DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

WATER-SUPPLY PAPER 343

GEOLOGY AND WATER RESOURCES OF TULAROSA BASIN, NEW MEXICO

BY

O. E. MEINZER AND R. F. HARE

Prepared in cooperation with the New Mexico Agricultural Experiment Station

WASHINGTON
GOVERNMENT PRINTING OFFICE
1915

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GEOLOGY AND WATER RESOURCES OF TULAROSA BASIN, NEW MEXICO, AND ADJACENT AREAS.

By O. E. MEINZER and R. F. HARE.

INTRODUCTION.

LOCATION AND MAIN FEATURES.

West of the Great Plains in New Mexico, Texas, and old Mexico is a region consisting of isolated mountain ranges and intervening plains or broad open valleys. The Pecos and Rio Grande flow through several of these valleys, but in the region between these rivers there are other valleys which are entirely inclosed by higher ground and therefore have no drainage outlets. Examples of closed basins between the Pecos and Rio Grande in New Mexico are Estancia Basin, Encino Basin, Pinos Wells Basin, and Tularosa Basin. (See fig. 1.)

Tularosa Basin is bounded on the east by the Jicarilla, Sierra Blanca, and Sacramento mountains and on the west by the Chupadera Plateau and the Oscuro, Little Burro, San Andreas, and Organ mountains. Northward it rises gradually to form the Mesa Jumanes, which ends in an abrupt escarpment overlooking the Estancia Basin, but on the northeast it is terminated by the Gallinas Mountains. On the south it is separated from the Hueco Basin, which extends southward to the Rio Grande, and from other basins east of the Hueco by a low indefinite divide which on the west approaches within a few miles of the Texas State line but swings northward in the vicinity of the Jarilla Mountains. Tularosa Basin has a maximum length of about 150 miles, a maximum width of about 60 miles, and an area of approximately 6,000 square miles. It is crossed by the one hundred and sixth meridian of longitude and by the thirty-third and thirty-fourth parallels of latitude, and includes parts of Otero, Lincoln, Dona Ana, and Socorro counties, and probably a small part of Torrance County.

The interior of the basin contains an extensive area of alkali flats and white gypsum sands, which lie about 4,000 feet above sea level, south of which is a large sandy desert that is rendered peculiarly monotonous by its slight relief and lack of definite drainage. The

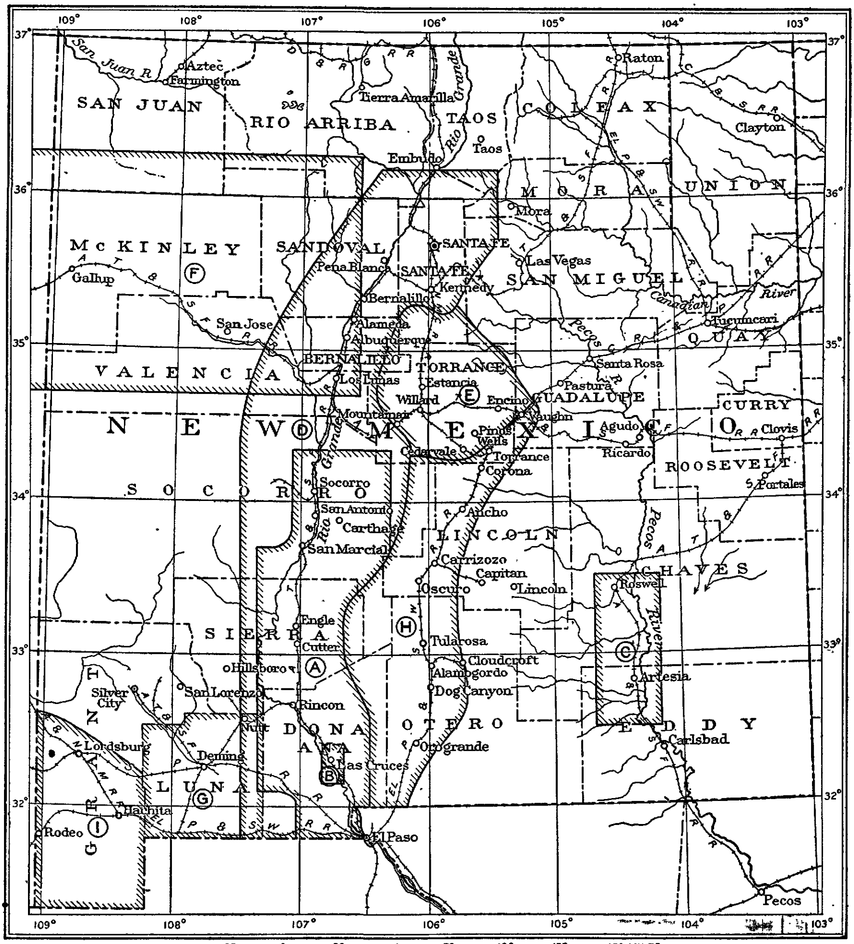


FIGURE 1.—Index map of New Mexico showing areas covered by U. S. Geological Survey water-supply papers and Bulletin 435. A, W. S. P. 123; B, W. S. P. 141; C, W. S. P. 158; D, W. S. P. 188; E, W. S. P. 275; F, Bull. 435; G, W. S. P. 345–C; H, W. S. P. 343 (includes Tularosa Basin and adjacent areas on the south and northeast); I, W. S. P. in preparation.

northern half of the basin includes between the mountain borders a plain that descends gradually from the Mesa Jumanes, 6,000 to 7,000 feet above sea level, to the alkali flats, but is broken by many hills, buttes, and ridges, and by a ribbon of extremely rough lava that extends along its central axis for more than 40 miles.

NAME.

The name Hueco Basin has been applied to the entire depression extending from the Mesa Jumanes to Mexico,[1] but it is commonly used only for the southern part; that is, the part which lies south of the low divide and is bordered on the east by the Hueco Mountains.[2] Among the early settlers the region north of the divide—that is, the general lowland region between the Mesa Jumanes and the Jarilla Mountains—was commonly called Tularosa Valley or Tularosa Desert, after the largest settlement and principal stream that it contained, and this name is still in use, although not recognized by many of the new inhabitants. It has also been used by G. B. Richardson[3] in his report on trans-Pecos Texas and by others and is indorsed by R. T. Hill. Other names that have been applied to the region are the Gran Quivira Valley,[4] the San Andreas Valley, the White Sands Plain, the Otero Basin, the Lanoria Mesa,[5] the Jarilla Bolson,[6] the Alamogordo Desert,[7] and the Sacramento Valley. The name Otero Basin was used in 1904 by C. L. Herrick,[8] and in more recent publications by D. T. MacDougal[9] and E. E. Free,[10] but it is not recognized by the inhabitants. The name Sacramento Valley has been applied to the region by the recent settlers in the vicinity of Alamogordo, after the Sacramento Mountains, which lie just back of Alamogordo, and this name was used by L. C. Graton and others in a report on the ore deposits of New Mexico.[11] It has, however, long been appropriated for the valley of Sacramento River, a stream in the Sacramento Mountains that discharges southward into the Salt Basin of Texas, and it can not without much confusion be applied to the basin west of the Sacramento Mountains. As the name Tularosa was the first to be attached to this region by the people, as it has become firmly rooted by a half century of use, and as it is free from objections it seems desirable that it should be retained and given general recognition.

[1] Hill, R. T., Physical geography of the Texas region: U. S. Geol. Survey, Topographic Atlas, Folio No. 3, p. 9, 1900.

[2] Richardson, G. B., U. S. Geol. Survey Geol. Atlas, El Paso folio (No. 166), 1909.

[3] Richardson, G. B., Report of a reconnaissance in trans-Pecos Texas: Univ. Texas Min. Survey, Bull. No. 9, p. 17, 1904. Also U. S. Geol. Survey Geol. Atlas, El Paso folio (No. 166), p. 2, 1909.

[4] Harrington, M. W., Lost rivers: Science, new ser., vol. 6, p. 265, 1885.

[5] Slichter, C. S., Observations on the ground waters of Rio Grande valley: U. S. Geol. Survey Water-Supply Paper 141, p. 15, 1905.

[6] Keyes, C. R., Geology and underground-water conditions of the Jornada del Muerto, N. Mex.: U. S. Geol. Survey Water-Supply Paper 123, p. 26, 1905.

[7] McBride, T. H., The Alamogordo Desert: Science, new ser., vol. 21, pp. 90–97, 1905.

[8] Lake Otero, an ancient salt lake basin in southeastern New Mexico: Am. Geologist, vol. 34, pp. 174–189, 1904.

[9] Botanical features of the North American deserts: Carnegie Institute of Washington Pub. 99, 1908.

[10] An investigation of the Otero Basin, N. Mex., for potash salts: U. S. Dept. Agr. Bureau of Soils, Circular 61, 1912.

[11] Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., U. S. Geol. Survey Prof. Paper 68, pp. 25 and 184, 1910.

CLIMATE.

The climate of Tularosa Basin is that which is typical of the arid Southwest. As a rule the sky is clear and the atmosphere is dry and rare. Consequently in both summer and winter the days are generally warm and the nights cool. The region is little affected, especially in summer, by the great cyclonic storms that farther north pass periodically across the continent, but most of the rain is produced by condensation from local ascending currents of air and accordingly falls in a few heavy storms in midsummer. Late in the autumn and early in the winter the weather is usually pleasant, but in these seasons there is little precipitation; the spring season is

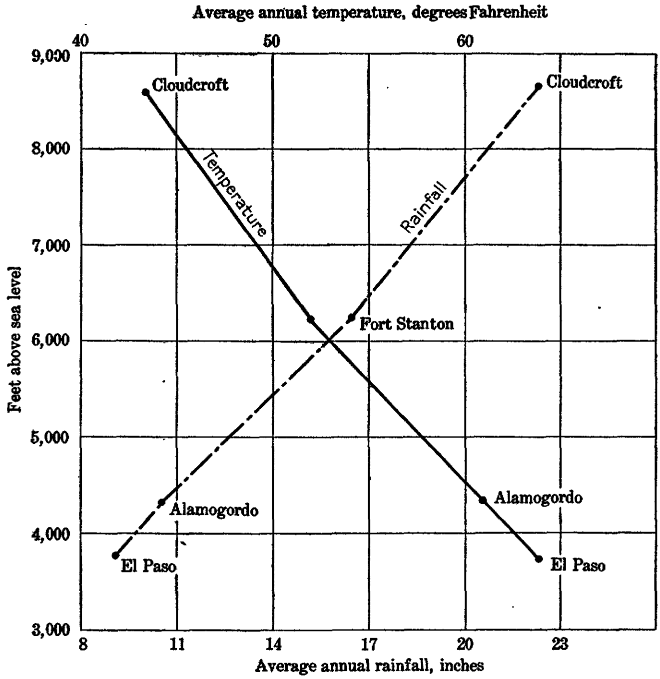
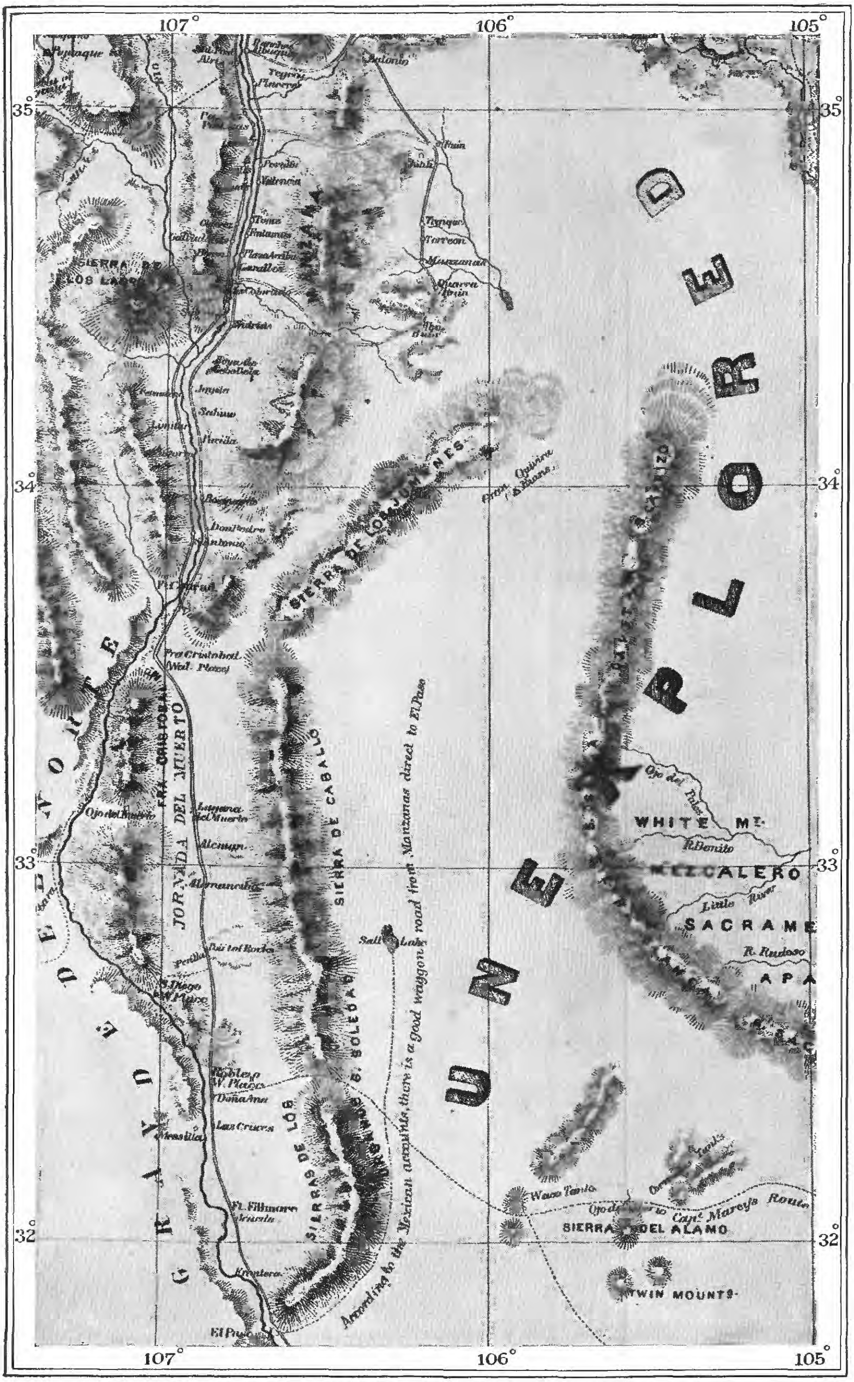


FIGURE 2.—Diagram showing general relation of temperature and rainfall to altitude in Tularosa Basin.

generally dry and windy. The average annual rainfall of the lowland plains is only about 10 inches, and its vegetation and physiographic features have a distinctly desert aspect. The high mountains at the borders of the basin receive more precipitation, are covered with forests, and give rise to several small streams that discharge into the desert.

The basin has a wide range in temperature, owing partly to differences in latitude but chiefly to differences in altitude. The hottest section is the southern portion of the desert lowland, and the coldest is the high peaks of the Sierra Blanca, which rise above the timber



MAP OF TULAROSA BASIN AND ADJACENT COUNTRY, 1851.

line. The elevated northern part of the basin, which merges into the Mesa Jumanes, has a much cooler climate than the low southern plain. The highest, lowest, and average annual temperatures, as reported by the United States Weather Bureau for the several stations in or near this basin, are given below. The general relations of temperature and rainfall to altitude in this region are shown in figure 2. (See also pp. 80–95.)

Temperatures in or near Tularosa Basin (degrees Fahrenheit)

Station.	Altitude, in feet, above sea level.	Length of record, in years.	Highest temperature.	Lowest temperature.	Average annual temperature.
Fort Stanton	6,231	20	105	−18	51.9
Cloudcroft	8,650	7	83	−10	43.2
Alamogordo	4,338	9	109	0	61.0
El Paso, Tex	3,762	24	105	− 5	63.7

HISTORY.

When the Spaniards made their advent in New Mexico in the sixteenth century the Pueblo Indians, who are peaceful and industrious and in all respects much more civilized than the Apaches, had a number of villages near the upper Rio Grande, and several in the eastern foothills of the Manzano Mountains and in the region farther southeast, including Chilili, Tajique, Abo, Quarra (Quarac or Cuara), and Tabira (probably Gran Quivira, Pl. IV).

During the three centuries that the Spaniards controlled New Mexico they were concerned chiefly with the Pueblo Indians. The natural course for the Spanish missionaries and adventurers coming from old Mexico to the Pueblo villages was by way of the Rio Grande, and hence the Rio Grande route was early established and was the main artery of travel when the region became a part of the United States in 1845 (Pl. IV). Coming from old Mexico, the main road reached the Rio Grande at or near El Paso and led northward along the east side of the river to the old town of Dona Ana. Beyond this point it left the Rio Grande, and for nearly 100 miles crossed the open desert that is separated from the river by the San Diego, Caballos, and Fra Cristobal mountains, and from Tularosa Basin by the San Andreas Range. This desert made a powerful impression on the imagination of the early travelers, and, because of its dangers from lack of water and from Apache depredations, it came to be known as the Jornada del Muerto, or "Journey of the dead."

The Spaniards extended their rule and religion to the Manzano villages and to Gran Quivira, where the ruins of large stone churches still testify to their presence, but there was little to attract them far into the Tularosa desert, which was even larger and more dangerous than the Jornada del Muerto. Consequently the early history of this part of New Mexico is almost a blank.

Gran Quivira, which was a village of considerable size, as is shown by the extensive ruins that remain, was situated in a region which at present is remote from any irrigation supply and has only a small domestic water supply obtained from wells. Some traces remain of what has been described as an aqueduct leading from the Gallinas Mountains, but at the present time even these mountains contain no permanent stream of any consequence.[1] A current tradition ascribes the drying up of springs that are supposed to have existed at Gran Quivira to the volcanic eruption that produced the lava west of Carrizozo, but this tradition has not been authenticated; there is no close connection between the two localities, and the lava appears to be older than the ruins. According to one authority, the only water supply was stored rainwater.[2] Gran Quivira, as well as Abo, Quarra, and other frontier pueblos were probably abandoned on account of Apache depredations about 1672,[3] shortly before the Pueblo revolution.

Aside from the gold placers in the Jicarilla region, the one natural resource of Tularosa Basin that seems to have attracted the Mexicans in the old days was the salt found on the alkali flats. At the time of the Mexican cession and prior to that time, a wagon road led from El Paso over the desert east of the Franklin, Organ, and San Andreas mountains, to the alkali flats, and a northward continuation of this road is said to have extended to Manzano, in Estancia Valley (Pl. IV). The heavy wooden wheels of the oxcarts and the irons with which the oxen were shod are still occasionally seen along this old Mexican salt trail. According to one report the salt was derived from Malpais Spring or Salt Creek, a few men being sent in advance of the main expedition to lead the water over an alkali flat, where it evaporated and deposited its content of salt.

In 1846 Gen. Kearney entered New Mexico from the northeast, and until the completion of the two trans-continental railroads, about 1880, New Mexico was connected with the eastern part of the United States by the famous Santa Fe trail. During this period Tularosa Basin again lay remote from the beaten paths of travel.

