weathered, but contain only a few joints and fracture zones that admit water to greater depths; the Tertiary sandstone, conglomerate, and tuff have a more open texture and no doubt receive water more freely than the denser formations. On the whole the percolation into the bedrocks is unimportant, and except in a few fissures and solution channels the circulation through them is very sluggish.

A small quantity of water, however, no doubt reaches the valley fill through passages in the bedrock. The water of the Spencer and Darrough hot springs appears to be of such origin.

SUMMARY.

Estimates based on a consideration of all available information in regard to intake lead to the conclusion that the contributions from all sources to the ground-water supply of Big Smoky Valley amount to several tens of thousands of acre-feet a year. Most of this supply is in the upper valley but a considerable part is in the lower valley.

GROUND-WATER DISCHARGE.

PROCESSES AND AREA.

The contributions of water to the underground reservoir are balanced by losses from this reservoir. The losses occur chiefly through the return of the ground water to the surface but in smaller part through percolation out of the basin by way of underground passages. The return water reaches the surface by flowing from springs or by rising through the capillary pores of the soil or the roots and stems of plants; it is all eventually evaporated. Ground water is returned to the surface over an area of about 160 square miles, or 100,000 acres, in the upper valley, and about 45 square miles, or nearly 30,000 acres, in the lower valley. The principal groups of springs and the areas of capillary discharge are shown in Plate II (in pocket). The principal leakage out of the basin is believed to be at the west end of the lower valley.

SPRINGS.

CHARACTER AND DISTRIBUTION.

In the largest mountains, such as give rise to perennial streams, springs are numerous, and many of them yield freely, but in the lower and more barren ranges springs are very scarce, as is shown by the maps (Pls. I and II), and nearly all of them are small. Most of the mountain springs are fed by water that percolates near the surface and they are found at points where barriers of compact rock bring this water out of the ground. They do not, of course, discharge any of the main body of ground water that is stored in the valley fill but rather feed the streams that contribute to the main body.

The valley springs, on the other hand, are, with few exceptions, found in low places where the upper surface of the main body of ground water is practically at the surface of the land. They are caused by the overflow of the underground reservoir, which, already full, is constantly receiving new supplies.

The main west-side spring line of the upper valley extends, with a sinuous course, due to differences in the sizes of alluvial fans, from the Vigus ranch to Wood's ranch, a distance of more than 30 miles, and includes innumerable springs that discharge a part of the copious underground supply received from the Toyabe Range. On the east side of the upper valley there is no spring line comparable to that on the west side, probably because the supply from the Toquima Range is smaller than that from the Toyabe Range, but numerous springs similar to those on the west side are found for a distance of 3 miles in the vicinity of the Charnock ranch, and a group of hot springs, called on the map Spencer Hot Springs, is situated on the east side near the north end of the valley. The lower valley, whose ground-water contributions are smaller and less concentrated than those of the upper valley, has no spring line except such as is formed by a few water holes a short distance west of Millers.

On the alluvial slope between the main west-side spring line and the mountains a few springs which flow from fault scarps are apparently produced by impounding caused by dislocation of the valley fill. At San Antonio and the constricted outlet of Ione Valley springs are produced by barriers of a different sort.

The springs of Big Smoky Valley have some of the features characteristic of springs in other parts of the Great Basin.[1] Hot springs are found at Darrough's ranch, on the flat east of McLeod's ranch, and near the north end of the valley; pool springs are found at the Charnock ranch, Alice Gendron's ranch, and other places; mound springs are found at the Charnock ranch, the Spencer Hot Springs, San Antonio, and other places. As in many other valleys, the principal spring pools are reported to extend to profound depths but on actual measurement are found to be only moderately deep.

WEST-SIDE SPRING LINE.

Daniels Springs.—The northernmost group of springs observed along the west-side spring line are on the Vigus ranch and the flat between this ranch and the Daniels ranch. One-fourth mile north of the Daniels ranch house there is a spring that has been developed by ditching and now yields approximately 1 second-foot. (See also analysis, p. 154.) South of the Daniels ranch the spring line is interrupted by the large beach ridge in that vicinity.

Gendron Springs.—South of the Daniels beach ridge the spring line passes through the Spaulding salt marsh, northeast of Frank Gendron's ranch, and thence swings southwestward to Mrs. Alice Gendron's ranch. Only small springs were observed on the salt marsh.

Blue Spring, on the east side of the lower road, half a mile north of Mrs. Gendron's house, is a pool about 75 feet in diameter, sur-

[1] Meinzer, O. E., Ground water in Juab, Millard, and Iron counties, Utah: U. S. Geol. Survey Water-Supply Paper 277, pp. 41-45, 124-126, 129-133, 1911.

rounded by tules, willows, cat-tails, and buffalo-berry bushes. Its discharge consists largely of seepage and is not large. The pool was said to be very deep, but in a number of soundings that were made no depth greater than 16 feet was found. The water has about normal temperature.

Springs yielding water of good quality (see analysis, p. 154) with an observed temperature of 61° F., issue at Mrs. Gendron's house, and there are also small springs at the margin of the barren flat a mile east of the house.

McLeod Springs.—Numerous springs yielding water of good quality are found in the meadow directly east of McLeod's house, some of them issuing from small deep pools. They give rise to seepage over a considerable area and to small streams where the water is collected in ditches. A flow of about 30 gallons a minute was measured in a ditch leading from one group of these springs. In the spring nearest the house a temperature of 57½° F. was observed. A hot spring is reported to issue from a small mound on the barren flat less than a mile east of McLeod's house.

Numerous seepage springs whose aggregate yield is considerable are found on the east side of the lower road about midway between McLeod's house and Millett.

Millett Springs.—Springs similar to those on McLeod's and Mrs. Gendron's ranches are found at Millett, in a meadow extending east and southeast of Millett, and along the lower road leading northward from Millett. They yield small quantities of good water. (See analysis, p. 154.) There are also seepages along the edge of the barren flat less than a mile east of the road.

Jones Springs.—Springs similar to those already described issue on both sides of the main road for a distance of a mile in the vicinity of the Jones ranch. None of them are large, but in the aggregate they yield considerable water, much of which evaporates without forming definite streams.

Rogers Springs.—A spring directly east of the house at the Rogers ranch yields several gallons a minute at its low stage in the fall, the water being of good quality (see analysis, p. 154) and issuing at a temperature of 54° F. In the large meadow that extends south, east, and north-northeast from the ranch house there are many other springs, which are generally small but together yield much water, especially in the early part of the season.

Moore Lake Spring.—A small but definite spring, which, in September, 1913, yielded about a gallon a minute, emerges on the northwest shore of Moore Lake, at the base of the small modern strand (Pl. II in pocket). Although the soil in the environs of the spring is intensely alkaline, as is shown by the analysis on page 161, and the water in the lake is rendered brown by the dissolved sodium carbonate, the spring water, which boils up from the sand without coming much in contact with the soil, is remarkably pure, as is shown by the analysis on page 154. The temperature of the water is 51° F.

Logan Springs.—No springs except the one at Moore Lake were found between the Rogers beach ridge and the Logan ranch. At Mrs. Logan's house and along a belt extending southwestward from her house there are many small springs similar to others along the spring line that have already been described. The spring at the house, which is typical of the group, yields a small supply of good water (see analysis, p. 154) at a temperature of about 58° F. A little gas escapes with the water.

Darrough Hot Springs.—The most notable group of springs along this remarkable spring line is at the Darrough ranch. The water of most of these springs is at temperatures far above the normal for this region. The water from the largest springs is discharged with great amounts of steam, and its temperature after discharge ranges up to 198° F., showing that the water is above the boiling point before it escapes from the ground. The principal developed spring yields about one-third second-foot, and the combined yield of the various springs in this vicinity amounts to more than 1 second-foot. Algae of brown and white color grow freely in the hot water, the white ones having been observed in water at 180° F. Calcareous material is deposited in rather meager amounts, sodium carbonate and the black stain which it produces being more in evidence. Some hydrogen sulphide gas also escapes. The analysis given on page 154 shows that the water is not highly mineralized although containing more dissolved matter than the other waters along the spring line that were analyzed.

The water issues from bowldery fill but probably comes originally from the underlying rock, the heat being due either to igneous intrusion or to faulting that opened deep fissures, or to both causes. Less than 100 feet from the main hot spring and at a level a few feet higher there is a small spring that issues at a temperature of only 61° F., which is almost the normal temperature for this region. This spring is significant in showing that the supply of the hot springs is derived from a distinctly different source than the ordinary spring water.

A well-appointed hotel and bathhouse are maintained at these springs for the accommodation of visitors, by many of whom the water is used medicinally.

Moore Springs.—Some of the largest springs along the spring line are east of the main road on Moore's ranch. Several springs at the house and within a short distance south of the house were, in September, 1913, together supplying between 2 and 3 second-feet and much water was escaping at other points on the ranch. The observed temperatures ranged between 53° F. and 59½° F.

Small springs, marking the position of the spring line, are found at the schoolhouse three-fourths mile north of Moore's house, and at points respectively 1¼ and 2 miles south-southeast.

Wood Springs.—The southernmost springs of the west-side spring line are at Wood's ranch and are of the general character of the other springs along this line. They yield small quantities of good water.

FAULT-SCARP SPRINGS.

The escarpments west of Bowman's, Mrs. Alice Gendron's, and McLeod's ranches give rise to springs and seeps and support water-loving bushes and grasses. The principal spring at the Bowman scarp yields a large part of one second-foot, and several of the springs at the Gendron scarp together yield a small stream of water of good quality (see analysis, p. 154), but the other springs are small.

The ground water, moving down the slope through buried stream gravels, has apparently been impounded by the faulting movement, which has probably thrust impervious, clayey deposits across its path. The impounding is sufficiently effective to bring the water to the surface and to cause some overflow, but probably most of the water passes the barrier without coming to the surface.

Gillman Spring, between Crooked and Globe creeks, 3 miles north of Schmidtlein's ranch, issues from gravelly valley fill just east of a ledge of limestone that forms the margin of the mountains in that locality. The facts that it is near the limestone ledge, that it is in line with one of the prominent scarps of the region (Pl. I), and that it is in an exposed position high above the main shallow-water area and remote from any canyons that could supply seepage from the mountains, indicate that this spring is situated on a fault along which the water rises, probably from solution channels in the limestone. Its flow is said to fluctuate considerably with the season. It was about two-fifths of a second-foot on September 29, 1914, apparently about the same on April 26, 1915, and about three-fifths of a second-foot on June 30, 1915. (See pp. 80, 82.) The temperature of the water on September 29 was 54° F.

SPENCER HOT SPRINGS.

The hot springs on the east side of the valley, near the north end, are shown in Plate II and figure 6 and are described in part on page 50. The water issues at a number of places as small but definite springs and as indefinite seepage in a belt nearly a mile long adjacent to low ridges that belong to the Toquima Range. The springs are all small, the flow from the main spring being only 6 gallons per minute, but the total discharge of the area, including the seepage immediately disposed of by evaporation, is greater than would appear on casual observation.

The temperature of the water ranges from about normal at the East Spring (fig. 6) to 144° F. at the Main Spring. The temperature of the North and Center springs (fig. 6) is 117° F. The water contains more dissolved matter than that of Darrough Hot Springs, but it is not excessively mineralized. (See analysis, p. 154.) Some calcium carbonate is no doubt precipitated by the release of carbon dioxide as soon as the water reaches the surface and is therefore not shown in the analysis. Some hydrogen sulphide also escapes from the water, and black material, probably a sulphide, is deposited.

The high temperatures of the water and the exposures of limestone and partly disintegrated crystalline rock below the eruptive rocks, which compose the greater part of the ridges adjacent to the springs, indicate that the water heads in the bedrock and may come from considerable depths.

CHARNOCK SPRINGS.

For a distance of about 3 miles along the base of the alluvial slope in the vicinity of the abandoned Charnock ranch there are numerous springs resembling those along the west-side spring line and apparently representing an undeveloped east-side spring line. Near the north end of the group are several mound springs of small discharge (p. 50). Farther south there are many pool springs surrounded by rushes and containing clear water in which algae are growing. The spring at the cabin near the south end of the group is a pool about 20 feet in diameter and 10 feet deep, yielding several gallons per minute of water of good quality (see analysis, p. 154) and about normal temperature. The largest spring observed is one-half mile northeast of the cabin and consists of a pool about 20 feet in diameter and 20 feet deep from which flows about a second-foot of water at a temperature of 80° F. The travertine deposits (p. 61) and possibly the well-developed mounds (p. 50) also suggest thermal conditions.

SAN ANTONIO SPRINGS.

At the abandoned stage station of San Antonio the ground water comes to the surface, giving rise to a group of small springs and other shallow-water phenomena. As this station is on a sloping surface 650 feet above the main shallow-water area of the lower valley and 400 feet above Midway, where the water table is 124 feet below the surface (Pl. II, in pocket), it is inferred that there is here an underground barrier which impedes the sinking of the ground water that is contributed in large amounts by Peavine Creek and other sources north of San Antonio and that is moving slowly southward. This barrier may be formed by Tertiary strata such as outcrop a short distance east of SanA ntonio or merely by a dense layer of Pleistocene fill.

SPRINGS AT THE MOUTH OF IONE VALLEY.

At the mouth of Ione Valley, 6 miles west of Cloverdale, there are two small springs, known as Warm Spring and Black Spring (Pl. II, in pocket), and in October, 1913, a small stream (10 gallons per minute was measured), supplied entirely by ground-water seepage, was flowing in a deep recently cut gully in the vicinity of Warm Spring. The analysis given on page 154 shows that the water of Warm Spring is of fairly good quality. This spring is improperly named, as the temperature of its water is only 55° F., or about the normal for this region. Black Spring probably derives its name from the black stains in the surrounding soil produced by the sodium carbonate in the water.

SPRINGS IN THE SOUTHERN PART OF THE LOWER VALLEY.

The large shallow-water area of the lower valley does not contain a single true spring, in which respect it is in striking contrast to the shallow-water area of the upper valley, which is fringed with a countless number of springs. A short distance below Millers the ground water stands very near the surface, and the water table is in a few places exposed by shallow natural or artificial excavations, as at Millers Pond and at the French well (Pl. II, in pocket), but no hole was found from which the water flows.

DISCHARGE FROM SOIL AND PLANTS.

PROCESSES.

By discharge from soil is meant the elevation of water by the force of capillarity through the minute openings in the soil, from the water table to the land surface, and its conversion at the surface into atmospheric vapor by the process of evaporation. The rise of ground water through capillary openings in the soil is a process entirely different from the flow or seepage from springs. The latter is due to the force of gravity, the water being returned to the surface by hydraulic pressure; the former is due to the force of molecular attraction between soil and water acting against gravity. The seepage from a spring may be so small that it evaporates without forming any stream, but if this seepage were protected from evaporation and were allowed to collect it would form a small stream or pool. On the other hand, no stream or pool is ever formed from ground water that rises by capillarity because the water molecules are held by the soil molecules until they are released by evaporation. If by any means evaporation is prevented the entire process stops and there is no more loss of ground water. The process is the same as that which takes place in the wick of a kerosene lamp.

Discharge from the main body of ground water below the water table is also effected by some kinds of plants, which absorb the water through their roots, elevate it to their leaves and other parts above ground, and thence send it into the atmosphere as vapor. The discharge from plants is known as transpiration. The roots do not need to extend into the zone of saturation, but may absorb the capillary moisture above the water table. The discharge by plants differs from the inorganic process in being less definitely limited in the depth from which it may lift water.

CRITERIA.

KINDS OF CRITERIA.

The areas in which discharge from soil or plants is taking place can be determined by observing (1) the moisture of the soil and the position of the water table, (2) the appearance of soluble salts at the surface and the distribution of these salts in the soil, and (3) the distribution of plants of certain species that feed on ground water.

MOISTURE OF SOIL AND POSITION OF WATER TABLE.

The water table is the surface below which the ground is saturated. From it the water rises in the capillary openings to definite heights, which are determined by the texture of the soil and other conditions. Except in very fine grained material this capillary rise is less than 10 feet. Inorganic capillary discharge can take place only where the water table is so near the surface of the ground that the capillary water rises within reach of atmospheric evaporation.

Where the soil is moist at the surface, or even within a few inches of the surface, appreciable capillary discharge may be suspected unless the moisture can be accounted for by recent rains, the flow of a stream or irrigation ditch, the seepage from a spring, or some other cause. In such a place a test can be made by boring or digging a hole. If the surface moisture is due to capillary rise, the soil will be moist in the entire section to the water table, the amount of moisture gradually increasing with the depth. When the water table is reached water will seep into the hole and will stand in it at a definite level. If this water is withdrawn, a new supply will seep in until the hole is again filled to the original water level. As the capillary rise is generally less than 10 feet the application of this test as a rule involves only a moderate amount of labor. Where the soil is very fine grained, however, the difficulties may be greater and the results less definite than elsewhere, because the capillary rise may be considerably more than 10 feet and the material may be too dense to allow seepage into the hole even when the hydrostatic level has been reached.

Such tests give the most reliable results in the fall after a long period of drought and intense evaporation, when there is least interference by moisture derived from the surface. In this season allowance must, however, be made for the normal seasonal lowering of the water table whereby areas that discharged earlier in the year are no longer within the capillary range. In such areas no moisture is visible at the surface, and the boring may reach a depth of several inches or even a few feet before the moist zone is encountered, although other surface indications may show that there has recently been capillary discharge. When in a dense soil the zone of capillary moisture retreats from the surface and probably also when the potential evaporation is considerably greater than the actual capillary rise in such soil, the soil near the surface will become dry and will shrink greatly so that huge cracks are formed. The efficacy of sun cracks in disposing of soil moisture has been demonstrated in dry-farm experiments, and there is little doubt that in the shallow-water tracts they are effective in disposing of ground water.

It is not always necessary to bore a hole to determine the position of the water table, as in many localities the desired information can be obtained from springs, water holes, or other natural or artificial excavations.

SOLUBLE SALTS.

When ground water evaporates it deposits at the surface the salts which it held in solution and which form powdery efflorescence, white crusts, or crystals of salt attached to the stems of plants and other objects. Sodium carbonate also produces a characteristic brown discoloration of the soil. The visible salt deposits are valuable as a criterion because they give concrete evidence that water has been discharged into the atmosphere. Like each of the other criteria it must be applied with discretion and must from time to time be checked by determinations of the position of the water table. Although salt visible at the surface generally indicates recent ground-water discharge, it may be produced by the evaporation of water from other sources, such as springs, wells, streams, irrigation ditches, or merely the soil moisture derived from recent rains. Playas that do not have shallow water do not as a rule show salt deposits at the surface, even though they are the beds of desiccated lakes.

The salts at the surface are readily redissolved and may be carried back into the ground. Hence the appearance of the surface in any given locality may differ at different seasons, and ground water is discharged in places where no salt is visible. Analyses show that as a general rule where ground water is evaporating the soil contains large quantities of salts and the salts are concentrated near the surface; whereas outside the areas of ground-water discharge the soil does not contain much soluble material, and the quantity present increases from the surface downward. There are, however, many exceptions to this general rule.

VEGETATION.[1]

Ground-water discharge is shown with considerable fidelity by plants of certain species that are found almost exclusively in shallow-water districts. Of course no species can be relied upon as an infallible indicator, for any of them will grow under conditions that closely resemble those in the shallow-water areas, such as alkali land kept constantly wet by irrigation water. The evidence afforded by plants must be used discreetly in connection with corroborative evidence and must be checked by borings to determine the position of the water table. Moreover, the plants differ somewhat in different regions and are not the same in Big Smoky Valley as in some other valleys, so that criteria developed in one valley must not be too freely applied in another.

With respect to their relation to the water table the dominant native plants of Big Smoky Valley can be divided into three groups: (1) Those which utilize the water derived from below the water table and are found almost exclusively in shallow-water areas, (2) those which utilize water from below the water table where it is available but are not confined to shallow-water areas, and (3) those which do not utilize water from below the water table and habitually grow in areas too far above it to be affected by ground water.

Salt grass (*Distichlis spicata*) is the most common and reliable indicator of shallow ground water in Big Smoky Valley. The wild grass in the better type of hay meadows also no doubt utilizes ground water, but it will not endure as much alkali as the salt grass.

The succulent alkali-resistant bush often called samphire (*Spirostachys occidentalis*) is less common than salt grass, but it is equally reliable as an indicator of shallow water.

The buffalo-berry bush (*Shepherdia*) is abundant in the shallow-water area of the upper valley and was also observed in some of the canyons that carry underflow.

Giant reed grass (*Phragmites communis*) is found in many places in the main shallow-water area of the lower valley, but was not seen except where the ground water is near the surface. Giant rye grass (*Elymus condensatus*) is abundant at the Rye Patch, in Ralston Valley, where it indicates shallow water.

Rabbit brush, or broom sage (*Chrysothamnus graveolens*), is one of the most common plants in the shallow-water areas of Big Smoky Valley. It prefers the parts of these areas that have some drainage, but also grows in very alkaline soil and is a fairly reliable indicator of shallow water.

Big greasewood (*Sarcobatus vermiculatus*) is abundant in the shallow water areas, where it no doubt receives a part of its supply from the

[1] The plant species mentioned in this report were, with a few exceptions, identified by Dr. P. B. Kennedy, botanist, Nevada Agricultural Experiment Station, but he is not responsible for the field interpretations.

main body of ground water, but it is not confined to these areas. It grows extensively in the sand hills in or near the shallow-water areas and in the zone between the shallow-water areas and the upland areas of atriplex and little greasewood (Pl. II), generally where the depth to the water table is less than 50 feet. Its roots go deep, and it is believed to feed on ground water wherever it has opportunity. According to Mr. Cahill, of the United States Forest Service, men prospecting for water in the gulches near Tonopah in the early days of that camp considered the presence of this bush as one of the most favorable signs, and its roots go to depths of more than 20 feet in order to get ground water. In the zone of intermediate vegetation, where the depth of water is moderate, the greasewood probably obtains a part of its supply from the main body of ground water; but because of the uncertainty on this subject and the indefiniteness of the greasewood boundaries this zone has not been included in Plate II with the areas of ground-water discharge.

Birch trees are numerous in the canyons and there is ample evidence that their distribution indicates the distribution of shallow water in the mountain regions, but these trees are not found in the alkaline shallow-water areas in the valley. Willow and cottonwood trees also live largely on ground water. Cottonwoods can endure much alkali, but willows favor localities with some drainage. Wild roses likewise grow only in places with abundant water and not much alkali.

The iodine weed (*Suaeda torreyana*) grows in alkaline soil and is generally found where more than an ordinary supply of moisture is available, but in Big Smoky Valley it appears not to be a reliable indicator of shallow ground water, as it grows in places that are far above the water table, especially in the southwestern part of the lower valley, where it was seen in the undrained areas on the landward side of the beach ridges and elsewhere.

The tall shrubby salt bush (*Atriplex torreyi*) is not common in Big Smoky Valley but grows in a few localities. It can endure considerable alkali and is generally found in low places having more than an ordinary supply of moisture, but it is not a reliable indicator of shallow water.

The spiny salt bush (*Atriplex confertifolia*), which in parts of Utah and Nevada is known as shadscale, is the most abundant and widely distributed species in Big Smoky Valley. It is the dominant plant on the large areas represented by the upper and middle parts of the alluvial slopes which are very arid and have a soil nearly devoid of humus. It commonly grows far above the water table and has no connection with it.

The little greasewood (*Sarcobatus baileyi*) is commonly associated with *Atriplex confertifolia* and is characteristic of arid slopes and plains that lie too high above the water table to be influenced by ground water. Its appearance is extremely dry and lifeless, especially during the long autumn drought.

Common sagebrush (*Artemisia tridentata*) is found chiefly in the intermediate zone near the base of the alluvial slopes, where there are better supplies of moisture from flood waters than on the higher parts of the slopes and where the soil does not contain excessive quantities of alkali. It is found also along streams and in other localities that have good drainage but a better water supply than the ordinary desert. It occupies some of the land that is most promising for agriculture. So far as known sagebrush does not utilize water derived from the zone of saturation and is not an indicator of shallow ground water.

White sage, sweet sage, or winter fat (*Eurotia lanata*) grows on the upland plains far above the water table. It was observed in especial abundance in the southeastern part of the lower valley and in Ione Valley.

The interior of large playas, such as the Millett and McLeans flats, are entirely barren over extensive areas (Pl. II). The inability of plants of any species to exist in these areas shows exceptionally adverse conditions, but it is not an indication of ground-water discharge, for barrenness is as characteristic of some of the flats having water at considerable depths as of those having shallow water. Whether a barren flat belongs to the deep-water or shallow-water type can be determined by the character of the vegetation that fringes it and by the other criteria that have been given. Distinct indicators of shallow water, such as *Distichlis spicata* and *Spirostachys occidentalis*, which characterize the fringe of the Millett, Moore Lake, and McLeans flats, are not found in the fringe of the playa in Alkali Spring Valley or the small flats in the vicinity of Seyler Peak and between Midway and Cloverdale, where the ground water lies at considerable depth. At the margins of these small flats the vegetation consists almost exclusively of shadscale (*Atriplex confertifolia*), but at the margin of the playa in Alkali Spring Valley there is considerable greasewood (*Sarcobatus vermiculatus*), which is not here supplied from the zone of saturation unless it is able to draw the ground water from a depth of 50 feet.

AREAS OF DISCHARGE.