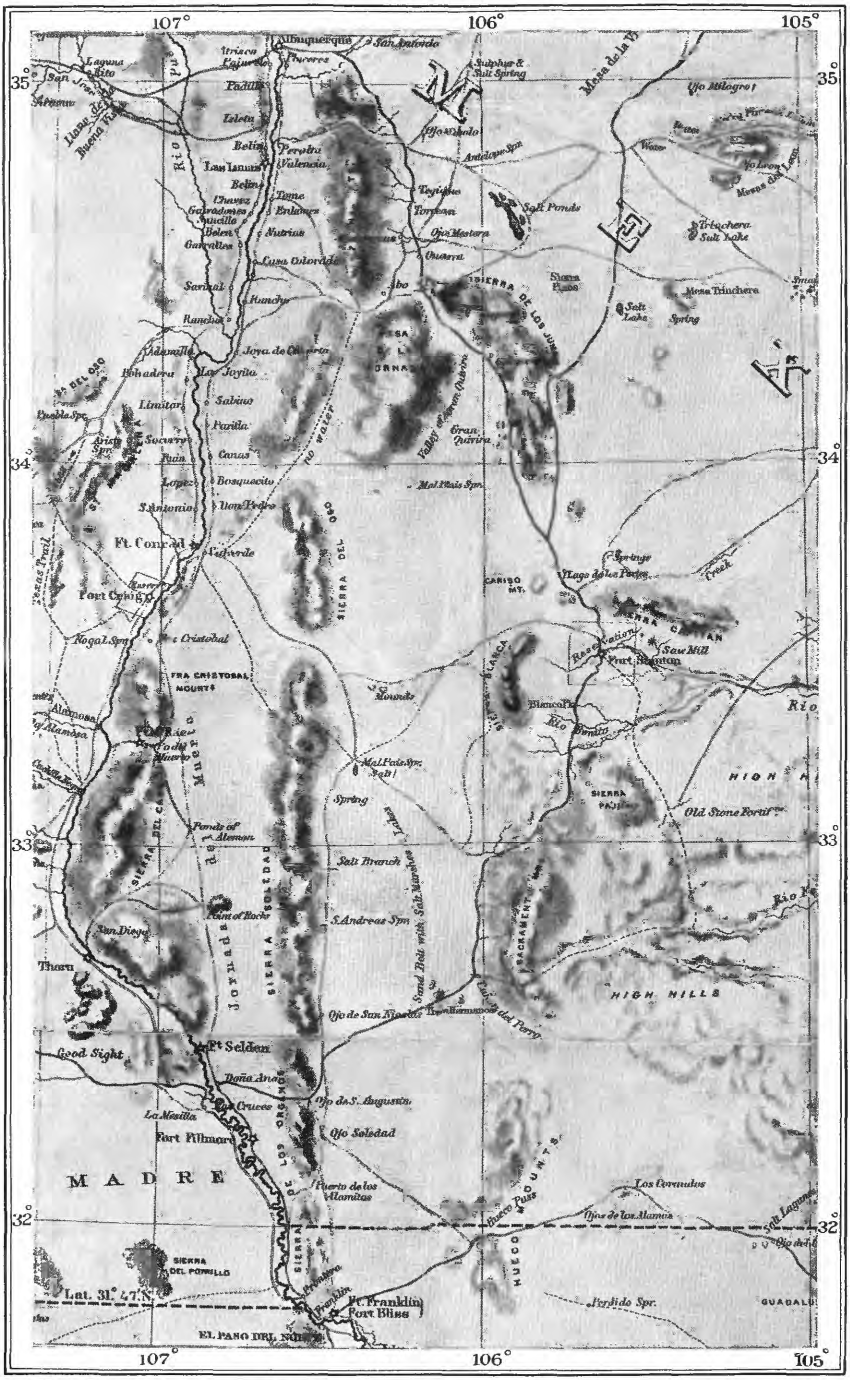
In 1849 Capt. R. B. Marcy made an expedition eastward from Dona Ana, on the Rio Grande, to Preston, Tex.[4] This expedition apparently came through San Agustin Pass, at the north end of the

[1] Bancroft, H. H., Native races of the Pacific States of North America, vol. 4, pp. 663 and 672.

[2] Hodge, F. W., The language of the Piro. Quoted in Twitchell, R. E., The leading facts in New Mexican history, vol. 1, pp. 231–233, Cedar Rapids, Iowa, 1911.

[3] Bancroft, H. H., History of Arizona and New Mexico: Works of Bancroft, vol. 17, p. 170, San Francisco, 1889.

[4] Thirty-first Cong., 1st sess., Senate Ex. Doc. 12 and House Ex. Doc. 45.



MAP OF TULAROSA BASIN AND ADJACENT COUNTRY, 1859-1867.

Organ Mountains, bore southeastward nearly to the present State line, and then traveled eastward in the vicinity of the Hueco, Corundas, and Guadalupe mountains, running north of the Salt Lakes of trans-Pecos Texas. The expedition therefore crossed only the southern part of Tularosa Basin (Pl. IV).

In December, 1853, Maj. J. H. Carleton, with a squadron of cavalry, made an expedition from Albuquerque to Gran Quivira by way of Abo Canyon and Estancia Valley, but he did not go farther south. He wrote an interesting account of the region that he traversed and of the Gran Quivira, where extensive excavations for the hidden treasure had already been made.[1]

When Fort Stanton was established, about 1855, several roads were opened from this fort to the forts on the Rio Grande.[2] The road from Fort Stanton to Albuquerque led northwestward through Punta del Agua and thence over roads already in use, by way of Abo Canyon or by way of the other ancient villages of the Manzano foothills and Tijeras Canyon. The road to Dona Ana and the forts of that vicinity led southward across the "Mesa," lying back of the Sierra Blanca, came down one of the canyons of the Sacramento Mountains, passed southward near the base of the Sacramento front, crossed the desert south of the white sands and led through San Agustin Pass to the Rio Grande. A road was also early constructed from Fort Stanton, through the vicinity of Carrizozo, across the lava bed, to the Rio Grande. The old salt road, in its general course, also continued to be used to some extent (Pl. V).

About 1861 an agricultural settlement was made by a group of Mexicans from the Rio Grande valley. This settlement was on Tularosa River, about 15 miles above the present village of Tularosa. The location was unfavorable because of the ease with which the Apaches could harass the settlers from the surrounding mountains. Consequently in 1862 the inhabitants moved downstream and established the present village of Tularosa, where some of the adobe houses were fortified, and trouble with the Indians occurred at intervals until 1881. The second permanent settlement in the basin was made at La Luz in 1864, also by Mexicans. In the course of time Americans, many of them discharged soldiers from Fort Stanton, settled in these villages. The first cattle ranches were started in the decade between 1870 and 1880. During the early days of their existence there was much lawlessness and some serious encounters between opposing cattlemen.

[1] Carleton, Maj. J. H. Diary of an excursion to the ruins of Abo, Quarra, and Gran Quivira, in New Mexico: Smithsonian Institution, Ninth Ann. Rept., pp. 296–316, 1855.

[2] Bancroft, H. H., History of Arizona and New Mexico: Works of Bancroft, vol. 17, p. 670, San Francisco, 1889.

Placer gold mining is said to have been carried on in some of the gulches near Jicarilla about the middle of last century, in Baxter Gulch, near Whiteoaks, in the fifties and sixties, and in Dry Gulch, near Nogal, as early as 1865.[1] In the latter part of the seventies there was much prospecting in these districts, and about 1880 mining developments of importance were made.

In the early days Tularosa Basin was connected by stage routes with both the Pecos and Rio Grande valleys. At one time a mail route extended from Fort Summer, on the Pecos, to Fort Stanton, and thence across the northern part of Tularosa Basin to the Rio Grande. After 1881, when the railroad between Albuquerque and El Paso was completed, mail routes extended from San Antonio to Whiteoaks, and from Las Cruces to Tularosa by way of San Agustin Pass and Point of Sands.

A new epoch in the history of the basin was opened about 1898 when the El Paso & Northeastern Railroad (now a part of the El Paso & Southwestern system) was built through the region. Alamogordo came into existence at this time and for some years enjoyed great prosperity as a railroad, lumbering, and trade center. Somewhat later Carrizozo and the other towns along the railroad were started, and recently Cloudcroft has attracted attention as a summer resort.

INDUSTRIAL DEVELOPMENT.

As nearly as can be estimated from the census report, between 7,000 and 8,000 persons lived within the drainage area of Tularosa Basin in 1910, and nearly an equal number lived on the high land that lies east of this basin and drains into the Pecos. The population of the basin averages not much over one person to the square mile but is very unequally distributed, nearly all of the inhabitants being found on the east side—in the towns along the railroad, on farms or ranches near the railroad, or in the mountain recesses farther east. The western part of the basin is very sparsely populated, and a large area at the center is entirely without inhabitants. The large plain north of the lava bed is also almost uninhabited.

The railroad that traverses the basin has made the region accessible and has brought in a large proportion of its inhabitants, but it has not yet produced any substantial industrial development.

The industries of the region are mining, lumbering, stock raising, agriculture, and fruit growing, none of which are at present being conducted on an extensive scale.

The mineral wealth that is sufficiently important to have attracted prospectors and to have received a certain amount of development includes gold, copper, silver, lead, iron, turquoise, coal, gypsum, clay,

[1] Graton, L. C., U. S. Geol. Survey Prof. Paper 68, pp. 176–183, 1910.

Glauber's salt, and common salt. By far the most valuable product has been gold, the total output of which has amounted to several million dollars.

Metalliferous deposits have been found on the east side of the basin in the Gallinas, Jicarilla, Whiteoaks, Nogal, Tularosa, and Jarilla districts, in all of which except the Tularosa district gold is the most important. In the Whiteoaks district the production up to 1904 was estimated at $2,860,000; in the Nogal district the total production may amount to $250,000; and in the Jarilla district to $100,000, but in none of these places has there been much activity in recent years. The production of the other districts has been small. Metalliferous deposits, including copper, lead, gold, and silver, have also been found and exploited to some extent at various points in the Organ, San Andreas, and Oscuro mountains, but except on the west side of the Organs very little has been produced. At Estey elaborate improvements were made but not much ore has been extracted. Deposits of iron ore have been discovered on the Chupadera Plateau but have not yet been developed.[1]

Coal has been mined near Capitan and Whiteoaks, and has been prospected in Willow Hill, near Carrizozo, in Milagro Hill, near Oscuro, and in the Little Burro Mountains, near Murray. Clay and ledge gypsum are used in a small brick and cement plant at Ancho, and gypsum sand has locally been used to a small extent in making stucco. Some developments have also been made in the deposits of Glauber's salt, or sodium sulphate, in "Soda Lake," west of the white sands. The common salt that occurs in some of the salt marshes was formerly gathered for local consumption but is practically unused at present.

The timber in the Indian reservation and in the large national forests of the Sacramento Mountains, Sierra Blanca, and Jicarilla Mountains constitutes a valuable resource. The railroad from Alamogordo into the Sacramento Mountains was built chiefly to develop the lumbering industry, and much work was for a time done by the mills erected at Alamogordo. Certain complications, however, put a check on this industry, and very little lumber has been sawed in recent years.

The extensive uncultivated desert and mountain tracts afford a range for cattle, horses, sheep, and goats. Cattle ranches predominate in the southern part of the region and sheep ranches in the northern, while a few goat ranches are found in the mountains. In 1911 the amount of range stock was small in comparison with the area of the grazing lands, and a number of the old ranches were abandoned. It appears that the range had been overstocked and

[1] Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., The ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68, 1910.

that a series of dry years preceding 1911 caused a serious shortage in the food supply and resulted in a general retrenchment in the ranching business. At best a large part of the desert area affords only meager forage.

Agriculture is practiced both with and without irrigation. The irrigation is accomplished with the water from several small streams that rise in the Sacramento Mountains and the Sierra Blanca, and to a slight extent with water pumped from wells. The irrigation farming at Tularosa, La Luz, and Alamogordo, and in the valleys of Three Rivers and other mountain streams constitutes the most substantial industry of the region. The principal crops are alfalfa and fruit. The alfalfa hay is generally in good demand, a part being required for local consumption and a part being shipped to El Paso and other points not far away. Peaches, apples, and other fruits are also shipped, but the fruit industry is capable of much development if fruit growers' associations are organized and more modern methods are introduced in other respects. Farming without irrigation is practiced with good results on the high land east of the basin, excellent crops of oats and other cereals being raised, but dry farming on the lowland plain has on the whole been unsuccessful.

The healthful climate of this region is a valuable resource and has attracted a considerable proportion of the present inhabitants. Cloudcroft, the principal summer resort, is picturesquely situated on the Sacramento Mountains overlooking the desert, but is conveniently reached by rail.

PURPOSE AND HISTORY OF THE INVESTIGATION.

After the railroad was built many home seekers came into Tularosa Basin and settled on claims within a few miles of the railroad. The ordinary supplies of water for irrigation were already appropriated, but most of the new settlers came with the expectation of developing their land and making a livelihood by using dry-farming methods, the possibilities of which in this section of the country have been greatly overstated by unscrupulous, poorly informed, or overzealous persons. With the general failure of dry farming the need of some sort of irrigation supply was strongly felt by all, and the feasibility of developing new supplies by storing flood waters or sinking wells became the general subject of discussion. Many of the settlers left their claims and moved out of the country; others remained because of the wholesome climate or with the expectation of selling their farms after they had obtained titles to them; but still others remained with the determination to profit by the experience they have acquired, and to devise methods by which they can wrest a living from their homesteads. In 1911 many of the settlers were still in the basin, but the great majority were producing little or nothing, and only a very few had substantial incomes from their farms.

Vast tracts of arable land, potentially capable of producing crops of great value, are at present lying practically idle. At the same time waters stored underground remain unused, and large floods discharged into the desert at irregular intervals either evaporate from the surface or sink underground without producing more than an insignificant amount of useful vegetation. The availability of this unused supply for irrigation on the land now unproductive because unwatered is a problem of great and immediate importance, with which this paper is especially concerned.

The investigation of the region was made by the United States Geological Survey and the New Mexico Agricultural Experiment Station acting in cooperation. The general field work was done, chiefly in the autumn of 1911 but partly in 1912, by O. E. Meinzer, assisted for several weeks by Everett Carpenter, both of the Geological Survey. The base and topographic map of the area south of Three Rivers (Pl. II, in pocket) was made in the winter of 1911–12 by C. J. Ballinger, also of the Geological Survey. The analyses of the water and soil were made under the direction of Dr. R. F. Hare in the laboratories of the experiment station, Mesilla Park, N. Mex. The report was written by O. E. Meinzer, but Dr. Hare collaborated in the preparation of the parts dealing with the quality of the water and soil. Valuable well records and other data were generously furnished by the officials of the El Paso & Southwestern Railroad and numerous courtesies were shown by the citizens of the region.

PREVIOUS INVESTIGATIONS AND LITERATURE.

Tularosa Basin did not lie in the path of any of the large exploring and scientific expeditions which in the third quarter of the last century were sent by the United States Government to various parts of the West, except that of Capt. Marcy's expedition, which crossed the south end. Consequently very little was known, until recently, of the geography, geology, and water resources of this region.

The map forming Plate IV shows the meager knowledge of the geography of the region that existed in 1851. The map forming Plate V, which was published in 1867 but probably shows more nearly the state of knowledge in 1859, is much more detailed and shows the location of a number of watering places with considerable accuracy. In 1867 land surveys were made by the General Land Office of several townships in the vicinity of the newly established settlements of Tularosa and La Luz, and in the ensuing years much of the basin was surveyed, an especially large number of townships being covered in 1882. These land plats and the data obtained by the railroad survey are the principal sources of information on which the maps of the region at present in circulation are based. Recently parts of the Sacramento Mountains and the Sierra Blanca within the national forest have been mapped by the United States Geological Survey. (See Pl. III, in pocket.)

Through the mining, military, ranching, and agricultural activities in the region since the middle of the last century the main geologic features gradually became known, and since the railroad was constructed the region has been frequently visited by geologists, engineers, and botanists, and numerous brief descriptions of the basin have been published. All of these descriptions are based on cursory investigations. Some are accurate, although incomplete, and constitute valuable contributions to the knowledge of this section of New Mexico. Others are devoted chiefly to graphic portrayals of the marvels of the region interspersed with untenable hypotheses as to the origin of these marvels.

In 1870 the following note by George Gibbs on Tularosa Basin appeared in the American Naturalist:

> Gen. Aug. V. Kantz, United States Army, writing from Fort Stanton, N. Mex., informs me that there is a valley of some 200 miles long and 20 wide, lying between the Sierra Blanca and the San Andreas and Oscuro mountains, in which there is no stream and only a few alkaline springs and salt lakes or ponds. Where the road from Fort Stanton to El Paso crosses it, about 60 miles south of that post, is a plain of white sand, apparently granulated gypsum, which has drifted into mounds 40 and 50 feet in height. Water of a strongly alkali character is obtained by digging a few feet, and around the edges of the district salt marshes exist, where in the dry seasons great quantities of almost pure salt may be collected. The sand is so white and the plain so extensive as to give the effect of snow scenery. As I do not remember to have seen a description of the place in print I send you this note with a specimen of the sand.

In 1891 R. T. Hill and R. S. Tarr each published a brief but accurate description of the main features of the basin, and in 1900 and 1904 C. L. Herrick published papers which are the most comprehensive reports on the geology of the basin that have thus far been issued.

In his paper published in 1891 Hill outlines clearly the conditions affecting the underground water of bolson valleys, such as Tularosa Basin, and calls attention to the fact that the principal supplies are found in the valley fill, not in the rock formations. Many of the other papers touch on the ground-water conditions, but are for the most part speculative and contain few data. Theories alluded to, some of them repeatedly, are (1) that an ancient river flowed southward, perhaps from Estancia Valley, through this region to the Rio Grande; (2) that such a stream still percolates underground; (3) that it can be heard "rushing" below the lava bed and has produced sufficient underground erosion to cause the caving and consequent broken condition of the lava; (4) that the ancient river was diverted from the region by the extruded lava; (5) that the volcanic eruption caused the drying up of springs at Gran Quivira; (6) that this eruption made the climate more arid; and (7) that the flat-bottomed arroyos on the east side of the basin were at one time occupied by rivers.

Much valuable information was obtained through the drilling enterprises conducted in the last decade by the railroad company and by individuals and other companies. Certain investigations of the occurrence and quality of the underground waters have also been made by the experiment station, the railroad company, and the Alamogordo Improvement Co., and in 1912 the waters of the basin were examined by the United States Department of Agriculture for their content of potash.

The following is an incomplete list of papers dealing in whole or in part with Tularosa Basin:

Gibbs, George, Salt plains in New Mexico: Am. Naturalist, vol. 4, pp. 695–696, 1870. Note given on page 22.

Harrington, M. W., Lost rivers: Science, new ser., vol. 6, pp. 265–266, 1885. Describes remnants of a supposed old river bed. Mentions malpais and crater. Mentions Indian tradition of "a year of fire, when this valley was filled with flames and poisonous gases." Proposes the name "Gran Quivira Valley."

Hill, R. T., The Texas-New Mexican region: Geol. Soc. America Bull., vol. 3, pp. 85–100, 1891. Contains brief description of "Hueco-Organ Basin." Mentions white sands and malpais. Gives clear statement of underground water conditions. Mentions terraces, some of which are remnants of ancient shore lines. Brief descriptions of or references to this basin are found in other papers by the same author, especially in "Physical geography of the Texas region": U. S. Geol. Survey Top. Atlas, Folio No. 3, 1900.

Tarr, R. S., A recent lava flow in New Mexico: Am. Naturalist, vol. 25, pp. 524–527, 1891. Describes the younger lava bed and mentions salt marshes, gypsum deposits, ancient beaches, and "well-defined valleys that extend much farther than the present streams succeed in going." Mentions tradition that volcanic eruption caused the drying up of springs at Gran Quivira, but does express opinion.

Herrick, C. L., The occurrence of copper and lead in the San Andreas and Caballos mountains: Am. Geologist, vol. 22, pp. 285–291, 1898. Describes structure of San Andreas Mountains.

Herrick, C. L., The geology of the white sands of New Mexico: Univ. New Mexico Bull., vol. 2, No. 3, 1900; also Jour. Geology, vol. 8, pp. 112–128, 1900. Describes formations and structure of San Andreas Mountains and the intervening desert. Describes Mississippian limestone at Dog Canyon. Mistakes valley fill for Permian. Numerous springs are reported as "gushing out from beneath the thin sheet of black basalt," and water is said to be heard rushing below the malpais.

Turner, H. W., The copper deposits of the Sierra Oscura, N. Mex.: Am. Inst. Min. Eng. Trans., vol. 33, pp. 678–681, 1902. Contains notes on geology of vicinity of Estey. Strata are considered Upper Carboniferous and probably in part Permian.

Herrick, C. L., Lake Otero, an ancient salt lake basin in southeastern New Mexico: Am. Geologist, vol. 34, 1904, pp. 174–189. Describes mountains and basins. Suggests that an ancient river flowed south to the Rio Grande. States that the basin was occupied by an ancient lake, 1,600 to 1,800 square miles in area. Mentions structures that may be buried beaches. Recognizes the valley fill and divides it into formations called Otero marls and Tularosa beds.

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Keyes, C. R., Unconformity of Cretaceous on older rocks in central New Mexico: Am. Jour. Sci., 4th ser., vol. 18, pp. 360–363, 1904. Describes unconformity between Carboniferous and Upper Cretaceous in canyon in Chupadera Plateau.

Keyes, C. R., Iron deposits of Chupadera Plateau: Eng. and Min. Jour., vol. 78, p. 78, 1904. Describes sandstones at least 800 feet thick resting on Carboniferous with marked unconformity. Dikes are said to penetrate the Carboniferous but nowhere the Cretaceous. Other papers by Keyes allude to this region.

Smith, E. P., and Dominian, Leon, Notes on a trip to White Oaks, N. Mex.: Eng. and Min. Jour., vol. 77, p. 799, 1904. Describes strata in vicinity of Whiteoaks as consisting of shale, sandstone, and limestone, pierced by dikes and containing Cretaceous fossils. Successive lava flows of differing character are also mentioned. States that "the entire region appears to have been known to prospectors and miners two centuries ago, at which time it is said the Spaniards worked on the Jicarilla placers." Shallow wells yield unsatisfactory supplies but better water horizons are predicted at greater depths.

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Slichter, Charles S., Observations on the ground waters of Rio Grande valley: U. S. Geol. Survey Water-Supply Paper 141, pp. 14–21, 1905. Describes briefly the "Lanoria Mesa," including lava bed, gypsum sands, and alkaline character of the water.

Brady, F. W., The white sands: Mines and Minerals, vol. 25, pp. 529–530, 1905. Describes white sands and the region in general; associates white sands and dry climate with volcanic eruption. Lava is said to have diverted the assumed ancient river to another valley. Mentions Spanish legend that valley was "inhabited by prosperous people before the eruption destroyed river and brought about present desolation."

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Campbell, M. R., Coal in the vicinity of Fort Stanton Reservation, Lincoln County, N. Mex.: U. S. Geol. Survey Bull. 316, pp. 431–434, 1907. Describes fossiliferous Upper Cretaceous section at Fort Stanton.

MacDougal, D. T., Botanical features of the North American deserts: Carnegie Institution of Washington Pub. 99, 1908. Gives brief description of "Otero Basin," with special reference to the flora of the white sands.

Lee, W. T., and Girty, G. H., The Manzano group of the Rio Grande valley, N. Mex.: U. S. Geol. Survey Bull. 389, 1909. Discusses the upper Pennsylvanian rocks of New Mexico, and gives section in San Andreas Mountains.

Girty, G. H., The Guadalupian fauna and new stratigraphic evidence: New York Acad. Sci. Annals, vol. 19, No. 6, pt. 1, pp. 135–147, 1909. Contains data on the geology and paleontology of the Sacramento Mountains obtained by Mr. Girty and G. B. Richardson.

Lindgren, W., Graton, L. C., and Gordon, C. H., The ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68, 1910. Contains description of the geology and ore deposits of Lincoln, Otero, Socorro, and Dona Ana counties.

Free, E. E., An investigation of the Otero Basin, N. Mex., for potash salts: U. S. Dept. Agr. Bur. Soils Circ. 61, 1912. Contains a brief statement of the geology of the region, gives 19 analyses of water and soluble deposits, and discusses the chemical problems involved.

Hare, R. F., and Michell, M. S., Composition of some New Mexico waters: New Mexico Agr. Exper. Sta. Bull. 83, 1912. Contains 28 analyses of water from Tularosa Basin.

PHYSIOGRAPHY AND DRAINAGE.

GENERAL FEATURES.

Tularosa Basin may be regarded as consisting of a southern part made up of a low desert plain shut in on either side by precipitous mountain walls, and a northern part comprising mountains, plateaus, and upland plains that drain southward toward the desert (Pl. I, in pocket). The surface of the upland forming the northern half of the basin and of the mountains bordering the desert is the bedrock surface of the region or that surface thinly veiled and somewhat modified by recently deposited sediments. Its topography is controlled by the character and structure of the rock formations, and was largely fashioned by the erosive work of the streams on these exposed formations. In the low plain lying in the southern part of the basin the bedrock is in general deeply buried beneath younger sediments, and only at a few points do rocky buttes project above the débris surface, the comparatively small irregularities of which were produced mainly by the work of water and wind in carrying and depositing the loose sediments. The surface of the basin is therefore in its origin a composite developed in part by carving and cutting down and in part by building up; in other words, it is partly a destructional and partly a constructional surface.

Several physiographic features of special interest are found in this region, among which may be mentioned lava beds, cinder cones, alkali flats, or salt marshes, dunes of gypsum sand, flat-bottomed arroyos known as "lost rivers," and mounds associated with springs.

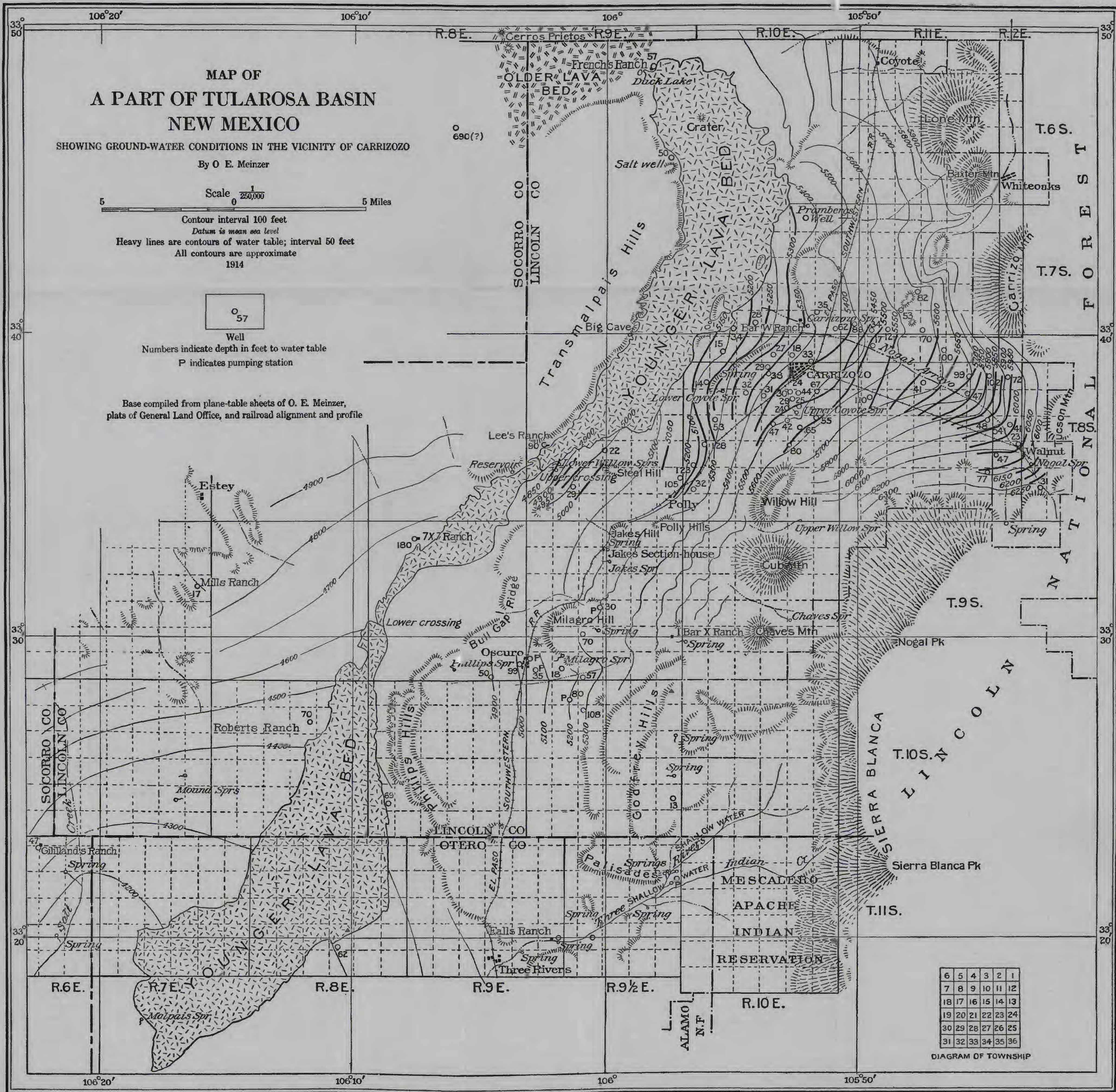
MOUNTAINS AND PLATEAUS.

SACRAMENTO MOUNTAINS.

The Sacramento Mountains lie east of the southern part of Tularosa Basin, and form about 50 miles of its mountain wall (Pl. I, in pocket). They consist essentially of a great plateau, which in its highest parts rises more than 9,000 feet above sea level, and approximately a mile above the desert plain to the west. This plateau descends gently eastward toward the Pecos Valley, forming a moderately dissected slope about 75 miles long; but on its west side it breaks off abruptly, the crest of the range being only a few miles from the edge of the desert plain. South of Alamogordo the edge of the plateau rises sheer above the plain, but farther north a bench of intermediate altitude intervenes between the plain and the high plateau (Pl. III, in pocket). South of Dog Canyon the escarpment retreats toward the east and the inclosing wall of the basin becomes low.

The high escarpment has been vigorously attacked by the weather and has been sculptured into a mountain front having almost infinite detail and presenting a vast panorama to one viewing it from the desert. The nearly horizontal beds of sedimentary rock that compose these mountains and outcrop in the escarpment give the distinctive pattern for the topography developed by the stream erosion, the alternate hard and soft ledges producing a succession of cliffs and slopes that contour the salients and reentrants of the mountain front. In its main features the topography of this front is of very youthful type. The canyons are steep and short and stream erosion is working headward at many points, gradually shifting the drainage divide farther east.

The crest of the Sacramento Mountains being near the west side of the range, most of this extensive upland region is drained toward the Pecos and only a narrow belt sends its waters toward the west. In the southern part of the range the drainage area of Sacramento River, which discharges southeastward into the Salt Basin of Texas, intervenes between the drainage areas of the Pecos Valley and Tularosa Basin, but its capture by Grapevine Canyon, one of the short steep canyons on the precipitous west slope, is impending (Pl. III, in pocket). The largest of the westward flowing streams is Tularosa River, which has a normal discharge of about 20 second-feet, obtained chiefly from large springs, and next in size are La Luz and Fresnal creeks. The other canyons of the west slope are either dry or have very little water.


MAP OF
A PART OF TULAROSA BASIN
NEW MEXICO
SHOWING GROUND-WATER CONDITIONS IN THE VICINITY OF CARRIZOZO
By O E. Meinzer
Scale 1/250,000
5 0 5 Miles
Contour interval 100 feet
Datum is mean sea level
Heavy lines are contours of water table; interval 50 feet
All contours are approximate
1914
Well
Numbers indicate depth in feet to water table
P indicates pumping station
Base compiled from plane-table sheets of O. E. Meinzer, plats of General Land Office, and railroad alignment and profile
106°20′
106°10′
106°
105°50′
33°50′
33°40′
33°30′
33°20′
R.6E.
R.7E.
R.8E.
R.9E.
R.9½E.
R.10E.
R.11E.
R.12E.
T.6S.
T.7S.
T.8S.
T.9S.
T.10S.
T.11S.
Cerros Prietos
French's Ranch
Duck Lake
OLDER LAVA BED
YOUNGER LAVA BED
Crater
Salt well
Coyote
Lone Mtn
Baxter Mtn
Whiteoaks
Carrizo Mtn
Prambergs Well
Bar W Ranch
Carrizozo Spr
CARRIZOZO
Big Cave
Transmalpais Hills
SOCORRO CO
LINCOLN CO
Lower Coyote Spr
Upper Coyote Spr
Nogal Arroyo
Jicarilla Mtn
Walnut
Nogal Spr
Lee's Ranch
Reservoir
Lower Willow Sprs
Upper crossing
Steel Hill
Polly
Polly Hills
Willow Hill
Upper Willow Spr
Spring
Estey
7X7 Ranch
Jakes Hill
Jakes Section-house
Jakes Spr
Cub Mtn
Mills Ranch
Chaves Spr
Chaves Mtn
Bar X Ranch
Nogal Pk
Lower crossing
Bull Gap Ridge
Milagro Hill
Milagro Spr
Oscuro
Phillips Spr
Phillips Hills
Godfrey Hills
Roberts Ranch
Mound Sprs
SOUTHWESTERN
EL PASO
LINCOLN CO
OTERO CO
Gilliland's Ranch
Salt Creek
Palisades
Springs
Three Rivers
SHALLOW WATER
Indian
MESCALERO APACHE INDIAN RESERVATION
Sierra Blanca Pk
SIERRA BLANCA
LINCOLN NATIONAL FOREST
Ealls Ranch
Three Rivers
Malpais Spr
ALAMO N.F.
DIAGRAM OF TOWNSHIP
6 5 4 3 2 1
7 8 9 10 11 12
18 17 16 15 14 13
19 20 21 22 23 24
30 29 28 27 26 25
31 32 33 34 35 36

SIERRA BLANCA.

The Sierra Blanca, which lies north of the Sacramento Mountains and with them forms a practically uninterrupted mountain wall, is the loftiest and most prominent of the ranges bordering the basin. It culminates near its south end in Sierra Blanca Peak, or White Mountain, whose altitude is 12,003 feet above sea level. From this peak the range extends for a distance of about 15 miles, trending first northward and then northeastward. At a number of points the general level of its crest is relieved by characteristic peaks, the highest and most conspicuous of which, next to Sierra Blanca, is Nogal Peak, nearly 10,000 feet above sea level. The highest point of the range is above the timber line and remains snowcapped longer than any other peak in the region. The Sierra Blanca, like the Sacramento Mountains, is in a sense the western edge of a great plateau, and for that reason appears much more lofty from the west than from the east. It differs, however, from the Sacramento Mountains in its topographic detail, the Sacramento Mountains having the castellated appearance produced by the weathering of nearly horizontal sedimentary beds of differing hardness, and the Sierra Blanca having the more massive appearance and less conventional pattern produced by the weathering and erosion of crystalline rocks. Its drainage area, like that of the Sacramento Mountains, is largest on the east side, the only stream on its west flank being Three Rivers, which heads near Sierra Blanca Peak.

TUCSON, CARRIZO, BAXTER, AND LONE MOUNTAINS.

North of the Sierra Blanca the mountain chain is represented by a number of more or less isolated mountains separated by easy passes, beyond which is a somewhat more continuous range known as the Jicarilla Mountains. The principal isolated masses are Tucson, Carrizo, Baxter, and Lone mountains. (See Pl. I, in pocket, and Pl. VI.) Carrizo Mountain is a massive and compact ridge over 9,000 feet high, lying northeast of Carrizozo, from which point it is in full view. Tucson Mountain is a lower ridge lying nearly due east of Carrizozo and occupying the reentrant between the Sierra Blanca and Carrizo Mountain. Lone Mountain is a rather complicated mass lying south and east of Coyote station, its highest peak rising over 7,000 feet above sea level. Baxter Mountain is a smaller rock mass lying southeast of Lone Mountain and some distance northwest of Carrizo Mountain, from which it is separated by an open pass. The mining town of Whiteoaks lies at the southeast base of Baxter Mountain.

Large draws yielding great quantities of flood water discharge through the gaps between the mountains and smaller draws head on the west flanks of the mountains themselves, but there are no permanent streams in these ranges. One of the largest streamways is Nogal Arroyo, which discharges through the gap between Tucson Mountain and the north end of the Sierra Blanca.

JICARILLA MOUNTAINS.

The Jicarilla Mountains lie north of Lone Mountain in the region east of Ancho. They have a number of picturesque peaks, the most prominent of which is Jacks Peak, near the north end. The range is drained by several large arroyos, but has no permanent stream. Ancho Arroyo leads westward past the village of Ancho.

GALLINAS MOUNTAINS.

The Gallinas Range is an isolated mountain mass projecting above the plateau country at the northeast corner of Tularosa Basin. It lies west of the railroad and approximately 20 miles northwest of the Jicarilla Mountains. It has a few springs but no permanent stream. Largo Arroyo drains much of its south flank and leads southward to the vicinity of Ancho.

The region east of the Gallinas and north of the Jicarilla Mountains is part of an extensive plateau that is broken here and there by low mesas and escarpments.

CHUPADERA PLATEAU.

The high plain that lies in the northern part of Tularosa Basin and is continuous with the Mesa Jumanes is bounded on the west for over 30 miles by a continuous escarpment from 100 to several hundred feet high. This escarpment is the edge of a more elevated surface known as the Chupadera Plateau. The plateau is cut by a number of canyons, but most of these head near the edge and have not dissected the plateau far from its margin. The edge of the plateau is partly covered with timber, which adds to the prominence of the escarpment, as viewed from the nearly treeless plain to the east.

Almost due west of Coyote station the monotony of the escarpment is broken by the Cerros Prietos—two volcanic cones that occupy a conspicuous position on the plateau near its margin. South of the Cerros Prietos the escarpment disappears for a few miles, but farther south, and extending to a short distance south of the upper crossing of the lava, is a hilly country that may be regarded as a greatly dissected southern limb of the Chupadera Plateau. This hilly region, which in Plates I (in pocket) and VI (p. 26) is called the Transmalpais Hills, attains its maximum relief a little north of west from Carrizozo, where hills several hundred feet high occur. Its eastern margin, representing the escarpment of the plateau, is contiguous to the west edge of the lava bed. (See Pls. I and VI.)

Chupadera Plateau has only a few small springs, and in its entire extent, from north of Gran Quivira to south of the upper crossing, it contains only dry arroyos.

OSCURO MOUNTAINS.

The Oscuro Range, which is about 25 miles long, lies west of the southern part of Chupadera Plateau and trends nearly due north and south. It consists mainly of an eastward-dipping block of sedimentary beds; its crest is near the west margin; its east slope, partly determined by the dip of the rock, is long, gradual, and indefinite, although steeper than the east slope of the Sacramento Mountains, in which the dip is more gentle; and its west slope is short, precipitous, and at intervals gashed by deep, short canyons. Since this range is on the west side of Tularosa Basin, its long, gentle slope is inclined toward the basin and its steep slope away from it. Consequently when viewed from the basin it has a less imposing appearance than the Sacramento Mountains. Its crest is comparatively even but has a few projecting peaks, the highest of which is nearly 8,000 feet above sea level. The Oscuro Range merges on the north with Chupadera Plateau, but is to some extent separated from the Transmalpais Hills by an intervening plain or open draw. At the south and southeast the foothills of the range are bordered by débris slopes that extend to the southern desert plain. The east side of the range, with its belt of foothills, is drained by several large draws, but there is no permanent stream and very few springs.

LITTLE BURRO MOUNTAINS.

The northern part of the Oscuro Mountains is bordered on the west by a desert plain, but the southern part is separated from this plain by a small low range known as the Little Burro Mountains. The Little Burro Mountains have the same trend and the same general structure and form as the Oscuro Mountains, their west slope being steep and short and their east slope relatively long and indefinite. The sag between these two parallel ranges is known as Oscuro Gap.

SAN ANDREAS MOUNTAINS.

The San Andreas Mountains extend with a general north-south trend from the Little Burro Mountains to the Organ Range, and for a distance of 80 miles form the west wall of Tularosa Basin. The extreme north end of this range lies west of the Little Burro

Mountains and parallel with them, the sag between the two ranges forming Mockingbird Gap, which is the most open and most easily traversed pass between Tularosa Basin and the region to the west. For a distance of 10 miles or more from the north end the range trends toward the south or a little east of south, then it retreats toward the west and again resumes a southward, and, farther on, a southeastward trend. Near the protruding angle are Capitol Peak and Salinas Peak, the latter 9,040 feet above sea level, according to the Wheeler Survey, and, owing to its exposed position, second only to Sierra Blanca Peak in its prominence as viewed from the desert. The range is remarkably continuous and unbroken, and south of Salinas Peak it has no peaks that rise far above the general crest line. The two principal notches are Lava Gap and Sulphur Canyon, both utilized by wagon roads. The range terminates at the south with San Agustin Peak, which is less than 7,000 feet above sea level.

The San Andreas Range has one steep and one gentle slope and belongs to the same structural and topographic type as the Sacramento, Oscuro, and Little Burro ranges. Its steep slope, however, faces in the opposite direction and overlooks Tularosa Basin from the west, just as the steep scarp of the Sacramento Mountains overlooks it from the east. The dip of the rocks is on the whole greater in the San Andreas than in the Sacramento Mountains, and consequently the west slope of the San Andreas is shorter and less gentle than the east slope of the Sacramento Mountains. Within a compartively short distance from the crest the rocks pass beneath the Jornada del Muerto, a desert plain that in some respects resembles the desert plain of Tularosa Basin. The weathered and eroded edges of the sedimentary beds of the San Andreas Range have the castellated appearance that characterizes the beds in the Sacramento and other mountains of the same type, this topography being well exhibited on Capitol Peak and on other peaks in the same vinicity where the formations lie nearly horizontal. Farther south the beds dip more steeply toward the west and their exposed eastern edges give the crest of the range a notched appearance.

Like most of the mountains of this region, the San Andreas Range has but few springs and no permanent streams, but discharges occasional floods through canyons that are normally dry.

ORGAN MOUNTAINS.

South of the San Andreas Range the mountain wall is continued by the Organ and Franklin ranges, both of which have a general north-south trend. The Franklin Range extends to El Paso and forms a part of the inclosing wall of the Hueco Basin. The gap between the San Andreas and Organ ranges is known as San Agustin

Pass, and is traversed by the road leading from Tularosa Basin to Las Cruces. The opening between the Organ and Franklin ranges is known as Fillmore Pass.

The Organ Mountains have a rugged, serrate topography produced by the weathering of the crystalline rocks, of which they are largely composed. The steeply projecting crags, conspicuous from great distances on both sides of the mountains, have by their resemblance to organ pipes given the name to the range. The highest peak is about 9,000 feet above sea level.

JARILLA MOUNTAINS.

The Jarilla Mountains lie at the south end of Tularosa Basin and are separated from both Sacramento and Organ ranges by broad stretches of desert lowland. They form a low range hardly 10 miles long. Like the other ranges in this region they have a general north-south trend. They contain no permanent streams and no springs.

NORTHERN PART OF INTERIOR AREA.

GENERAL FEATURES.

The mountains and plateaus that have been described form the borders of Tularosa Basin and divide the waters that are retained within its limits and drained toward its low interior area from the waters that are sent in other directions. As has been explained the large, relatively depressed surface that lies within the mountain borders and constitutes most of the area of the basin is composite in its origin. The northern part is essentially a rock surface that descends from about 7,000 feet above sea level at the north end, where it constitutes the Mesa Jumanes, overlooking Estancia Valley, down to only a little over 4,000 feet where the rock surface passes under a deep filling of rock débris. The southern part is a plain formed by the débris filling, and the boundary between the northern and southern parts must be drawn along the line where the rock surface plunges beneath the débris. This line extends from Three Rivers in a north-northwesterly direction to the lava bed, as indicated by the hachures in Plates I (in pocket) and VI (p. 26), thence north to a point some distance beyond the 7 X 7 ranch, thence west and southwest along the margin of the foothills of the Oscuro Mountains. North of this line the topography is mainly the expression of rock structure and stream erosion, although somewhat influenced by stream deposition; south of this line rock structure and stream erosion have only a minor influence on the topography.