Except for tracts containing plants of uncertain significance such as greasewood, the areas of ground-water discharge can be shown on a map with nearly as much precision as rock outcrops. In Plate II (in pocket) these areas are indicated for Big Smoky Valley, but the shallow-water tracts in the mountains are not shown. The boundaries are most sharply defined where the angle between the water table and the land surface is relatively large and the transition from shallow-water to deep-water conditions is rapid; they are least definite where the angle is very slight and there is a wide transition zone in which capillary water may be discharged in the spring, when the water table stands high, but not in the fall, when it stands low, and in which capillary water may be discharged in places where the soil is fine grained and of high capillary range but not in places where the soil is coarser. In these wide transition zones the two types of vegetation are intermingled, the shallow-water species gradually yielding to the others in the direction of deeper water. Salt grass and samphire are practically confined to the areas of capillary discharge, rabbit brush persists somewhat farther, and big greasewood grows in association with sagebrush and shadscale far beyond the limits of any other indication of ground water.

The largest area of ground-water discharge is in the interior of the upper valley. It extends a distance of 40 miles, attains a maximum width of more than 8 miles, and covers a surface of about 160 square miles. (See Pl. II, in pocket.) Its northern extremity is only a few miles south of Spencer Hot Springs and its southern extremity is near Wood's ranch. In all this distance the process of ground-water evaporation is uninterrupted except where the large beach ridges cross the axis of the valley. The northern and southern limits of the area are somewhat indefinite, owing to the very gradual increase in the depth to water along the axis of the valley.

The shallow-water area next in size occupies the lowest parts of the lower valley and extends from a short distance below Millers to a line west of the Silver Peak Railroad (Pl. II). It is about 17 miles long, 5 miles in maximum width, and comprises about 45 square miles. The northeastern limits of this area are indefinite because the increase in the depth to water in this direction is very gradual.

A few other areas of discharge are found in Big Smoky Valley, but they are very small in comparison with the two large areas mentioned. They are at San Antonio, at the mouth of Ione Valley, and at the Cloverdale and Peavine ranches (Pl. II). The last two are not essentially different from seepages farther up the canyons. The large areas occupy the two principal depressions of the valley and owe their existence and size to the fact that the ground water, ever seeking a level, comes to the surface where the surface is lowest. The small areas do not occupy depressions but are believed to owe their existence to underground barriers across the course of movement of the ground water.

The water table crops out over a rather indefinite area in the vicinity of San Antonio, ground water being returned to the surface by capillary rise through the soil and by transpiration. At the ranch the presence of the water table is shown by springs and by a well in which the water stands only 4 feet below the surface. Over a wider area ground-water discharge is shown by the moist condition of the soil, the crusts of alkali, the black stains produced by sodium carbonate, and the abundant growth of salt grass and other plants that indicate shallow water. At the springs, where there is a sufficient current to prevent the accumulation of alkali, there are tules and water cress, and on a small spring mound, where the drainage is comparatively good, wild roses grow luxuriantly. In front of the ruined ranch house there were in 1913 two healthy lombardy poplars and three box-elder trees growing without attention, obviously utilizing the supply of ground water. Beyond the area in which salt grass is found there is rabbit brush and big greasewood associated with sagebrush and shadscale (*Atriplex confertifolia*). These four species are found beside a recently cut gully 10 feet deep, about a mile west of San Antonio. At the time this gully was seen, in September, 1913, it carried nearly one second-foot of water but it was not obvious whether this water came entirely from Peavine Creek or in part from ground-water seepage, nor whether the greasewood and rabbit brush were utilizing water from the zone of saturation or merely soil moisture supplied from surface sources. The shallow-water conditions do not extend far north. The area along the axial draw was examined from the Seyler Peak flats to the road 2 miles north of San Antonio, and no evidences of ground-water discharge were found, the vegetation consisting chiefly of *Atriplex confertifolia*. The same is true of the areas along the distributaries of Peavine Creek where they are crossed by the Cloverdale road.

The area of ground-water discharge at the mouth of Ione Creek is obviously due to rock formations that hem in the outlet and bring a part of the underflow to the surface. Capillary discharge is taking place in the wide Pleistocene stream valley (pp. 46, 47, and fig. 5) from Black Spring to a point about 2 miles farther up the valley (Pl. II in pocket). The position of the water table is shown by Black and Warm springs, and more precisely by the small stream which, in October, 1913, rose about one-half mile above Warm Spring in a recently cut gully and was supplied entirely by ground-water seepage. From Black Spring to about the point where the small stream rises the surface contains crusts of alkali and black stains of sodium carbonate and the vegetation consists chiefly of salt grass, rabbit brush, big greasewood, and the tall saltbush (*Atriplex torreyi*). Near Warm Spring the gully is only about 5 feet deep, and in October, 1913, water was drawn to the surface by capillarity. Near the source of the stream the gully was about 9 feet deep and the capillary water rose only to a level 3 feet below the surface, but some salt grass was growing in this place. Up the valley from this point the evidences of shallow water gradually disappear. Five miles above Warm Spring the ground in the stream valley was dry, but the vegetation consisted of big greasewood, the tall saltbush (*Atriplex torreyi*), and a small amount of rabbit brush. These plants are somewhat ambiguous as indicators. They probably draw on the ground-water supply but may owe their presence to floods, the evidences of which were very distinct in the stream valley. A few miles farther upstream these species give way to *Atriplex confertifolia*, which predominates also on the dry bench lands.

RELATION OF DISCHARGE TO WATER TABLE.

A small amount of specific data on the relation of soil and plant discharge to the position of the water table in Big Smoky Valley in the fall of 1913 is given in the following table:

Data relating to position of water table, capillary rise, and kinds of vegetation in areas of ground-water discharge, Big Smoky Valley.

Location.	Date of observation.	Depth to water table.	Capillary rise.	Vegetation.
	1913.	*Feet.*	*Feet.*	
Schmidtlein's well, 2¾ miles east of house	Sept. 18	11.7	6.6	Greasewood, salt grass, rabbit brush.
Well on SW. ¼ sec. 2, T. 15 N., R. 44 E.	Sept. 19	17.4	8.1	Sagebrush.
Vigus ranch	...do	3.0	[a] 3.0	Salt grass.
Indians' well, ½ mile west of house at Daniels's ranch.	Sept. 22	6.5	6.0	Greasewood, salt grass, rabbit brush, sagebrush.
Alice Gendron's ranch well, ½ mile west of house.	Sept. 11	11.0	....	Greasewood.
McLeod ranch well, nearest the house	...do	[b] 7.5	....	Salt grass, etc.
Millett well, ¼ mile northwest of store	...do	14.0	....	Greasewood.
Playa 1 mile east of Millett	...do	1.6	[a] 1.6	Barren.
Jones ranch well at house	Sept. 29	9.0	....	Rabbit brush, salt grass, etc.
Jones ranch windmill, ½ mile south of house	Sept. 10	2.5	[a] 2.5	Rabbit brush, salt grass, cultivated vegetables.
Rogers ranch well, west of house	Sept. 27	7.0	[a] 7.0	Salt grass and other native grasses.
Millett's south ranch, ½ mile south of Rogers ranch.	Sept. 10	6.0	....	Salt grass, willows.
Barker ranch	Sept. 26	12.0	....	Sagebrush, greasewood, rabbit brush.
Crowell ranch, north well	Sept. 10	6.5	....	Salt grass and other native grasses.
Crowell ranch well, at house	Oct. 9	11.4	....	Greasewood, sagebrush, willows.
Well 1½ miles southeast of Wood's ranch	Oct. 1	19.0	3.0	Sagebrush.
Gully ¼ mile above Warm Spring	Oct. 3	9.0	6.0	Salt grass, greasewood, rabbit brush, *Atriplex torreyi*.
San Antonio	Sept. 7	4.0	[a] 4.0	Salt grass, poplar, and box-elder trees, etc.
Well east of Millers Pond	Oct. 8	4.5	....	Salt grass, sacaton.
NE. ¼ sec. 30, T. 3 N., R. 40 E.	Oct. 9	2.7	[a] 2.7	Salt grass, greasewood, rabbit brush.
NE. ¼ sec. 36, T. 3 N., R. 39 E.	...do	2.7	[a] 2.7	Do.
French well	Sept. 1	2.0	[a] 2.0	Salt grass, samphire.
Desert well	...do	10.0	([c])	Salt grass.

[a] Capillary water reaches surface.
[b] Possibly lowered slightly by pumping with windmill from a well near by.
[c] Near margin of area of discharge.

In the shallow-water areas the water table normally undergoes a seasonal fluctuation, due to differences in the rate of evaporation, on the one hand, and of recharge on the other. During the hot, dry months of summer and fall, when the contributions of ground water are lightest, the losses by discharge into the atmosphere are heaviest. Consequently the water table is lowered, the capillary lift is generally increased, the areas of discharge are contracted, and the flow of springs is diminished. The data given in the above table are based on observations made in September and October, when the water table was near its lowest level.

Later in the fall, when evaporation becomes less intense, a gradual rise in the water table and increase in the flow of springs takes place even before there is any rain, the recovery being due not to greater increments but to smaller losses. In the early spring the recovery reaches its maximum, the water table being at the highest levels and the flow of springs most copious.

The fluctuations of the water level in the well at the house of F. J. Jones, on the west side of the road, nearly 3 miles south of Millett, are shown in the following table and in Plate XII. The data presented show the general law of annual fluctuation and the amounts of fluctuation at a typical point in the shallow-water area during the period from September, 1913, to May, 1916. They show that the fluctuations in water level are not produced chiefly by the seasonal distribution of the precipitation but follow closely the variations in temperature and humidity, which are the principal factors in determining the rate of evaporation. The rise in water level occurs largely during the season when the stream flow is least and the fall in water level largely during the season when the stream flow is greatest. Although this condition could be explained as due to differences in recharge by assuming a great lag in the water-level fluctuations, it is much more satisfactorily explained by differences in temperature and humidity. In short, the data indicate that the fluctuations in water level in the shallow-water area are produced by variations in discharge rather than by variations in recharge, and, moreover, that ground-water discharge is quantitatively important. During the summer the water table falls about 2½ to 3 feet. This fall implies that if the formation contains 20 per cent of pore space at least 6 inches of water is removed during the period of decline. The water in this particular locality is either discharged upward through the soil and vegetation or is removed by percolation in the direction of the playa to be brought to the surface in another locality.

Depth of water level below platform in the house well of F. J. Jones, 3 miles south of Millett.

[F. J. Jones, observer.]

	Feet.		Feet.
Sept. 29, 1913	9.0	June 1, 1915	8.2
Oct. 1, 1913	9.0	July 1, 1915	8.9
Nov. 6, 1913	8.5	Aug. 1, 1915	9.5
Dec. 4, 1913	8.2	Sept. 1, 1915	10.9
Jan. 12, 1914	8.0	Oct. 1, 1915	10.3
Feb. 4, 1914	7.8	Nov. 1, 1915	9.3
Mar. 2, 1914	7.5	Dec. 1, 1915	8.6
Apr. 2, 1914	8.0	Jan. 1, 1916	8.3
May 3, 1914	8.1	Feb. 1, 1916	7.8
Aug. 1, 1914	9.3	Mar. 1, 1916	7.3
Sept. 1, 1914	10.0	Apr. 1, 1916	7.6
Oct. 1, 1914	9.6	May 1, 1916	7.8
Nov. 1, 1914	8.7	June 1, 1916	8.3
Dec. 1, 1914	8.3	July 1, 1916	8.8
Jan. 1, 1915	7.8	Aug. 1, 1916	10.0
Feb. 1, 1915	7.6	Sept. 1, 1916	10.9
Mar. 1, 1915	7.5	Oct. 1, 1916	10.1
Apr. 1, 1915	7.4	Nov. 1, 1916	8.8
May 1, 1915	7.8	Dec. 1, 1916	8.2

At the low-water stage, when the investigation was made, the water stood within a foot or two of the surface over only comparatively small tracts, at intermediate depths over considerably larger tracts, and near the limit of capillary rise over probably the greater part of the areas of discharge. There were also large areas which at the time of the investigation were just above the limits of capillary rise, but which were supporting shallow-water plants and bore evidence of coming within these limits during a part of the year.

RATE OF DISCHARGE.

The rate of ground-water discharge depends on the condition of the atmosphere, the character of the soil, the capillary lift, and the nature of the vegetation.

The most valuable series of observations and experiments on the rate of discharge of ground water from soil and vegetation were made in Owens Valley, Cal., in 1908 to 1911, by C. H. Lee.[1] In the experiments made with tanks filled with soil Mr. Lee obtained the results shown in the following table. By applying these results to the part of Owens Valley that was investigated he determined the average rate of loss from soil and vegetation throughout the area of ground-water discharge to be equivalent to a depth of water of a little less than 2 feet a year.[2]

[1] Lee, C. H., An intensive study of the water resources of a part of Owens Valley, Cal.: U. S. Geol. Survey Water-Supply Paper 294, 1912.
[2] Idem, p. 131.

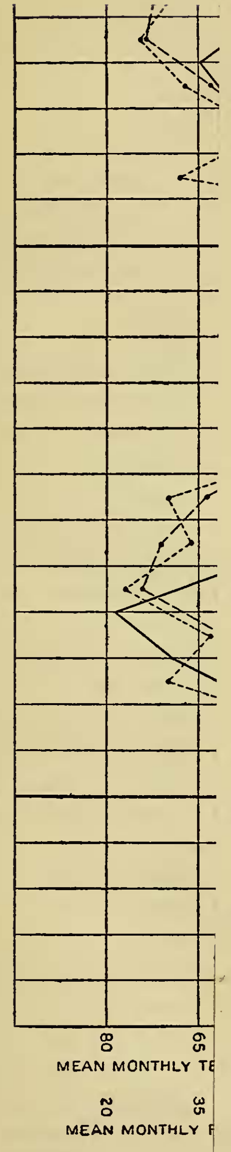


DIAGRAM SHOWIN

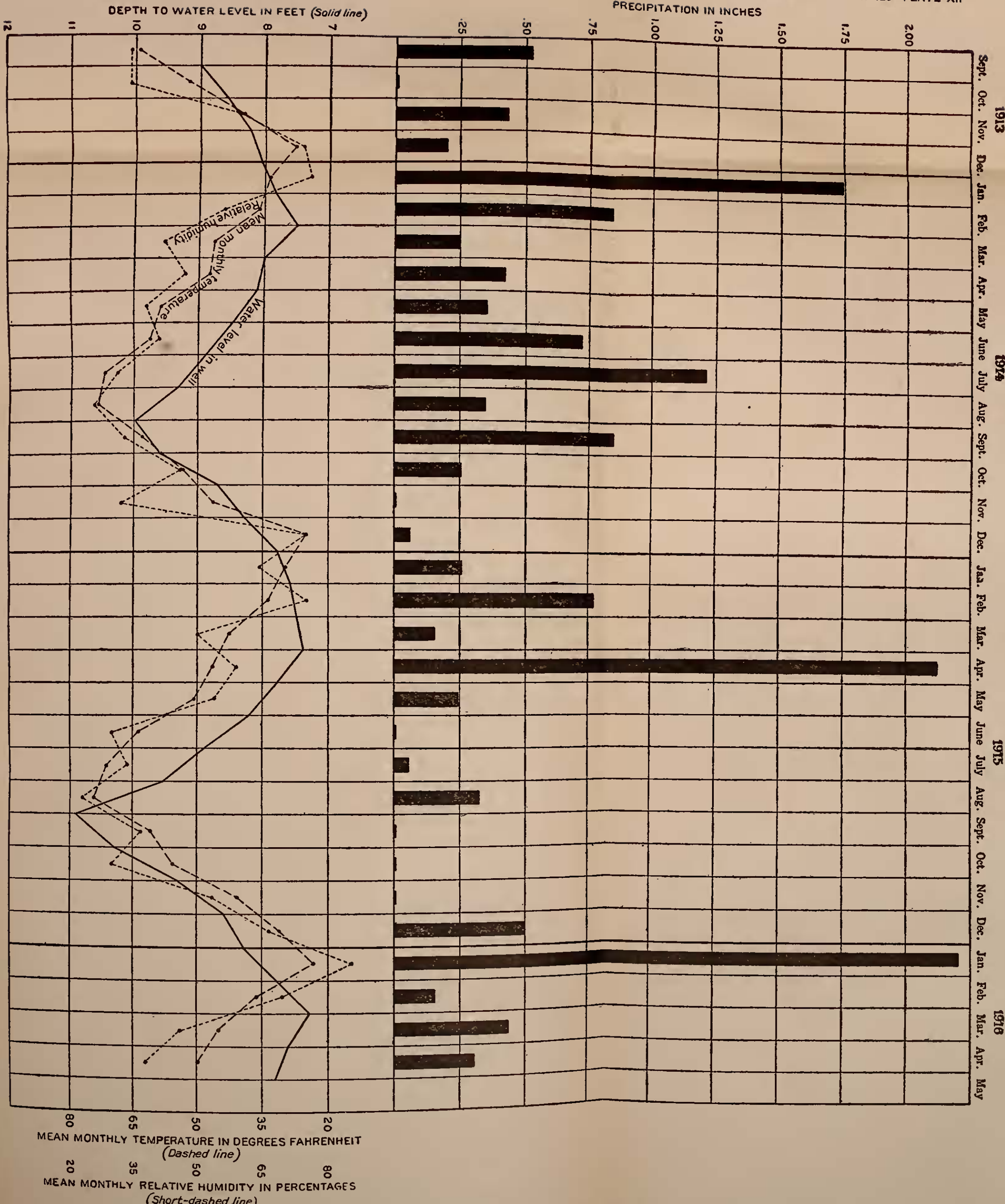


DIAGRAM SHOWING FLUCTUATIONS OF THE WATER LEVEL IN THE WELL OF F. J. JONES AND THEIR RELATION TO PRECIPITATION, TEMPERATURE, AND HUMIDITY.

Rate of ground-water discharge from soil and vegetation in tank experiments made near Independence, Cal.

[By C. H. Lee.[1]]

Average depth to ground-water surface in soil tank.	Total depth of water evaporated in one year (1910–11).	Condition of surface.
Feet.	*Inches.*	
1.28	39.95	Sand without vegetation.
1.34	43.10	Sod with good growth of salt grass.
1.94	42.67	Do.
2.92	30.46	Do.
3.92	23.31	Sod with medium growth of salt grass.
4.49	22.51	Sod with vigorous growth of salt grass.
4.94	7.91	Sod with scattered growth of salt grass.

The average temperature of the atmosphere is about 8° F. less at the Jones ranch, in the northern shallow-water area of Big Smoky Valley, than at Independence, Cal., in the shallow-water area investigated by Mr. Lee. If the assumption that at the same temperature, in any given season of the year, evaporation from a water surface takes place at the same rate in Big Smoky Valley as in the Independence district, Cal., is applied to Lee's data,[2] it is found that the difference of 8° F. makes a difference in the annual evaporation from a water surface of about one-fifth to one-fourth of the amount in the Independence district. By applying the same factor to evaporation from soil and vegetation the conclusion is reached that if the conditions of soil, vegetation, and depth to water were the same in the northern area of Big Smoky Valley as in the Independence district the annual discharge would amount to about 1½ feet. Over a belt of the northern area of discharge paralleling the west margin the conditions are favorable for rapid discharge, but over much of the middle and eastern parts the rate of discharge is slow. The quantity is also diminished by the irrigation and flood waters that evaporate from this area, although this factor is to some extent balanced by the discharge through greasewood and other plants outside the area mapped. The data at hand seem to indicate that the average annual loss of ground water from the area of discharge in the upper valley is not less than one-half foot and not more than 1 foot, in other words, that the quantity of water discharged from the main body of ground water in the upper valley is between 50,000 and 100,000 acre-feet a year, or between about 8 and 17 per cent of the precipitation on the north basin. So many uncertain factors are involved, however, that this estimate may be considerably in error. It is estimated on the basis of relative areas that about 26 per cent

[1] Lee, C. H., An intensive study of the water resources of a part of Owens Valley, Cal.: U. S. Geol. Survey Water-Supply Paper 294, pp. 119–122, 1912.

[2] Idem, pl. 10.

of the discharge occurs north of the Daniels beach ridge, about 57 per cent between this ridge and the Rogers beach ridge, and about 17 per cent in the area still farther south (Pl. I).

In the lower valley the average temperature is considerably higher than in the upper valley and over about one-third of the area of discharge, chiefly in the locality between Millers Pond and the Desert well, the porous soil and the slight depth to the water table indicate heavy loss of ground water, but over the clayey parts of the barren tract, which occupies about 7,000 acres, and over much of the western part of the area, even where there is some vegetation, the discharge is small and in some places practically negligible. The data at hand seem to indicate that the aggregate amount of ground water discharged from the lower valley is between 10,000 and 30,000 acre-feet a year, or between about 2 and 5 per cent of the precipitation on the south basin.

It should be remembered that the estimates of both contributions and discharge are based on inadequate data, that only a part of the total supply can be recovered through wells, and that if the wells are not widely distributed the recoverable part will form only a small proportion of the total supply. It should also be remembered that the estimates are less certain for the lower than for the upper valley.

WATER LEVELS.

Over areas of 160 square miles in the upper valley and 45 square miles in the lower valley the water table, or upper surface of the main body of ground water, is generally within 10 feet of the surface of the ground. These shallow-water areas practically coincide with the areas of ground-water discharge, already referred to (pp. 97–100) and shown on Plate II. The northern area extends along the axis of the upper valley for a distance of about 40 miles from a point about 7 miles southeast of Spencer's ranch to a point less than a mile southeast of Wood's ranch, and is interrupted only by the large beach ridges near the Daniels and Rogers ranches. The southern area extends along the axis of the lower valley without interruption for a distance of 18 miles from a point 2½ miles southwest of Millers to a point just west of the Silver Peak Railroad. The outlines of these shallow-water areas were determined partly by examining wells and boring holes to the water table, but more largely by interpreting surface indications of shallow water afforded by the moisture in the soil, the soluble salts at the surface, and certain species of native plants. (See pp. 93–97.)

As a rule the water table rises from the shallow-water areas, where the ground water is discharged, toward the mountains, whence the principal contributions of ground water are received. The slope of the water table furnishes the dynamics that propel the ground water from its source to its outlet. The gradient of the water table is automatically adjusted by the amount of work that has to be done to transfer the water from the intake to the exit, and the amount of work is determined by the quantity of water to be transferred and the resistance to percolation of the formation through which it is carried. Other things being equal, a steep gradient of the water table indicates an abundant water supply.

In some places on the west side of the upper valley, where the contributions to the ground-water supply are large, the water table rises about as rapidly as the surface of the ground and hence is within 10 feet of the surface at points more than 100 feet above the flats. In general, however, the slope of the water table is much less than that of the land surface.

The lines on Plate II showing depths to water of 50 and 100 feet, respectively, are based on determinations, from the topographic map and by the use of the hand level, of the slope of the land surface and on reasonable assumptions as to the slope of the water table. In the lower valley there are several comparatively deep wells that give some control of the 50-foot and 100-foot lines, but in the upper valley there are no wells with water levels more than 20 feet below the surface. Although these lines are only forecasts and will without doubt be found to be considerably in error in some localities, they are believed to be of value in directing developments.

According to the best estimates that can be made the areas with specified depths to water are as follows:

Estimated areas having specified depths to the water table in Big Smoky Valley, Nev.

Depth to water table.	North basin (upper valley).	South basin (lower valley).	Total.
Total areas:	*Acres.*	*Acres.*	*Acres.*
Less than 10 feet (alkali land)	100,000	30,000	130,000
Less than 50 feet	170,000	70,000	240,000
Less than 100 feet	215,000	120,000	335,000
Areas exclusive of alkali land:			
Less than 50 feet	70,000	40,000	110,000
Less than 100 feet	115,000	90,000	205,000
Areas exclusive of alkali, gravelly, and sandy land:			
Less than 50 feet	45,000	20,000	65,000

The rate at which the depth of water increases in each direction from the ends of the large shallow-water area in the upper valley is uncertain. This uncertainty is due to the very gradual rise of the land surface. North of the shallow-water area along the axis of the valley the gradient is so slight and the character of the vegetation changes so gradually that there is reason to believe that the water stands within 50 feet of the surface to a point some distance north of the Spencer Hot Springs and that even as far north as the Lincoln Highway it can easily be reached by drilling. At the south end of the shallow-water area the water table is about 5,640 feet above sea level, the barren flats in the vicinity of Seyler Peak are about 5,700 feet above sea level, and the point where the divide crosses the axis of the valley (a short distance north of these flats) has an altitude of not much more than 5,700 feet above sea level. At San Antonio the water table appears at the surface 5,400 feet above sea level, or 300 feet lower than the Seyler Peak flats. From the vicinity of Wood's ranch to San Antonio the water table therefore descends about 240 feet. It probably rises for some miles before it begins to descend toward San Antonio. The large supply from Peavine Creek undoubtedly helps to keep up the water level, and it is not probable that the depth to water is very great anywhere along the axis of the valley between Wood's ranch and San Antonio.

South of San Antonio the water level drops rapidly, and at Midway station, 11 miles southwest of San Antonio, it is 124 feet below the surface, 4,883 feet above sea level, or 520 feet lower than the water level at San Antonio. There are also sudden drops in the water level at the outlet of Ione Valley and at the mouths of many of the canyons.

In the abandoned Montezuma well, 10 miles south of Midway, the water stood 43 feet below the surface, according to reliable report, which would be 4,783 feet above the sea, or 100 feet below the water level at Midway. According to these data the average slope of the water table is nearly 50 feet per mile between San Antonio and Midway, and about 10 feet per mile between Midway and Montezuma well.

In an abandoned well 4 miles southeast of the Montezuma well (Pl. II) the water level is 202 feet below the surface, or at an altitude distinctly lower than the water level at the Montezuma well. It can not be assumed that the ground water is draining southward, through the débris-filled gap between Lone Mountain and the San Antonio Range, into Alkali Spring Valley, because the water table in that valley stands considerably higher, as is shown in the table on page 148. Neither is it reasonable to assume that the San Antonio Range and the broad slope adjacent to it do not contribute enough ground water to keep the water table inclined toward the valley. It may be, however, that the supply from the San Antonio Range is so much smaller than that which comes from the north and northwest that the axial trough of the water table is crowded some distance east from the axis of the valley itself.