BENCHES AND ROCK ESCARPMENTS.

The region north of this line is not a single plain, but in large part consists of a series of plains arranged in tiers, each forming a bench or terrace. The edge of each of these benches consists of a ledge of relatively hard rock that dips toward the bench and protects it from denudation, but projects as an escarpment over the plain that lies next below in the tier. The outcropping ledge that forms the rim of a bench may be almost level with the surface of that bench, as the ledges west and north of Carrizozo, or it may form a ridge rising several hundred feet higher, as Milagro Hill and Willow Hill, with the result that the bench is more or less hemmed in on both sides. The escarpments have been dissected by stream erosion, but on the benches the irregularities of the rock surface have in many places been smoothed over by stream deposition. On the whole, however, the benches seem to represent a beveled west-sloping surface that may be correlated with rock terraces extending up the mountain valleys and may have been formed by planation in an earlier denudation cycle.

These ridges and ledges with their accompanying benches are the most characteristic features of the northern half of the basin. They are most prominent between Three Rivers and Carrizozo, are smaller but no less typical between Carrizozo and Ancho, but are nearly absent over the areas west of the lava beds and between the lava beds and Gran Quivira. South of Oscuro they have a general north-south trend, but farther north they generally extend in a northeastward direction. On the whole they orient themselves with the mountain blocks, both ridges and mountain ranges having a general north-south arrangement and, with the exception of the San Andreas Mountains, a prevailing easterly dip.

One of the most typical and best developed tiers of benches and escarpments is in the vicinity of Oscuro. The Phillips Hills and Bull Gap Ridge form the exposed edge of a large bench whose dissected west-facing front, several hundred feet high, has the aspect of a small mountain range. Milagro Hill, a typical escarpment also several hundred feet high, is next in the series, overlooking this bench and forming the exposed edge of a second bench that lies farther east and at a higher level. The Godfrey Hills, with their steep west-facing escarpment several hundred feet high and the upland on their east side, form another step in the same tier. Still farther back, overlooking the upland east of the Godfrey Hills and all of the lower benches, is the Sierra Blanca, which forms in a sense the last huge step in the tier. Intervening between the Godfrey and Phillips hills are several smaller escarpments that have the same general structure.

The largest ridge north of the Godfrey Hills is the Tres Cerros, consisting of Willow Hill, Cub Mountain, and Chaves Mountain, which are in a line extending south from Carrizozo and have west-facing fronts more than 1,000 feet high. Between these hills and the lava bed are numerous ridges of the same type, including Jakes Hill, the Polly Hills, Steel Hill, and smaller escarpments without names.

West of Carrizozo, in the vicinity of Lower Coyote Spring, is a small escarpment that is hardly observable from the southeast, but forms a distinct northwest-facing cliff that persists to a point several miles north of the Bar W ranch. Between this escarpment and

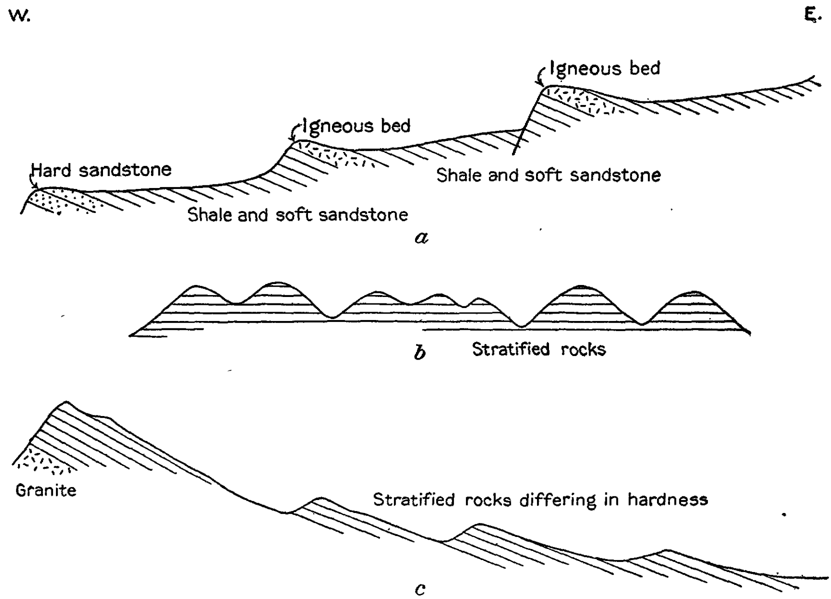


FIGURE 3.—Sections illustrating the rock structure and resulting topography of the northern part of Tularosa Basin. *a*, Benches and escarpments on the east side of Tularosa Basin; *b*, Transmalpais Hills; *c*, Oscuro Mountains and foothills.

Coyote station is another typical though small escarpment that faces the northwest and forms a more conspicuous ridge. It is in line with several other small ridges farther southwest that are entirely surrounded by lava. A few ridges also occur north of Coyote. (See Pl. I, in pocket.)

OTHER HILLS AND RIDGES.

The plain between Gran Quivira and the lava beds is not greatly broken by ridges or scarps and only slightly dissected by arroyos. The hill country west of the lava beds lacks entirely the longitudinal, terraced arrangement. It is essentially a greatly dissected plateau underlain by horizontal rock beds. The foothills of the Oscuro Mountains form parallel ridges whose steep sides face the mountains and whose gentle slopes are in the direction of the dip. They have the longitudinal alignment, but not the terraced arrangement of the features on the east side. The three types of rock structure and resulting types of topography are illustrated in figure 3.

SINK HOLES.

Large sink holes are found on the plain north of the lava beds, in the hill country west of the lava, and in other sections where the Carboniferous formation, chiefly limestone and red beds, include layers of gypsum. (See pp. 57–60.) Good examples of such sink holes are the big cave, fully 50 feet deep, near the east margin of the lava (Pl. VI, p. 26) and the sink in the arroyo followed by the west road to Gran Quivira, about 5 miles north-northeast of the Cerros Prietos. (Pl. I, in pocket.) Both of these sinks receive considerable drainage at the present time, but many sink holes that were once functional in receiving flood waters and conducting them away through underground passages have long ago become choked up, and gentle depressions with no outlets have resulted. Undrained depressions have also been formed through the dissolving and removing of gypsum strata by subterranean waters and the subsequent settling of the surface. The northern part of the plain between Gran Quivira and the lava beds consists largely of gentle undulations with undrained depressions, and may be said to have a typical gypsum-sink topography. (See Pl. XV, *A*, p. 48.) Red Lake, near Coyote station (Pl. I, in pocket), is a depression of this type.

VOLCANOES AND LAVA BEDS.

YOUNGER LAVA BED.

The most impressive physiographic features of the northern part of Tularosa Basin are two lava beds and three volcanic cones, one cone surmounting the younger bed and two the older. The lava beds are commonly called "malpais," a Spanish term meaning bad land. The younger bed lies along the central axis of the basin, west of Carrizozo, Oscuro, and Three Rivers, and is accurately shown in Plate VI. It extends in a south-southwesterly direction, has a length of 44 miles, a maximum width of 5½ miles, and an area of about 120 square miles.

The lava, extruded at the crater shown in Plate VI and possibly from other vents now concealed, flowed along the axis of the basin and solidified in a long ribbon-like body. It does not, however, have an exact axial position, for the crater and northern lobe of lava lies slightly west of the axis, whereas the southern lode lies east of it.

The statement has repeatedly been made that the lava occupies an ancient river channel, but this inference appears to be entirely conjectural, as no traces of any ancient channel could be found either at the south end of the bed or farther north. In all probability the axis of the basin was occupied before the extrusion by a large arroyo that conducted the flood waters of the northern section to the southern desert region, and in a more humid epoch it may have been occupied by a permanent stream.

The relation of the lava bed to the existing topography is obvious, and shows that not only the main axial depression but also the present hills and ravines were in existence at the time of the volcanic eruption. In the northern part the lava was obstructed in its flow by the rock ridges on the east and still more by the hills on the west. Where the lava came in contact with a ridge it was checked in its movement but flowed over the surrounding plain, either leaving the ridge in a peninsular reentrant, locally known by the Spanish name "rincón," or else completely encircling it so that it formed an island (Pl. VI). Where the lava flowed against the hills on the west side it sent tongues up the ravines and produced an exceedingly sinuous line of contact with numerous rincons occupied by hills closely embraced by lava. Farther south where the lava flowed out upon the open plain and was not hampered by hills on either side, its margin is more regular, but even here there are some large rincons. (See Pl. VI.)

As is shown in Plate VI, the lava bed consists of two expanded lobes connected with each other by a long narrow neck. The north lobe and its gradual constriction toward the south can be explained on the assumption that the lava was derived from the crater near the north end and was governed in its flow by the contour of the surface over which it was poured. The material of the southern lobe was probably also derived from the crater and deployed when it reached the open plain, but it may have been extruded from vents farther south that are now concealed.

The surface of the lava bed descends toward the south with the axis of the basin at an average rate of about 30 feet per mile, in addition to which the north lobe slopes toward the east and the south lobe slopes more gently toward the west. As shown in Plate VI the volcanic cone is situated about 2½ miles from the north end of the lava bed and 1½ miles from the margin at the point of nearest approach. The top of the cone is estimated to be about 5,700 feet above sea level, or a little more than 200 feet above the plain that borders the northern part of the lava bed. The surface rises gently from the margin of the lava toward the crater, but most of the ascent of over 200 feet occurs within a few rods of the summit.

The margin of the lava bed is a rugged cliff or steep slope ranging in height from only a few feet in localities where the adjacent plain has become silted up by flood waters to a maximum of nearly 50 feet. Along a considerable part of the margin there is a well-defined lava terrace intermediate in height between the general surface of the bed and the surface of the adjacent plain. This terrace, which is shown in figure 4 and Plate VIII, *A*, was probably formed by liquid lava breaking out from beneath the congealed crust.

The surface of the lava bed is so rough that it defies adequate description. It can not be traversed for any distance by horses or cattle, and even man can only with great effort make his way over it. It contains small areas that are roughened only by minor irregularities or by a flow structure such as is shown on the slab in Plate VII, *B*, but these smooth tracts are interrupted by abrupt pits, fissures, or caverns, from 5 to 20 feet deep, by chaotic heaps of broken slabs and sharp, angular chunks of lava, or by masses of jagged and ropy fragments. (See Pls. VII and VIII.)

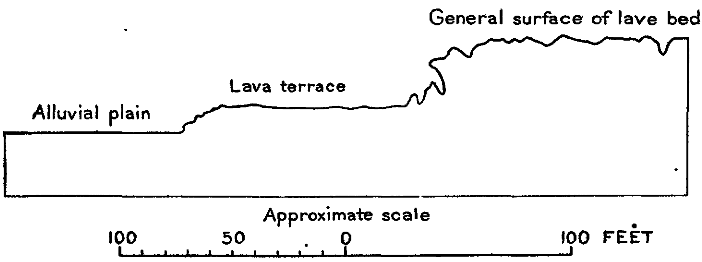
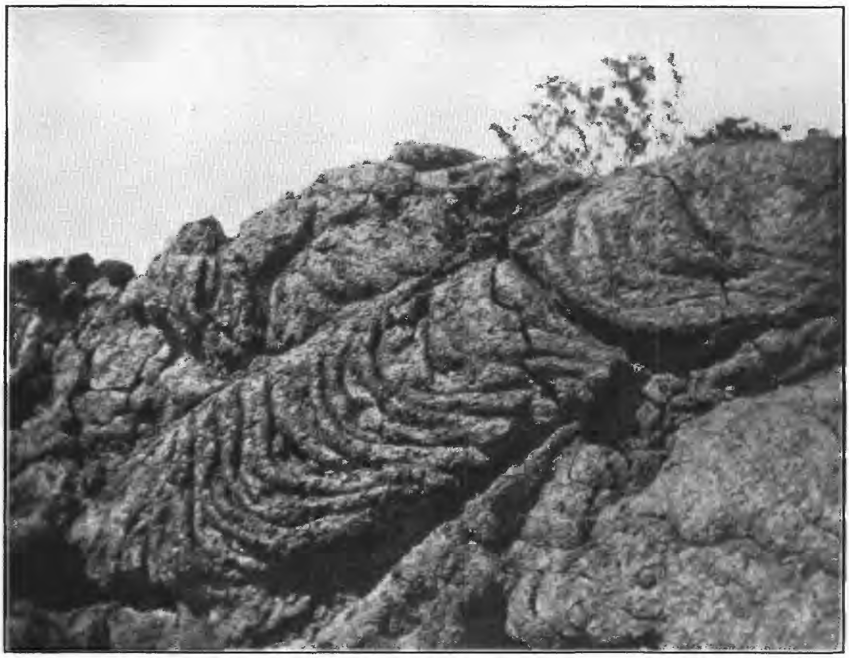


FIGURE 4.—Profile showing marginal terrace of younger lava bed.

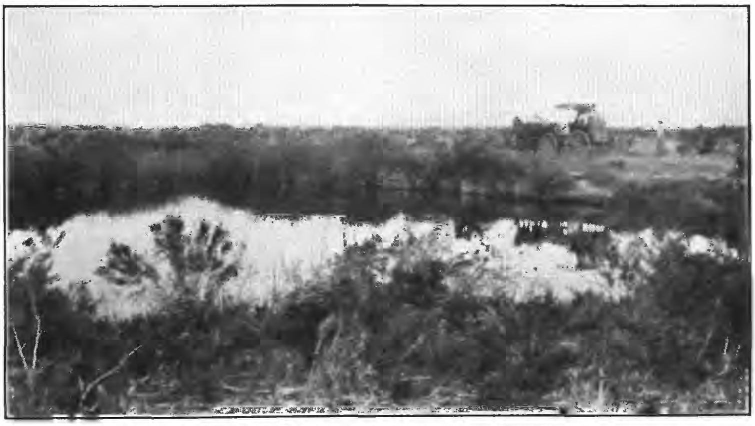
The irregularities of the surface have by several writers been ascribed to an undermining of the bed by subterranean waters, but there is no evidence that undermining has taken place to any appreciable extent and it is difficult to conceive how this agency could possibly produce the existing condition. On the west side of the lava there are several sink holes, into which some flood water escapes, but it is doubtful whether these have affected the topography of the lava bed in even the slightest degree. The water of Malpais Spring, the only spring that issues from the lava, is perfectly clear, and consequently removes no mechanical sediments. It carries out several tens of thousands of cubic feet of soluble earth yearly, but this would amount to only a small fraction of an inch beneath the entire bed in a century. Even if liberal allowance is made for material removed by the underflow that does not come to the surface, the assumed undermining process seems quantitatively as well as qualitatively inadequate. There can be little doubt that the irregularities were produced at the time the lava was erupted, the solidified portions being undermined, broken, and carried along by the fluid lava.

A. EDGE OF YOUNGER LAVA BED, SHOWING FISSURE.



B. YOUNGER LAVA, SHOWING ROUGHNESS OF SURFACE.

A. EDGE OF YOUNGER LAVA, SHOWING TERRACE.



B. SINK HOLE EXTENDING BELOW GROUND-WATER LEVEL.

C. SALT CREEK, SUPPLIED FROM GROUND-WATER SEEPAGE.

When the lava flowed down the axis of the basin and solidified in that position it to some extent blocked the outlets of the tributary watercourses, producing shallow depressions that were flooded after heavy rains. Duck Lake, at the north end of the lava bed, was probably formed in this manner. By the silting up of these impounded areas mud flats have been produced that are treacherous in wet weather. In many places shallow channels have been cut along the margin of the lava, forming outlets for the flood waters, and on the west side some of the water is discharged through marginal sink holes.

OLDER LAVA BED.

The older lava bed lies northwest of the younger and forms approximately a right-angled triangle whose right angle is in the northwest corner, whose north and west sides are, respectively, about 7½ and 5½ miles long, and whose area is somewhat less than 25 square miles. Its position and extent is shown approximately in Plates I and XVII. It forms a much less distinctive physiographic feature than the younger bed.

Except for the features produced by the lava itself, the topography of the region was nearly the same at the time of the first eruption as it is at the present time. The escarpment of the plateau, the hills and ravines west of the lava, and the draw leading toward the southwest were all in existence. The two volcanic vents were at the edge of the plateau, and the molten material flowed from them in directions determined by the contour of the surface. Toward the west it extended hardly one-half mile when its course was obstructed by limestone hills, the smallest of which were submerged by the molten flood, while the larger formed effective barriers but were partly engulfed by tongues of lava that extended up the ravines. North of the craters the lava was also obstructed, and in general extended less than a mile from the northern vent. But toward the east and south it was less hampered in its movement and therefore extended much farther. The lava flowing toward the east appears to have been poured over the edge of the plateau in a sort of huge cataract and to have deployed widely over the low plain to the east, in a few places forming islands out of rocky crags, which it surrounded but did not submerge. The lava also found a rather steep slope toward the south, and for a considerable distance followed a drainage line that led southwestward.

The surface of the old lava bed is not nearly so rough as that of the younger bed. In most places it is possible to drive across it with a wagon, and in some localities at the lower levels the lava is covered with sediments to such an extent that its limits can not be ascertained by surface appearances. The greater smoothness of the older lava surface is largely the result of changes that have taken place since the eruption, but it may also be due partly to original differences.

Post-volcanic sedimentation and erosion have taken place at the margin of the bed, where the drainage is adjusting itself to the obstructions produced by the lava. These changes are similar to those found at the margin of the younger bed, but are clearly of greater extent. A few erosion lines have also been cut into the lava itself, whereas no erosion features whatever can be seen on the younger bed. Examples of erosion on the older bed are furnished by the gash on the southwest flank of the south cone and by the small gulches at Indian tank and Serano tank.

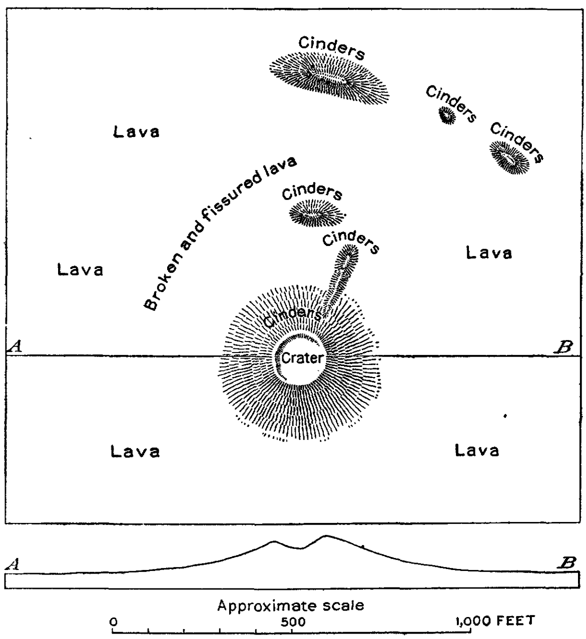


FIGURE 5.—Sketch map and section of volcanic cone on the younger lava bed.

YOUNGER VOLCANIC CONE.

The general flatness of the younger lava bed as viewed from a distance is relieved near its north end by a volcanic cone, a sketch map and profile of which are shown in figure 5. So difficult of access is this cone that strange and wholly unwarranted stories in regard to it are current even among people that live only a few miles away. The conspicuous part of the volcanic eminence is a steep, symmetrical, cinder-covered cone, approximately 100 feet high, with a crater 150 to 200 feet in diameter and depressed 20 to 35 feet below the rim, as shown by the profile, *AB*, in figure 5. This steep cone stands at the apex of a much larger and flatter lava cone that is at least a mile in total diameter and hardly 100 feet in total height. Northeast of the crater there are several ridges or heaps of cinders concentric with the rim of the crater, all less than 50 feet high. Northwest of the crater is an area of extremely broken lava, the largest fissures being about 20 feet deep. The steep cinder cone is probably a feature formed near the close of the volcanic activity rather than the structure from which the bulk of the lava was emitted. The cinder ridges have no craters and may have been built of materials ejected from the cinder cone and lodged in their present position by the wind, although it is more probable that they were ejected from openings where they occur.

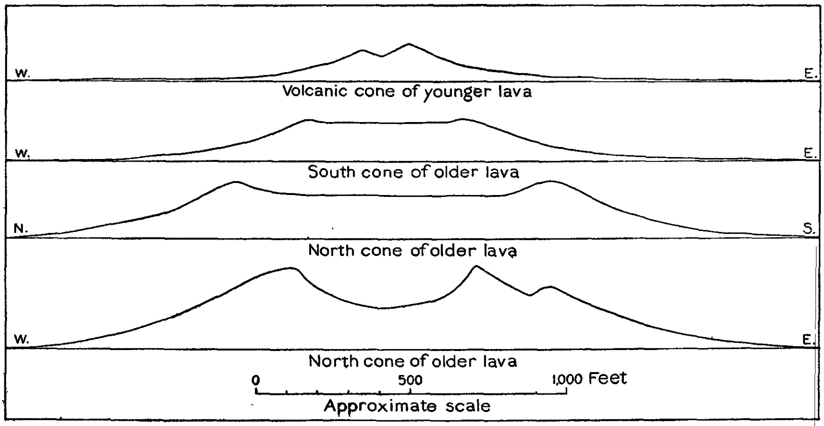


FIGURE 6.—Profiles of volcanic cones.

OLDER VOLCANIC CONES.

The two volcanic cones of the older lava bed (the Cerros Prietos, shown on Pls. I, in pocket, and VI, p. 26) stand at the east edge of the Chupadera Plateau, about 6 miles west of the north end of the younger bed, and are less than a mile apart. The rim of the crater of the northwest cone is 250 to 300 feet above the general level of the plateau, nearly 1,000 feet above the plain at the southeast base of the older lava, and nearly 6,500 feet above sea level. The top of the southeast cone is 50 to 100 feet lower. The northwest cone is the larger of the two, but both are much larger than the younger cone (fig. 6).

The southeast cone, which stands somewhat more than 100 feet above the surrounding surface, is very symmetrical and exhibits a smooth cinder-covered surface, except in one locality on its southwest flank where it has been cut open by recent erosion. It is crowned by a saucer-shaped crater about 500 feet in diameter and 10 to 15 feet deep. No cinder ridges or other features such as are found in the environs of the younger cone occur in relation to this volcano.

The northwest cone is the largest and least symmetrical of the three, as is shown by the profiles in figure 6. Its crater is elliptical in ground plan, the east-west diameter being about 600 feet and the north-south diameter about 1,000 feet. The rim of the crater has two lateral cusps that stand more than 100 feet above the bottom of the crater and between 200 and 300 feet above the surrounding plain. At the north and south ends the rim sags and is only about 50 feet above the bottom of the crater. The asymmetric character of the cone is due to a structure that appears to be the remnant of a second rim encircling the principal rim and suggests that the volcano may have had a rather complex history. This cone, like the other, has no cinder ridges such as are found at the cone on the younger lava. Its flanks are trenched in a few places by small gullies.

SOUTHERN PART OF INTERIOR AREA.

GENERAL FEATURES.

South of Three Rivers, on the east side of the basin, and south of the 7 X 7 ranch, on the west side, the rock surface passes beneath a great accumulation of sediments derived in geologically recent time from the waste of the mountains. The surface of this southern section, as has already been explained, was formed by the disposition of these sediments through the agencies of water and wind. It constitutes an elongated shallow basin with steeply sloping sides but a large interior area whose inclination is almost imperceptible.

The marginal slopes are built by the floods that from time to time issue from the canyons of the surrounding ranges and are composed of the rock waste that these floods sweep along with them. The shape and size of such slopes depend on the character of the adjacent mountains and of the floods to which they give rise. The mountain flanks facing this basin are, as a rule, short and steep, and their short, steep canyons shed the storm waters in sudden freshets of brief duration, with the result that most of the débris carried out of the canyons is piled near their mouths in short, steep, alluvial fans. This condition is probably nowhere better shown than at Alamogordo, where the descent from the mountains to the desert is very abrupt. Larger and more gently sloping fans have been built north of Alamogordo by La Luz and Fresnal creeks, Tularosa River, Rinconada Creek, and Three Rivers (Pl. II, in pocket) and in the northwest by several large draws heading in the northern part of the San Andreas Range.

The plain that lies at the foot of the alluvial slopes and occupies the interior of the basin is in general concave upward, but in some parts it is slightly convex, as in the region several miles west of Alamogordo, where an imperceptibly gentle swell of the surface shuts off the view of that city from the plain west of the swell. The southwestern part of the plain is the lowest, because most of the sediments of which the plain was built were derived from the east and north.

Nearly level plains have in some places been produced by stream gradation, but the flatness of the extensive desert plain of Tularosa Basin suggests, though does not prove, that the region was for a long time submerged and was built up by the uniform sedimentation that takes place at the bottom of a body of standing water. Although the plain as a whole is nearly level, there are imposed on it a number of characteristic minor irregularities, which are described in succeeding paragraphs.

BUTTES.

A few rocky buttes project above the desert plain, most of them near a line extending generally northward from the Jarilla Range. They are the peaks of mountains that have been nearly submerged by sediments. They are not large, but by reason of their isolation they form conspicuous and well-known landmarks, the most important being Cerrito Tularosa, about 8 miles southwest of Tularosa, and the group of buttes southwest of Dog Canyon which the Mexicans have long called the Tres Hermanos, or "Three Brothers" (Pls. I and II, in pocket).

FAULT SCARPS AND SHORE FEATURES.

Among the most conspicuous and characteristic of the physiographic features of this region are a series of cliffs and terraces which interrupt the regularly curving profiles of the stream-built slopes that border the southern part of the basin (Pls. I, IX, X, and XI). These features are, with a few exceptions, below the 4,250-foot contour, but they occur at several levels between that contour and the desert flat. Single cliffs range from only a few feet to more than 50 feet in height, but the maximum combined height of successive cliffs in the same locality may be more than 100 feet. Cliffs and terraces extend along the west side of the basin almost continuously from a point between Ritch's and Baird's ranches (T. 17 S., R. 4 E.) to the low divide south of Coe's ranch. Crossing this divide they extend along the west side of the Hueco Basin to El Paso, maintaining throughout about the same maximum altitude above sea level. Features of the same type are found on the east side of Tularosa Basin, extending from the vicinity of Dog Canyon southward as far as the region was examined. A cliff at a considerably higher level can also be traced for several miles along the slope bordering the Sacramento Mountains between Alamogordo and La Luz.

Terraces have been observed in this region by several geologists, and have been regarded by them as shore lines, fault scarps, or débris accumulations caused by floods. R. T. Hill,[1] in his paper on the Texas-New Mexican region, states:

> The Hueco-Organ basin [comprising the Hueco and Tularosa basins] is accompanied by many terrace benches around its border. These are of two kinds: (1) Remnants of ancient shore lines; and (2) delta deposits of débris brought down by present floods upon the mountains. The terraces are especially well shown in the pass of the Rio Grande at El Paso, where on the northern side 7 or 8 tiers of them above the river level can be traced.

R. S. Tarr,[2] in an article published about the same time, states:

> On the foothills of the mountains are quite distinct beaches, which, with other evidence, tend to prove that this is the site of Quaternary lakes.

C. L. Herrick,[3] in his paper entitled "Lake Otero, an ancient salt lake basin in southeastern New Mexico," states:

> Along the gradual slope west of the southern tongue of the malpais, erosion has exposed what seem to be remnants of old lake benches. At no other place have they been observed, though 3 or 4 distinct benches border the playas.

G. B. Richardson, in the El Paso folio, describes the benches on both sides of the Franklin Mountains, and regards the high-level benches on the east side as recent fault scarps. Ellsworth Huntington, in a trip through the region in 1912, observed the terraces west of the white sands and regarded them as ancient shore lines; the cliff east of Alamogordo, however, he regarded as a fault scarp.[4]

In general fault scarps and ancient shore lines are so different from each other that there is little chance of confusing them, but many of the features in this region, though they have the general appearance of both, lack the distinctive characteristics of either to such an extent that it is difficult to determine their true origin. The fact that cliffs and terraces are found on both sides of Tularosa Basin gives no clue to their origin. Recent faulting, such as would be shown by scarps on the alluvial slopes, would be expected to occur along ancient fault lines, where the earth's crust is already broken. Such ancient fault lines are believed to exist on both sides of the basin. (See pp. 74, 75.) On the other hand, if the basin were once occupied by a lake, shore features would in all probability be formed on both sides. In the scarp on the slope between Alamogordo and La Luz displacement is indicated by the fact that bedrock, mantled by valley fill, occurs on what would be the upthrow side, and abuts against valley fill on the downthrow side. A displacement of about 2 feet was also observed by Richardson in the unconsolidated deposits

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[1] Geol. Soc. America Bull., vol. 3, p. 96, 1891.
[2] A recent lava flow in New Mexico: Am. Naturalist, vol. 25, p. 524, 1891.
[3] Am. Geologist, vol. 34, p. 185, 1904.
[4] Oral statement to author.

A. STRATIFIED VALLEY FILL AT EL PASO.

B. CLIFF AND TERRACE FEATURES NORTH OF SAN AGUSTIN PASS.

CLIFF AND TERRACE FEATURES EAST OF FRANKLIN MOUNTAINS.

at El Paso. On the other hand, some of the features on the west side of the basin and also southeast of Dog Canyon suggest a lake origin.

The cliffs and terraces, although maintaining the same general altitude throughout the region and broadly following the sinuosities of the contours, lack for the most part the precise horizontal lines which are so distinctive of ancient strands. But this condition is not absolute disproof of a lake origin. Where the waves of a lake form a cliff the base of the cliff and the terrace at the base are virtually horizontal, but the upper edge of the cliff is of course an irregular line. When the lake subsides the high land back of the cliff is eroded and the eroded material is deposited over the terrace in alluvial cones. By this process the base of the cliff also becomes an irregular line. At the same time the terrace is largely destroyed by both deposition and erosion.

The cliffs and terraces are not accompanied by well-preserved beach ridges, bars, or spits, but in a few places there are features that appear to have been formed by the waves. Southeast of Globe Spring there is a large alluvial fan that is contoured by the terrace features. On the edge of at least one of these terraces gravel hills are conspicuous from the upslope as well as the downslope side of the fan, suggesting remnants of a large but greatly eroded beach ridge. Along the divide south of Coe's ranch large but indistinct ridges somewhat resembling beach ridges swing across the plain. Along the road about 3 miles southeast of Ritch's ranch a gravelly ridge having the appearance of a beach ridge runs parallel with the edge of the alkali flat. A somewhat similar feature was observed several miles southeast of Cerrito Tularosa. Suggestions of a beach are also seen on the large alluvial fan 10 miles southeast of Dog Canyon near the road to Lee's ranch. Some indistinct terraces were found around the Jarilla Mountains and the isolated buttes, but they are nowhere well developed, although the isolation of these projecting land masses should have subjected them to especially strong wave action. The relatively rapid descent of the plain in a belt midway between the railroad and the white sands, and a similar rapid descent near the alkali flats on the west side of the basin south of Ritch's ranch, are features such as are produced by rapid sedimentation near the shore of a lake or sea. A more pronounced drop in the surface of the plain is traceable along a line that extends through the Lomitas, Gray, and Chosa ranches. All these features are, however, indefinite, and it is difficult to conceive that a lake which stood high enough to have formed them should have left so few other shore features.

Extensive observations in connection with the present investigation, though not producing conclusive evidence, have led to the belief that the prominent cliff and terrace features were caused, at least for

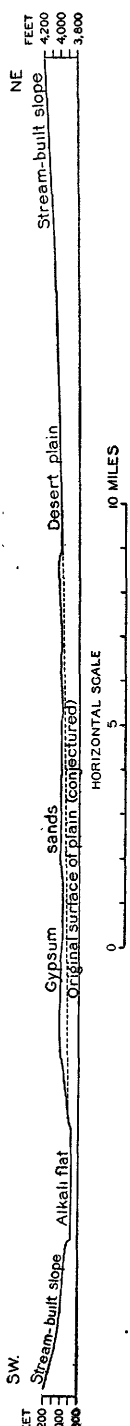


FIGURE 7.—Profile across southern part of alkali flat and gypsum sands.

the most part, by faulting, and that shore features were poorly developed or largely destroyed by post-lacustrine changes. The best evidences of the existence of an ancient lake are not physiographic.

ALKALI FLATS.

Lying within the low desert area, principally near its west margin, are several large alkali flats and an indefinite number of smaller ones, together covering an area of about 165 square miles (Pl. II, in pocket, and fig. 7).

The most characteristic of these flats constitute definite topographic features. They are not indistinct sags in the surface of the plain but sharply defined basins with nearly level floors 10 to 30 feet below the general surface of the plain and in some localities 30 to 50 feet below the surface of adjacent dunes. In many places the descent from the plain or dune surface to the flat is a sheer cliff but in others it is less abrupt.

These depressions could not have been formed by stream erosion for they have no outlets, and they are clearly not sink holes nor ancient shore features. That they were formed by wind erosion is definitely proved by the fact that the excavated material generally lies in dunes on the plain immediately east or northeast of the depression from which it was obviously derived, the material having been borne in the direction of the prevailing storm winds, which blow from west and southwest. In some places the even surface of the flats is interrupted by mesas with comparatively flat tops and steep sides, which are remnants of the original plain not yet removed by the wind.

Some of the smaller flats lie in shallow and indefinite sags of the general surface, but even these are accompanied on their east or northeast sides by wind-built ridges, which show that they are of eolian origin.

The floors of the flats are not normally covered with water, and in many places they are so firm that a wagon can be driven over them, even where no road has been made. However, they stand only slightly above the water table, and the ground beneath them is nearly everywhere moist from the upward seepage of

A.

B.

CLIFF AND TERRACE FEATURES NEAR SAN AGUSTIN PASS.

FRESHLY DEPOSITED GYPSUM SAND.

the ground waters. Ordinarily wind erosion does not develop flat surfaces, but the flatness of these depressions is manifestly caused by the water table, which limits the depth to which the wind can erode. The floors of the flats are not entirely level, but slope very gently, just as the water table might be expected to slope. From the north to the south end of the system of large flats, a distance of somewhat less than 30 miles, the surface descends a little over 100 feet. A line of levels carried across the flat in the vicinity of Baird's ranch showed a difference in level of only 3 feet in the first 4 or 5 miles east of the west margin.

Alkali flats occupying well-defined depressions have been observed in the Estancia, Encino, and Pinos Wells basins in central New Mexico[1] and also in certain parts of the Great Plains; for example, in the shallow-water belt in the vicinity of Portales, N. Mex. They are not, however, characteristic of the closed basins of most parts of the arid West. The great development of these depressions in certain New Mexico basins is probably related to the gypseous character of the deposits in these basins and their consequent susceptibility to wind erosion. The absence of the depression features in many other basins is probably due to the presence of heavy clay that is not readily attacked by the wind.

The depressions of this region, like those in other parts of New Mexico, tend to develop an elongated form with the long axis extending approximately north and south, at right angles to the direction of most effective winds.

DUNES.

In Tularosa Basin, as in other arid regions, the wind has been at work over wide areas, eroding, transporting, and depositing materials, and thereby producing physiographic features that are distinctive of the activity of this agency. The chief material handled by the wind in most localities is quartz sand, but in this region gypsum is very abundant at the surface and gypsum sand is consequently more important than quartz sand as a wind-borne material. (See Pls. XII, XIII, and XIV, *B*.)

The most conspicuous area of wind deposits is a tract of freshly deposited gypsum sands, 270 square miles in extent, lying on the east side of the large alkali flat (Pl. II, in pocket). The unique feature of this area is not its topography but the unusual material composing the dunes and the resulting snow-white appearance of a large part of the area. The irregular, hummocky, ripple-marked surface resembles so closely the surface of an ordinary dune area in which quartz sand is the material handled by the wind that detailed description is not necessary. The gypsum sand was deposited on the

[1] Geology and water resources of Estancia Valley, N. Mex.: U. S. Geol. Survey Water-Supply Paper 275, pp. 25, 78, and 82, 1911.

original surface of the desert plain and consequently the general level of the dune area is somewhat higher than that of the surrounding plain where little or no gypsum was deposited by the wind. The largest dunes rise over 50 feet above the plain level, but within the dune area there are low, swampy, tracts that may represent the original surface of the plain or may have been developed by the erosion of that surface by the wind.

A definite relation exists between the white sands and the large alkali flat, which is floored and walled with crystallized gypsum. The white sands lie on the east side of the flat (Pl. II, in pocket) and are composed of the broken gypsum crystals wrested from it by the storm winds. The east margin of the white sands is in most places sharply defined, the white, granular gypsum deposits ending abruptly like a snow bank on its leeward side. The sands, still driven by the storm winds, are gradually shifting eastward and encroaching on the plain. Roads that formerly followed the margin of the dune area are now covered with gypsum sands and new roads have been started farther east. In some places the margin is reported to have advanced about a mile in 20 years.[1]

The area of fresh gypsum-sand dunes has rather definite limits, as shown in Plate II, but the entire area that has been more or less affected by the drifting of gypsum sands and other gypseous material extends much farther and has less distinct boundaries. It reaches southward in a wedge-shaped area to a point a few miles south of Parker Lake, eastward within a short distance of Alamogordo, and northward (outside of the quartz-sand area) about to the lava bed. Within this larger area the surface is nearly level, but includes numerous low ridges and shallow depressions, some of them obviously formed by the wind but others hardly discernible or not readily differentiated from the sink holes. This large region is covered with desert vegetation and is not at present subjected to vigorous wind work. Whether its topography represents an older epoch of dune formation or merely a less vigorous phase of wind activity is not evident.

North of the white sands the dune area is continued as a belt of quartz sand which covers more than 100 square miles and lies east and northeast of the northern alkali flats (Pl. II, in pocket). As in the white sands, the east margin is sharply marked but the west margin is indefinite, the entire region east of the flats being more or less affected by wind work.

Low sand dunes of a more reddish hue are found over a wide area in the southern part of the basin. They extend a number of miles

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

WIND-ERODED GYPSUM SAND, SHOWING BEDDING.

A. BANK OF MID-SLOPE ARROYO, SHOWING STRATIFIED GYPSUM UNDERLAIN BY RED ADOBE.

B. GYPSUM-SAND AREA.

north, west, and east of the Jarilla Mountains and south to the Texas line. A large part of this area has no definite drainage, but contains numerous small arroyos that maintain themselves for only short distances among the drifting sand and end in shallow depressions often called "lakes." This undrained belt constitutes the indefinite divide between the Tularosa and Hueco basins.

SINK HOLES.

Sink holes are found not only in the areas underlain by gypsiferous bed rock but also in the parts of the desert plain underlain by recently deposited gypsum. They are especially abundant in a belt several miles wide lying east of the principal dune area, some of the largest sink holes of this type being found in the vicinity of Cerrito Tularosa (Pl. XV, *C*). They occur most commonly along the margins of the arroyos (fig. 43), and range in size from tiny openings resembling gopher holes to caverns at least 10 feet in diameter at the top. Even the small holes will admit large quantities of flood water. The water discharged from Shoemaker's flowing well (Pl. XVIII, *B*, p. 158) is drained into one of these sinks.

Several water holes have been formed apparently by the sinking of the surface beneath the present ground-water level, examples of which are the pond situated a little over 2 miles southwest of Shoemaker's flowing well and in the same flat-bottomed arroyo as that well (Pl. VIII, *B*), the pond at a ranch about 1½ miles north of the same well (NE. ¼ sec. 35, T. 14 S., R. 8 E.), and several water holes observed in the arroyo in sec. 9, T. 15 S., R. 9 E. The pond southwest of the flowing well is fully 400 feet long and stands about at a level with the arroyo. The pond at the ranch north of the flowing well is somewhat smaller but occupies a circular depression about 10 feet deep. The ground water fills the bottom of this depression and drains southwestward through a rather definite underground channel that has caved in at several places and forms a second pond before the water finally disappears below the surface.

Small mounds occur on the southwest sides of some of the sink holes that are filled with water, the material of which they are built apparently having been brought by the wind and captured by the vegetation and moist soil on the windward sides, whereas but little wind-borne material reached the opposite sides.

The belt having gypseous soil and abundant sink holes is characterized, at least in many localities, by a gently undulating topography and shallow undrained depressions. These irregularities are probably chiefly of sink-hole origin although some of them are no doubt due to wind. Since both solution and wind work are related to the gypseous character of the soil they are largely coextensive, and in many places it is therefore difficult to differentiate between the features produced by these very different agencies. This difficulty is increased by the fact that the texture of the gypseous material, which might give a clue to its origin, is greatly altered by the solution and reprecipitation that is constantly taking place near the surface.

ARROYOS.

With respect to their origin the arroyos that trench the steam-built slopes and desert plain belong to four groups, namely, (1) the arroyos that dissect the portions of the slopes above the cliff and terrace features (pp. 41–44); (2) the arroyos in the upper parts of the slopes not interrupted by cliffs; (3) the arroyos on the east side of the basin extending from the foot of the steep slopes about to the white sands; and (4) the arroyos in the lowest parts of the plain that lead directly into the alkali flats.

The cliffs that interrupt the regular profiles of the stream-built slopes have thrown out of adjustment the streamways that descend from the mountains to the desert plain. Consequently, the flood waters discharged from the mountain canyons have eroded the slopes above the cliffs, but have formed alluvial cones at the bases of these cliffs.