In the well of the Desert Power & Mill Co., at Millers, the water level is about 38 feet below the surface, or 4,750 feet above the sea. This is about 30 feet below the water level at the Montezuma well and indicates a southwestward gradient in the water table between these two points of somewhat less than 10 feet to the mile.

At the French well, situated only slightly above the level of the playa, which is 4,720 feet above the sea, the water level is almost at the surface. It is therefore approximately 60 feet below the water level at the Montezuma well and approximately 30 feet below the water level at Millers. According to these levels the gradient of the water table is about 6 feet to the mile between the Montezuma well and the French well and about 4 feet to the mile between Millers and the French well. Some depression of the water table in the vicinity of Millers has no doubt been produced by heavy pumping in that vicinity in recent years, but there is no indication that the depression has been very great.

On the two sides and at the southwest end of the shallow-water area of the lower valley the water table does not, as a rule, have much gradient, and the depth to water, therefore, increases rapidly away from the flat. This condition is in striking contrast to that on the west side of the upper valley, the difference being due to the great difference in the amounts of water contributed by the bordering mountains. In the dug well on the south side of the railroad at Blair Junction the water stood, when measured on September 2, 1913, exactly 100 feet below the surface, or at a level only about 4,700 feet above the sea, and probably a little below the level of the flat. This low level may be due to local depression caused by pumping from the railroad well at Blair Junction, or it may be due, at least in part, to leakage of the ground water westward into the basin occupied by Columbus Marsh.

WATER-BEARING CAPACITIES.

The coarse clean sand or grit derived from granite is porous and yields water freely. The arkosic grit derived from rhyolite and other igneous rocks of fine grain also generally yields water freely, but it contains more fine material and when it disintegrates it becomes quite compact. The pebbles derived from the angular fragments resulting from the weathering of slate and limestone may produce porous deposits but the pores are likely to be sealed to some extent by the cementation of calcium carbonate. The sediments derived from the tuffs are largely fine silt and form dense deposits that will yield little water. The sediments derived from the other stratified Tertiary rocks are also in general unpromising as water producers.

In the upper valley there are no wells that have been pumped at a rate of more than a few gallons a minute, but the evidence furnished by the character of the rocks in the adjacent mountains and the character of the sediments as shown at the surface and in well sections indicates that in most places between the 100-foot line and the flat wells yielding moderately large supplies can be obtained. (See Pl. II, in pocket.) The well drilled at the Crowell ranch was visited when the drill had reached the depth of 87 feet, to which depth the drillings were nearly all coarse, clean sand or grit, composed chiefly of quartz grains but in part of fragments of granite, rhyolite, and slate. Large amounts of coarse sand were also reported in the two wells of Frank Gendron (p. 59) and in other drilled wells. In the areas adjacent to mountains in which limestone and slate predominate, as between Birch and Carsley creeks, the yields may average less than in the areas of granitic sediments, but there is no reason to believe that even in these areas wells will be failures.

The detritus underlying the upper parts of the alluvial slopes contains bowlders that would interfere seriously with drilling; that underlying the large central flat is probably chiefly fine material; but that underlying the lower parts of the slopes, where ground-water developments are the most promising, is of intermediate coarseness, and probably consists in most places of beds of sand or gravel alternating with layers of clayey material. Although the fill is deep in the upper valley, the results obtained in drilling operations in many other valleys of the same type indicate that the most valuable water supplies will probably be found within the first few hundred feet of the surface, but several wells sunk to considerable depths would be desirable to test for possible deep-seated artesian horizons.

In the lower valley the conditions are less promising than in the upper valley because the fill is shallower and contains more sediments derived from tuffs and less derived from granite. However, there is evidence that in that part of the area having less than 50 feet to water which lies northeast of the alkali area (Pl. II) the fill is deep enough to form a dependable ground-water reservoir.

The well at Midway is 135 feet deep and ends in gravelly fill; the Montezuma well was dug to a depth of 47 feet and ended in gravel; the well 4 miles southeast of the Montezuma well (Pl. II) was dug to a depth of 202 feet and ends in gravelly fill. In the vicinity of Millers, at the edge of the mountains, the depth to rock is less. At the abandoned Kelsey station (2 miles from Goldfield Junction, on the Goldfield-Crow Spring road (Pl. II), a well 90 feet deep ended in shale. The well of the Desert Power & Mill Co. is 63 feet deep, and the Belmont well is about 50 feet deep, but there is no definite information as to whether these two wells reached bedrock.

The available data in regard to the yields of the wells in the area northeast of the alkali area of the lower valley are also rather favorable.

The Desert Power & Mill Co. well is situated two-fifths mile north of the railway station at Millers, the top of the shaft or floor of the pump house being about 35 feet below the railway, or about 4,795 feet above sea level. The shaft is 6 by 12 feet in cross section, is cased with heavy timber, and extends to a depth of 68 feet below the floor of the pump house, or about 63 feet below the surface of the ground. Most of the supply is said to come from the bottom of the well, but there is also a tunnel that furnishes water. The well is pumped with a 5-inch 2-stage Byron Jackson vertical centrifugal pump driven by a 20-horsepower motor connected with the electric line of the Nevada-California Power Co. On September 1, 1913, the well was tested by pumping into a large calibrated tank at the mill. The pump was run at normal speed from 4 a. m. to 8 a. m.; it was stopped from 8 a. m. to 11.20 a. m., and again run from 11.20 a. m. to 2 p. m., when it was stopped a second time. The highest level to which the water rises in the well, according to Mr. C. H. Los Kamp, who is in charge of the pumping station, is 43.2 feet below the floor of the pump house. At 11 a. m. the water stood 45.3 feet below the floor, at 12.10 p. m. it stood 58.3 feet below, and just before stopping the pump at 2 p. m. it stood 60.4 feet below. The pumpage from 12.26 p. m. to 1.29 p. m. was 25,225 gallons, or 400.4 gallons per minute. The well is pumped nearly one-half of the time and is reported to have supplied as much as 5,000,000 gallons, or about 15 acre-feet, in a month.

The well of the Belmont Milling & Development Co., situated a short distance west of the Desert Power & Mill Co. well (Pl. II), is a shaft 6 by 12 feet in cross section, cased with lumber, and sunk to a depth of about 50 feet. Its normal water level is about 37.5 feet below the surface. The pump that is used has a capacity of about 400 gallons per minute, but the yield of the well, according to information given by Mr. James Morris, who is in charge of the pumping plant, is only about 90,000 gallons in 11 hours, or about 140 gallons per minute.

The Montezuma well, now abandoned, was used many years ago by freighters, who hauled ore to Austin from the Montezuma mine, near Goldfield, and was later used for a time by freighters operating between Tonopah and Manhattan. It was an uncased dug well, reported to end in gravel, and to yield generous supplies of good water. As many as 150 head of horses are said to have been watered from this well in one night. The Kelsey well is also said to have yielded amply for stock-watering purposes. The 135-foot dug well at Midway, also uncased, is reported to have been tested at 27 gallons per minute for 5 hours with a resultant lowering of the water level of about 7 feet.

The well of William Kane, situated about 9 miles north-northwest of Millers (Pl. II), was drilled to a depth of 700 feet and is lined with 6-inch casing. It is said to pass through sandy or gravelly deposits, except near the bottom, where it penetrates 30 feet of "limestone and quartzite." The first water, struck at a depth of 120 feet, did not rise above its original level, but a supply struck at 670 feet rose within 90 feet of the surface. According to Mr. Kane, the owner, a pump cylinder $4\frac{1}{2}$ inches in diameter, placed 150 feet below the surface, was operated with a 24-inch stroke at the rate of 30 strokes per minute for four hours continuously without noticeably affecting the supply. The yield, measured by the miner's-inch method, is reported by Mr. Kane to have been 5 inches, or about 45 gallons per minute.

In the southwestern part of the lower valley the ground-water prospects are unfavorable in several respects. The Tertiary formations appear to be near the surface and wells with large yields can probably not be obtained. There is a possibility of obtaining supplies by drilling deep into the Tertiary strata, but the prospect is too poor to make deep drilling advisable, at least until the more promising supplies from the Quaternary fill in other parts of the valley have been developed. The railroad well at Blair Junction is 4 by 6 feet in cross section and 115 feet deep, with a 22-foot tunnel at a depth of 113 feet. It is cased with lumber to a depth of 100 feet. The last 5 feet is in Tertiary sandstone that contains volcanic fragments, and the water is said to be derived from this sandstone. About 15,000 gallons are pumped daily, but pumping at the rate of about 40 gallons per minute for two and one-half hours temporarily exhausts the supply.

ARTESIAN SUPPLIES.

DEVELOPMENTS.

In the last two years seven flowing wells have been sunk in the upper valley, and drilling was in progress when the valley was last visited. These wells are all in or very near the area of ground-water discharge, which has more or less alkaline soil and a depth to water not generally exceeding 10 feet.

In 1913 a flowing well was drilled on the ranch of Frank Gendron and two were drilled on the claim of Ed Turner, 2 miles south of the Darrough Hot Springs (Pl. II). The Gendron well, which was variously reported as 133 and 190 feet deep, revealed the approximate section shown on page 59. The well was finished with a 6-inch casing, but some of the water comes up on the outside of the casing. The flow is only a few gallons a minute.

The two wells of Ed Turner, which are finished with 6-inch casings, are situated only 3 feet apart. They are reported to be respectively 40 and 90 feet deep. The strongest flow is said to come from the depth of 30 feet. The 40-foot well is said to have yielded originally about 40 gallons a minute and the 90-foot well about 30 gallons, but their combined yield at the time the wells were visited was only about 30 gallons a minute.

Late in 1913 a well was drilled at the Crowell ranch which encountered little except sand and which is reported to have a small flow.

In 1914 two flowing wells were drilled on the ranch of Fred Jones, and one at Millett, and in October of that year drilling was in progress in a well one-half mile northeast of Millett.

Both of the Jones wells are 6 inches in diameter and are finished with standard casings without perforations, the water entering through the open end at the bottom of each well. The first well was drilled to a depth of 68 feet, where the first flow was struck, and the second to a depth of 127 feet, where a stronger flow was encountered in a 10-foot bed of gravel below a layer of dense clay or hardpan, also about 10 feet thick. The water table was encountered 8 or 9 feet below the surface. The 127-foot well discharged from a pipe with outlet 14 feet above the surface, and the water would no doubt have risen higher. The flow of the 60-foot well was at first about 75 gallons a minute but later diminished to about 30 gallons. The flow of the 127-foot well was measured on October 7, when it was found to be 120 gallons a minute. The cost of the 127-foot well was as follows:

Cost of 127-foot well of Fred Jones.

Drilling:	
100 feet at $1 per foot	$100.00
27 feet at $1.50 per foot	40.50
Casing:	
124 feet at $0.65 per foot	80.60
Total cost of well	221.10

The flowing well at Millett is similar to the Jones wells and is 101 feet deep. The water table was struck a few feet below the surface; the first flow, yielding about 8 gallons a minute, was struck at 61 feet; and the second flow, about 40 gallons a minute, was struck at the bottom. On October 6 the flow through a 2-inch pipe 8 feet above the surface was 32 gallons a minute.

PROSPECTS.

The prospects of obtaining flowing wells are, as a rule, best where the water table is nearest the surface, and no money should be spent in drilling for flows outside of the 50-foot boundaries shown on Plate II. The most favorable conditions are found in the shallow-water area on the west side of the upper valley, where the slope from the mountains is steep and the water supply is abundant, but there are also prospects on the east side between the Charnock Springs and Wood's ranch. To a large extent the flowing-well area will be found to be in the areas of alkali soil, but it may be possible to get satisfactory flows on some good land just outside of the alakali areas, especially at the bases of the alluvial fans of Kingston Creek, Twin Rivers, and Jefferson Creek. Even where the soil contains considerable alkali flowing wells will be profitable provided there is enough slope to make the removal of the alkali practicable, as is the case near the west edge of the alkali area in the upper valley, and provided the yield of the wells is large enough to make the cost per acre comparatively small, as is the case with the Jones well.

The conditions for obtaining flowing wells in the lower valley are believed to be less favorable than in the upper valley because the fill is not so deep, the contributions to the ground-water supply are smaller, and the principal sources of supply are farther from the shallow-water area. If there is any drilling for flowing wells it should be done a short distance west or southwest of Millers, where the soil is still fairly good but the water table is not much more than 10 feet below the surface.

Flows could probably be obtained by drilling deep wells into the Tertiary strata in the lowest parts of the lower valley, but on account of the probable small yields and poor quality of water it is not likely that such wells would be worth what they would cost.

Generally where flows are obtained in the valley fill there are several sand or gravel beds with artesian water that are separated from each other, more or less effectually by beds of clayey material. In order to get the largest possible yield a well should penetrate as many of these artesian beds as practicable.

CONSERVATION.

The artesian reservoirs of Big Smoky Valley are relatively small and their confining beds are not very effective in preventing escape of the artesian water, but they are recharged each year by comparatively large supplies that enter the ground only a few miles from where the flows are obtained and at much higher levels—conditions which produce steep hydraulic gradients and the maintenance of artesian pressure in spite of heavy leakage. Flowing wells that tap these artesian reservoirs furnish an easier means of escape for the water that would otherwise be eventually discharged by nature through weak parts of the confining beds. Flowing wells will therefore recover for economic use a supply that would otherwise be practically wasted by nature from year to year.

These facts show the desirability of developing the supply for irrigation, but they give no excuse for wasting artesian water. The escape of water from a flowing well necessarily provides some relief to the pressure and thereby reduces the yield of other wells drawing from the same reservoir. Also a flowing well depletes to some extent the supply in its immediate vicinity and hence tends to reduce its own head and yield. Consequently the waste of any artesian water, either through imperfectly cased wells or through wells that are left open when the water is not needed, increases the cost per second-foot of the water recovered and the cost per acre of land reclaimed with this water. This higher cost is borne in part by the man who wastes the water and in part by his neighbors.

Great stupidity has been shown by the inhabitants of most flowing-well areas in their reckless disregard of obvious principles of water conservation, and it is partly for this reason that most artesian basins have proved disappointing. It is to be hoped that in the developments in Big Smoky Valley more wisdom will be exercised, and that the waste of the artesian water will be prevented (1) by using good casing, (2) by inserting the casing tightly through the confining beds, and (3) by closing the wells when the water is not used.

METHODS OF DRILLING.

Drilling can be done with standard cable percussion rigs,[1] mud scow outfits such as are used in many of the débris-filled valleys of California,[2] hydraulic rigs of either rotary [3] or spudding type,[4] or combination percussion and hydraulic rigs.

Cable percussion rigs are the most reliable for general exploratory work and should be used for drilling in hard formations, such as the Tertiary rocks, or in bowldery deposits, such as underlie the alluvial slopes in some localities. These rigs are, however, comparatively slow in operation and are not well adapted for penetrating quicksand. They will not lend themselves to the most economic development of the ground waters of the valley.

Mud scows, which are essentially bailers with heavy cutting shoes at the bottom, have been very widely and successfully used for drilling pump wells of large diameter for irrigation purposes in ordinary valley fill, and they would no doubt be well adapted for similar use in Big Smoky Valley. They might, however, not be successful where much quicksand is encountered.

Hydraulic outfits, in which water is pumped downward through hollow drill rods and comes up on the outside bringing the drillings with it, provide a rapid means of sinking wells in soft, fine-grained material. The rotary machines are necessarily heavy and somewhat expensive and are used in deep drilling. In machines of the other type, usually provided with expansion cutting drills, the drill rods are alternately lifted and allowed to drop, as in percussion rigs. These light, inexpensive machines are used to a considerable extent for drilling flowing wells in fine valley fill and they are well adapted for similar use in Big Smoky Valley. The wells drilled with these outfits are generally small, but there appears to be no reason why they could not be used successfully for holes 6 inches in diameter, which is the smallest diameter recommended for wells to be used for

---

[1] Bowman, Isaiah, Well-drilling methods: U. S. Geol. Survey Water-Supply Paper 257, pp. 34–59, 1911.

[2] Idem, pp. 66–70.

[3] Idem, pp. 70–75.

[4] Idem, pp. 75–78.

irrigation. The ascending muddy water plasters the walls of the well, producing a remarkably effective mud casing. Even in a deep well in soft material it is generally not necessary to insert casing until the entire hole has been drilled. This plastering or puddling process makes the hydraulic rigs the most successful for penetrating quicksand, but it involves the danger of shutting out valuable water-bearing beds.

The most serious difficulty that has been met in drilling in Big Smoky Valley is produced by beds of quicksand, which are always hard to handle. If the bed is not too thick it may be possible to drive the casing through it into a firmer formation, or if the sand does not run too freely it may be possible to bail out enough to allow the casing to be driven down little by little. Entrance of sand into the well can to some extent be prevented by keeping the well as full of water as possible, thereby producing a back pressure. Other methods of penetrating quicksand consist of (1) freezing the formation, which is too expensive for ordinary water wells; (2) inserting cement, which sinks into the quicksand and sets, after which it can be drilled through; and (3) puddling with mud by the hydraulic process. The puddling method is the most practicable for use in Big Smoky Valley.

For pump wells of large diameter double stovepipe casing, about No. 12 gage, such as is widely used in California, is probably the most economical casing that is adequate. It is commonly used in wells sunk with mud scows, where it is inserted as fast as the hole is made. In flowing wells it is advisable to use the somewhat more expensive standard screw casing. Wells in the valley fill should not be left uncased. In pump wells the casing should be perforated at every water-bearing bed, either before or after it is inserted. Flowing wells, in order to yield the largest amount possible, should be sunk through the entire bed that furnishes the artesian water and should have their casings perforated where they pass through this bed. Generally there are several satisfactory artesian horizons below the one in which the first flow is struck, and in order to get strong flows all of them should be penetrated and the artesian water admitted by perforating the casing. Perforations may be circular holes one-fourth to one-half inch in diameter or vertical slits one-fourth to one-half inch wide.

QUALITY OF WATER AND OF ALKALI IN SOIL.

SOURCES OF DATA.

In the tables on pages 153–161 are given the results of 90 analyses—57 of water samples and 33 of the water-soluble contents of soil samples. Forty-one of the water samples and 28 of the soil samples were collected in Big Smoky Valley, and the others were collected in Clayton, Alkali Spring, and Ralston valleys. (See pp. 127–146.)

All the soil analyses and most of the water analyses were made for this investigation by S. C. Dinsmore. The analyses not made by Dr. Dinsmore were obtained from various sources, as indicated in connection with the tables. Acknowledgments are due the Goldfield Consolidated Water Co., the Desert Power & Mill Co., and the Pittsburgh Silver Peak Mining Co. for analytical data generously furnished to the Geological Survey.

DISSOLVED SUBSTANCES.

The dissolved mineral matter consists chiefly of calcium (Ca), magnesium (Mg), sodium (Na), bicarbonate (HCO_3), carbonate (CO_3), sulphate (SO_4), and chlorine (Cl), with smaller amounts of silica (SiO_2), iron (Fe), and nitrate (NO_3). Potassium (K) and sodium (Na) were generally not determined but were calculated from the reacting values of the determined bases and acids and were reported together.

The analyses show wide range among the waters of Big Smoky Valley (1) in the total dissolved solids, (2) in the amounts of each constituent, and (3) in the proportions of the constituents. In the following table is given the range among the samples analyzed, exclusive of W4, which was no doubt greatly concentrated by evaporation in the well, and W23 and W24 which may have been thus concentrated. The table shows that the range is greatest for the radicles whose compounds are most soluble, like sodium, sulphate, and chlorine, and least for silica and bicarbonate, whose compounds are less soluble but generally available to the natural waters, bicarbonate being derived partly from the carbonates in the rock and partly from the carbon dioxide of the atmosphere and of decayed vegetation.

Range in mineral constituents in waters of Big Smoky Valley.[a]

	Lowest (parts per million).	Highest (parts per million).	Range (ratio of highest to lowest.)
Total dissolved solids	104	4,038	39
Silica (SiO_2)	10	100	10
Calcium (Ca)	13	397	31
Magnesium (Mg)	1.9	71	37
Sodium and potassium (Na+K)	Trace.	1,218	Very great.
Carbonate and bicarbonate radicles (expressed as HCO_3)	75	807	11
Sulphate radicle (SO_4)	Trace.	1,174	Very great.
Chlorine (Cl)	4	1,361	340

[a] Except W4, W23, and W24.

PROVINCES.

With respect to quality of water, Big Smoky Valley can be divided roughly into three provinces—the upper valley, the part of the lower valley northeast of a northwest-southeast line through a point 4 miles southwest of Millers, and the part of the lower valley southwest of that line. (See Pl. II, in pocket.) The general differences in the waters of these provinces are shown by the following tables and by the diagrams in figure 9, which is based on the averages given in the first table.

Average mineral content of water from Big Smoky Valley.

[Parts per million.]

	Number of samples.	Total dissolved solids.	Silica (SiO_2).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).
Upper valley:										
Streams	4	233	18	48	11	13	11	160	32	7
Springs [a]	9	221	28	44	7	13	5	140	34	9
Wells [b]	11	329	26	63	15	29	2	224	42	35
All samples [a] [b]	24	273	26	53	11	21	5	181	37	21
Lower valley:										
Northeast province (all samples)	8	558	59	40	10	122	3	273	89	60
Southwest province (all samples)	6	5,753	66	91	26	1,947	18	690	1,191	1,933

[a] Except S5. [b] Except W4 and W12.

Number of water samples from Big Smoky Valley having specified contents of dissolved solids.

Parts per million.	Number of samples.		
	Upper valley.	Northeast province of lower valley.	Southwest province of lower valley.
Less than 200	9	0	0
200 to 500	14	5	0
500 to 1,000	2	2	1
More than 1,000	2	1	5
	27	8	6

Number of water samples from Big Smoky Valley having specified contents of certain mineral constituents.

Basic radicles.

Parts per million.	Calcium (Ca).			Magnesium (Mg).			Sodium and potassium (Na+K).		
	Upper valley.	Northeast province of lower valley.	Southwest province of lower valley.	Upper valley.	Northeast province of lower valley.	Southwest province of lower valley.	Upper valley.	Northeast province of lower valley.	Southwest province of lower valley.
Less than 10	0	0	0	17	4	2	13	0	0
10 to 50	13	6	2	8	4	3	7	3	0
50 to 100	13	2	1	2	0	1	5	1	0
100 to 500	1	0	3	0	0	0	1	4	2
More than 500	0	0	0	0	0	0	1	0	4
	27	8	6	27	8	6	27	8	6

Number of water samples from Big Smoky Valley having specified contents of certain mineral constituents—Continued.

Acid radicles.

Parts per million.	Bicarbonate radicle (HCO_3).			Sulphate radicle (SO_4).			Chlorine (Cl).		
	Upper valley.	North-east province of lower valley.	South-west province of lower valley.	Upper valley.	North-east. province of lower valley.	South-west. province of lower valley.	Upper valley.	North-east. province of lower valley.	South-west province of lower valley.
Less than 10	0	0	0	3	0	0	13	0	0
10 to 50	0	0	0	14	2	0	11	5	0
50 to 100	5	0	0	8	4	1	1	2	1
100 to 500	21	7	4	0	2	2	1	1	1
More than 500	1	1	2	2	0	3	1	0	4
	27	8	6	27	8	6	27	8	6

With few exceptions the waters of the upper valley contain only moderate amounts of mineral matter, those of the northeastern province of the lower valley contain somewhat larger amounts, and those of the southwestern province of the lower valley are highly mineralized. Nearly all the samples from the upper valley and most of those from the northeast province of the lower valley contain less than 500 parts per million of total solids, whereas all but one of the samples from the southwest province contain more than 1,000 parts. One-third of the samples from the upper valley contain less than 200 parts of total solids, the lowest being 104 parts, but none of those from the lower valley contains less than 200 parts.

The mineral matter dissolved in the waters of the upper valley consists chiefly of calcium and the bicarbonate radicle. Magnesium, sodium, the sulphate radicle, and chlorine are present in relatively small amounts. In one-half of the samples the calculated sodium content is less than 10 parts per million and in none except that from Spencer Hot Springs (S5) and the concentrated solution from the playa (W4) is it more than 100 parts. In one-half of the samples the content of chlorine is less than 10 parts per million and in only a few is it more than 15 or 20 parts. In nearly two-thirds of the samples the sulphate radicle is less than 50 parts per million and in all except W4 and W12 it is less than 100 parts. In most of the samples the reacting values of the sulphate radicle and chlorine exceed together the reacting values of sodium and potassium (fig. 9), but in some samples sodium and potassium are in excess.

The waters from the northeast province of the lower valley generally contain somewhat less calcium and magnesium than the waters of the upper valley, but their average content of sodium is nearly six times as great. The average content of calcium in the samples from the upper valley is two to three times that of the sodium, but in the samples from the northeast province of the lower valley it is only about one-third that of the sodium. The waters of the northeast province of the lower valley are also somewhat higher in chlorine and sulphate, chlorine being not less than 18 parts and the sulphate radicle, with one exception, not less than 50 parts per million. Sodium is, however, generally in excess over the chloride and sulphate radicles, and therefore the waters belong to the sodium carbonate type and usually leave black alkali on evaporation (fig. 9).