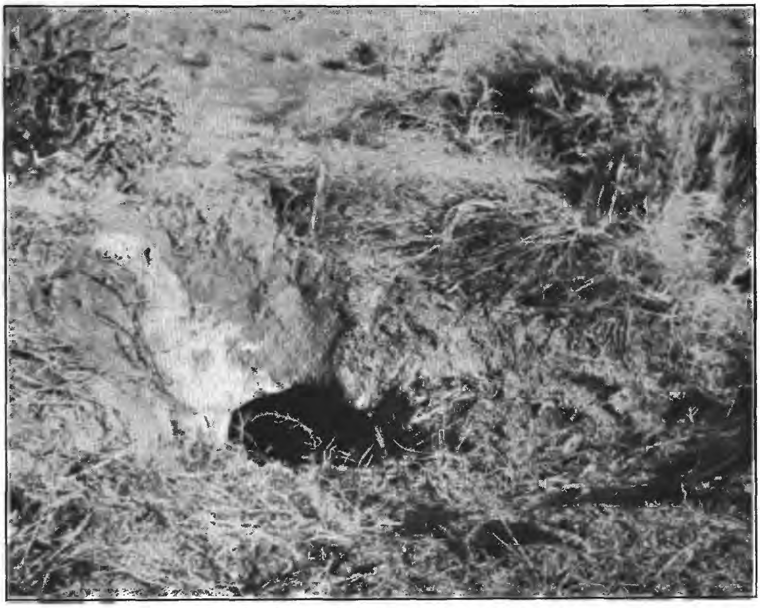
Even where the slopes are not broken by cliffs the upper parts are as a rule trenched by the large arroyos that cross them. Much of the high-level erosion is relatively old and is probably due to the fact that the large canyons emerge from the mountains at lower levels than the small ones, and also that all of the canyons have been progressively cut down and therefore discharge at lower levels than they did in the past.[1] Some of the trenches that cross the upper slopes are, however, of a different character, having practically vertical walls and all the characteristics of extreme youth. Some of them have been cut since the white men came into the region—a few possibly by a single flood—and they are probably to be attributed, at least in part, to changes made by man. A good example of the recently cut arroyos is the precipitous gorge that leads from the mouths of Fresnal and La Luz creeks, and is crossed by the road between Alamogordo and La Luz and also by the road between La Luz and Cloudcroft.

When followed downstream the high-level gullies and arroyos gradually become more shallow and eventually disappear altogether, their flood waters either spreading over the slopes or following ill-defined streamways. But on the east side of the basin, in townships 14 to 17, there is an entirely different group of arroyos which begin several miles farther down the grade, where the distinct slope

[1] Geology and water resources of Sulphur Spring Valley, Arizona: U. S. Geol. Survey Water-Supply Paper 320, pp. 29 and 30 and figs. 3 and 4, 1913.

A. SINK HOLES IN AREA UNDERLAIN BY PENNSYLVANIAN ROCKS.

B. STRATIFIED GYPSUM IN BANK OF ALKALI FLAT.



C. SINK HOLE IN INTERIOR GYPSUM PLAIN.

merges into the gently inclined desert plain. They are shallow where they begin, but increase gradually in depth for several miles downstream until their bottoms are from 25 feet to nearly 50 feet below the general upland level, beyond which they gradually become more shallow. The arroyos farthest north extend to the dune area, but the southernmost disappear completely before they reach the sands. (See Pl. II, in pocket, and fig. 8.) Some of the northerly arroyos persevere through the sands for several miles, but others are definitely blocked and have miniature strands formed in the soft gypseous materials by the impounded flood waters. These arroyos are characterized by their flat bottoms, great width, and general lack of features showing recent erosion. The fact that some of them begin

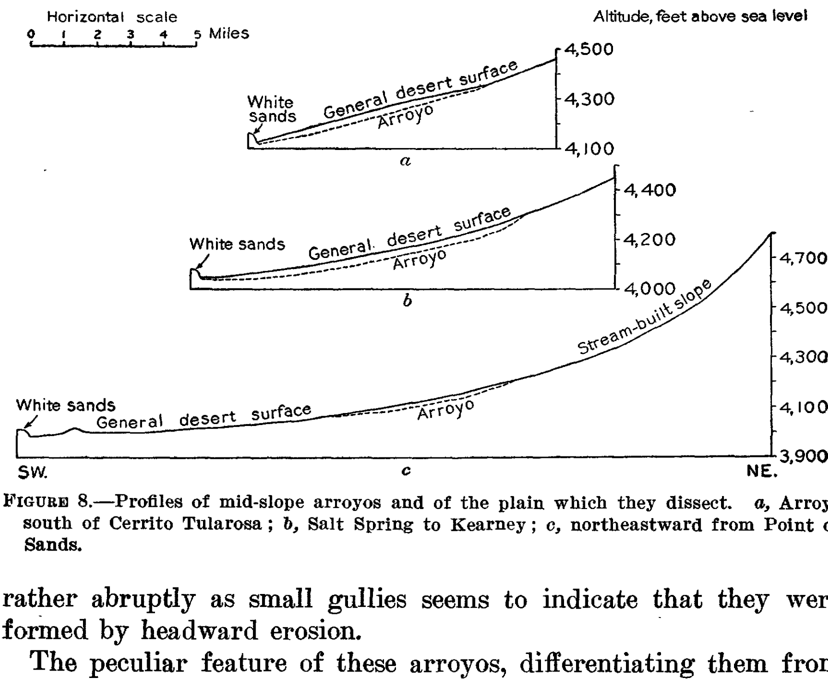


FIGURE 8.—Profiles of mid-slope arroyos and of the plain which they dissect. *a*, Arroyo south of Cerrito Tularosa; *b*, Salt Spring to Kearney; *c*, northeastward from Point of Sands.

rather abruptly as small gullies seems to indicate that they were formed by headward erosion.

The peculiar feature of these arroyos, differentiating them from nearly all other arroyos in desert basins that have been described, is that they are found only within certain vertical limits on the débris slope and that, where not obstructed by dune sands, they fade out completely in both directions. It is popularly believed that they were formed at a time when the climate was more humid, and that they were once occupied by broad streams. Although their origin is probably associated with climatic changes, the simple assumption of greater run-off does not adequately account for the peculiarities of these arroyos, and there is no reason for believing that they were ever occupied by any large permanent streams.

The slopes of a débris-filled basin that are built by streams from the mountains form a grade that is delicately adjusted to these streams. As a rule the grade is steepest near the mountain border and diminishes gradually down the slope until in the interior of the basin the surface is nearly level. The profile of a stream-built slope is therefore normally concave upward. It is significant that in the belt traversed by the arroyos under discussion the regular concavity of this profile is interrupted, and that in some parts of the belt an actual upward convexity exists. This convexity is imperfectly shown by figure 8, but can be better observed in the field. For example, Alamogordo is not in view from the plain several miles west of that town, because of the upward swell of the intervening surface in the zone affected by the arroyos. This gentle swell could have been created by a slight deformation of the underlying beds or by aggradation resulting from some climatic change. Such swells are commonly produced in basins of this kind when they are occupied by lakes. If a slope that is graded by stream action, as described above, becomes partly submerged, the adjustment represented by the grade is disturbed, and a slope with a different profile is gradually developed. A large amount of sediment is likely to be deposited near the shores of the lake. If the tributary streams occupy definite valleys deltas will be built, but if the floods spread over the slopes in sheets, sedimentation will take place all along the shore. After the lake disappears the ancient shore line forms a swell or upward convexity in the profile of the slope, which is subjected to erosion and in time becomes dissected by gullies that develop headward. Small gullies of this type have been observed in other ancient-lake basins; for example, in Sulphur Spring Valley, Ariz.,[1] but broad, well-developed arroyos, such as the mid-slope arroyos of Tularosa Basin, have not hitherto been ascribed to such an origin. Other possible explantions of the convexity are deposition by floods (quoted from Hill on p 42) or ancient eolian deposition.

These arroyos are obviously related to the largest streams in the basin, namely, Tularosa River and Fresnal and La Luz creeks (Pl. I, in pocket). There is probably a double reason for this relation. First, these large streams furnished the greatest amount of débris for aggradation; then, when the conditions changed, they furnished the greatest amount of water for the erosion of the aggraded swell and the reestablishment of the original grade. The great maturity of these arroyos as compared with the postlacustrine gullies of other basins, such as Sulphur Spring Valley, may be due to the large amounts of storm water discharged through them or to their greater antiquity.

[1] Geology and water resources of Sulphur Spring Valley, Arizona: U. S. Geol. Survey Water-Supply Paper 320, p. 42, 1913.

The low-level arroyos are gullies or small canyons cut into the plain and draining into the alkali-flat depressions, the grade of their streamways being accordant with the floors of these depressions. They have evidently developed since the depressions were excavated by the wind, mainly through headward erosion, and their depth is regulated by the depth of these depressions. Their youth is shown by their steep, freshly cut walls and by the short distance that most of them have been cut back from the margins of the alkali flats. The valley of Salt Creek belongs to this group, but is much larger and longer than any of the other arroyos. In the lower few miles of its course it has a flat bottom one-fourth mile or more in width and precipitous walls about 40 feet in maximum height of gypsum and clay of pure white and delicate shades of red. Although this canyon is essentially the product of stream erosion, a part of the excavating work was probably done by the wind in a manner similar to that in which the alkali-flat depressions were formed, wind work being indicated by certain irregularities in the width of the canyon, and by wind deposits on the east side.

Since the alkali flats practically coincide with the water table, the streamways of the tributary arroyos are also near the water level. In the vicinity of Salt Creek the slope of the water table is such that the creek has cut down to and tapped the underground waters, thereby becoming a permanent stream. In November, 1911, the flow of the creek at a point 10 miles above its mouth (NW. $\frac{1}{4}$ sec. 15, T. 12 S., R. 6 E.) was estimated at one-half second-foot, while at a point 2 miles above its mouth (sec. 20, T. 13 S., R. 6 E.) it had practically no surface flow, though there was some seepage through the sand in the bed of the creek.

MEADOW SOUTH OF THE WHITE SANDS.

A narrow strip of level meadow land extends almost without interruption from the south end of the large alkali flat in the vicinity of Lucero's ranches to the divide south of Coe's home ranch, near the Texas line (Pls. I and II, in pocket). This meadow is bordered on the west by the steep stream-built slope of the San Andreas and Organ mountains and on the east by the hummocky, wind-blown gypsum and red-sands areas. It has so much of the appearance of an ancient river bed that it has been regarded by many persons as the former outlet of Tularosa Basin, but the topography of the region probably makes this explanation untenable. The meadow has at present no southward grade. In some localities the flood waters drain in one direction and in others in the opposite direction, and the lowest point on the Texas line is about 100 feet higher than the meadow in the vicinity of Lucero's ranches, 50 miles farther north. Moreover, the meadow is definitely interrupted at the divide south of Coe's ranch. It may possibly represent the bed of a stream that flowed northward; more probably it is a feature developed in large part by the wind.

FEATURES PRODUCED BY SPRINGS.

Mounds built by springs are found over an area several square miles in extent on the plain a short distance west of the southern part of the lava bed, in T. 10 S., R. 6 E. (See Pl. XVI.) Twenty-nine of these mounds are shown on the map forming figure 9, and a few other poorly preserved ones probably exist in the region adjacent to the area covered by the map. A typical mound of this group forms a low, flat, symmetrical dome at the top of which is a shallow, circular depression that may contain water. The largest of the mounds are fully 600 feet in diameter and 15 to 20 feet in height, and have "craters" ranging in diameter from 50 to 125 feet.

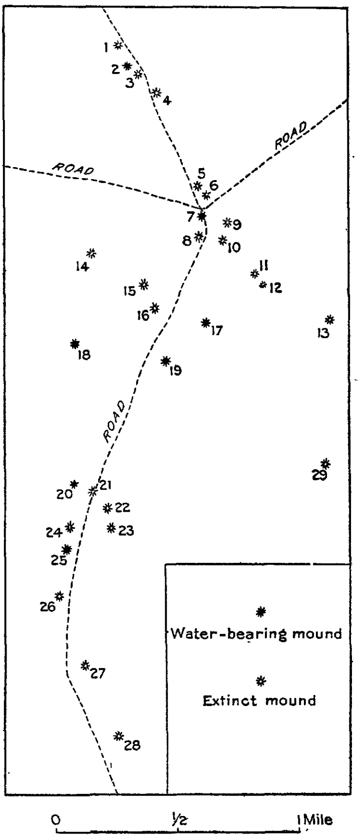


FIGURE 9.—Map showing Mound Springs in T. 10 S., R. 6 E.

The mounds are composed of a feltwork of vegetable fibers partly converted into peat, with interstitial black silt, gray gypsum, and other substances, the whole having a mottled, black and gray appearance. The vegetable matter was produced and partly protected from decay by the spring water; the sandy sediments were brought by the wind, stopped by the growing vegetation, and secured by the moisture of the springs from further wind attack; the gypsum was in part precipitated from the water and in part deposited by the wind. As a mound developed it formed a sort of vertical tube that was relatively impervious at the outside and porous at the center, with the result that the water rose to its apex and its growth tended to continue.

There are two kinds of mounds—those that at present have an overflow or at least a central pool of living water, and those that are no longer water bearing. The extinct mounds outnumber the active

A.

B.

MOUND SPRINGS.

ones in the ratio of about 3 to 1. They are on an average larger although flatter and less conspicuous than the active mounds. The materials of which they are composed have become firmer and more compact, the gypsum forming hard ledges at the top. Through the oxidation of these materials, no longer protected by water, their color has been changed from blue-black, which characterizes the water-bearing mounds, to a dull red that does not differ greatly from the hue of the rest of the desert. Apparently a mound grows in the manner described until its water level is some distance above the surface of the surrounding plain, but when it reaches a height above which the water will not rise by hydrostatic pressure its development ceases and the pool of water is ceiled by the same process which built the mound. Eventually the water may break out at a lower level in the adjacent plain, with the result that the old mound is drained and the development of a new mound is begun.

The fact that the water rises in the mounds considerably above the level of the plain shows that it is under artesian pressure and indicates that it comes from a comparatively deep source.

The following tables give approximate data in regard to several of the mounds:

Approximate data relative to several mounds of the Mound Springs group.

Number on map.	Diameter.	Height.	Presence of water at the surface.	Height of water level above plain.	Discharge.
	Feet.	*Feet.*		*Feet.*	
2	....	8	Water........	3	None.
7	600	18	.....do........	10	Several gallons per minute.
8	400	13	No water........	....	
15	700	....	.....do........	....	
16	600	....	.....do........	....	
17	....	....	Water........	....	None.
18	....	....	.....do........	....	
19	250	13	.....do........	5	Do.
20	250	10	.....do........	6	Do.
25	250	6	.....do........	3	1 gallon per minute.
26	500	16	No water........	....	
27	600	....	.....do........	....	

GEOLOGY.

GENERAL FEATURES.

The sedimentary formations of Tularosa Basin belong chiefly to the Carboniferous, Cretaceous, and Quaternary systems, but Paleozoic sedimentary rocks older than the Carboniferous may be represented, and sedimentary rocks of Triassic, Jurassic, and Tertiary age may be present. The igneous rocks are chiefly of pre-Carboniferous (probably pre-Cambrian), Tertiary, and Quaternary age, but there may also be igneous rocks that were erupted after the Carboniferous period but before the Cretaceous sediments were laid down and also near the close of the Cretaceous period.

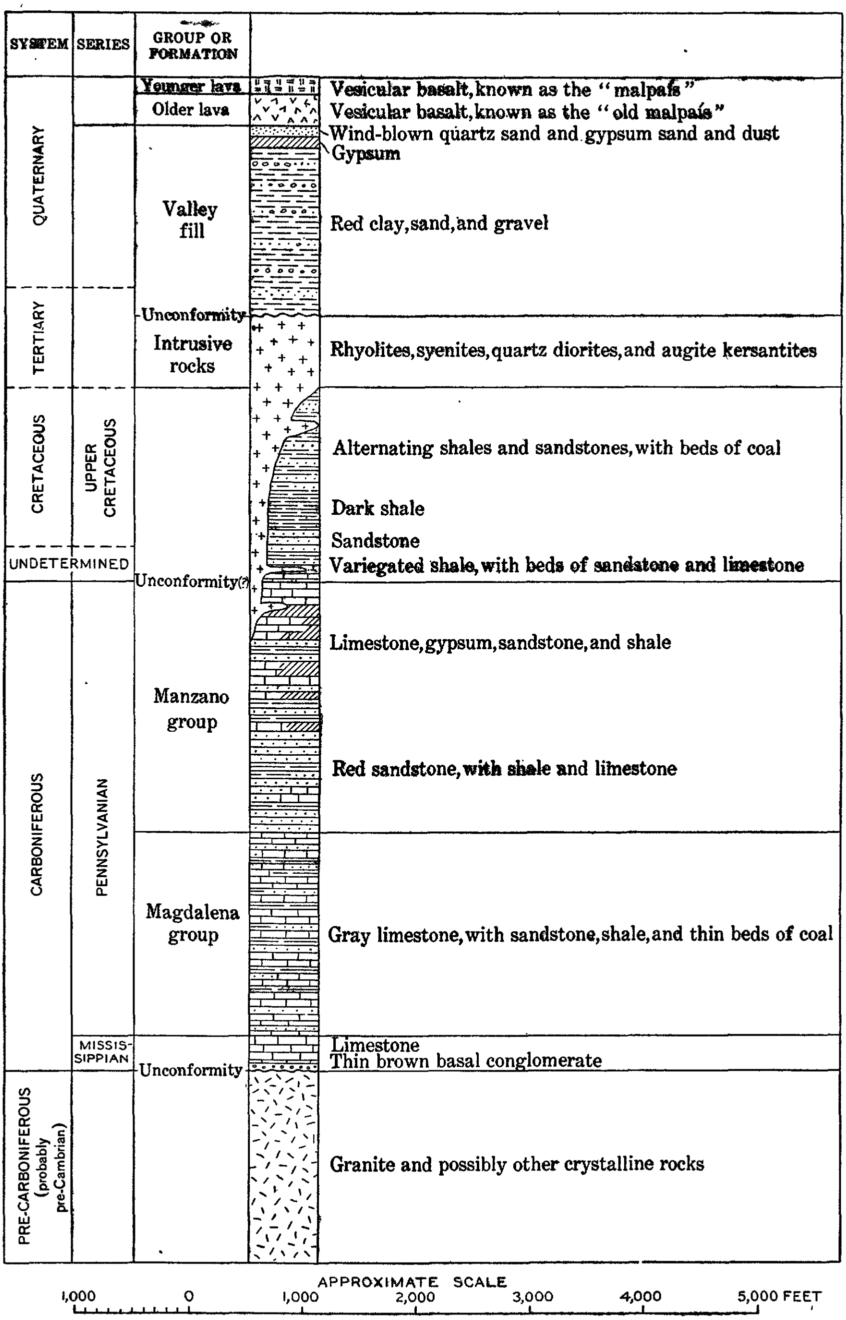
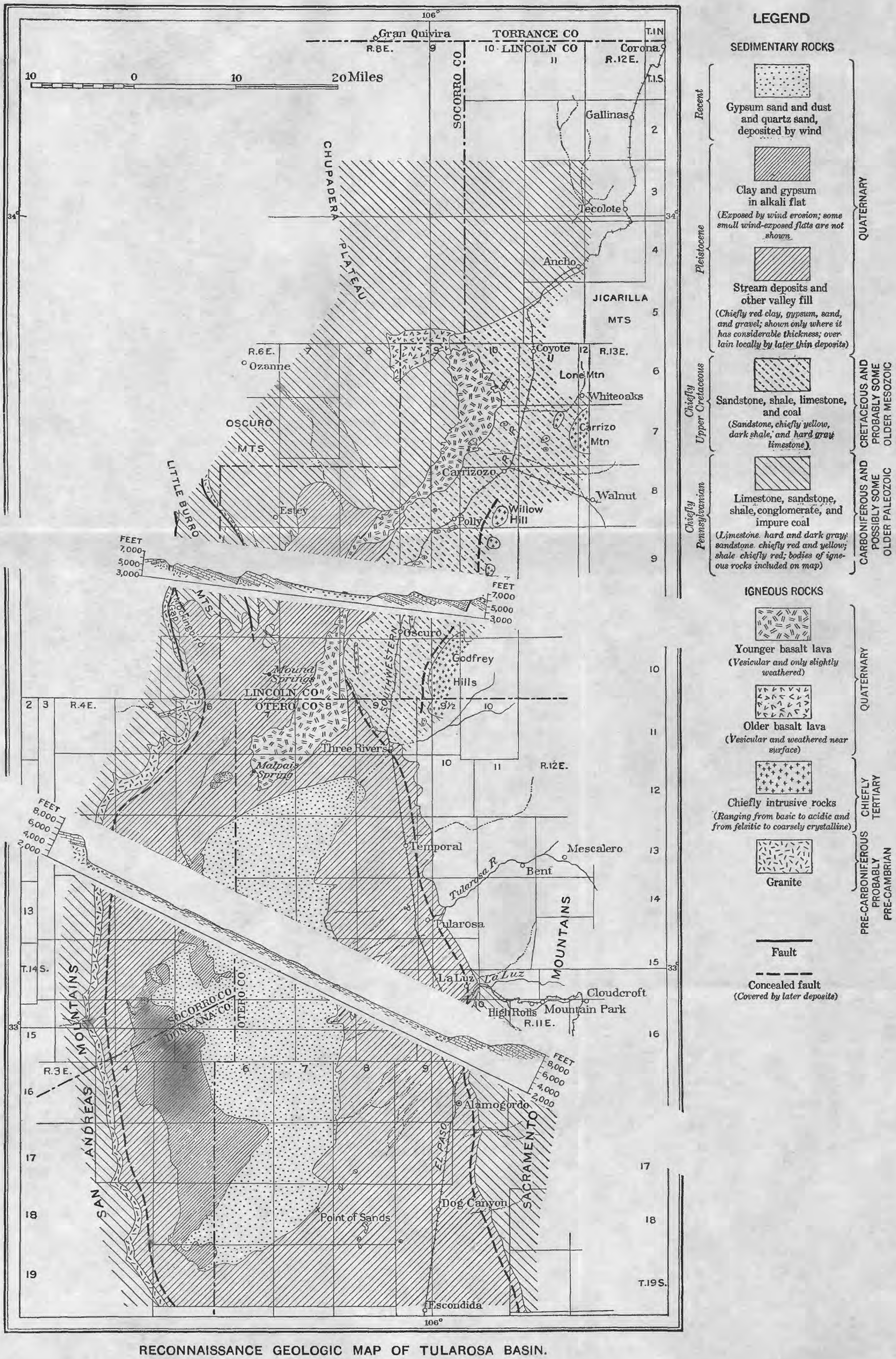


FIGURE 10.—Columnar section of formations in Tularosa Basin (based on reconnaissance survey).



RECONNAISSANCE GEOLOGIC MAP OF TULAROSA BASIN.

On the crystalline basement, which is probably pre-Cambrian, rests a thick body of limestone, sandstone, shale, and gypsum, which is chiefly or wholly of Carboniferous age and which forms the bulk of the Sacramento, San Andreas, Little Burro, and Oscuro ranges, and underlies most of the northern part of the basin. Lying stratigraphically above the Carboniferous rocks, and outcropping in the ridges and mountains east of the lava beds between Three Rivers and Whiteoaks, are alternating beds of sandstone, shale, and limestone, with a few seams of coal, belonging chiefly or wholly to the Cretaceous system. Intruded into both Carboniferous and Cretaceous strata, but found in greatest abundance in the northeastern quarter of the basin in association with the Cretaceous strata, are igneous rocks of differing composition and texture. Resting on the older formations and filling the southern part of the basin to great depths are poorly consolidated deposits of clay, sand, gravel, gypsum, and other materials, chiefly of Quaternary, but probably in part of Tertiary age. Spread over the surface in certain tracts of the northern part of the basin and resting in part on the Quaternary sediments is the basalt of the two lava beds. The character, thickness, and age of these formations are shown in the columnar section, figure 10, and their areal distribution and relations are shown in the map forming Plate XVII. The geology of the region has not been studied in detail, and both the section and the map are therefore only approximately correct.

PRE-CARBONIFEROUS GRANITE.

Crystalline rocks outcrop below the sedimentary beds in a practically uninterrupted band along the lower half of the east side of the San Andreas Mountains from Mockingbird Gap to the south end of the range, in a narrow band at the west base of the northern part of the Little Burro Mountains, and along the lower part of the west face of the Oscuro Mountains except near their south end where the overlying beds plunge beneath desert sediments. In some places they form more than one-half of the lofty Oscuro escarpment. Wherever the basal crystalline rocks of these mountains were observed they consist of massive reddish granite and are separated by an erosion surface from the overlying sedimentary beds. In the Franklin Mountains, situated south of Tularosa Basin (Pl. I, in pocket), Richardson[1] found pre-Cambrian rocks consisting of rhyolite porphyry and quartzite with intrusions of granite that are at least in part of more recent origin. In the Manzano Mountains and the Pedernal and adjacent hills, situated north of Tularosa Basin, are extensive exposures of schist, quartzite, granite, and other igneous rocks, all apparently older than the Carboniferous

[1] Richardson, G. B., U. S. Geol. Survey Geol. Atlas, El Paso folio (No. 166), p. 3, 1909.

rocks that lie above them.[1] In the mountains of Tularosa Basin, which occupy a position intermediate between the Manzano and Franklin ranges, the equivalents of the quartzite and schist have not been observed, but the granite of this region should probably be correlated with the granite in the Manzano Mountains and the highlands east of Estancia Valley. This granite is probably all pre-Cambrian, but careful examination may show that a part of it is, like some of the granite of the Franklin Mountains, of more recent origin.

CARBONIFEROUS SEDIMENTARY ROCKS.

DISTRIBUTION.

The Carboniferous system is represented in Tularosa Basin by strata aggregating nearly or quite a mile in total thickness and lying at or near the surface over about 2,000 square miles, or about one-third of the total area of the basin. This system includes a lower series known as the Mississippian, and a much thicker and more widely exposed upper series known as the Pennsylvanian.

RELATION TO OLDER ROCKS.

In northern New Mexico Pennsylvanian strata rest directly on the crystalline basement, believed to be pre-Cambrian, but in a number of localities in the southern part of the State older Paleozoic beds occur below the Pennsylvanian and rest on the erosion surface of the pre-Cambrian crystallines. In the Franklin Mountains Richardson has found Cambrian sandstone 300 feet thick, Ordovician limestone 1,200 to 1,400 feet thick, and Silurian limestone about 1,000 feet thick, on which rest unconformably at least 3,000 feet of Pennsylvanian rocks.[2] Cambrian and Ordovician beds have also been found by Gordon in the Caballos Range.[3] How far north the Cambrian, Ordovician, and Silurian beds extend before they are wedged out between the Carboniferous and pre-Cambrian is not known. In the vicinity of Mockingbird Gap no fossils were found in the beds immediately above the granite, but lower Pennsylvanian fossils were found in the talus near the granite contact and in place at a considerable distance above the contact. Paleozoic formations older than the Carboniferous are probably either absent or but poorly developed in Tularosa Basin.

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[1] Meinzer, O. E., Geology and water resources of Estancia Valley, N. Mex.: U. S. Geol. Survey Water-Supply Paper 275, p. 11, 1911.

[2] Richardson, G. B., U. S. Geol. Survey Geol. Atlas, El Paso folio (No. 166), 1909.

[3] Gordon, C. H., and Graton, L. C., Lower Paleozoic formations in New Mexico: Am. Jour. Sci., 4th ser., vol. 21, pp. 390–395, 1906.

MISSISSIPPIAN SERIES.

In northern New Mexico Mississippian, or lower Carboniferous, as well as older Paleozoic formations, are generally absent, but in the southern half of the State beds containing Mississippian fossils have been found in several localities. In Tularosa Basin the Mississippian series is represented by limestones that are exposed in the lower part of the west side of the Sacramento Mountains. Fossiliferous Mississippian limestones several hundred feet thick were found by C. L. Herrick in the vicinity of Dog Canyon, and lower Mississippian fossils have been identified by G. H. Girty from limestones at the base of the Sacramento Range east and northeast of Alamogordo. No rocks containing Mississippian fossils have yet been found in other parts of the basin. In the northern part they would in general be concealed below the Pennsylvanian beds, but if Paleozoic formations older than the Pennsylvanian exist in the ranges on the west side they must be exposed and will be identified when the rocks are studied more carefully.

PENNSYLVANIAN SERIES.

Outcrops.—The Pennsylvanian series is greatly developed in Tularosa Basin. Practically the entire series is present and is thrice repeated in the exposures of the region; first, in the Sacramento Mountains; second, in the Little Burro and Oscuro mountains and the region lying farther east and northeast; and, third, in the San Andreas Mountains. In the northern part of the basin the beds lie nearly horizontal and are generally concealed, but still farther north, on the east side of the Manzano Mountains and the north edge of the Mesa Jumanes, the greater part of the series is again exposed.

Subdivisions.—The Pennsylvanian series of New Mexico has been divided into two groups—the lower known as the Magdalena and the upper known as the Manzano,[1] both of which are represented in Tularosa Basin in nearly full development. The Magdalena group consists of gray limestone and minor amounts of sandstone and shale of predominantly gray hue. The Manzano group consists largely of sandstone and shale, but contains also considerable limestone, especially near the top, and much gypsum interbedded with the rocks. The sandstones and shales of the lower part of the group have a prevailing red color, which, however, is more noticeable in the northern than in the southern part of the region.

Sacramento section.—Both the Magdalena and Manzano groups are exposed on the west flank of the Sacramento Mountains. Lime-

[1] Lee, W. T., and Girty, G. H., The Manzano group of the Rio Grande valley, N. Mex.: U. S. Geol. Survey Bull. 389, 1909.

stones, shales, and sandstones containing Magdalena fossils here rest on the Mississippian beds or have their base concealed by talus deposits. Above these, constituting the middle part of the mountain escarpment east of Alamogordo, lie several thousand feet of sediments that are largely clastic and of red color. Still farther up, forming the top of the mountain at Cloudcroft and extending some distance north of the Indian agency, are limestones bearing Manzano fossils. The total thickness of the Pennsylvanian series in these mountains is rendered somewhat uncertain by faulting, but it is probably not much less than 5,000 feet.

Several isolated limestone buttes, nearly submerged by desert sediments, extend in a chain with a general north-south trend across the plain a few miles west of the base of the Sacramento Mountains. At the north end of the chain is Cerrito Tularosa (sec. 12, T. 15 S., R. 8 E.); farther south, a short distance northeast of the Point of Sands, are two small limestone domes (situated, respectively, on sec. 28, T. 17 S., R. 8 E., and sec. 6, T. 18 S., R. 8 E.); and still farther south are the two buttes of the Tres Hermanos group (secs. 28 and 33, T. 18 S., R. 8 E.). In all of these buttes were found Manzano fossils, which correlate their beds with the limestones at Cloudcroft and the Indian agency, at altitudes several thousand feet higher. Pennsylvanian fossils were also found in the dark limestones of the Jarilla Range.

Oscuro section.—Pennsylvanian fossils were collected in three principal localities on the west side of the basin and were identified by G. H. Girty, of the United States Geological Survey, who also examined the Carboniferous fossils collected in other parts of the region. The first of the three localities is at a coal prospect in the Little Burro Mountains, one-half mile north of Thomas McDonald's ranch (about sec. 8, T. 9 S., R. 5 E.); the second is in the eastern foothills of the Oscuro Mountains, about three-fourths mile west of Estey and near the pipe line; the third is in a large canyon at the east edge of the Chupadera Plateau, about 4 miles north of the Cerros Prietos (about W. ½ sec. 12, T. 5 S., R. 8 E.).

The Little Burro Mountains consist of a series of low ridges composed of beds that dip about 20° E. At the base of the series resting on the granite is a dark brown conglomerate only 5 to 10 feet thick, containing well-rounded quartzose pebbles. Above this is a succession of strata consisting of gray limestones and minor amounts of coarse gray sandstones and gray calcareous shales, estimated to have a total thickness of over 2,000 feet. Next in upward succession and forming the easternmost hills of the Little Burro group, are compact dull-red sandstones and red shales, with a total thickness of probably not less than 1,000 feet. The fossils were collected in the midst of the gray group of beds and are of Magdalena age. Closely associated with the fossiliferous beds is a seam of impure coal, somewhat more than a foot thick, on which considerable development work was at one time done.

The Oscuro Mountains, which lie east of the Little Burro Range and parallel with it, have the same structure and repeat the same sedimentary series. The stratified beds rest on the granite and dip eastward. The lower gray beds are exposed immediately above the granite and form the upper part of the west-facing escarpment. The beds that lie stratigraphically higher and have a prevailingly red color outcrop in the eastern foothills of the range. The formations in the vicinity of Estey dip in general about 20° E. and consist of red and blue sandstone, red sandy shale, blue and drab shale, and gray limestone. The horizon from which the fossils were collected is a bed of massive, hard, gray limestone about 8 feet thick, outcropping between beds of dark red sandy shale and forming a conspicuous ledge along the hillsides. The fossils belong either to the Magdalena or the lower part of the Manzano group. The beds in which they occur are no doubt stratigraphically above the gray beds in which fossils were collected in the Little Burro Range and the lower part of the Sacramento Mountains.

Gray limestone with much interbedded gypsum predominate (1) in the hills west of the lava beds, (2) in the eastern part of the Chupadera Plateau from the Cerros Prietos at least as far north as Gran Quivira, and (3) in the northern and western parts of the plain lying between the lava beds and Gran Quivira. The limestones of the greater part of this region are nonfossiliferous, or nearly so, but in certain localities they yield fossils in great abundance. The fossils collected at the east edge of the plateau are Manzano types, and this is probably the age of the rocks of this entire region, including the Mesa Jumanes to the escarpment overlooking Estancia Valley, on the top of which G. B. Richardson, of the United States Geological Survey, found Pennsylvanian fossils.[1] The limestones, gypsum beds, and associated sandstones[1] of this large region apparently belong to the middle or upper part of the Manzano group and rest on the red beds exposed on the east sides of the Oscuro, Little Burro, and Manzano ranges. Toward the southeast they pass beneath Cretaceous or older Mesozoic sediments and volcanic rocks, but are stratigraphically continuous in a general way with the beds of the Sacramento Mountains. According to Keyes they pass beneath Cretaceous beds in the western part of the Chupadera Plateau. Sandstones that may be post-Pennsylvanian are found between the lava beds and Ancho, but limestone and gypsum outcrop at Ancho.

[1] Lee, W. T., and Girty, G. H., The Manzano group of the Rio Grande valley, N. Mex.: U. S. Geol. Survey Bull. 389, p. 21, 1909.

San Andreas section.—Practically the entire Pennsylvanian series is again exposed in the San Andreas Mountains, but it here dips west instead of east. The oldest formations, consisting of gray limestone and clastic beds, outcrop above the granite in the upper part of the east-facing escarpment; red beds come to the surface mainly west of the crest; and above them lie beds of limestone, gypsum, sandstone, and shale. At the top of the series are about 500 feet of massive limestone, classified by W. T. Lee[1] as the uppermost Carboniferous formation known in this part of New Mexico.

CRETACEOUS SEDIMENTARY ROCKS.

Cretaceous and perhaps older Mesozoic deposits lie at or near the surface over a large part of the area east of the lava beds, between Coyote station and Three Rivers (Pl. XVII). They are exposed in numerous localities in the valley of Three Rivers, in the Godfrey Hills, in the region south, west, and north of Oscuro, in Milagro Hill, on the upland east of Milagro Hill, in Willow Hill, in numerous small ridges between Milagro Hill and Carrizozo, in the escarpments between Carrizozo and the younger lava bed, in the region between Carrizozo and Coyote station, and in the region about Whiteoaks. The most northerly point at which Cretaceous fossils were observed is where the railroad crosses the draw just south of Coyote. Buff and red sandstones outcrop at many places in the region between Coyote and Ancho and between Coyote and the lava beds, but no fossils were found in these sandstones and their age remains a matter of conjecture. The strike of the beds is in general parallel to the trend of the escarpments shown in Plate VI. In the vicinity of Oscuro the dip is nearly east, but northward it becomes increasingly southeast, until in the vicinity of Red Lake it is nearly due south, and north of Coyote it is west of south.

The Cretaceous deposits consist of alternating beds of sandstone, shale, and limestone. The sandstones are soft and commonly of a buff color where exposed. The shales, which are generally soft and of dark hues, are not so conspicuous in outcrops as the sandstones, but they form a large part of the total thickness in well sections. No red sandstones or shales containing Cretaceous fossils were found, but dark purplish red and variegated beds occur along the northwest margin of the Cretaceous area which belong either to the lower part of the Cretaceous or between the Cretaceous and Pennsylvanian. Strata of hard gray limestone containing abundant Cretaceous fossils outcrop in a few localities, but do not form a large part of the total Cretaceous section. Coal has been found in outcrops in the vicinity of Whiteoaks, in Willow Hill, and in Milagro Hill, and

[1] Op. cit., p. 29.

was encountered in drill holes at Carrizozo and in the valley of Three Rivers.

The following generalized stratigraphic section in this region is reported by Carroll H. Wegemann, of the United States Geological Survey, who worked in that field in 1912:

Stratigraphic section, Sierra Blanca coal field, New Mexico.[1]

	Feet.
1. Coal-bearing formation; shale, sandstone, and thin beds of limestone containing two to eight beds of bituminous coal that differ greatly in thickness; a few leaf impressions; fresh water	630
2. Shale, sandstone, and limestone; the upper third of this division consists of shale interbedded with impure limestone, weathering buff and containing numerous fossils; below are interbedded sandstone and shale; and at the base lies a heavy stratum of sandstone, which usually forms an escarpment	440
3. Shale, dark gray and bluish, having near its base two or more thin beds of bentonite and a bed of blue limestone; fossils collected near the base identified as Benton; estimated thickness	500
4. Dakota (?) sandstone; buff, coarse sandstone, interstratified at its top with thin beds of shale resembling that of the Benton; contains plant impressions but nothing sufficiently well preserved for identification; possible representative of the Dakota sandstone (Upper Cretaceous) and Comanche series (Lower Cretaceous)	175
5. Morrison (?) formation; shale, variegated pink and green, containing thin beds of limestone, conglomerate, and beds of white sandstone; possible representative of the Morrison formation; estimated thickness	590
6. Limestone (Carboniferous), gray; estimated thickness	700
7. Red beds (Carboniferous).	

Fossils were collected in the following five localities in Tularosa Basin: (1) Along a draw south of Oscuro, on the west side of the railroad, in NW. ¼ sec. 24, T. 10 S., R. 8 E.; (2) along the railroad north of Oscuro and west of Milagro Hill, in center of sec. 19, T. 9 S., R. 9 E.; (3) along the railroad between Carrizozo and Coyote, in NW. ¼ sec. 7, T. 7 S., R. 11 E.; (4) in Coyote Hill, in NW. ¼ sec. 18, T. 8 S., R. 10 E.; and (5) on the east side of Willow Hill. These fossils were examined by T. W. Stanton, of the United States Geological Survey, who reported that they apparently belong to the Montana group of the Upper Cretaceous series and represent approximately the horizon of No. 2 in Mr. Wegemann's section. The first four localities apparently represent a belt of outcropping strata

[1] Wegemann, C. H., Geology and coal resources of the Sierra Blanca coal field, New Mexico: U. S. Geol. Survey Bull. 541, p. 426, 1914.

of Montana age that extends along the trend of the escarpments from near Coyote to a point south of Oscuro. East of this belt younger coal-bearing Cretaceous beds, correlated with No. 1 in the above section, come to the surface. Underlying the benches west of the fossiliferous belt is probably the shale designated No. 3 in the above section, and still farther west, in the escarpments near the younger lava bed, is probably the sandstone designated No. 4, Dakota (?), in the above section. The red and variegated beds that outcrop in the belt that lies between Coyote and Red Lake and extends southwestward to the younger lava are probably to be correlated with No. 5, Morrison (?), in the above section. The section is probably in part repeated by faulting in Willow Hill, the Godfrey Hills, and some of the northern escarpments. In Nogal Arroyo near Walnut there are outcrops of red shale and sandstone that are no doubt older than the Upper Cretaceous series (Nos. 1 to 4 of the above section).

The section of the 965-foot well at Oscuro, except for a few feet at the top, appears to consist of Cretaceous or other strata younger than the Pennsylvanian. (See fig. 33.) The deep wells at Carrizozo appear to pass through about 1,000 feet of Cretaceous or other strata younger than the Pennsylvanian, but the gypsum and limestone near the bottom of the 1,125-foot well probably belong to the Carboniferous system. (See fig. 32.)

TERTIARY INTRUSIVE ROCKS AND IGNEOUS ROCKS OF UNCERTAIN AGE.

Intrusive rocks that differ widely in texture and mineralogic composition are found in numerous localities throughout Tularosa Basin. They include rhyolites, syenites, quartz diorites, and augite kersantites, according to E. S. Larsen, of the United States Geological Survey, who examined the specimens collected. They form dikes and sills in both the Carboniferous and Cretaceous sedimentary beds but are most abundant in the latter. The great masses of igneous rock that form the cores of several ranges from the Sierra Blanca to the Jicarilla Mountains, inclusive, were not carefully examined but are probably batholithic bodies formed from molten magmas erupted after the Cretaceous sediments had been deposited.

Intrusive rocks predominate in the Godfrey Hills, the Palisades, the valley of Three Rivers, and the region between the Godfrey Hills and the Sierra Blanca. They have here been injected into the Cretaceous strata in such quantities that the latter outcrop in comparatively fragmentary and isolated masses. In other parts of the Cretaceous area the igneous rocks form a smaller proportion of the outcrops and have disturbed the sedimentary beds less violently. Their most characteristic position is at the top of the Cretaceous escarpments, which they protect from erosion. Thus igneous rocks are found on the crest of the Phillips Hills, Milagro Hill, Jakes Hill, Polly Hills, Willow Hill, the escarpment north of the Bar W ranch (in T. 7 S., R. 10 E.), and the escarpment next north (in the southern part of T. 6 S., R. 10 E.). The igneous masses in these positions appear to be sills—their magmas having been intruded between Cretaceous beds and the beds above having been more recently removed by erosion. The rock that caps Milagro Hill is a dark gray augite kersantite with huge augite crystals, and the same bed is probably represented in Jakes Hill, Willow Hill, and several other escarpments. In many places in the Cretaceous area dikes of igneous rocks cut the sedimentary beds, and some of these dikes, more resistant to weathering than the sedimentary beds, form conspicuous ridges. The buttes northeast of Carrizozo (in the south-central part of T. 7 S., R. 11 E.), consist of soda rhyolite that is different from most of the igneous masses associated with the Cretaceous of this region. Their relation to the Cretaceous beds is concealed by the mantle of detritus that surrounds them.