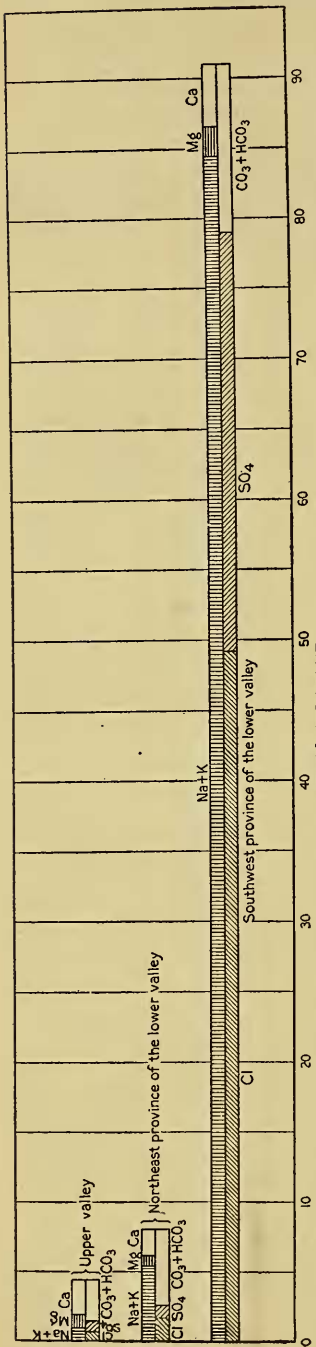


FIGURE 9.—Diagrams showing relative quantities of the principal radicles dissolved in the average waters of the three provinces of Big Smoky Valley, in reacting values. (See Water-Supply Paper 274, p. 167.) Reacting value $= \frac{\text{Parts per million} \times \text{valence}}{\text{atomic weight}}$.

In the southwest province it was difficult to obtain satisfactory samples because there are no springs and only a few wells, most of which are in ruins. Enough samples were obtained, however, to show that the waters are much more highly mineralized than those in other parts of the valley. The relative proportions of the various constituents are not very different from those in the waters of the northeast province except that the preponderance of sodium over calcium is still greater. These waters are high in sulphate and chlorine, some of them being distinctly salty, but they generally contain sodium in considerable excess over these two radicles, and on evaporation they deposit sodium carbonate, or black alkali, as well as sodium chloride and sodium sulphate.

RELATION OF QUALITY TO GEOLOGIC FORMATIONS.

The greater part of the mineral matter dissolved in the water of the upper valley is derived from the limestones and calcareous slates that are widely distributed in the adjacent mountains, and the principal compound contributed by these formations is calcium carbonate. The abundant granitic rocks are much less soluble than the limestones and slates, but their effect on the character of the water and on the kinds of alkali deposited by the water on evaporation is discernible. Though most of the analyses do not show an excess of sodium over chlorine and sulphate, sodium carbonate (black alkali) is present in the soil throughout the alkali area.

The rocks in the basin tributary to the northeast province of the lower valley are chiefly Tertiary eruptives, which, like the granitic rocks, yield waters that are only slightly mineralized but sodium carbonate in type. The high content of sodium in this province, as compared with that in the waters of the upper valley, is doubtless due to the presence of some Tertiary sedimentary beds, whereas the comparatively small content of calcium is due to the relative scarcity of limestone and calcareous slate.

The high mineral content of most of the waters in the southwest province is apparently due to salts contributed by the Tertiary sedimentary beds, which underlie much of this part of the valley and outcrop in the adjacent hills and mountains. The character of the mineral matter suggests that the Tertiary beds were formed, at least in part, under conditions of concentration that resulted in the deposition of soluble salts. The conditions may have been not unlike those in the Quaternary period, for the Quaternary lake and playa beds of either the upper or the lower valley would, if leached, produce waters of the same general character as the highly mineralized waters of the lower valley. Most of the calcium salts would be left behind and the more soluble carbonates, chlorides, and sulphates of sodium would go into solution. The salts can not have been derived from the concentration of sea water because their proportions differ from those in sea water, in which chlorine alone exceeds sodium and potassium. The highly mineralized waters of Clayton Valley more nearly resemble sea water in composition. (See p. 146.)

RELATION OF QUALITY TO CONCENTRATION PROCESSES.

Concentration of the soluble load carried by the water has been an important geologic process in Big Smoky Valley. This process in the lake epoch was somewhat different from that occurring at present when the climate is too arid for lakes to exist. During the lake epoch the dissolved substances nearly all reached the lakes and were deposited on the lake bottoms by long-continued evaporation. What has become of these salt deposits is not definitely known. During arid epochs dissolved substances are deposited by evaporation of both surface and ground waters in the lowest parts of the interior depressions. The surface waters carry to the playas not only a soluble load but also a load of suspended silt and clay, part of which is so fine that it is not generally deposited until the water evaporates. Thus the surface waters tend to seal the soluble materials by layers of fine sediment and to leave them disseminated through the dense playa deposit as the playa is gradually built up. The ground waters that emerge in the low places bring up with them some of the soluble substances that have been buried, and they thus tend to effect concentration at the surface. There is evidence, derived chiefly from deeper borings in other playas similar to those of Big Smoky Valley, that the fine deposits underlying the playas form dense cores, through which the ground water circulates so sluggishly that it is not effective in raising the soluble substances to the surface. On the other hand, there is evidence from the data obtained in this and other investigations that in the relatively porous deposits of the wet zone surrounding a playa there is active circulation and rise of ground water, so that soluble substances are nearly or quite as thoroughly removed from these deposits as from deposits beneath the upper parts of the alluvial slopes.

Some of the samples of purest water from the upper valley were obtained from the wet zone surrounding the playa, in which the ground water is rising and alkali is deposited at the surface. Seven of the nine samples with less than 200 parts per million of total solids come from this zone. They include the samples from Frank Gendron's flowing well (W3), Millett's flowing well (W5), a well only 10 feet deep at the Rogers ranch (W8), and the spring at the edge of Moore Lake (S11). The sample from Mr. Gendron's flowing well contains less mineral matter than any other water collected in Big Smoky Valley, the sample from South Twin River being second, and that from the spring at Moore Lake third. The great purity of the water of the spring at Moore Lake (Pl. II) is especially remarkable, as it issues in a locality where the surface is extremely alkaline, as is shown by the soil analysis (A7, p. 161).

As the wet zone surrounding the playa has perceptible slope, the rains and flood waters that flow over it dissolve and carry to the playa the soluble substances that are left at the surface by the evaporating ground waters. On the playa the soluble matter is disposed of by deposition with fine sediments, as already indicated.

The history of the soluble substances derived from erosion of the mountains during an arid epoch when there is no lake appears, therefore, to be as follows: Part is carried by the surface waters directly to the playa, and part is carried by the ground waters, which generally move from the mountains toward the playa but, being blocked by the clay core underlying the playa, return to the surface in the surrounding zone, where they evaporate and deposit their soluble load; the soluble matter thus deposited is then washed into the playa by surface water; on the playa the soluble matter from both sources is deposited with the fine sediments and largely remains disseminated through these sediments as the playa is built.

During the processes leading to concentration most of the less soluble substances are left behind when more soluble salts are removed. This explains why the relative proportions of sodium are greater and those of calcium less in saturated solutions (W4), alkali crusts (A5, A7, and A9), and the water-soluble component of alkali soils (other analyses, p. 161) than in the more dilute water samples. The content of calcium is very small in most of the soil samples whose analyses are given on page 161, as is shown by the low value for hardness. The few that contain much calcium (A1, A12, and A14) doubtless derived it from calcium sulphate. The soluble matter concentrated at or near the surface in the low places and disseminated through the playa deposits at great depths consists chiefly of sodium chloride, sulphate, and carbonate, and is commonly called alkali.

The soil analyses (p. 161) show that all three salts are present in considerable quantities and that none of them predominates greatly over the others. Sodium chloride is the most abundant constituent of the alkali in the samples from the flat east of Millett (A6) and in several others and it is widely distributed. It is the dominant salt in the Spaulding salt marsh. Sodium carbonate and bicarbonate predominate in several samples and are present over most of the area occupied by the alkali tracts. Sodium sulphate is dominant in some samples and is widely distributed. Calcium sulphate is present in considerable quantities in only a few samples and its occurrence appears to be rather localized.

Sodium chloride can be recognized by its salty taste, sodium sulphate by its salty and bitter taste, and sodium carbonate by its soapy taste and the burning sensation when it is taken into the mouth, and also by the black or brown discoloration that it produces in the soil where there is vegetable matter.

RELATION OF QUALITY TO USE.

DOMESTIC USE.

There are wide differences in the effects of some waters on persons who drink them, and many of the supposed effects, either curative or injurious, are doubtless imaginary. A water may be avoided in one community as unfit to drink and water similar in composition may be prized in another for its medicinal properties. Many waters widely regarded as having specific curative properties are essentially similar in composition to city supplies used daily by thousands of people without apparent peculiar effect. The effect of any mineral ingredient is generally greater on a person unaccustomed to the water than on one who has used it for a long time. Moreover, a person, after drinking a strong water for some time, may become unable to detect any disagreeable taste in it or may even prefer it to less strongly mineralized water. For example, the supply at Blair (S17, p. 154) contains 774 parts per million of chlorine, and is therefore salty to the taste, whereas the supply at Millers (W17, p. 157) contains only 74 parts of chlorine, an amount too small to be tasted; but an inhabitant of Blair reported that when she visits Millers the water tastes so insipid to her that she adds a little salt before drinking it.

A judgment of potability based on total solids alone is unsatisfactory, because the different constituents do not have the same physiologic effect. The so-called Michigan "standard of purity" specified 500 parts per million as the allowable limit of total solids, a limit entirely too low. MacDougal,[1] judging from experience in desert regions, states that waters containing 2,500 parts per million of dissolved salts may be used for many days without serious discomfort; that those containing as much as 3,300 parts can be used only by hardened travelers; and that those containing 5,000 parts or more are inimical to health and comfort, but might suffice for a few hours to save the life of a person who had been wholly without water.

Water that contains 250 or 300 parts per million of chlorine in the form of common salt is generally slightly brackish, and water containing larger amounts is correspondingly more salty to the taste, 1,000 parts per million being near the limit of potability. About 400 parts of the sulphate radicle is generally perceptible to the taste. Strong sulphate waters are laxative, and waters containing several hundred parts per million of this radicle are prized by some persons for their medicinal properties. Hardness of water is caused by the presence of calcium and magnesium.

The tables on pages 153–158 show that practically all the stream, spring, and well waters of the upper valley are good for domestic use, that most of the waters of the northeast province of the lower valley are fairly good, and that most of those of the southwest province are poor or unfit, though the water from the Desert well (W22) is classified as good for drinking. The classification in respect to quality for domestic use in the tables of analyses is based entirely on the amounts of the dissolved mineral constituents. It gives no information as to whether the waters are polluted with disease-bearing organisms or with poisonous substances like cyanide from mill tailings.

---

[1] MacDougal, D. T., Botanical features of North American deserts: Carnegie Inst. Washington Pub. 99, p. 109, 1908.

USE IN BOILERS.

Silica, calcium, magnesium, iron, and aluminum are scale-forming materials, and among these calcium usually occurs in greatest amount. Dissolved and suspended substances of all kinds probably affect the tendency to foam, but as compounds of sodium and potassium are more soluble than those of most other substances commonly found in water they remain in solution in the boiler water after most of the other substances have been precipitated, and therefore the tendency to foam is commonly measured by the amount of these two elements in the boiler feed.

Under the high temperatures in boilers, magnesium, iron, and aluminum may be precipitated as hydrates, and the acid thus released may cause corrosion. Carbonate and bicarbonate counteract this tendency, but sulphate, and especially chlorine, increase it.

Most waters of the upper valley are fairly good for use in boilers, but will deposit a moderate amount of rather soft scale. Much of the scale-forming material can be removed by heating the water before it is admitted into the boilers. The waters of the northeast province of the lower valley will perhaps form less scale than the waters of the upper valley, but their tendency to foam is greater. The waters of the southwest province are objectionable chiefly because of their high content of sodium and consequent tendency to foam. The supplies at Millers and Blair Junction are among the softest waters in the valley and will not form large amounts of scale, but on account of their rather high sodium content they may cause foaming in locomotive boilers.

USE FOR IRRIGATION.

Plants can endure a larger amount of dissolved mineral matter than animals, but the soil solution on which they subsist is generally more strongly concentrated than the water applied in irrigation, as some of the alkali in the soil goes into solution. Moreover, irrigation water that evaporates leaves its soluble content, and thus adds to the amount of alkali in the soil and to the concentration of the soil solution. If soil is well drained, alkali can from time to time be washed from it, and highly mineralized waters can be successfully used for irrigation; but if the drainage is poor even water of low mineral content may eventually cause injurious accumulation of alkali. One year or even a few years of irrigation do not give a fair test if the conditions are such that the alkali is accumulating. The injury to plants is caused chiefly by the sodium salts, among which the carbonate, or black alkali, is most injurious, the sulphate is least injurious, and the chloride is intermediate.

The stream, spring, and well waters of the upper valley are generally of good quality for irrigation, and except where the soil is already impregnated with alkali they will not produce injurious effects. The waters of the northeast province of the lower valley contain larger but not excessive amounts of alkali, and most of them are satisfactory for irrigation, except where the soil already contains injurious amounts of alkali. Some of the waters of the southwest province might be used for irrigation but all are unsatisfactory. The water from the railway well at Blair Junction is used to irrigate a few trees, which appear to be suffering from the alkali that is deposited.

The analyses show that the two most injurious salts in the soil of the alkali areas are sodium chloride and sodium carbonate, the chloride being more abundant but the carbonate more injurious. Difficulty with these two salts may be expected within the alkali areas as shown on the map (Pl. II), but not all the land within these areas is irreclaimable. Indeed much of the land now irrigated in the upper valley with stream and spring waters lies in the alkali area and has been made fairly productive by persistent and intelligent effort.

The northeast limits of the area of alkali soil in the lower valley are not very definite, and some alkali may be encountered beyond the boundary shown on the map (Pl. II). Reclamation of the land in the alkali area of the lower valley is not believed to be practicable, the drainage being much poorer than that of the reclaimed alkali land in the upper valley.

PUBLIC SUPPLIES.

TONOPAH.

DEVELOPMENT OF SUPPLY.

In the first years of Tonopah's existence water was brought to the town on burros. Small amounts were afterward obtained by shallow wells, the presence of greasewood being used as an indication of an underflow. Wells were sunk and a pumping plant was installed about 1904 at a locality known as the Rye Patch, at the axis of Ralston Valley, about 11 miles northeast of Tonopah. This water was piped to a reservoir on the high ground north of the city. (See Pl. XIII.) The waterworks are owned and operated by the Water Co. of Tonopah.

PHYSICAL FEATURES OF SOURCE.

Ralston Valley is a long débris-filled valley with an interior drainage. It heads east of the Toquima Range at a low divide that separates it from Monitor Valley farther north. The axial drainage line leads southward through the Rye Patch, 20 miles south of the divide, to a large terminal playa. According to Ball[1] a well sunk in this playa did not strike water until it reached a depth of 240 feet, indicating underground escape of the water into another basin and the absence of ground-water discharge. In the vicinity of the Rye Patch the axis is marked by a shallow stream valley, in the banks of which outcrops of lava indicate the presence of a rock barrier not far below the surface. Rock is reported to have been struck at the pumping plant at the depth of 55 feet and to have been penetrated to a depth of 162 feet. The flood plain in this vicinity supports a typical shallow-water flora, consisting of salt grass, big greasewood, rabbit brush, giant rye grass (*Elymus condensatus*), and giant reed grass (*Phragmites communis*). The adjacent alluvial slopes support the usual arid upland vegetation of salt bush (*Atriplex confertifolia*) and little greasewood, but there is a narrow transition zone characterized by big greasewood and iodine weed. The ground is moist in some localities from the surface down and there is active ground-water discharge. The northern limits of the shallow-water area were not determined, but they are known to be some distance up the valley. Below the pumping station the conditions change rapidly; in less than a mile all indications of ground water disappear and characteristic upland vegetation, consisting of salt bush (*Atriplex confertifolia*), little greasewood, and white sage, extends across the axis of the valley. Apparently, therefore, the only locality in the 50 miles from the Monitor divide to the playa in which ground water comes to the surface is at the Rye Patch, where an underground barrier doubtless exists.

WELLS.

Ten 14-inch wells were originally sunk at intervals of about 100 feet in an east-west line across the flood plain at right angles to the axis of the valley. On the rock, which was struck 55 feet below the surface, there is said to be a 10-foot bed of clay, above which there is clay, sand, and the gravel from which the water is derived. The water table was originally 8 feet below the surface, but in 1913 it was a few feet lower. The yield seems gradually to have declined, more likely by clogging of the wells than by diminution of the supply, until in 1913 it was only a few thousand gallons an hour.

Two large wells have been sunk in the same locality, one 8 by 12 feet by 45 feet deep, the other 5 by 6 feet by 60 feet deep. They are pumped with centrifugal pumps and contribute largely to the supply. An infiltration ditch, discharging by gravity, furnished about 9,000 gallons an hour until it was damaged by a flood in the fall of 1913.

[1] Ball, S. H., A geologic reconnaissance in southwestern Nevada and eastern California: U. S. Geol. Survey Bull. 308, p. 83, 1907.

Recently three wells were sunk somewhat less than 100 feet apart along an east-west line at the axis of the valley 4,400 feet north of the pumping plant, where the water table is only about 5 feet below the surface and ground water is being discharged through soil and vegetation. These wells are 12 inches in diameter and range in depth from 46 to 51 feet. They pass through about 4 feet of gray silt loam and then chiefly through clean sand and gravel to the bottom, where bowlders were struck. They are lined to the bottom with No. 12 double stovepipe casing with small perforations. A yield of 100 gallons a minute is reported by Mr. M. P. Shepard, foreman of the pumping plant, to have been obtained in a test of one of these wells with a drawdown of 20 feet, and a yield of 150 gallons a minute with a drawdown of 25 feet. With larger perforations the yield would probably have been greater.

A test well 65 feet deep, 2 miles farther up the valley, struck water at a depth of about 5 feet and passed chiefly through clean gravel to the bottom, where bowlders were encountered. Mr. Shepard reports that this well was pumped 8 hours at the rate of 50 gallons a minute with a drawdown of only 16 inches.

The supply in this valley is apparently a definitely limited underflow, but larger quantities could doubtless be recovered by a more widely distributed system of wells, which would get the water that now escapes toward the south.

PUMPING PLANT AND DISTRIBUTING SYSTEM.

The pumping plant includes three electrically driven triplex pumps, each with a capacity of about 7,000 gallons an hour. They force the water through an 8-inch pipe line 11 miles to the distributing reservoir, which is 603 feet above the pumps and has a capacity of 232,000 gallons. From this reservoir the water is carried by gravity through the distributing system, which includes 31 hydrants and 780 service connections.

CONSUMPTION OF WATER.

According to Mr. F. A. Burnham, manager of the water company, the average daily consumption is 300,000 gallons, of which all but 40,000 gallons is used at the mines and mills. The gross per capita consumption is 40 gallons a day, but exclusive of the water used at the mines and mills it is only 6 gallons a day.

COST.

The maximum charge for water formerly was $10 per 1,000 gallons, but it has been reduced to $3.25, the price decreasing with the amount consumed to a minimum of $1 per 1,000 gallons. As at Goldfield

(p. 152), there is a marked relation between the cost of the water and the per capita consumption as compared with other communities where water is cheaper.

QUALITY.

As shown by the analysis on page 157, the water contains only moderate amounts of mineral matter and resembles in composition the water of upper Big Smoky Valley, especially in the small content of sodium and the predominance of calcium. It is of good quality for domestic use and for irrigation, but forms some scale in boilers. The sanitary conditions are also good provided reasonable precautions are taken to prevent pollution in the vicinity of the wells.

MANHATTAN.

Most of the water supply for Manhattan is furnished by the Manhattan Water Co. Until the fall of 1913 the regular supply was pumped from two dug wells, 4 by 8 feet in cross section, situated 1,000 feet apart in a gulch on the Tonopah road, 1¼ miles from Manhattan. The upper well is reported to be 60 feet deep, all except the first 6 feet being in black slate, from which the supply is derived. The lower well is reported to be about 50 feet deep with a 12-foot tunnel, the upper 40 feet being in gravel or other detrital material and the rest in black slate. The water is reported to enter chiefly from the bottom of the gravel. The upper well yields more than the lower, but neither freely supplies water. The upper well is equipped with an electrically driven pump with a capacity of 35 gallons a minute, and the lower well with a similar pump with a capacity of 20 gallons. These pumps are operated throughout the day, but without running at full capacity they remove the water that accumulates in the wells overnight in five to seven hours, after which the pumpage is small.

In the fall of 1913 the daily supply from the two wells was reported to be only 12,000 to 15,000 gallons, though the daily consumption was 20.000 to 25,000 gallons. The unusually low yield was attributed to the scanty snowfall of the preceding winter. The deficiency was temporarily met by pumping from the Big Four mine, which was about 500 feet deep and received seepage from veins and fissures below the depth of 250 feet. Water pumped from the mine was also used for milling. At the same time a well was drilled, 35 feet south of the upper dug well, through slate to a depth of 125 feet, and a small yield was obtained by shooting it with dynamite. Both flat and meter rates are in effect, and the latter range from $6.75 to $3.15 per 1,000 gallons. Several houses in the upper part of Manhattan are supplied through a system of pipes from a 50-foot dug well at the head of the main street.

ROUND MOUNTAIN.

Round Mountain is supplied by a privately owned gravity system, which takes water from the underflow of Shoshone Creek, the surface flow being diverted farther up for hydraulic mining. The usual family rate is $3.50 a month.

MILLERS.

The domestic supply at Millers is obtained from the well of the Desert Power & Mill Co. (pp. 108–109). The water is pumped to a tank on a small hill south of the settlement and is distributed by gravity. The water is freely used, the common charge being a flat rate of $1 a month for water and other privileges.

IRRIGATION.

DEVELOPMENTS.

The acreage of irrigated land in the basin of Big Smoky Valley is difficult to estimate because many of the irrigated fields merge with partly irrigated or nonirrigated meadows, and these in turn merge with unproductive marsh or desert. According to estimates based on the measured or reported dimensions of fields at each ranch, the total area regularly irrigated in the basin is about 2,500 acres, of which about one-half is in alfalfa and one-half in wild grass, the acreage of all other crops being very small. In addition there is about 5,000 acres of meadow land that is occasionally flooded or naturally subirrigated and that ranges from fairly productive grass land to nearly worthless salt-grass marsh. Practically all the irrigated land is in the north basin except about 300 acres along Peavine and Cloverdale creeks. (See Pl. II.)

Most of the water used for irrigation is taken from the numerous small mountain streams, but a part is from valley springs along the western spring line and at the Charnock ranch. Less than 5 acres was irrigated with water from wells in 1913 and 1914. Most of the stream water is used on land near the mouths of the canyons or in open places within the canyons, but a considerable part is led in ditches down the alluvial slopes and is used in the alkali area or on intermediate tracts. The meadow lands and nearly all the land irrigated from springs lie within the alkali area, but the alkali has been largely removed from the best fields in this area. The tracts of good soil adjacent to the alkali area generally lie above the springs, but they could be more largely utilized than they are at present for irrigation with stream waters.

Much stream water is lost by percolation into the porous sediments underlying the upper parts of the alluvial slopes. Where the water is used on the porous soil near the canyons the percolation occurs largely after the water has been applied to the land; where it is used on the tighter soil at lower levels the loss is chiefly by percolation from the ditches that lead from the mouths of the canyons to the irrigated fields several miles distant. The soil of the arroyos leading from the canyons is generally very porous, and to some extent loss has been avoided by using the water on the upland adjacent to the arroyos instead of using it on the floors of the arroyos themselves, or by leading it through ditches on the upland rather than taking it down the natural streamways. Only a part of the loss is, however, prevented by these means. The only effective methods of conserving the water supply would be (1) to prevent excessive percolation by constructing water-tight ditches from the canyons to the tracts of satisfactory soil, or (2) to recover the water, after it has sunk into the ground, through wells in the shallow-water areas. Both methods involve heavy expenditures, but both will probably in time be used.

An experiment in waterproof ditch construction has been made by Mr. Frank Gendron, who lined with stone a ditch about 2 miles long leading from Decker Canyon to his ranch. Although no cement was used, the ditch is practically water-tight, as is shown by the measurements made July 2, 1915 (p. 75), and by the absence along its margins of moisture or of vegetation other than the ordinary desert brush. The data indicate that without this ditch most of the water would be lost. The ditch is reported by the owner to have cost about $4,000, all in labor, which, according to the figures on page 75 is a rather high cost per unit of water utilized.

It is believed that improvement of ditches to prevent seepage is practicable at other places in the valley, but before any work is undertaken the bulletins on the subject by the Department of Agriculture should be consulted and all necessary information should be procured in order to obtain the best possible results at the lowest possible costs. In some places it may be advisable to construct water-tight ditches only on the parts of the slopes where percolation is largest. The installation of pressure pipe, which would not only conserve the water but would also develop power that could be used for pumping, is worthy of consideration, although as a rule its cost would doubtless be prohibitive. Its use might be found economically feasible on the steep, porous, upper parts of the slopes, although not feasible on the lower parts having less gradient and less percolation.

The duty of the water is also diminished by the great seasonal fluctuation of the streams. The smallest streams usually flow at their maximum stage in April or May, begin to dwindle in May or June, and fail to reach the fields before the summer is far advanced. Not only is their water totally lost during most of the summer, but the season in which a part of it reaches the fields is so brief that it is impossible to make good use of even this small supply. The large streams as a rule reach their maxima somewhat later than the small streams and they maintain considerable flow throughout the irrigation season, but their seasonal fluctuations are also so great that the high-stage waters can not be utilized to good advantage. The construction of reservoirs to regulate the flow is probably impracticable for most of the streams, but no investigation of reservoir sites has been made. The development of supplementary supplies by pumping from wells gives greater promise of being economically feasible.

CROPS AND MARKETS.

The short season, with cold spring and autumn, places a strict limit on the kind and quantity of crops that can be raised here, although this is less true of the vicinity of Millers than of the upper valley, where irrigation is now practiced. The isolation of the region also places limitations on the kinds of crops that can profitably be produced. The mining towns afford a market for hay, vegetables, fruit, butter, and eggs, which, however, is uncertain and easily glutted. Although this market is of distinct benefit to the present ranchers, especially in keeping up the price of hay, it can not be depended on to support new settlers or to make costly water-supply developments profitable.

The most valuable staple crop now raised is alfalfa, which is cut only two or three times in the season, and probably does not give an average annual yield of more than 3 tons an acre. At present alfalfa brings the largest returns when sold at the local mining towns, but its permanent value depends on its worth when fed to live stock. The cattle in the region depend largely on the range, even in the winter, but the most thrifty ranchers appreciate the value of a reserve supply of hay to supplement the range, especially in severe winters. Alfalfa requires a large amount of water and some dependable crops could perhaps be found that would yield greater returns for the quantities of water used.

Utilization of the supplies now going to waste would involve heavy costs and is practicable only to the extent that the developed water can do a large duty measured in financial returns. This requires crops of high value for the amount of water consumed, cultural methods that will spare the water supply as much as possible, and arrangements by which the developed water can do extra duty in supplementing existing irrigation supplies. Much can no doubt be accomplished along these lines if systematic experiments are undertaken by the State experiment station.

IRRIGATION FROM WELLS.

WELLS.

Irrigation can be accomplished with water from flowing wells and with water pumped from nonflowing wells. Where flowing wells are used the expenditure for the wells is practically the only item of cost that is chargeable to the water supply; where pumped wells are used the cost of the water includes not only the expenditure for the wells but also the cost of pumps, engines or other source of power, and other necessary equipment, together with the operating expenses, which include fuel, lubricating oil, attendance, and repairs. However, in most valleys similar to Big Smoky Valley that have been thoroughly tested, flowing water can be obtained only in restricted areas, often where the soil is poor and where the yield of the wells is relatively small; hence extensive developments are likely to require the installation of pumping plants.

Flowing wells are preferably finished with standard screw casing, 6 to 8 inches in diameter. Where flows are not expected the double stovepipe casing is adequate and somewhat less expensive and can be used in sizes ranging in diameter from 8 to 12 inches. The depths to which it is advisable to sink irrigation wells differ from place to place and range from less than 100 feet to several hundred feet. In some places a given quantity of water is obtained at the lowest cost by sinking one rather deep well; in others the same quantity is obtained at the lowest cost by sinking two or more shallow wells. If, however, two or more wells are sunk in the same locality they should, for the sake of economy in operation, be connected, if practicable, with the same pump. Great pains should be taken to develop the largest possible yield from every well by having the casing perforated at every satisfactory water-bearing bed with as many and as large perforations as is practicable, and by cleaning the well thoroughly by heavy pumping in order to remove the fine sediments and to produce a gravel strainer around the casing. Large yields not only keep down the cost for well construction per unit of water developed, but they also, by diminishing the drawdown, keep at a minimum the cost of lifting the water.

PUMPS.

Horizontal centrifugal pumps are in general the best pumps for lifting irrigation supplies from wells in areas where the water table is not far below the surface. As only shallow-water areas are at present to be considered for reclamation by means of well water these pumps are recommended for use in Big Smoky Valley. They should be set in pits just above the high-water level and should draw from the wells by suction. If a pump is not supplied with this manner of installation by the well from which it draws, additional wells should be sunk and fitted with suction pipes that connect with the pump. The yield should, if possible, be determined by an experimental plant before the permanent outfit is bought and installed. At least 100 gallons a minute should be obtained from a well if a plant is to be fairly economical. A single well yielding 100 gallons a minute can be pumped with a small centrifugal pump for the irrigation of 10 to 15 acres, but the cost per acre-foot of water will be less if several such wells are sunk about 50 feet apart, and all are drawn upon by a single pump of larger capacity. Of course if each of a group of 5 wells yields 100 gallons a minute when pumped alone the total yield of all pumped simultaneously will, on account of mutual interference, be considerably less than 500 gallons a minute. In some parts of the valley several hundred gallons a minute can probably be obtained from a single properly constructed well.

The cost of pumping water depends largely on the efficiency of the pump and other machinery, and the efficiency depends on numerous mechanical details which are better understood by the mechanic than by the farmer but must be mastered by every farmer who hopes to make a success of pumping for irrigation. They are subjects of general application, which can not be adequately discussed in this paper but which are admirably treated in a booklet by Charles A. Norcross, entitled "Irrigation pumping in Nevada,"[1] and are treated also in various phases in the Government publications listed below. No one should undertake pumping for irrigation in Big Smoky Valley without first carefully reading the bulletin by Mr. Norcross. Some of the Government reports listed below are more or less out of date, owing to improvements made in pumping machinery since they were published. Books issued by private publishing houses and the catalogues of firms that manufacture pumping machinery and engines also contain much valuable information and advice on this subject. Most of the manufacturing firms employ engineers or expert mechanics who will assist farmers in planning installations suited to their particular needs.

Reports published by the United States Geological Survey on pumping appliances.[2]

Wilson, H. M., Pumping for irrigation: Water-Supply Paper 1, 1896.
Murphy, E. C., Windmills for irrigation: Water-Supply Paper 8, 1897.
Hood, O. P., New tests of certain pumps and water lifts used in irrigation: Water-Supply Paper 14, 1898.
Perry, T. O. Experiments with windmills: Water-Supply Paper 20, 1899.
Barbour, E. H., Wells and windmills in Nebraska: Water-Supply Paper 29, 1899.
Murphy, E. C., The windmill: Its efficiency and economic use, Part I: Water-Supply Paper 41, 1901.

[1] Norcross, C. A., Nevada Bur. Industry, Agr., and Irr. Bull. 8, 1913.

[2] The older reports are largely out of date. Nos. 1, 8, 14, 20, 29, 41, and 42 are out of stock. Most of the rest are no longer available for free distribution but can be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

Murphy, E. C., The windmill: Its efficiency and economic use, Part II: Water-Supply Paper 42, 1901.

Slichter, C. S., Field measurements of the rate of movement of underground waters: Water-Supply Paper 140, 1905.

Slichter, C. S., Observations on the ground waters of Rio Grande valley: Water-Supply Paper 141, 1905.

Slichter, C. S., The underflow in Arkansas Valley in western Kansas: Water-Supply Paper 153, 1906.

Slichter, C. S., The underflow of the South Platte Valley: Water-Supply Paper 184, 1906.

Meinzer, O. E., Kelton, F. C., and Forbes, R. H., Geology and water resources of Sulphur Spring Valley, Ariz.: Water-Supply Paper 320, 1913. Also published as a bulletin of the Arizona Agricultural Experiment Station.

Bryan, Kirk, Ground water for irrigation in Sacramento Valley, Cal.: Water-Supply Paper 375, pp. 1–49, 1915.

Mendenhall, W. C., Dole, R. B., and Stabler, Herman, Ground water in San Joaquin Valley, Cal.: Water-Supply Paper 398, 1916.

Reports published by the United States Department of Agriculture on pumping appliances.

Mead, Elwood, The relation of irrigation to dry farming: Yearbook for 1905, pp. 423–438.

Le Conte, J. N., and Tait, C. E., Mechanical tests of pumping plants in California: Bull. 181, 1907.

Gregory, W. B., The selection and installation of machinery for small pumping plants: Cir. 101, 1910.

Fuller, P. E., The use of windmills in irrigation in the semiarid West: Farmers' Bull. 394, 1910.

POWER.

The cost of the power is usually the largest single item in the total cost of pumped well water. With a given efficiency the power necessary to pump an acre-foot of water is directly proportional to the height that the water is lifted. When the pump is operated the water surface in the well is drawn down from its normal level to some lower level, where it usually remains approximately stationary while the pump is running; but when the pump is stopped the water in the well returns about to its normal level. The total lift is the distance from the water level while the pump is in operation to the level of the outlet of the discharge pipe; that is, it is the depth to water table plus the drawdown. If the depth to the water table is 25 feet and the drawdown with a certain rate of pumping is 15 feet the total lift is 40 feet.

Possible sources of power that may be considered for irrigation pumping in Big Smoky Valley are (1) electric current from commercial lines, (2) distillate used in small internal-combustion engines installed at the individual pumping plants, (3) electric current produced by a central power plant using low-grade distillate or other fuel shipped into the valley, (4) electric current produced by a power plant at the coal mines near Blair Junction, and (5) electric current produced from local water power.

The line of the Nevada-California Power Co. crosses the area in the lower valley in which depth to water is less than 50 feet and runs to Round Mountain, which is less than 5 miles from the similar area in the upper valley, but an extension of many miles would be required to bring the current to the northern part of the shallow-water area of the upper valley. (Pls. I and II.) According to the schedule of rates for industrial power effective March 5, 1914, in the region in which Big Smoky Valley is situated the charge for electric current is 3¼ cents per kilowatt-hour if less than 1,000 kilowatt-hours are used in a month and, according to a sliding scale, is somewhat lower if more current is used. The cost of electric power at 3¼ cents per kilowatt-hour in a plant with an efficiency of 40 per cent is shown for various lifts in the following table:

Cost of electric current for pumping at 3¼ cents per kilowatt-hour with 40 per cent efficiency.

Pumping lift (feet).	Cost for 1 acre-foot of water.	Annual cost for 1 acre, assuming depth of irrigation of 2½ feet.
10	$0.80	$2.00
20	1.60	4.00
30	2.40	6.00
40	3.20	8.00
50	4.00	10.00

The most practical source of power during at least the experimental stage of pumping consists of internal combustion engines using distillate and installed at the pumping units. The installations should be approximately as shown in figure 10. A shelter should be made for the engine and well and they should be protected from floods. With distillate costing 15 cents per gallon, with an engine developing 1 horsepower-hour on one-seventh gallon, and with a pump and drive having 35 per cent efficiency, the cost for fuel is nearly the same as the cost for electric current shown in the above table.[1] Recently much progress has been made in adapting small internal combustion engines to the use of low-grade distillates, which are much cheaper than gasoline or other high-grade distillate.[2]

The Coaldale coal deposits, a few miles southwest of Blair Junction, have been described by J. H. Hance,[3] of the United States Geological Survey, who makes the following statement:

The analyses show that the coal has a high heat value and is bituminous, but this desirable feature is partly offset by a high percentage of ash-making constituents.

[1] Norcross, C. A., Irrigation pumping in Nevada: Nevada Bur. Industry, Agr., and Irr. Bull. 8, p. 37, 1913.

[2] Smith, G. E. P., Oil engines for pump irrigation: Arizona Agr. Exper. Sta. Bull. 74, 1915.

[3] Hance, J. H., The Coaldale coal field, Esmeralda County, Nev.: U. S. Geol. Survey Bull. 531, p. 322, 1913.

The coal keeps well, slacks very little, and may meet an economical and efficient use in the gas producer. By using it as a gas coal, a power plant might be established at the mines, and the neighboring towns and camps supplied with electric power more cheaply than under present conditions. However, it probably will not bear transportation charges, such as prevail in this State, and can scarcely have extensive use as a domestic fuel.

No power plant should, however, be constructed until irrigation with ground water has passed the experimental stage and a supply large enough to justify the necessary expenditure has been assured.

The streams that discharge into the upper valley have steep slopes but carry little water, especially in late summer. The cost

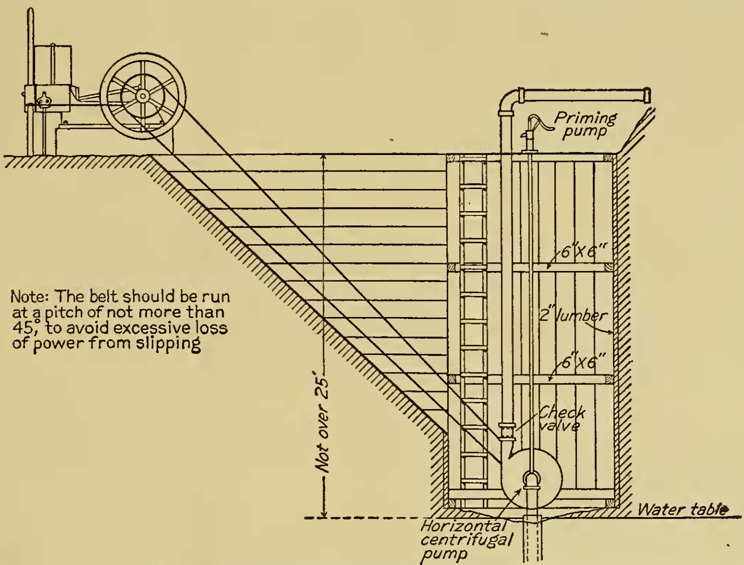


FIGURE 10.—Pumping plant, consisting of a horizontal centrifugal pump driven by an internal combustion engine. After Norcross.

of developing water power from these streams for pumping would probably be prohibitive, but the matter is worthy of investigation. According to current-meter measurements made October 1, 1914, Kingston Creek discharged 6.68 and 7.21 second-feet at two points $3\frac{1}{2}$ miles apart and differing in elevation, according to aneroid determination, not less than 800 feet. During most of the irrigation season the flow is no doubt considerably greater. With an over-all efficiency of $33\frac{1}{3}$ per cent, the power from $7\frac{1}{2}$ second-feet of water falling 800 feet would lift 50 second-feet of well water from a depth of 40 feet. At $3,000 per second-foot, the value of this quantity of water would be $150,000.

COST.

The most uncertain item in the initial cost of a pumping plant is the cost of the wells, the uncertainty in this item being due to the large local variations in the depth and yield of water-bearing beds and the impossibility of predicting the depth and yield accurately. If a well 100 feet deep yields 450 gallons a minute and the drilling and casing cost $2 a foot the cost for this item is only $200 a second-foot; but if a well 200 feet deep yields only 100 gallons a minute the cost, at the same rate for drilling and casing, is $1,800 a second-foot.

If the cost of a pumping plant with one second-foot capacity is $1,200, including wells, pump, engine, and accessories, the interest on the investment at 7 per cent amounts to $84 a year, and the depreciation and repairs reckoned at 10 per cent of the initial cost, amount to $120 a year, making the annual charge for interest, depreciation, and repairs $204. If the plant is operated an average of 12 hours a day for 100 days it will yield 100 acre-feet during the irrigation season. The charge for interest, depreciation, and repairs will therefore on these assumptions be $2.04 per acre-foot of water. This charge must be added to the cost of operation in order to ascertain the total cost of the water.

If the cost for power is as shown in the table on page 134 and the total lift is 40 feet, the cost per acre-foot will be $3.20 plus $2.04, or a total of $5.24, exclusive of labor, lubricating oil, taxes, and the conducting and applying of the water to the fields. This is the cost of the water delivered by the pump and does not take account of any loss in storage or distribution. On the above assumptions, disregarding loss, the annual cost of power, interest, depreciation, and repairs will amount to $13.10 per acre, if 2½ feet of water are applied during the irrigation season.

If there is poor success with the wells, if the lift is higher than 40 feet, if fuel costing more than 15 cents a gallon is used, if the installation is poor or the operation of the pump and engine is unskillful, if the plant is in operation less of the time or breakdowns are frequent, or if more water is required per acre, the cost per acre may be higher than calculated above. If there is very good success with the wells, if the lift is less than 40 feet, if the cost of electric current is less than 3¼ cents a kilowatt-hour, or the cost of distillate less than 15 cents a gallon, if the efficiency of the plant is higher than assumed, or if by good methods of irrigation and cultivation or the wise selection of crops the duty of the water is increased, the cost per acre may be lower than calculated above.

At present pumping for irrigation is probably practicable only (1) for raising high-priced crops or (2) for raising ordinary crops where conditions are exceptionally favorable. The principal favorable conditions referred to are (1) soil that is not injuriously alkaline, sandy, or gravelly, (2) small depth to the water table (not much more than 10 feet), and (3) water-bearing beds at moderate depths that will yield freely.

The following table gives the estimated costs of the water thus far obtained from flowing wells, the cost of drilling and casing being calculated at the same rate as in the Jones wells (p. 111), although the actual cost for some of the wells was greater.

Estimated cost of irrigation water developed from flowing wells in Big Smoky Valley.

Owner.	Depth of well.	Cost of well.	Yield—			Cost per second-foot.	Cost per acre-foot.[a]
			Per minute.	Second-feet.	Per season of 150 days.		
	Feet.		*Gallons.*		*Acre-feet.*		
Fred Jones	127	$221.10	120	0.267	79.4	$225	$0.47
Do	68	112.20	30	.067	19.8	1,675	.96
A. B. Millett	101	167.00	40	.089	26.5	1,870	1.07
Ed Turner	90	148.50	30	.067	19.7	3,200	1.84
Do	40	66.00					
Frank Gendron	133 (?)	219.45(?)	10 (?)	.022 (?)	6.6 (?)	9,975 (?)	5.65 (?)

[a] Interest at 7 per cent and depreciation at 10 per cent.

The estimate of 10 per cent a year for depreciation in pumping plants and flowing wells is arbitrary. The depreciation will probably be as great in flowing wells as in pumping plants but it will involve different factors. It will not include the wear and tear of pumps and engines but it will include the gradual diminution in yield that characterizes many flowing wells, especially where there is much development.

The above table shows that in the areas where flows of any consequence can be obtained the cost of artesian water is much less than the cost of pumped water. Wells can profitably be sunk to obtain water for irrigation in all such areas even though the soil may contain undesirable amounts of alkali, as is generally true where flows are obtained. However, the satisfactory flowing-well areas will no doubt be found to be small and easily overdeveloped, and the reclamation of any considerable amount of land will probably be possible only by pumping.

FAVORABLE AREAS.

The areas best adapted for the development of ground water for irrigation in the upper valley are shown as nearly as is possible in Plate I. The tracts best adapted for pumping lie within the area that is bounded on the one side by the area of alkali soil and on the other by the lines of 50 feet depth to water.

Beginning in the axial part of the valley east of Spencer's ranch, the principal tract widens southward till it reaches the alkali area, thence it extends as a broad belt along the northwest flank of the alkali area to the latitude of Schmidtlein's ranch, thence as a narrower belt on the west side of the alkali area nearly to Millett, where it becomes very narrow. From the Jones ranch it extends as a belt of moderate width nearly to the Logan ranch, where it again becomes very narrow. A short distance south of Moore's ranch it expands into a belt of moderate width and thence extends to Wood's ranch and southward for at least several miles along the axis of the valley. It also includes a belt on the east side of the alkali area that extends northward to the Crowell ranch. A few small tracts may be found in other localities on the east side. The areas most promising for irrigation with artesian water are the lower parts of the tract just outlined and small parts of the alkali area, especially along its west margin.

The area best adapted to pumping in the lower valley is in the vicinity of Millers and is shown on Plate II as bounded on the southwest by the alkali area and on its other three sides by the line representing a depth of 50 feet to water. If any flowing wells of value for irrigation are obtained in the lower valley they will probably be in the lower part of this area, but the prospects even there are not especially good. The rest of the lower valley is practically without prospects.

CONCLUSIONS.

1. Several tens of thousands of acre-feet of ground water is probably contributed each year to the underground reservoirs of Big Smoky Valley. A part of this supply could be recovered for irrigation.

2. Most of this water is in the upper valley, but a part is in the vicinity of Millers in the lower valley.

3. The water is in general of satisfactory quality for irrigation. Nearly all the poor water is in the southwestern part of the lower valley, where prospects for irrigation are practically lacking.

4. A small part of the ground-water supply can be recovered by flowing wells, but full use of the supply is possible only by pumping.

5. Throughout the extensive areas in which the depth to the water table does not exceed 10 feet the soil contains injurious amounts of alkali.

6. In the areas in which the depth to the water table ranges between 10 and 50 feet there is enough good soil to utilize all the available ground water. These areas, however, also contain considerable gravelly, sandy, and alkaline soil.

7. There are some prospects of obtaining flowing wells wherever the water table is near the surface, but the prospects are best on the west side of the upper valley.

8. The flowing-well areas will be found to lie chiefly within the areas of alkali soil, but they may extend into adjacent areas of good soil.

9. Full utilization of the ground-water supply for irrigation will not be economically practicable until cheaper power or more valuable crops can be introduced than are now in sight.

10. Developments that may be practicable at present are (*a*) the sinking of flowing wells of moderate depths in the restricted areas where fairly copious flows can be obtained and the soil is not irreclaimably alkaline; (*b*) the sinking of nonflowing wells and the installation of pumping plants for raising high-priced crops or for raising ordinary crops in localities where the conditions are exceptionally favorable or where the well water can be used to supplement surface-water supplies.

11. The raising of high-priced crops is practicable to only a small extent. Vegetables and small fruits could, it is believed, be profitably raised in the vicinity of Millers to supply Tonopah, Goldfield, and other local markets.

12. The principal favorable conditions necessary to make pumping profitable for raising ordinary crops, such as alfalfa, are soil that is not injuriously alkaline, sandy, or gravelly; small depths to the water table (not much more than 10 feet); and water-bearing beds that lie at moderate depths and will yield freely.

13. Ground-water developments along some of the lines indicated could be made by the ranchers now in the valley, who could afford to take some chances and who could advantageously use the well water to supplement their fluctuating supplies of surface water.

14. A small number of new settlers could probably make a livelihood by irrigating with ground water in Big Smoky Valley provided they had a few thousand dollars each to make the necessary developments and used good judgment as to location.

15. Existing conditions do not warrant the influx of a large number of settlers nor of any without means to sink wells and make other necessary improvements. Ill-advised immigration will inevitably lead to disappointment and suffering.

CLAYTON VALLEY.

LOCATION AND DEVELOPMENTS.

Clayton Valley comprises an area of about 570 square miles in Esmeralda County, Nev., between the 117th and 118th meridians, and just south of the 38th parallel. It is bounded on the north by the southwestern part of the basin of Big Smoky Valley, on the east by the basin of Alkali Spring Valley, in which Goldfield is situated, and by another small basin, and on the west and south by the basin of Fish Lake Valley. It extends within about 7 miles of the California State line. Its principal settlement is Blair, which is connected by the Silver Peak Railroad with the Goldfield & Tonopah Railroad at Blair Junction. At Blair is a 120-stamp mill, in which the metals, chiefly gold, are removed from ores mined in the vicinity. The site of the old mining town of Silver Peak is 3 miles south of Blair. (See fig. 1 and Pl. XIII.)

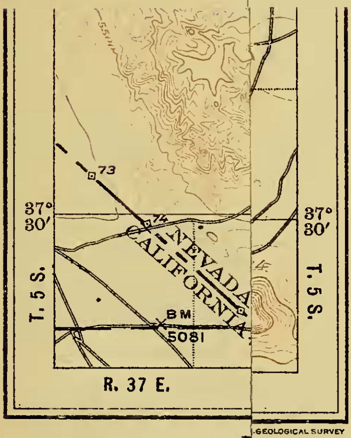
PHYSIOGRAPHY.

The basin includes a mountainous border, a playa, and an alluvial slope that extends like a huge hopper from the mountains to the playa.

A crescentic belt of the Silver Peak Range, more than 30 miles long, nearly 5 miles in average width, and in a number of places reaching altitudes of more than 9,000 feet above sea level, discharges its water and detritus into the valley from the west and south. A considerable area, culminating in Montezuma Mountain, 8,426 feet above sea level, discharges into the valley from the east, and an area culminating in Lone Mountain discharges, from altitudes reaching up to 8,500 feet above sea level, into the valley from the northeast, chiefly through Paymaster Canyon. The valley is separated from Alkali Spring Valley only by a narrow rock divide and from Big Smoky Valley by a broader but lower divide covered in part by detritus.

The alluvial slope is broadest on the south and southwest, whence the largest contributions of detritus are received. Apparently little detritus reaches the valley from Paymaster Canyon. The even surfaces of the alluvial slopes are interrupted by numerous rock buttes and by gravelly ridges, which are probably outcrops of Tertiary or early Pleistocene deposits, as well as by sand dunes, some of which are large.

of about 50 feet to the water table

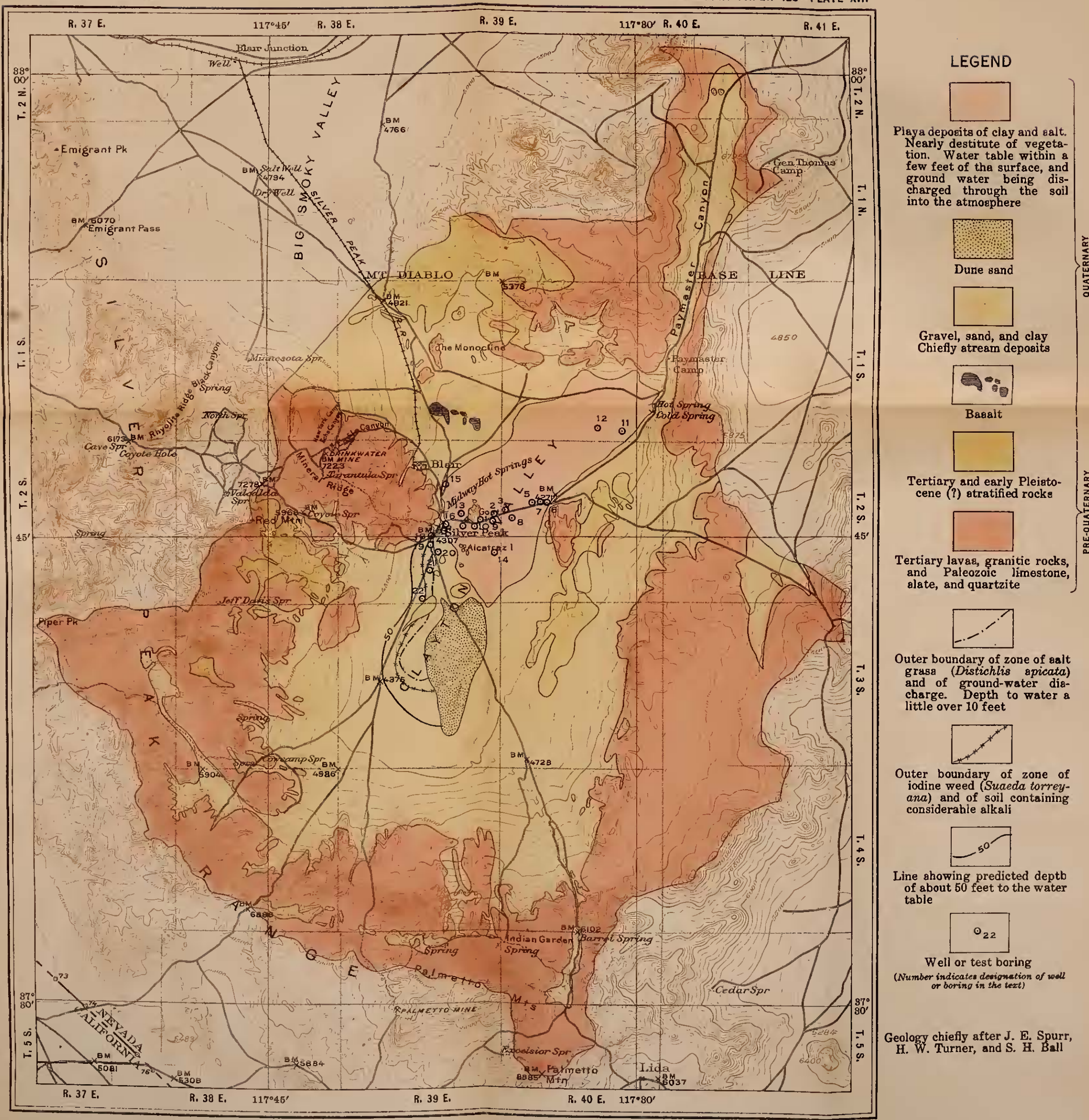


⊙22

Well or test boring

(Number indicates designation of well or boring in the text)

Geology chiefly after J. E. Spurr, H. W. Turner, and S. H. Ball



ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY

MAP OF THE DRAINAGE BASIN OF CLAYTON VALLEY, NEVADA

Showing geology, vegetation, and ground-water conditions

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

2 1 0 2 4 6 8 10 Miles

Contour interval 100 feet.

Datum is mean sea level.

1917

The playa is about 10 miles long, 3 miles wide, and 32 square miles in area. At a bench mark on the southeast side the altitude is 4,271 feet above sea level, or nearly a mile below the highest peaks at the margin of the basin. The playa lies in the northern part of the basin, having been crowded away from the large mountains that yield much detritus toward the low divides that yield little. It is flat and barren, and quite distinct from the tributary alluvial slopes, both in topography and in the character of the underlying sediments. It is largely covered with salt, except when it is temporarily submerged by a thin sheet of water. A striking feature of the playa is a group of rock buttes that bear a compelling resemblance to islands in a sea of water. The largest, which is called Goat "Island," doubtless after the island of that name in San Francisco Bay, covers nearly one-fourth square mile, and rises about 350 feet above the flat. Alcatraz "Island," a smaller butte, is shown in Plate XIV, taken from an excellent photograph by C. D. Walcott.

GEOLOGY.

The pre-Quaternary rock systems are, with certain exceptions, the same as those exposed in the basin of Big Smoky Valley (pp. 51–56). They consist of (1) Paleozoic limestone, slate, and some impure quartzite, (2) granitic rocks intrusive into the Paleozoic strata, (3) Tertiary lavas, and (4) Tertiary sedimentary beds. Almost no field work was done on the bedrocks, the geology shown on the map (Pl. XIII) being taken with slight modifications from the maps of Spurr[1] and Ball,[2] which, however, are not wholly in accord. The Tertiary sedimentary rocks are shown separately on the map because of their probable influence on the salt content of the Quaternary deposits and the water they contain. The large area of Tertiary rocks on the east side of the valley was mapped by Ball as Siebert lake beds, but the other outcrops belong chiefly or wholly to the Esmeralda formation, which borders the southwestern part of the Big Smoky Valley (pp. 53–56).

The Quaternary lava shown on the map as lying 2 miles northeast of Blair includes a basaltic cinder cone whose east side disappeared, allowing the lava to flow out in that direction and leaving a deep crater with a horseshoe rim. The weathering and gullying that have taken place show that this cone is older than many of the cinder cones of the West and places it without much question in the Pleistocene rather than the Recent epoch.

The Quaternary sedimentary beds consist of three distinct formations: (1) The gravelly stream deposits, which on account of the

---

[1] Spurr, J. E., Ore deposits of the Silver Peak quadrangle, Nev.: U. S. Geol. Survey Prof. Paper 55, 1906.

[2] Ball, S. H., A geologic reconnaissance in southwestern Nevada and eastern California: U. S. Geol. Survey Bull. 308, 1907.

"desert pavements" at the surface appear to be more gravelly than they really are; (2) the dune sands, which are large shifting masses in the area south of the playa; and (3) the playa deposits, the character of which has been shown by an interesting series of borings (Nos. 1 to 14 in Pl. XIII) made by Dole.[1] The Quaternary fill is probably underlain in most places at no very great depths by Tertiary sedimentary beds and is probably derived in large part from the erosion of these beds after they were deformed, as is suggested by Spurr. Tertiary sediments doubtless once rested on the older rocks in the lower parts of the mountains in places from which they have been removed by erosion.

The logs of the 14 borings made by Dole, the deepest of which extended 55 feet below the surface, are summarized by him as follows:[2]

Brown mud 5 to 20 feet deep forms the upper layer of the marsh. Because of the intense heat the surface of this mud is usually baked dry and hard enough to support the weight of teams. Small scattered tracts have become dry enough to be pulverulent for a depth of 1 to 2 feet, but over the greater part of the playa 4-foot holes are sufficiently deep to strike soft mud. As this layer is composed of very small particles and contains a large proportion of clay, the strong salt waters in it circulate very slowly. The mud contains a great quantity of salt, though the crystals are small. The brines obtained from it are very strong, and the surface is generally covered to a depth of one-eighth to one-quarter of an inch by a white crust of salt that has crystallized from solutions drawn to the surface by capillarity.

The upper mud along the west shore of the playa, particularly west of the "islands," contains nodules of calcareous tufa, which apparently have been formed by deposition of calcium carbonate from the hard waters percolating into the marsh from Mineral Ridge. The record of boring No. 13 shows that clay under the mud west of the "islands" is underlain by white tufaceous materials, but no salt occurs at a depth less than 41 feet except that in the abundant weak brines.

Well-defined beds of clay containing crystals of gypsum were penetrated east of Goat "Island" in borings Nos. 3 and 6, and these are underlain by beds of crystallized salt containing saturated brine. Very stiff black, blue, red, gray, and brown clays underlie the beds of salt or mixed salt and clay in boring No. 3 to a depth of 55 feet, but in boring No. 6 the clays are interrupted by a stratum of gypsum-bearing clay below the salt and a 6-inch stratum of salt at 47 feet below which clay was again encountered.

Except a shallow bed of light-gray calcareous material at 16 feet nothing but clay containing weak brine was struck to a depth of 40 feet in boring No. 14, at the south end of the playa.

Borings Nos. 11 and 12 indicate that the beds of salt in the northeastern part of the marsh are denser than those farther south. The mud is underlain by clay and that in turn by crystallized salt so hard that it has to be drilled. A much harder formation, probably calcareous tufa, was struck below the salt in both borings at a depth of about 36 feet.

The data afforded by the six deeper borings lead to the conclusion that the northeastern two-thirds of the playa is underlain at a depth of about 20 feet by beds 5 to 15 feet thick of crystallized salt mixed with more or less clay. It is doubtful

[1] Dole, R. B., Exploration of salines in Silver Peak Marsh, Nev.: U. S. Geol. Survey Bull. 530, pp. 330–345, 1913.

[2] Idem, pp. 338–340.

ALCATRAZ "ISLAND," IN CLAYTON VALLEY.

A hill of Cambrian limestone nearly submerged by playa deposits. Photograph by C. D. Walcott.

if deposits of so great extent occur west of Goat "Island" or south of Alcatraz "Island." Besides these beds practically all other strata to a depth of 50 feet contain appreciable proportions of salt that readily dissolves in water percolating through them.

The remarkable feature of this playa is the large amount of salt that it contains. As suggested by Dole, most of this salt was probably derived by leaching from the Tertiary strata, which, according to Spurr, are part of the deposits of interior lakes and would therefore probably contain saline materials. The salt deposits underlying the present playa are, according to this explanation, reconcentrations of the salt that was contained in the basin at the beginning of the Quaternary period. The relatively large amounts of chlorine suggest that part of the salt may have been derived from sea water (p. 146).

No physiographic evidence of the existence of an ancient lake has been found, but the thick beds of buried salt can not well be accounted for except on the assumption that they are desiccation products of ancient salt lakes. There is no difficulty in assuming that in the humid epoch, when large lakes existed in Big Smoky Valley, the water supply of Clayton Valley was sufficient to form at least a small permanent lake. Dole suggested the possibility of an overflow into Clayton Valley from a large lake in the lower Big Smoky Valley, but the highest beaches observed in the lower Big Smoky Valley are less than 4,800 feet above sea level, or considerably below the lowest point of the divide, and no indications of overflow were found. Moreover, in view of the fact that the upper valley contained a lake of its own and shows no signs of overflow, it is improbable that a lake would have formed in the lower valley large enough to have reached a level necessary for discharge into Clayton Valley.

OCCURRENCE AND LEVEL OF GROUND WATER.

On the map (Pl. XIII) Nos. 1 to 14 represent borings made by Dole, all of which yielded brine. No. 15 represents a large dug well at the edge of the playa just below Blair. It formerly furnished the water supply for the mill at Blair but was abandoned on account of the saltness of the water. No. 16 represents a large excavation which receives water from springs that issue from limestone at the edge of the playa and are reported to yield 350,000 gallons a day. These springs furnish the supply for Blair through a pipe line. No. 17 represents a well at the transformer station of the Nevada-California Power Co. No. 18 represents a shallow well at the ranch of Fred Meginnes which yields a potable supply and is more or less typical of a group of shallow wells finding water just above bedrock.

Nos. 19 to 22 represent abandoned dug wells. Hot and cold springs yielding salty water issue along the edge of the playa between Blair and Silver Peak and at the northeast end of the playa. The data as to the depths and water levels of some of the borings and wells are given in the following table, the data for Nos. 1 to 14 being for May or June, 1912, and those for Nos. 15 to 22 for October, 1913.

Depths and water levels of test borings and wells in Clayton Valley, Nev.

No.	Depth of hole.	Depth at which water was struck.	Depth at which water stood in completed hole.	No.	Depth of hole.	Depth at which water was struck.	Depth at which water stood in completed hole.
	Feet.	*Feet.*	*Feet.*		*Feet.*	*Feet.*	*Feet.*
1	29.0	....	2.0	11	38.3	22.5	6.5
2	14.0	4.0	2.5	12	36.0	8.5	1.8
3	55.0	4.0	2.3	13	41.0	4.0	1.0
4	11.5	3.0	2.5	14	40.0	8.0	4.0
5	12.5	2.0	....	15	38.0	....	4.5
6	52.0	21.0	....	19	....	....	12.5
7	17.0	4.0	2.5	20	....	....	11.0
8	13.0	(a)	....	21	28.0	....	23.0
9	13.0	(a)	....	22	40.0	....	32.0
10	8.0	3.0	....				

[a] No water.

The data afforded by these borings and the character of the vegetation and the soil show that the valley fill acts as a reservoir, just as it does in Big Smoky Valley, and that this reservoir is filled with water practically to the level of the playa. The shallow-water area is closely confined to the playa except on the southwest, where it extends along the axis of the valley several miles beyond the end of the playa, as is shown in Plate XIII. In this part of the valley the average width of the zone in which the depth to the water table is between 10 and 50 feet is believed to be about a mile.

SOURCE AND DISCHARGE OF GROUND WATER.

The climate of Clayton Valley is distinctly arid, and is comparable to that of the lower part of the lower Big Smoky Valley. (See p. 67.) The tributary mountain areas also appear arid although they doubtless receive considerably more precipitation than the valley. The Silver Peak Range contains numerous small springs, but the water supply is insufficient to maintain any permanent streams. Nevertheless the total quantity of water annually precipitated on the basin is large, and part of it finds its way into the underground reservoir. There is evidence that water is also received underground from Alkali Spring Valley and possibly contributions are received from other adjacent basins, all of which are considerably higher than the playa of Clayton Valley.

The playa covers about 32 square miles, but the total area with ground-water discharge is not less than 40 square miles, or 25,000 acres. South of the playa there is an area of salt grass, indicating shallow water, over several square miles. Salt grass is found even where the depth to the water table slightly exceeds 10 feet, and at well No. 21 the capillary rise is 11.5 feet. The denseness of the clay that underlies most of the playa and the small amount of salt concentrated at the surface indicate that the rate of ground-water evaporation on the playa is not rapid, but the total discharge from the basin probably amounts to several thousand acre-feet a year.

SOIL AND VEGETATION.

Gravelly soil is found on the upper and middle parts of the alluvial slopes, and it extends to the edge of the playa almost everywhere except on the south side. Gravelly soil also covers the low hills south of Silver Peak that are shown on the map (Pl. XIII) as Tertiary or early Pleistocene deposits. South of the playa the line of 50-foot depth to water west of the dune area roughly marks the inner limit of soil that is too gravelly for agriculture, although there is some very gravelly soil inside and some fairly good loam soil outside of this line. Extremely sandy soil is found in the area shown on the map as covered by dune sands and in some adjacent areas that lack dune topography.

The playa is destitute of vegetation except near the margin, where scattered samphire (*Spirostachys occidentalis*) and salt grass (*Distichlis spicata*) maintain an existence. Around the playa, where the depth to the water table does not greatly exceed 10 feet there is a zone of salt grass, with some rabbit brush (*Chrysothamnus graveolens*), samphire, and iodine weed (*Suaeda torreyana*). This zone is narrow except south of the playa, where it expands into an area of considerable size, indicated on the map. Within the salt-grass zone there is doubtless too much alkali, chiefly sodium chloride, for successful agriculture. Outside of this zone in the part of the valley south of the playa there is a zone in which iodine weed, big greasewood (*Sarcobatus vermiculatus*), the tall shrubby salt bush (*Atriplex torreyi*) and the common spiny salt bush (*Atriplex confertifolia*) are associated (Pl. XIII). The soil in this zone contains some alkali, but not as much as the salt-grass zone, the amount of alkali apparently differing from place to place. Outward from this area, in the direction of the mountains, first the iodine weed and then the big greasewood and *Atriplex torreyi* disappear or become scarce, while the common salt bush (*Atrilex confertifolia*), often called shadscale, becomes dominant. Over the extensive gravelly and arid tracts of the middle and upper parts of the alluvial slopes this salt bush maintains its supremacy.

It is evident from the above discussion that most of the soil of Clayton Valley is too gravelly, sandy, or alkaline for cultivation, but there is a small area, lying chiefly between the 50-foot line and the salt-grass boundary, that can apparently be classed as agricultural soil. Several analyses of soils from this valley are given in the table on page 161.

QUALITY OF WATER.

All the ground waters of Clayton Valley that were examined are highly mineralized. Those beneath the playa are saturated brines. The mountain springs, which were not examined, doubtless contain less mineral matter than the wells and springs in the valley. The best waters are those from the large spring and the wells in the village of Silver Peak, which supply Silver Peak and Blair. Even these waters are, however, highly mineralized, as is shown by the analyses on pages 154 and 157.

Sodium and chlorine are in excess of other mineral constituents. The brines below the playa contain little except sodium chloride and this salt predominates in all waters that have been analyzed (p. 158). The supply from the well of the Nevada-California Power Co., which is the least mineralized water analyzed, contains 548 parts per million of chlorine, and the spring water that is supplied to Blair contains about 800 parts. In well No. 21, where the water table is 23 feet below the surface, the chlorine content is 1,665 parts per million, and in well No. 22, where the water table is 32 feet below the surface, the chlorine content is 1,165 parts.

The water differs from that of Big Smoky Valley in being not of the black alkali type. Instead of containing sodium in excess of chlorine and the sulphate radicle, many of the samples, including the four just mentioned, contain chlorine in excess of sodium and potassium. The large amounts of sodium in the waters of Clayton Valley can be accounted for by ordinary processes of concentration; the excess of chlorine may be due to concentration of sea water in the Tertiary period.

GROUND-WATER PROSPECTS.

Clayton Valley was examined at the time of the Big Smoky Valley investigation partly because of local interest in the feasibility of irrigation with well water. A pumping plant with a 5-horsepower gasoline engine is reported to have been in operation at well No. 22 during two seasons for the irrigation of garden truck. Failure is said to have been due to the work of chipmunks and wind-driven sand and to the large quantities of water required by the gravelly soil. The information available indicates that although water underlies Clayton Valley in considerable quantities it can not be successfully utilized for irrigation because of its saline character and other unfavorable conditions.

ALKALI SPRING VALLEY.

LOCATION AND DEVELOPMENT.

Alkali Spring Valley lies almost entirely in Esmeralda County, Nev., south of Big Smoky Valley and east of Clayton Valley. The drainage basin embraces an area of only 310 square miles but, like the basins of Big Smoky Valley and Clayton Valley, it has no drainage outlet. Goldfield is in the southern part of the basin, and Tonopah is only 3 miles from its north edge. It is crossed by the Tonopah & Goldfield Railroad, which at Goldfield connects with the Las Vegas & Tonopah and the Tonopah & Tidewater lines. In 1913 Goldfield was an important mining and milling center, although not so active as in earlier years. (See p. 13.) Aside from Goldfield there are a few old mining localities in the mountains surrounding the valley, and in the valley itself there are several wells that have been sunk in connection with mining developments. (See Pl. XV.)

PHYSIOGRAPHY.

The mountainous areas tributary to Alkali Spring Valley are low, disconnected, and arid. The highest point is Montezuma Peak, 8,426 feet above sea level. The other peaks are only barren buttes. There are no streams and almost no springs within the mountainous areas.

The valley consists of a funnel-shaped alluvial slope that drains from all directions toward an interior playa, occupying the lowest part of the basin at a level 4,850 feet above the sea. The funnel is, however, not symmetrical, as the slope is about 5 miles wide on the east side, whence most of the detritus is derived, and much narrower and steeper on the west side, along the narrow mountain wall that separates the valley from Clayton Valley. The playa is a clay flat covering about 5 square miles. It is destitute of vegetation over most of its area, but in some parts contains clumps of greasewood or other bushes. Except at its northeast end it is rather definitely separated from the surrounding slope by its flat, barren, clayey surface. No beach ridges or other indications of an ancient lake have been found.

GEOLOGY.

The geology of the basin has been described by Ball [1] and in the vicinity of Goldfield by Ransome.[2] The rocks include (1) Paleozoic limestone, etc., (2) pre-Tertiary granitic rocks, (3) Tertiary sedimentary beds (chiefly the tuffaceous Siebert lake beds), and (4) Tertiary and perhaps Pleistocene lavas.

The valley fill underlying the alluvial slope is of the ordinary detrital character, probably containing less well assorted gravel than the fill of the larger basins. The valley contains no dunes comparable to those in Clayton Valley.

The playa is underlain by homogeneous gray clay or silt-clay, which appears to extend with little or no interruption to a depth of 50 feet, where water is struck, indicating more porous material. In the two drilled wells, 389 feet deep, at the Neptune pumping plant, about one-fourth mile from the southeast edge of the playa (Pl. XV), alternating beds of clay and fine sand were penetrated, the best water-bearing sand being found at 289 feet and lower levels. At 389 feet drilling was stopped by a hard formation, possibly bedrock.

OCCURRENCE AND LEVEL OF GROUND WATER.

The wells that have been sunk in Alkali Spring Valley prove the existence of ground water in the valley fill. (See Pl. XV.) The data in regard to the depths and water levels of these wells are given in the following table:

Wells in Alkali Spring Valley, Nev.

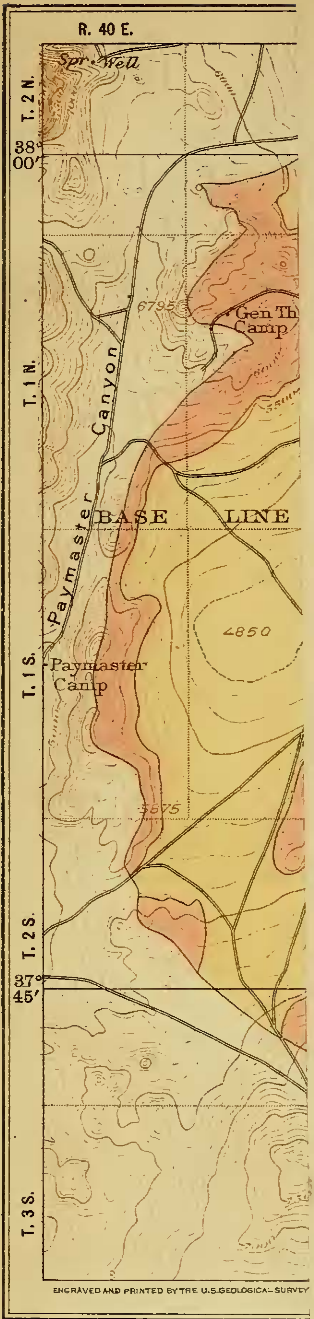
Designation.	Type.	Depth.	Altitude of top of well above sea level.	Depth to water table.	Altitude of water table above sea level.
		Feet.	*Feet.*	*Feet.*	*Feet.*
Gottschalk well	8-inch casing	125–400	4,901	[a] 61	4,840
Klondike well	Dug 4½ by 5½ feet, with tunnel	160	4,970 (?)	[b] 148	4,822 (?)
Ramsay well	Dug, 6-foot diameter		4,994	[c] 221	4,783
Neptune drilled well	10-inch casing to 300 feet +	389	4,850	[d] 40	4,810
Neptune dug well	Dug	50	4,850	47.5	4,803

[a] 65.5 feet below top of casing.
[b] Reported by H. O. Lohr, in charge.
[c] 211.5 feet below U. S. Geol. Survey bench mark.
[d] Reported by C. G. Patrick, manager, Goldfield Consolidated Water Co.

The two drilled wells at the Neptune pumping plant are situated 700 feet apart and are cased with 10-inch pipe, without strainers or perforations, that ends a little more than 300 feet below the surface. According to Mr. C. G. Patrick, manager of the Goldfield Consolidated

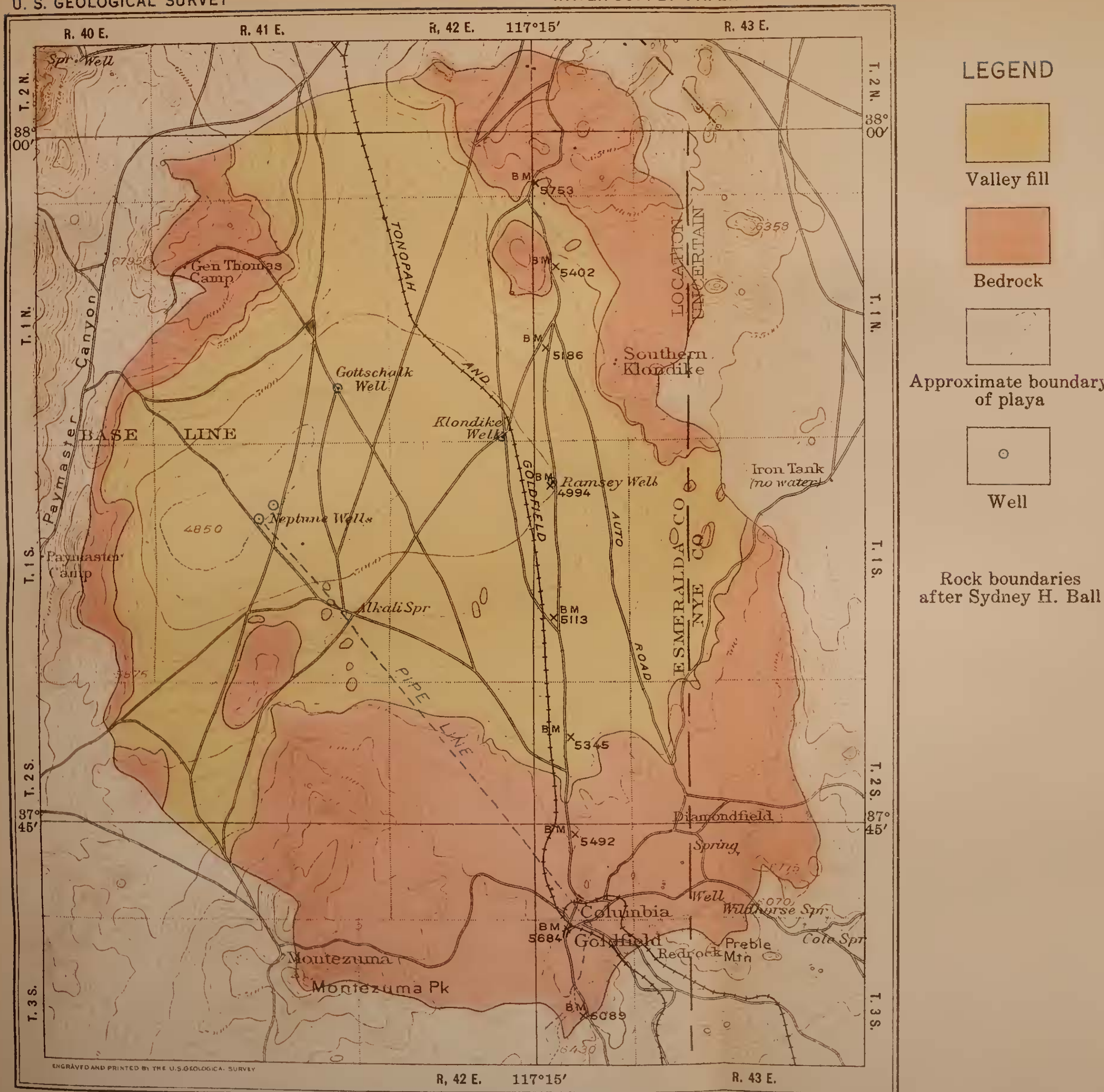
[1] Ball, S. H., A geologic reconnaissance in southwestern Nevada and eastern California: U. S. Geol. Survey Bull. 308, 1907.

[2] Ransome, F. L., Emmons, W. H., and Garrey, G. H., The geology and ore deposits of Goldfield, Nev.: U. S. Geol. Survey Prof. Paper 66, 1909.



MAP OF THE I

2 1



MAP OF THE DRAINAGE BASIN OF ALKALI SPRING VALLEY NEVADA

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

2 1 0 2 4 6 8 10 Miles

Contour interval 100 feet.

Datum is mean sea level.

1917

Water Co., double-acting cylinder pumps were installed in both wells 150 feet below the surface and were operated at 120 gallons per minute each. As much as 120,000 gallons a day has been pumped from one well for at least a month at a time.

The 160-foot dug well at Klondike is used for locomotive supplies. According to Mr. H. O. Lohr, foreman of the pumping plant, this well is usually pumped at the rate of 2,350 gallons an hour, or nearly 40 gallons a minute, which produces a drawdown while the pump is in operation, of about 9 feet. Mr. Lohr further reports that the well has been pumped at about 2,000 gallons an hour for 56 hours continuously, but that from August to November its yield is generally diminished to such an extent that it can be emptied by long continuous pumping.

Alkali Spring is about 5,100 feet above sea level and in 1913 its normal flow was reported as about 55,000 gallons a day. The temperature was said to be about 115° F. An analysis of the water is given on page 154. The spring was not visited, but the following description, given by Sydney H. Ball,[1] is based on field work in 1905:

> Alkali Spring is located 11 miles northwest of Goldfield. The waters originally rose at a number of small seeps, but recently the Combination Mines Co., of Goldfield, drove a tunnel into the gentle slope, concentrating the flow in a single channel. According to Mr. Edgar A. Collins, of this company, about 85,000 gallons of water per day flows from the spring and is pumped to the Combination mill at Goldfield. The water is clear, slightly alkaline in taste, and smells of hydrogen sulphide.
>
> At the mouth of the 40-foot tunnel the temperature of the water is about 120° F., and at the breast it is at least 140° F. The stream flows from residual bowlders and soil of the later rhyolite, and the bowlders are badly decomposed and crumble readily in the hand. One hundred yards north of the pumping station is a low dome of grayish brown travertine, probably an abandoned vent of the spring.

SOURCE AND DISCHARGE OF GROUND WATER.

The mountainous areas that discharge upon the alluvial gravels of Alkali Spring Valley are so small and arid that they furnish comparatively little water, yet they have occasional freshets that undoubtedly make some contributions to the underground reservoir. If 5 per cent of the precipitation in the basin finds its way to the underground reservoir the annual contributions amount to about 5,000 acre-feet.

It seems necessary to assume that if there were no leakage out of the basin the water table would rise until it stood near enough the surface to permit discharge of ground water through the soil and vegetation, as in Clayton Valley and in both basins of Big Smoky Valley, but the conditions in Alkali Spring Valley differ essentially from those in the other valleys. At the Neptune wells, which are on the playa, the water table in October, 1913, stood at a depth of 47½ feet. The playa is flat and smooth and is destitute of vegetation over extensive tracts.

[1] Ball, S. H., A geologic reconnaissance in southwestern Nevada and eastern California: U. S. Geol. Survey Bull. 308, pp. 19, 20, 1907.

In some places, especially near the borders, there are clumps of vegetation including much big greasewood, but no salt grass, samphire, or any other of the familiar indicators of ground water so commonly encountered in the shallow-water areas of Big Smoky Valley and Clayton Valley. Moreover, the soil is dry to an indefinite depth and there is no surface accumulation of alkali, although considerable alkali is disseminated through the playa formation. (See analysis, p. 161.) At all points where the playa and its borders were examined the conditions were found to be similar to those in the vicinity of the Neptune wells. No indications of ground water discharge were observed with the possible exception of the greasewood, which may draw water from a depth as great as 47½ feet.

The water levels revealed by the wells leave much uncertainty as to the shape of the water table and the consequent direction of the underflow. The water stands slightly higher above sea level in the Gottschalk and Klondike wells than in the Neptune wells, indicating a slope of the water table of a few feet per mile and a slow westward movement of the ground water, but in the Ramsey well the water stands lower than in the Klondike well, although there is no apparent means of escape toward the east or southeast.

The most probable explanation of the disposal of at least a part of the ground water in Alkali Spring Valley is that there is leakage through the comparatively thin west wall of the valley into Clayton Valley, which lies much lower, the ground-water level being 530 feet lower under the playa of Clayton Valley than at the Neptune wells, only 6 miles distant. This explanation will also account in part for the great extent of the shallow-water area in Clayton Valley. No estimate can be made of the quantity of ground water available in Alkali Spring Valley, but the pumping that has been done at the Neptune and Klondike wells indicates a substantial supply.

QUALITY OF WATER.

The analyses given on page 157 indicate that the ground water of Alkali Spring Valley belongs to the same general type as that of the northeastern province of lower Big Smoky Valley (see pp. 115–118), for, like that water, it is only moderately mineralized and contains sodium in excess of calcium and magnesium. It is of much better quality than the water of Clayton Valley or that of the southwestern province of lower Big Smoky Valley, but it contains more mineral matter than most of the water of upper Big Smoky Valley.

The water from the Klondike well is of good quality for domestic and boiler use and for irrigation. The water from the Gottschalk well is softer than the Klondike water, but it contains an undesirable amount of sodium and bicarbonate. The water of Alkali Spring is characterized by its large content of sodium and sulphate, which are perceptible to the taste and doubtless have a cathartic effect. This water will readily foam in boilers and will deposit considerable alkali if used for irrigation. (See analysis, p. 154.)

GROUND-WATER PROSPECTS.

The valley fill of Alkali Spring Valley contains a supply of water that is of fairly good quality for domestic and boiler use and for irrigation. Although the quantity of water is not large it is adequate for ordinary domestic, stock, and industrial purposes, and would probably be adequate for a small amount of irrigation. The valley contains considerable good soil, but the depth to the water table is too great to make pumping for irrigation profitable under present conditions except possibly for intensive market gardening.

GOLDFIELD WATER SUPPLY.

The waterworks of Goldfield are owned and operated by the Goldfield Consolidated Water Co. The water is obtained from several sources. The principal supply, known as the Lida supply, comes from several springs 30 miles southwest of Goldfield and near Magruder Mountain, which reaches an altitude of 9,057 feet above sea level. (See fig. 11.) The yield of the springs, especially that of Hyde Spring, which is the largest, fluctuates considerably, being generally greatest in April and May and declining gradually during summer and fall. The increase in the spring is probably produced by the melting of snow on the mountains. Midsummer storms have little effect on the flow of the springs. The total dependable supply in times of low water is reported by Mr. Patrick, the manager, to be 400,000 gallons a day. The Lida system includes 5 pumping plants (see fig. 11) and 47 miles of pipe, ranging from 3 to 9 inches in diameter, the greater part of the main line being 7 inches in diameter. The water is in part conveyed by gravity, but some pumping is required, principally to lift the water from Hyde Spring, which issues at a level much lower than the other springs. The pumping is heaviest while the flow of the springs is least and the draft on the low-level sources is greatest.

The Alkali Spring (see p. 149) and Neptune (see pp. 148–149) supplies are drawn upon only when the Lida supply is inadequate, for the lift is greater and the water is of the poorer quality. The Alkali Spring water is forced through a 5-inch pipe by a triplex pump operated by an electric motor. The water from the Neptune wells is lifted by deep-well cylinder pumps to Alkali Spring.

On January 1, 1913, the distributing system of the Goldfield waterworks comprised 24 miles of pipe, 8 inches to one-half inch in diameter, 44 fire hydrants, and 492 service connections. The total consumption in the fall of 1913 was about 380,000 gallons a day, only about 10,000 gallons of which was metered for domestic consumption, the rest being used at the mines, mills, and railroad yards. The operating and general expenses in 1912 were about $43,000. The water rates ranged from $5.83 per 1,000 gallons for domestic use to 57½ cents per 1,000 gallons for large consumers. It will be noted that owing to the high cost of the water the per capita consumption is very small.

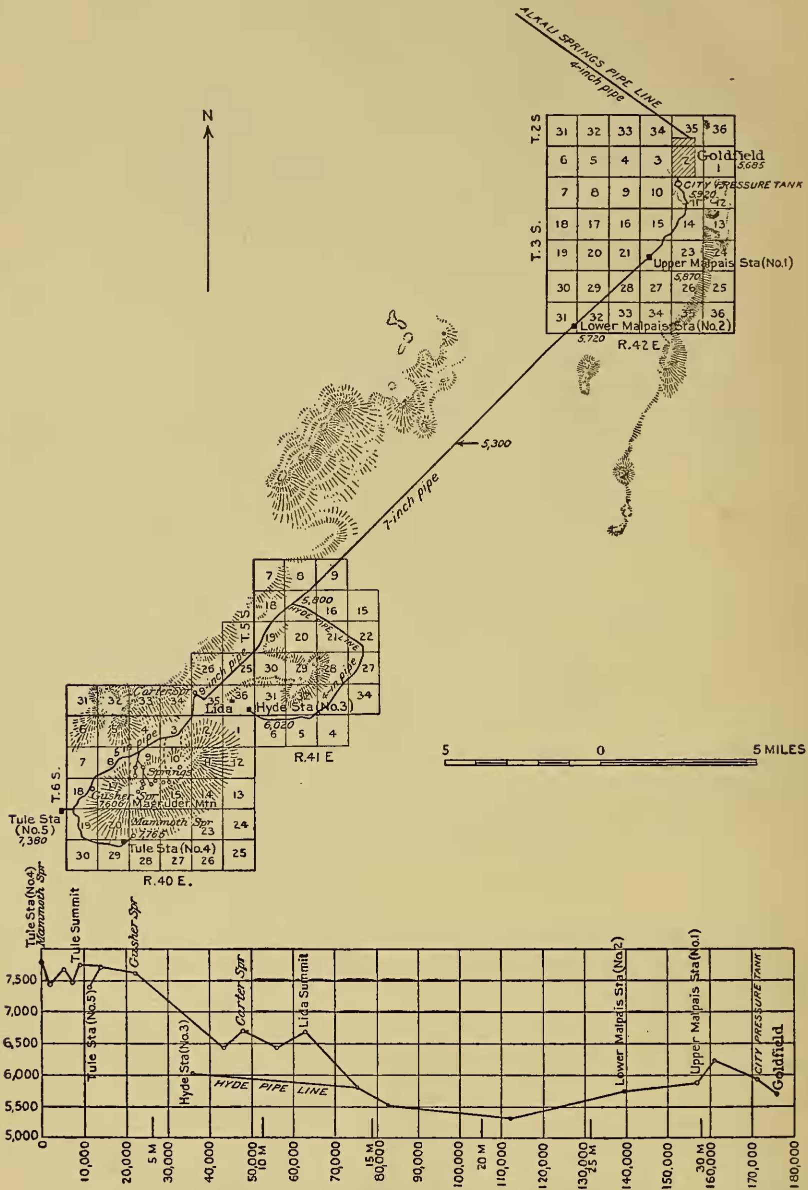


FIGURE 11.—Map and profile of the Lida system of the Goldfield waterworks.

The analysis on page 154 shows that the Lida supply contains only a moderate amount of dissolved mineral matter and resembles most nearly the waters of upper Big Smoky Valley. It is good for domestic use and for irrigation, but it deposits considerable scale in boilers.

ANALYSES OF WATERS AND SOILS.

The results of analyses of the stream, spring, and well waters of Big Smoky, Clayton, and Alkali Spring valleys are presented in the following tables. The index number corresponds to the number on Plate II (in pocket), indicating the locality where the sample was collected.

Analyses of water from streams and springs.

[Analyst, S. C. Dinsmore. For analytical data, see p. 154.]

No.	Source and location.	Date of collection.	Flow per minute.	Temperature.
	Streams in Big Smoky Valley.			
			Gallons.	*°F.*
S 1	Birch Creek below meadow 3 miles above mouth of canyon	Sept. 27, 1914	530	56
S 2	Santa Fe Creek at mouth of canyon, sec. 18, T. 16 N., R. 44 E.	Sept. 30, 1914	....	50
S 3	Kingston Creek at old mill near mouth of canyon, NE. ¼ sec. 35, T. 16 N., R. 43 E.	Oct. 1, 1914	3,270	46
S 4	South Twin River one-eighth mile below mouth of canyon	Oct. 7, 1914	1,570	....
	Springs in Big Smoky Valley.			
S 5	Spencer Hot Springs, 7 miles east of Spencer's ranch (main spring, fig. 6, p. 50)	Sept. 16, 1913	6	144
S 6	Daniels Spring, one-fourth mile north of house, near northwest corner sec. 22, T. 15 N., R. 44 E.	Sept. 22, 1913	450±	....
S 7	Mrs. Alice Gendron's spring at house	Sept. 12, 1913	Several.	61
S 8	Mrs. Alice Gendron's spring at garden 1.3 miles west of house	Sept. 11, 1913	....	....
S 9	Millett's spring at house	......do......	Several.	....
S 10	Charnock Springs (south spring at camping place)	Sept. 23, 1913	...do....	50
S 11	Spring at northwest margin of Moore Lake, SE. ¼ sec. 22, T. 12 N., R. 43 E.	Sept. 27, 1913	1	51
S 12	Mrs. H. M. Logan's spring at house	Sept. 30, 1913	Several.	58
S 13	Darrough Hot Springs (main spring at house)	......do......	150±	190
S 14	Round Mountain public supply; underflow of Shoshone Creek.	Sept. 9, 1913	....	....
S 15	Warm Spring, near mouth of Ione Valley, sec. 11, T. 8 N., R. 38 E.	Oct. 4, 1913	Few.	55
S 16	Crow Spring, 11 miles northwest of Millers, sec. 34, T. 5 N., R. 39 E.	Oct. 20, 1913	3	59
	Springs in Clayton Valley.			
S 17	Waterworks Spring, at Silver Peak, NE. ¼ sec. 22, T. 2 S., R. 39 E.[a]	....	[b] 500±	64
	Springs in Alkali Spring Valley and Goldfield supply.			
S 18	Alkali Spring, 11 miles northwest of Goldfield, NE. ¼ sec. 26, T. 1 S., R. 41 E.[c]	....	[b] 40±	120
S 19	Lida Spring supply of Goldfield waterworks, near Lida and Magruder Mountain (fig. 11).[d]	....	300±	....

[a] Analysis by S. C. Dinsmore; furnished by the Pittsburg Silver Peak Mining Co. See also analyses W 26 and W 27, p. 157.
[b] Reported.
[c] Analyst, A. A. Hanks; analysis recalculated. Ball, S. H., A geologic reconnaissance in southwestern Nevada and eastern California: U. S. Geol. Survey Bull. 308, p. 19, 1907.
[d] Analysis by O. H. Martin, Denver, Colo.; furnished by Goldfield Consolidated Water Co.; recalculated.

Analyses of water from streams and springs—Continued.

No.	Constituents, in parts per million.													Probability of corrosion.[a] [b]	Quality for boiler use.	Alkali coefficient.[a]	Quality for irrigation.	Quality for domestic use.	Mineral content.
	Total dissolved solids.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium [a] (Na+K)	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Nitrate radicle (NO_3).	Scale-forming ingredients.[a]	Foaming ingredients.[a]						
S 1	328	25	0.1	65	16	30	14	239	59	8	1.5	240	80	NC	Poor	130	Good	Fair	Moderate.
S 2	203	14	.05	59	10	7	10	169	36	7	0	200	20	?	Fair	260	...do...	Good	Do.
S 3	290	14	Trace.	48	12	13	19	151	31	6	1	180	35	?	...do...	230	...do...	...do...	Do.
S 4	112	22	Trace.	22	5	2	0	83	3.7	6	Trace.	95	5	?	Good	340	...do...	...do...	Low.
S 5	802	34	.2	57	18	197	12	646	52	28	0	230	532	NC	Bad	4	Poor	Fair	High.
S 6	302	14	Trace.	73	24	3.1	0	283	41	9	0	270	8.4	?	Poor	227	Good	Good	Moderate.
S 7	353	23	Trace.	92	9.1	7	4.8	224	62	19	0	310	20	?	...do...	107	...do...	...do...	Do.
S 8	137	10	0	42	2.1	.3	0	112	16	4	Trace.	140	.9	?	Fair	510	...do...	...do...	Low.
S 9	157	13	0	46	7.4	1.1	0	129	32	6	0	160	3	?	...do...	340	...do...	...do...	Moderate.
S 10	189	45	Trace.	27	4	11	0	96	17	8	.2	130	30	?	...do...	208	...do...	...do...	Do.
S 11	120	16	Trace.	28	1.9	6	0	80	13	4	8	100	17	?	...do...	404	...do...	...do...	Low.
S 12	131	18	Trace.	34	8	1	0	105	26	6	Trace.	130	5	?	...do...	340	...do...	...do...	Do.
S 13	382	88	Trace.	13	3	80	31	102	60	15	0	130	216	NC	...do...	14	Fair	...do...	Moderate.
S 14	220	24	Trace.	39	4.3	21	0	124	38	14	0	150	57	?	...do...	115	Good	...do...	Do.
S 15	267	62	Trace.	32	3	38	0	109	53	21	.4	160	103	?	...do...	71	...do...	...do...	Do.
S 16	539	36	Trace.	21	13	152	0	244	170	41	2	120	410	NC	Bad	10	Fair	Fair	High.
S 17	1,710	22	[c] 4	154	59	[d] 340	0	208	55	774	....	450	780	C	Poor	2.6	Poor	Poor	Do.
S 18	1,010	42	[c] 5	46	....	282	[e] 70	....	500	65	....	200	760	?	Bad	15	Fair	...do...	Do.
S 19	352	17	....	55	20	42	[e] 110	....	69	39	....	220	110	?	Poor	45	Good	Good	Moderate.

[a] Calculated. [b] NC=noncorrosive; ?=corrosion uncertain; C=corrosive. [c] $Fe_2O_3+Al_2O_3$. [d] Na=290; K=50. [e] Includes HCO_3.

Analyses of water from wells and borings.

[Analyst, S. C. Dinsmore. For analytical data see p. 157.]

Upper Big Smoky Valley.

No.	Owner or designation.	Location.	Type.	Depth.	Depth of water table below surface.	Tested capacity.	Use of water.	Date of collection.	Temperature of water.
				Feet.	*Feet.*	*Gals. per minute.*			*°F.*
W 1.	Geo. Schmidtlein	2¾ miles east of house	Dug	15	11.7	Several.	Stock	Sept. 18, 1913	
W 2.	E. J. Vigus	SW. ¼ sec. 2, T. 15 S., R. 44 E.	do	22	17.4	do	do	Sept. 19, 1913	
W 3.	Frank Gendron	Southwest of house	6-inch casing	133(?)	Flow.	10(?)	do	Sept. 20, 1913	
W 4.	Hole on playa [a]	1¼ miles east of Millett	Dug	5	1.6		None	Sept. 11, 1913	
W 5.	A. B. Millett	SW. ¼ sec. 5, T. 13 N., R. 43 E.	6-inch casing	101	Flow.	40	Domestic	Oct. 6, 1914	64
W 6.	Fred J. Jones	NE. ¼ sec. 19, T. 13 N., R. 43 E.	Dug	15	9	Several.	do	Sept. 29, 1913	54
W 7.	do	NW. ¼ sec. 29, T. 13 N., R. 43 E.	6-inch casing	127	Flow.	120	Irrigation	Oct. 7, 1914	53
W 8.	H. B. Rogers	West side of house	Dug	10	7	Several.	Domestic	Sept. 27, 1913	
W 9.	Barker ranch	North side of house	do	16	12		None	Sept. 26, 1913	53
W 10.	Crowell ranch	North well	do	12	6.5	Several.	Stock	Sept. 10, 1913	
W 11.		1½ miles southwest of Wood's ranch	do	20	19		Domestic	Oct. 1, 1913	
W 12.	Prospect shaft	Near mouth of Manhattan Canyon	do	90	85		None	Sept. 8, 1913	
W 13.	Manhattan public supply (upper well).	On road to Tonopah, 1¼ miles from Manhattan.	do	60		Several.	Domestic, etc.	do	

Lower Big Smoky Valley.

No.	Owner or designation.	Location.	Type.	Depth.	Depth of water table below surface.	Tested capacity.	Use of water.	Date of collection.	Temperature of water.
W 14.	San Antonio	At house	Dug	14	4		None	Sept. 7, 1913	
W 15.	N. H. Meyer	Midway station	do	135	124	27	Domestic	Sept. 6, 1913	
W 16.		Sec. 10, T. 3 N., R. 41 E.	do	210	202		None	Aug. 31, 1913	
W 17.	Desert Power & Mill Co. [b]	One-third mile north of depot at Millers	do	63	38	400	Domestic and milling.		
W 18.	Belmont Milling & Development Co.	One-half mile northwest of depot at Millers	do	50	37.5	140	Milling	Oct. 18, 1913	
W 19.		3 miles southwest of Millers; east of Millers Pond.	do	6	4.5		None	Oct. 8, 1913	
W 20.	Test hole	NE. ¼ sec. 30, T. 3 N., R. 40 E.	do	3	2.7		do	Oct. 9, 1913	
W 21.	French well	NE. ¼ sec. 27(?), T. 3 N., R. 39 E.	do	4	2		do	Sept. 1, 1913	
W 22.	Desert well	2 miles northeast of McLeans	do	12	10		do	Sept. 2, 1913	
W 23.		1 mile west of McLeans	do	50	50		do	Oct. 17, 1913	
W 24.		5 miles south and one-half mile west of McLeans, south side of railroad.	do	49	48		do	Oct. 16, 1913	
W 25.	Tonopah & Goldfield R. R. Co.	Blair Junction	do	115	100	25±	Railroad	Sept. 2, 1913	

[a] This water has probably been concentrated by evaporation. Loss on ignition, 5,010 parts per million. Specific gravity, 1.2448. Borax present.
[b] Analysis by Dearborn Chemical Co. furnished by Desert Power & Mill Co.; recalculated.

Analyses of water from wells and borings—Continued.

[For analytical data, see p. 157.]

Clayton Valley.

No.	Owner or designation.	Location.	Type.	Depth.	Depth of water table below surface.	Tested capacity.	Use of water.	Date of collection.	Temperature of water.
				Feet.	*Feet.*	*Gals. per minute.*			
W 26.	Well No. 21 (Pl. XIII)	SW. ¼ sec. 27, T. 2 S., R. 39 E.	Dug	28	23	....	None	Oct. 13, 1913	....
W 27.	Well No. 22 (Pl. XIII)	SW. ¼ sec. 34, T. 2 S., R. 39 E.	do	40	32	....	do	do	....

Alkali Spring Valley.

No.	Owner or designation.	Location.	Type.	Depth.	Depth of water table below surface.	Tested capacity.	Use of water.	Date of collection.	Temperature of water.
W 28.	Gottschalk well	Sec. 26, T. 2 S., R. 41 E.	8-inch casing	123–400	61	Several.	None	Oct. 21, 1913	....
W 29.	Tonopah & Goldfield R. R. Co.	Klondike	Dug	160	148	35	Locomotive and domestic.	Oct. 22, 1913	....

Ralston Valley.

No.	Owner or designation.	Location.	Type.	Depth.	Depth of water table below surface.	Tested capacity.	Use of water.	Date of collection.	Temperature of water.
W 30.	Water Co. of Tonopah	4,400 feet north of pump station. Middle one of three wells.	12-inch diameter	50±	5	150	Domestic, milling, etc.	Oct. 23, 1913	....

No.	Constituents in parts per million. Total dissolved solids.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K)[a]	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4).	Chlorine (Cl).	Nitrate radicle (NO_3).	Scale-forming ingredients.[a]	Foaming ingredients.[a]	Probability of corrosion.[b]	Quality for boiler use.	Alkali coefficient.	Quality for irrigation.	Quality for domestic use.	Mineral content.
W 1	764	46	1.5	93	58	98	0	422	90	171	3.4	420	265	?	Bad	12	Fair	Fair	High.
W 2	494	39	4.8	68	32	70	0	444	Trace.	68	3.6	290	192	NC	Poor	14	do	do	Moderate.
W 3	104	16	.2	22	2.6	4.4	0	75	8	4	0	90	12	?	Good	447	Good	Good	Low.
W 4	369,985	110	Trace.	80	Trace.	[c]143,616	29,400	3,965	18,624	168,812	82	....	....	....	Unfit	....	Unfit	Unfit	Very high.
W 5	179	24	Trace.	38	7	5	0	124	25	5	.25	160	15	?	Good	370	Good	Good	Moderate.
W 6	329	27	0	79	18	6	0	266	48	11	Trace.	290	16	?	do	185	do	do	Do.
W 7	239	24	Trace.	61	7	14	26	149	33	9	0	220	40	NC	do	180	do	do	Do.
W 8	180	14	Trace.	39	13	0	0	114	34	13	2.8	150	Slight.	?	do	157	do	do	Do.
W 9	439	38	.8	68	5.6	70	0	290	58	34	0	250	189	NC	do	19	do	do	Do.
W 10	224	14	Trace.	43	3.9	33	0	141	31	34	Trace.	150	89	?	Fair	54	do	do	Do.
W 11	321	32	Trace.	86	9	5	0	200	69	15	9.4	300	13	?	Poor	136	do	do	Do.
W 12	1,975	14	Trace.	397	71	56	0	151	1,174	41	.8	1,300	151	C	Very bad.	41	do	Bad	Very high.
W 13	346	13	Trace.	92	7	16	0	236	69	17	4	300	43	?	Poor	110	do	Good	Moderate.
W 14	313	28	Trace.	45	7.4	31	0	139	69	18	0	170	84	?	Fair	85	do	do	Do.
W 15	433	44	Trace.	73	8	45	0	187	95	42	3.6	270	124	?	Poor	43	do	do	Do.
W 16	1,189	74	0	51	14	352	0	807	11	192	0	250	950	NC	Bad	2.3	Poor	Poor	High.
W 17	490	50	(d)	26	16	114	[e]106	....	93	74	....	165	310	NC	Fair	13.2	Fair	Fair	Moderate.
W 18	363	81	Trace.	31	9	55	4.8	175	50	21	Trace.	190	148	NC	do	76	Good	Good	Do.
W 19	869	100	Trace.	40	11	190	19	309	169	69	Trace.	240	513	NC	Bad	7	Fair	Fair	High.
W 20	2,405	86	Trace.	51	17	765	28	356	781	501	0	260	2,065	NC	Unfit	2.5	Poor	Bad	Very high.
W 21	4,038	58	Trace.	164	22	1,218	0	317	917	1,361	0	580	3,289	?	do	1.3	do	Very bad	Do.
W 22	569	79	0	34	5.4	134	0	273	79	66	0	190	365	NC	Bad	8.3	Fair	Good	High.
W 23	6,156	64	Trace.	138	44	2,061	62	1,537	192	2,440	0	540	5,565	NC	Unfit	.55	Bad	Unfit	Very high.
W 24	20,267	58	Trace.	140	64	7,154	0	1,412	4,923	6,993	1	580	19,300	NC	do	.23	Unfit	do	Do.
W 25	1,086	51	Trace.	20	2.6	352	21	244	242	239	1	110	950	NC	Bad	3.9	Poor	Poor	High.
W 26	3,611	63	Trace.	278	65	997	12	636	227	1,665	0	990	2,692	?	Unfit	1.2	Bad	Very bad	Very high.
W 27	2,517	68	.2	271	57	517	0	190	227	1,165	0	960	1,396	C	Very bad.	1.7	Poor	Bad	Do.
W 28	523	71	4.5	17	9	125	0	212	120	44	Trace.	140	337	NC	Bad	.11	Fair	Poor	High.
W 29	406	52	Trace.	33	18	54	0	161	89	33	3.6	180	146	?	Fair	51	Good	Good	Moderate.
W 30	273	60	Trace.	51	14	.8	0	141	38	16	11	230	2.2	?	Poor	127	do	do	Do.

[a] Calculated. [b] NC=noncorrosive; ?=corrosion uncertain; C=corrosive. [c] Na=141,673; K=1,943. [d] $Fe_2O_3+Al_2O_3$. [e] Includes HCO_3.

Analyses of water from Silver Peak Marsh, Clayton Valley, Nev.[a]

Composition in milligrams per kilogram.

	1	2	3	4	5	6	7	8	9	10	11	12
Specific gravity at 20° C	1.2089	1.2019	1.0300	1.1722	1.0217	1.0226	1.0124	1.0177	1.0406	1.0281	....	....
Silica (SiO_2)	0	20	50	0	80	20	30	40	40	40	....	....
Iron (Fe)	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.
Aluminum (Al)	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.
Calcium (Ca)	1,800	940	790	2,800	580	420	130	220	470	490	170	150
Magnesium (Mg)	650	290	1,030	100	70	70	20	40	270	190	58	56
Sodium (Na)	97,180	95,190	13,620	77,480	9,650	10,110	5,770	8,370	19,210	13,030	352	195
Potassium (K)	7,290	5,890	1,290	6,590	930	930	500	800	2,060	1,180	21	15
Carbonate radicle (CO_3)	0	0	Trace.	0	0	Trace.	0	Trace.	Trace.	0	0	0
Bicarbonate radicle (HCO_3)	40	70	700	40	533	530	270	520	330	530	144	132
Sulphate radicle (SO_4)	2,360	4,420	540	2,210	410	480	580	690	610	610	95	160
Chlorine (Cl)	159,730	153,710	23,760	134,400	17,130	18,010	9,330	13,650	33,050	22,110	[b] 858	[c] 548
Total residue dried at 180° C	278,760	264,030	42,820	233,440	30,670	31,980	16,830	24,430	57,600	39,330	1,868	1,379
Total residue after ignition	270,990	262,670	41,610	228,440	29,960	31,530	16,620	24,180	56,240	38,620	1,672	1,209
Anhydrous residue [c]	269,110	260,570	41,440	223,660	29,120	30,310	16,500	24,070	55,890	37,920	1,630	1,195

Percentage composition of anhydrous residues.[d]

	1	2	3	4	5	6	7	8	9	10	11	12
Silica (SiO_2)	0.00	0.01	0.12	0.00	0.28	0.07	0.18	0.17	0.07	0.11	....	....
Calcium (Ca)	.67	.36	1.92	1.25	1.99	1.38	.79	.91	.84	1.29	10.43	12.56
Magnesium (Mg)	.24	.11	2.49	.04	.24	.23	.12	.17	.48	.50	3.55	4.70
Sodium (Na)	36.11	36.53	32.86	34.64	33.14	33.35	34.97	34.77	34.37	34.36	21.58	16.32
Potassium (K)	2.71	2.26	3.12	2.95	3.19	3.07	3.03	3.33	3.69	3.11	1.28	1.26
Carbonate radicle (CO_3)	.01	.01	.83	.01	.90	.86	.81	1.05	.29	.69	4.35	5.44
Sulphate radicle (SO_4)	.88	1.70	1.30	.99	1.41	1.58	3.52	2.87	1.09	1.61	5.83	13.40
Chlorine (Cl)	59.35	58.99	57.33	60.09	58.82	59.43	56.55	56.70	59.14	58.30	[a] 52.62	[b] 45.87

[a] Dole, R. B., Exploration of salines in Silver Peak Marsh, Nev.: U. S. Geol. Survey Bull. 530, p. 343, 1913. Analyses by Walton Van Winkle.
[b] Nitrate radicle 5.6 milligrams per kilogram, or 0.33 per cent.
[c] Nitrate radicle 5.0 milligrams per kilogram, or 0.42 per cent.
[d] Computed on the assumption that iron, aluminum, borates, and other radicles constitute 0.03 per cent of the anhydrous residue.

1. Composite from boring 3 at 15.5 feet and from 6 at 21 and 40 feet, June, 1912.
2. Composite from boring 11 at 27 and 35 feet and from 12 at 10, 20, and 27 feet, June, 1912.
3. Composite from boring 13 at 16, 31.5, and 40 feet, June, 1912.
4. Composite from boring 14 at 11 and 17 feet, June, 1912.
5. Water from hot salt spring under bathhouse near Silver Peak, Nev., June 8, 1912.
6. Water from cold salt spring at bathhouse near Silver Peak, Nev., June 8, 1912.
7. Water from cold salt spring at northeast end of marsh, June 14, 1912.
8. Water from hot salt spring at northeast end of marsh, June 14, 1912.
9. Water from boring 1 at 6 feet, June 1, 1912.
10. Water from boring 1 at 27 feet, June 4, 1912.
11. Water from spring at pumping station, Silver Peak, Nev., June 28, 1912.
12. Water from 30-foot well of Nevada-California Power Co. at Silver Peak, Nev., June 29, 1912.

Analyses of soils.

[Analyst, S. C. Dinsmore. For analytical data see p. 161.]

Big Smoky Valley.

No.	Location.	Physiographic situation.	Depth to water table.	Vegetation.	Depth of soil sampled.	Physical character of soil.
			Feet.		*Feet.*	
A 1	Six miles southeast of Spencer's ranch (SW. ¼ sec. 34, T. 17 N., R. 45 E.).	Gently sloping axial lowland.	a 13	Big greasewood and salt bush (*Atriplex confertifolia*).	0–1 1–4	Gray silt. Do.
A 2	160 feet west of Schmidtlein's well (NW. ¼ sec. 24, T. 16 N., R. 44 E.).	Nearly level lowland	12	Salt grass, big greasewood, and rabbit brush.	0–1 1–3	Gray silt clay. Do.
A 3	One-fourth mile west of Schmidtlein's well (NE. ¼ sec. 23, T. 16 N., R. 44 E.).	do	a 14	Sagebrush, salt grass, big greasewood, and rabbit brush.	0–1 1–3	Do. Do.
A 4	East of playa (NE. ¼ sec. 33, T. 14 N., R. 44 E.)	Gentle slope	a 17	Greasewood	0–1 1–4	Sandy loam.
A 5	Three-fourths mile east of Millett	Edge of playa	0	None	Surface crust.	
A 6	1¼ miles east of Millett	Playa, one-half mile from edge.	1.6	do	0–1 1–5 5–6	Clay. Do. Do.
A 7	Northwest margin of Moore Lake (SW. ¼ sec. 22, T. 12 N., R. 43 E.).	Flat near spring(?)	0	do	Surface crust.	
A 8	Crowell ranch, at north well (sec. 22, T. 11 N., R. 43 E.)	Level lowland	6.5	Salt grass and other grasses	0–1 1–1½	Peaty loam. Clay loam.
A 9	San Antonio (SW. ¼ sec. 17, T. 7 N., R. 42 E.)	Seepage area	4		Surface crust.	
A 10	One-fourth mile north of Montezuma Well	Gentle axial slope	a 50	*Atriplex confertifolia* and little greasewood.	0–½ ½–1½	Sandy loam. Silt loam.
A 11	One-half mile northwest of Belmont Well at Millers	do	a 33	*Atriplex confertifolia*, big greasewood, and rabbit brush.	0–1½	Do.
A 12	Along road between Millers and French Well, 5.2 miles from French Well.	do	a 23	*Atriplex confertifolia* and big greasewood.	0–1	Do.
A 13	Along road between Millers and French Well, 2.6 miles from French Well.	do	a 13	do	0–1	Do.
A 14	Along road between Millers and French Well, 1.5 miles from French Well.	do	a 8	Big greasewood, *Atriplex torreyi*, and iodine weed.	0–1 1–3	Do. Do.
A 15	SE. ¼ sec. 30, T. 3 N., R. 40 E	Level lowland	2.7	Salt grass, big greasewood, and rabbit brush.	0–½ 1/12–½ 2¼–2¾	Silt. Do. Sandy loam.
A 16	Southwest of mile post 37 (SW. ¼ sec. 32, T. 3 N., R. 39 E.)	Playa	(?)	None	0–1	Clay.
A 17	One mile southeast of Blair Junction	Ancient beach	a 60	*Atriplex confertifolia* and big greasewood.	0–1	Gravelly loam.

a Estimated.

Analyses of soils—Continued.

[For analytical data, see p. 161.]

Clayton Valley.

No.	Location.	Physiographic situation.	Depth to water table.	Vegetation.	Depth of soil sampled.	Physical character of soil.
			Feet.		*Feet.*	
A 18	Near well 21 (SW. ¼ sec. 27, T. 2 S., R. 39 E.)	Gentle slope	23	*Atriplex confertifolia*, big greasewood, and iodine weed.	0–1	Gravelly loam.
					1–4½	Loam.
A 19	Near well 22 (SW. ¼ sec. 34, T. 2 S., R. 39 E.)	do	32	*Atriplex confertifolia*	0–1	Gravelly loam.
A 20	SW. ¼ sec. 16, T. 3 S., R. 39 E.	do	*a* 25	*Atriplex torreyi* and grass	0–2	Sand.

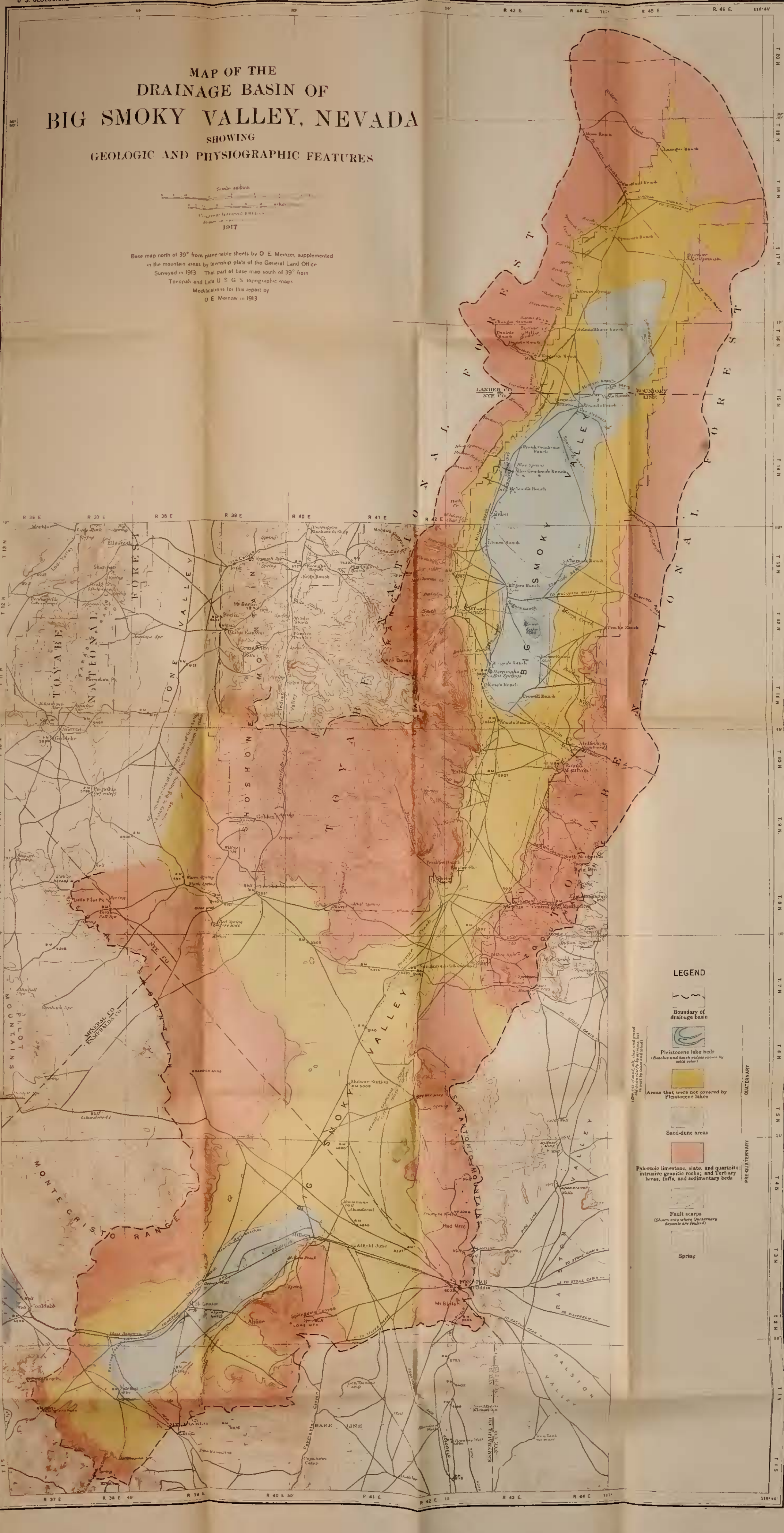
Alkali Spring Valley.

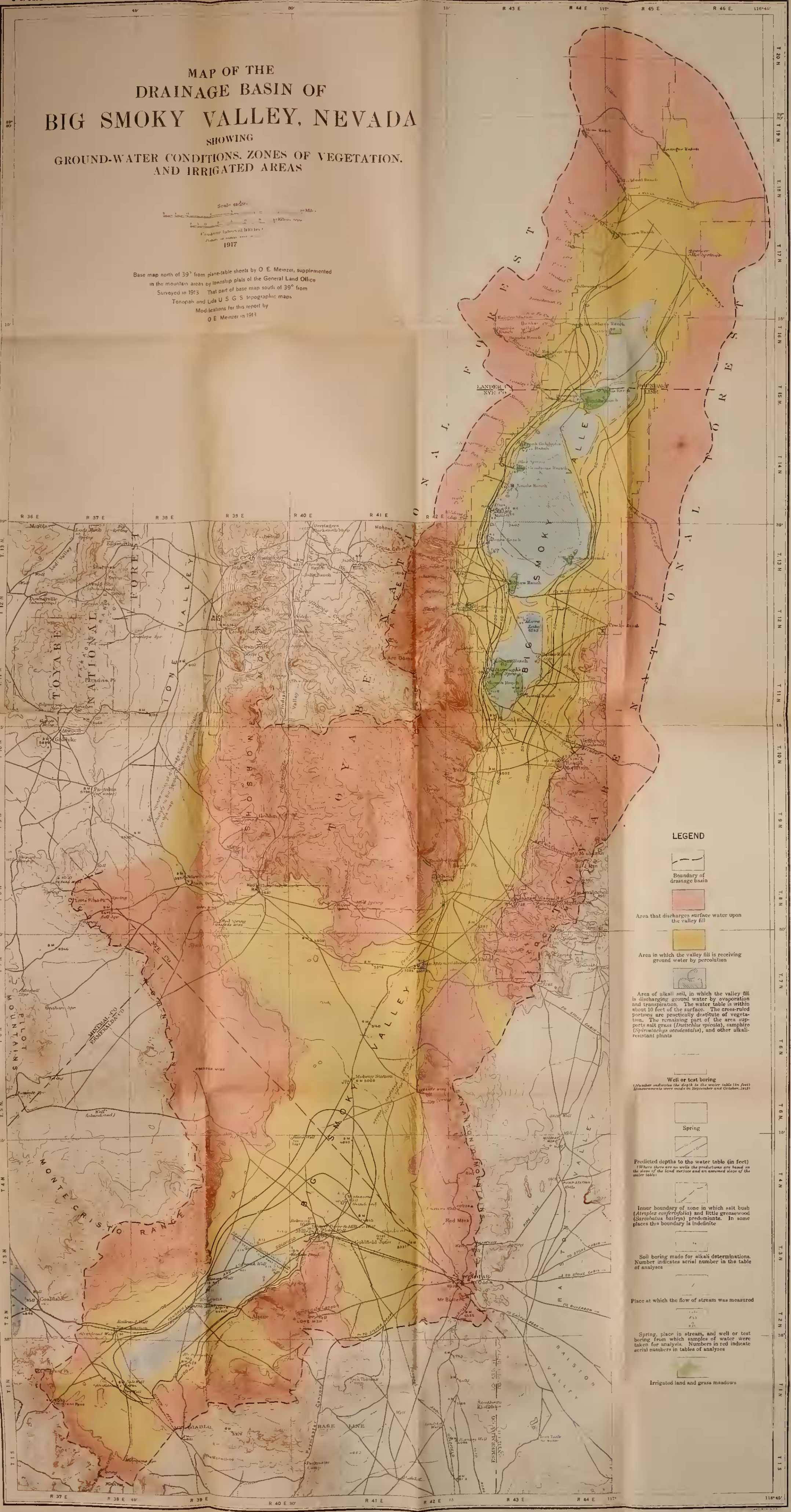
No.	Location.	Physiographic situation.	Depth to water table.	Vegetation.	Depth of soil sampled.	Physical character of soil.
A 21	Neptune wells (SW. ¼ sec. 9, T. 1 S., R. 41 E.)	Playa, one-fourth mile from edge.	47	None	0–1	Silt clay.

a Estimated.

No.	Depth of soil sampled.	Water-soluble portion of soil; constituents in percentages of total soil.								
		Total soluble solids.	Chlorine (Cl).	Chlorine as sodium chloride (NaCl).	Sulphate radicle (SO_4).	Bicarbonate radicle (HCO_3).	Carbonate radicle (CO_3).	Total hardness as $CaCO_3$.	Calcium (Ca).	Magnesium (Mg).
	Feet.									
A 1	0–1	1.60	0.07	0.12	0.80	0.28	0	0.97	0.029	Present.
	1–4	1.98	.25	.42	....	.25	.03	.16	....	
A 2	0–1	2.16	.17	.28	....	.25	0	.17	....	
	1–3	.90	.17	.28	....	.39	.02	.06	....	
A 3	0–1	.57	.07	.12	....	.30	Trace.	.13	....	
	1–3	1.40	.35	.58	....	.36	.05	.11	....	
A 4	0–1	.82	.05	.09	....	.25	.13	.03	....	
	1–4	1.91	.15	.24	....	.50	.02	.05	....	
A 5	Surface crust.	22.80	1.42	2.34	....	4.09	6.66	.06	....	
A 6	0–1	8.16	3.26	5.38	....	.51	.95	.06	....	
	1–5	4.84	2.28	3.76	....	.18	.29	.12	....	
	5–6	4.76	2.18	3.60	....	.25	.30	.03	....	
A 7	Surface crust.	38.40	.46	.76	....	6.41	10.38	.02	....	
A 8	0–1	.64	.07	.12	....	.21	0	.06	....	
	1–1½	1.09	.30	.49	....	.27	.06	.04	....	
A 9	Surface crust.	39.70	5.46	9.01	....	.94	1.25	.08	....	
A 10	0–½	.15	.01	.02	....	.16	0	.05	....	
	½–1½	.56	.01	.02	....	.28	Trace.	.02	....	
A 11	0–1½	.81	.05	.09	....	.28	Trace.	.04	....	
A 12	0–1	1.41	.42	.70	.13	.21	0	.23	.16	Trace.
A 13	0–1	.96	.31	.51	....	.25	0	.04	....	
A 14	0–1	3.58	.53	.88	2.26	.23	0	1.45	.64	Trace.
	1–3	1.50	.16	.26	....	.29	.03	.05	....	
A 15	0–½	3.15	.59	.98	....	.21	.32	.05	....	
	1/12–½	1.56	.21	.35	....	.36	.07	.04	....	
	2¼–2¾	.20	.02	.04	....	.16	0	.04	....	
A 16	0–1	2.50	.37	.61	....	.52	.23	.03	....	
A 17	0–1	1.32	.20	.33	....	.33	.03	.02	....	
A 18	0–1	.84	.05	.09	....	.28	Trace.	.03	....	
	1–4½	1.72	.28	.47	.91	.17	0	1.03	.32	Present.
A 19	0–1	1.40	.20	.33	....	.29	0	.06	....	
A 20	0–2	.30	0	0	....	.25	0	.04	....	
A 21	0–1	4.76	.71	1.17	....	.28	.36	.08	....	

INDEX.


MAP OF THE
DRAINAGE BASIN OF
BIG SMOKY VALLEY, NEVADA
SHOWING
GEOLOGIC AND PHYSIOGRAPHIC FEATURES
1917
Base map north of 39° from plane-table sheets by O. E. Meinzer, supplemented
in the mountain areas by township plats of the General Land Office
Surveyed in 1913. That part of base map south of 39° from
Tonopah and Lida U. S. G. S. topographic maps
Modifications for this report by
O. E. Meinzer in 1913
LEGEND
Boundary of drainage basin
Pleistocene lake beds
Areas that were not covered by Pleistocene lakes
Sand-dune areas
QUATERNARY
Paleozoic limestone, slate, and quartzite; intrusive granitic rocks; and Tertiary lavas, tuffs, and sedimentary beds
PRE-QUATERNARY
Fault scarps
Spring
BIG SMOKY VALLEY
TOYABE RANGE
TOQUIMA RANGE
SHOSHONE MOUNTAINS
IONE VALLEY
SAN ANTONIO MOUNTAINS
MONTE CRISTO RANGE
PILOT MOUNTAINS
RALSTON VALLEY
TOYABE NATIONAL FOREST
LANDER CO.
NYE CO.
MINERAL CO.
ESMERALDA CO.
Tonopah
Millers
Silver Peak
Round Mountain
Manhattan
Belmont
Berlin
Ione
Goldfield


MAP OF THE
DRAINAGE BASIN OF
BIG SMOKY VALLEY, NEVADA
SHOWING
GROUND-WATER CONDITIONS, ZONES OF VEGETATION, AND IRRIGATED AREAS
1917
Base map north of 39° from plane-table sheets by O. E. Meinzer, supplemented in the mountain areas by township plats of the General Land Office
Surveyed in 1913. That part of base map south of 39° from Tonopah and Lida U. S. G. S. topographic maps
Modifications for this report by O. E. Meinzer in 1914
LEGEND
Boundary of drainage basin
Area that discharges surface water upon the valley fill
Area in which the valley fill is receiving ground water by percolation
Area of alkali soil, in which the valley fill is discharging ground water by evaporation and transpiration. The water table is within about 10 feet of the surface. The cross-ruled portions are practically destitute of vegetation. The remaining part of the area supports salt grass (Distichlis spicata), samphire (Spirostachys occidentalis), and other alkali-resistant plants
Well or test boring
Spring
Predicted depths to the water table (in feet)
Inner boundary of zone in which salt bush (Atriplex confertifolia) and little greasewood (Sarcobatus baileyi) predominate. In some places this boundary is indefinite
Soil boring made for alkali determinations. Number indicates serial number in the table of analyses
Place at which the flow of stream was measured
Spring, place in stream, and well or test boring from which samples of water were taken for analysis. Numbers in red indicate serial numbers in tables of analyses
Irrigated land and grass meadows
BIG SMOKY VALLEY
TOYABE NATIONAL FOREST
TOYABE RANGE
SHOSHONE MOUNTAINS
IONE VALLEY
SAN ANTONIO MOUNTAINS
MONTE CRISTO RANGE
PILOT MOUNTAINS
RALSTON VALLEY
BASE LINE