Intrusive bodies are also found in the Carboniferous rocks, although less commonly than in the Cretaceous. Dikes and sills were seen in the Carboniferous rocks at numerous points in the Sacramento Mountains, in the vicinity of Ancho, in the vicinity of Gran Quivira, and at several widely separated localities in the Chupadera Plateau. The rock examined east of Ancho is quartz diorite; that in the canyon 5 miles north of the Cerros Prietos is syenite. Igneous rock, reported by C. H. Herrick as intrusive in the Carboniferous, occurs at the base of the Sacramento escarpment in the vicinity of Dog Canyon. The lone butte 5 miles southwest of Dog Canyon station (S. ½ sec. 31, T. 18 S., R. 8 E.) consists of granite (perhaps pre-Cambrian) and intruded masses of augite kersantite. Intrusive masses of igneous rock occur in the Jarilla Mountains associated with Carboniferous limestone. The Organ Mountains consist chiefly of granitic rock which, as shown by Lindgren,[1] are at least in great part a post-Carboniferous batholithic intrusion.

The intrusive rocks associated with the Cretaceous formations are younger than these formations, but they are apparently older than the faulting movements that produced the escarpments, and they have certainly existed during a long period of erosion. They are believed to be of Tertiary age, and may represent more than one epoch of volcanic activity within the Tertiary. The dikes and sills in the Carboniferous rocks may in part be older than those in the

[1] Lindgren, Waldemar, The ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68, p. 208, 1910.

Cretaceous, but they probably have the same age. Keyes reports certain dikes in the Chupadera Plateau that cut the Carboniferous beds but do not extend into overlying Cretaceous, and are regarded by him as pre-Cretaceous.

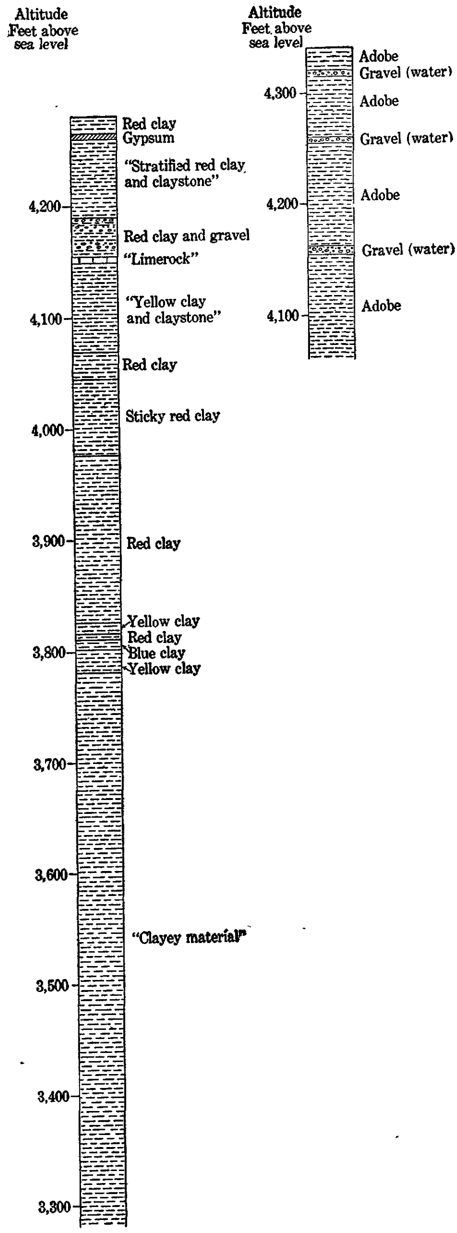

FIGURE 11.—Sections of deep test well near Alamogordo (NW. ¼ NE. ¼ sec. 26, T. 16 S., R. 9 E.) and of well at ice plant in Alamogordo.

TERTIARY (?) SEDIMENTARY ROCKS.

Reddish clastic deposits, some of them conglomeratic, occur at the surface over considerable areas in the mountains on the east side of the basin, especially in the region between Three Rivers and La Luz Creek. These deposits apparently rest unconformably on Carboniferous rocks and may be of Tertiary age. They do not come within the area covered by the map, Plate XVII, and because their age is unknown they are not represented in the columnar section on page 54.

VALLEY FILL (QUATERNARY AND TERTIARY (?)).

DISTRIBUTION, THICKNESS, AND AGE.

The indurated formations thus far described may be regarded as constituting a basin that has become partly filled with the rock waste brought by the streams from the mountains. Over nearly the entire desert area between the Sacramento and San Andreas mountains and extending south to the Rio Grande, this waste, derived from the older formations and commonly known as the "valley fill," reaches to depths of several hundred feet, and probably in most places to depths of more than 1,000 feet. Northeast of the Phillips Hills and north of the upper crossing of the malpais, however, the older rock formations are generally near the surface and the unconsolidated sediments are only locally as much as 100 feet deep. The valley fill can be seen to depths of 20 to 50 feet in the banks of arroyos and alkali flats, and occasionally to somewhat greater depths in open wells, but the larger part of these deposits are concealed from view and their character is unknown except as it is revealed by the drillings from deep wells.

In 1905 a test well sunk by the railroad company about 1½ miles west of Alamogordo and 5 miles from the base of the Sacramento Mountains (NW. ¼ NE. ¼ sec. 26, T. 16 S., R. 9 E.) was carried to a depth of a little over 1,000 feet without reaching the bottom of the unconsolidated fill (fig. 11). In 1910 two test wells were drilled about one-half mile north of Dog Canyon station (NE. ¼ sec. 14, T. 18 S., R. 9 E.) and not more than 5 miles from the base of the Sacramento Mountains. The first well reached a depth of 1,235 feet and the second about 1,800 feet, apparently without reaching the bottom of the unconsolidated valley fill. (See fig. 12.) At the El Paso city waterworks, a short distance northeast of Fort Bliss, a well was drilled to a depth of 2,285 feet, passing through nothing except valley fill, at least to a depth of 1,560 feet. (See fig. 13, p. 66.)

The valley fill was laid down after the basin was formed and is much younger than any of the sedimentary rocks found in the mountains. The upper part is undoubtedly of Quaternary age. The lower part is concealed and its age is not known, but the filling of the basin must have required a long time, and it is probable that the lowest sediments were deposited in the Tertiary period.

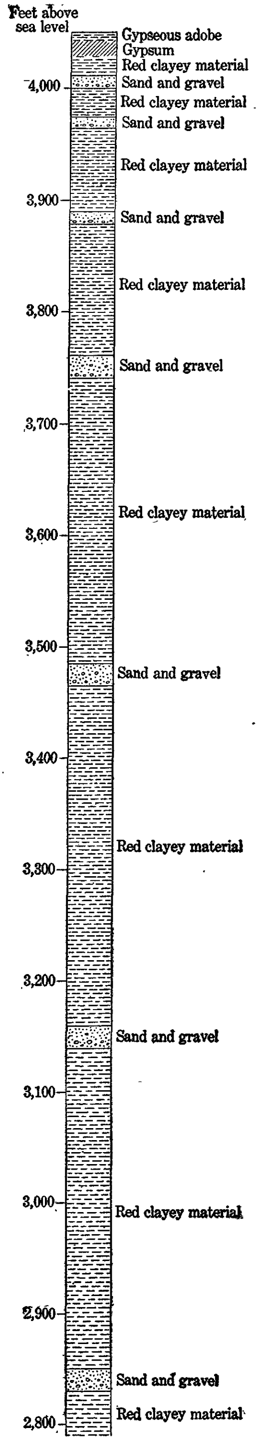

FIGURE 12.—Section of deep test well near Dog Canyon station.

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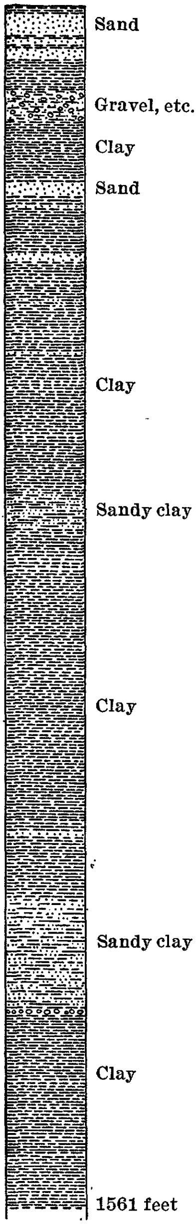


FIGURE 13.—Partial section of the deepest well at El Paso waterworks, north of Fort Bliss. After G. B. Richardson, U. S. Geol. Survey Geol. Atlas, El Paso folio (No. 166), 1909.

WATER-DEPOSITED CLAY, SAND, AND GRAVEL.

Most of the valley fill consists of clay or adobe, the latter having a matrix of clay with embedded coarser particles. Most of the clayey deposits have a reddish color and are gypseous and calcareous, passing through all gradations into deposits of nearly pure gypsum. Interbedded with the red clayey deposits are strata or lenses of sand and gravel, many of which also include much clayey material.

The character of these deposits is clearly related to the character of the derivative rock formations. The Pennsylvanian rocks exposed in the Sacramento, San Andreas, Little Burro, and Oscuro mountains include red shaly beds of great total thickness and comparatively small amounts of sandstone. When these red beds disintegrated they supplied the materials that comprise the thick unconsolidated red clayey deposits of the valley fill. According to the log of the 1,235-foot Dog Canyon test well (fig. 12), less than 10 per cent of the valley fill in that section consists of sand and gravel, nearly all of the rest being red clayey material. The logs of the 186-foot ice-plant well at Alamogordo and the 1,004-foot test well west of Alamogordo (fig. 13) show still smaller amounts of sand and gravel and greater amounts of red clay. The preponderance of red clayey material is also shown by other well logs and by exposures in dug wells throughout the area adjacent to the mountains just mentioned, although on the west side of the basin, where a part of the sediments are derived from granite, it is somewhat less noticeable than on the east side, where the granite is generally concealed.

Farther north, on the east side of the basin, where the débris is derived chiefly from Cretaceous sedimentary formations and igneous rocks, the clayey deposits are less red, and beds of sand and gravel are probably less rare. In the southern part of the basin, adjacent to the Organ Mountains, which are almost entirely granitic, the beds of sand are notably thicker and more numerous, as is shown by the section of the railroad well at Newman (fig. 14) and by the logs of the other wells drilled in that region. In the western part of the Hueco Basin the valley fill, derived chiefly from the Organ and Franklin mountains, is also less red and includes much more sand. For example, well No. 16 of the El Paso waterworks (fig. 15), which is 550 feet deep, passes through 16 beds of sand or gravel that together constitute 40 per cent of the section. Not only are the crystalline rocks, which furnish much coarse débris, abundant in the Organ and Franklin mountains, but the Pennsylvanian rocks exposed in these mountains contain no red beds.

The proportion of sand and gravel is also apparently greater near the mountains than in the interior of the basin, and greater within the first few hundred feet of the surface than farther down. In the wells drilled in the vicinity of Alamogordo several beds of sand and gravel are generally found between thick beds of clay within the first 200 or 300 feet of the surface, but little except clay has been discovered by deeper drilling. Three beds of sand or gravel, known respectively as the first, second, and third stratum, are locally recognized, but the available well sections do not show that the sandy or gravelly strata occur at the same horizons in different localities, or that they are everywhere present.

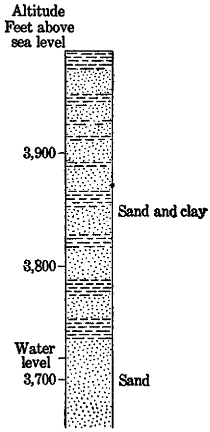


FIGURE 14.—Section of railroad well at Newman.

The beds of clay, sand, and gravel are largely stream deposits, but are in part lake deposits, and may include some ancient dune sands. Most of the valley fill that outcrops along the Rio Grande at El Paso has an irregular lenticular stratification that indicates stream deposition. At the El Paso waterworks over a score of wells 400 to 600 feet deep have been drilled at intervals of 300 feet (fig. 27) and careful logs were kept at each well. When these logs are arranged in order (fig. 15) it becomes obvious that the strata penetrated in the different wells can not be correlated and that they are chiefly of the irregular lenticular type found in stream deposits. At several points in the vicinity of El Paso, however, there are outcrops of horizontally laminated beds of clay and silt which were obviously deposited in a body of quiet water. The best exposure was seen at the corner of Mesa Avenue and Hill Street, where a recent excavation revealed about 35 feet of these beds lying unconformably below irregular gravelly stream deposits.

The sections exposed in numerous dug wells and natural outcrops in the region west of the Sacramento Mountains consist of the red, more or less gypseous and calcareous clay or adobe already mentioned. On the upper parts of the stream-built slopes this adobe contains embedded pebbles and bowlders and may show some rough stratification, but at the lower levels, to the depths that it is exposed, it is generally free of coarse material, shows no stratification or lamination, and is remarkably homogeneous throughout. It differs from ordinary stream deposits in the assortment of its material and

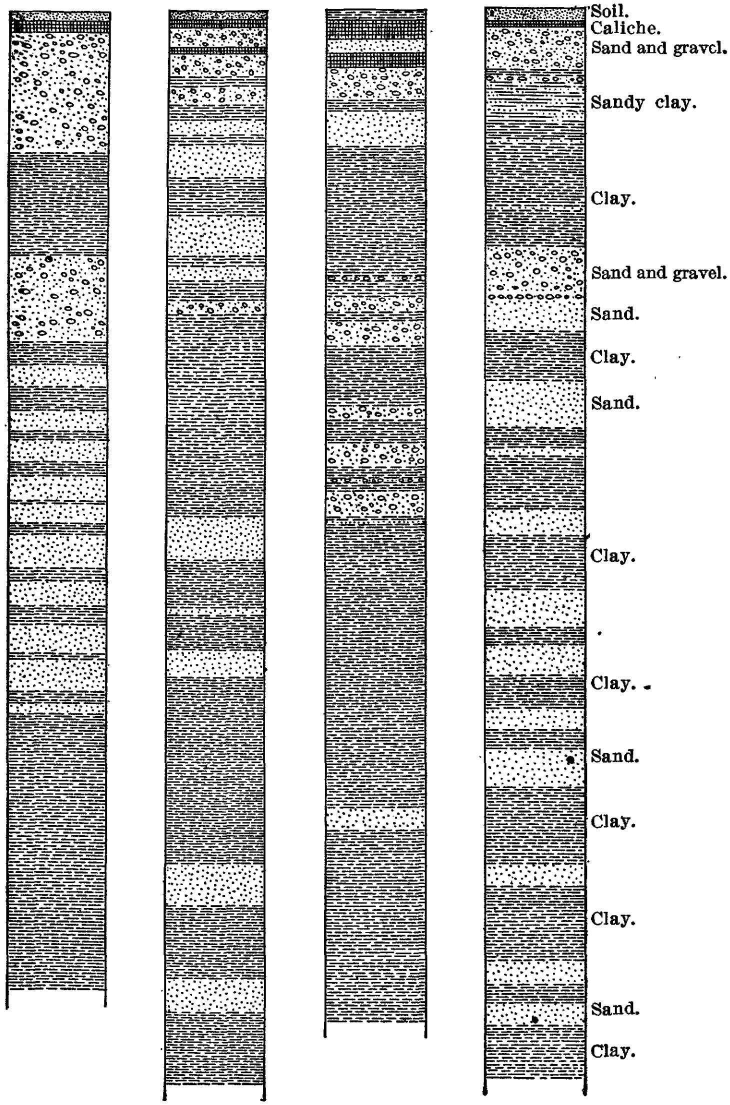


FIGURE 15.—Sections of four wells at El Paso waterworks.

lack of rough stratification, from ordinary lake deposits in its lack of regular stratification, and from ordinary wind deposits in its heavy clayey character and apparent absence of cross-bedding. The calcareous character of the adobe is shown by the large concretions, many of them cylindrical in form, which it contains.

Red clayey sediments form a veneer over the broad flat floors of the mid-slope arroyos, fill some of the sink-hole and wind-formed depressions in the gypsum belt to considerable depths, and cover parts of the plain adjacent to the malpais, especially on the west side. In all these locations they have been deposited very recently by sluggish flood waters and are so uncompact that they become excessively miry in wet weather. Deposition of clayey material can be observed in process when floods from the mountains or upper slopes spread in sheets over the smooth and nearly level lowlands, but it is uncertain to what extent the homogeneous adobe seen in outcrops and well sections may have been formed in this manner.

GYPSUM DEPOSITS.

One of the most remarkable features of the Tularosa Basin is the great quantity of gypsum found in the interior. This gypsum is derived from the gypsum beds in the Pennsylvanian rocks outcropping in the mountains. Since it is comparatively soluble it was brought to the low interior of the basin chiefly in solution in the surface and underground waters, and was redeposited when these waters evaporated, either from desiccating lakes or from springs or wet areas fed from underground sources. The deposits thus formed have been altered and further transported by repeated re-solution and redeposition and by wind work.

Gypsum underlies the southern part of the large alkali flat, all of the white sands area, and a section of the low desert plain extending southward to T. 22 S., Rs. 5 and 6 E., eastward to Dog Canyon and within a few miles of Alamogordo and Tularosa, and northwestward to a point beyond Malpais Spring. (See detailed descriptions on pp. 199–206.) It outcrops along most of the alkali flats (Pl. XV, *B*) in the outliers that project above the flats, in erosion remnants of the white sands (Pl. XIII), in the banks of the mid-slope and low-level arroyos (Pl. XIX, *A*), in many open wells, in sink holes (Pl. XV, *C*), and in the knolls and hummocks produced by sink holes and wind work throughout the gypseous portion of the desert plain. Its distribution is shown not only by outcrops and well sections, but also by the existence of sink holes and hummocky topography.

The gypsum seen in outcrops has several different forms, indicating corresponding differences in origin.

In the banks of the large alkali flat from the vicinity of Ritch's ranch to the southern extremity, and in outliers that project above this part of the flat, outcrops about 20 feet deep generally show gypsum with distinct horizontal bedding indicating deposition from the concentrated waters of an ancient lake (Pl. XV, *B*). Selenite crystals more than a foot long are found at the surface near the north Lucero ranch.

In the mid-slope arroyos and in the wells of the gypseous plain the section in downward succession is commonly as follows: (1) Soil, composed of impure gypsum or gypseous clay, from less than 1 foot to several feet thick; (2) hard massive gypsum resembling the bedrock ledges, from 1 foot to several feet thick; (3) soft, homogeneous gypsum—in only a few places showing horizontal bedding similar to that of the gypsum deposits adjacent to the alkali flat (Pl. XIV, *A*)—ranging in thickness from less than 5 feet to more than 10 feet; (4) red homogeneous gypseous adobe, to bottom of exposure. (See figs. 16 and 17.) The boundaries between the successive formations are indefinite, the transition from the gypsum to the underlying adobe being especially gradual. The hard gypsum ledge is prominent at the brinks of the mid-slope arroyos, where it has little or no cover of soil, and is seen at the surface in many knolls and hummocks. The main mass of gypsum in this section gives little evidence of its origin, but the occasional stratification shows that it is at least in part a lake deposit. The section is strikingly similar to the ordinary lime caliche section, where the soil is underlain by hard rocklike caliche, which is underlain by softer caliche that gradually changes downward into clayey material. It seems probable that the main mass of gypsum was deposited in an ancient lake, the clay deposits gradually giving way to the gypsum deposits as the lake waters became concentrated; that this gypsum was changed in form and texture and to some extent redistributed by solution and redeposition of soil waters through processes in some respects similar to those involved in the formation of caliche; that the soil is largely the product of wind work, and that wind rehandled some of the main mass of gypsum before the hard capping layer was formed. In some places, as already described, the gypsum is covered by recently deposited adobe.

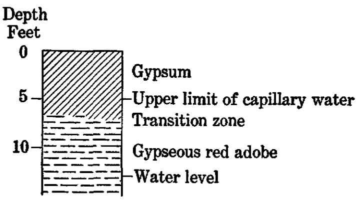


FIGURE 16.—Section in dug well 7 miles west of Tularosa (SE. ¼ sec. 25, T. 14 S., R. 8 E.), showing relation of gypsum to adobe and of capillary water to the ground-water level.

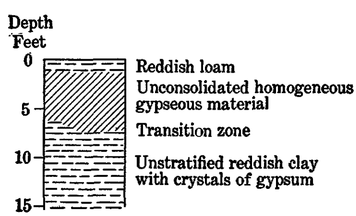


FIGURE 17.—Section in dug well of H. W. Schofield (SW. ¼ sec. 2, T. 17 S., R. 9. E.), showing relation of gypsum to adobe.

The main body of gypsum sand lies east of the large southern alkali flat and is derived chiefly from the bedded gypsum that was removed by the wind in the development of the flat but in part from the gypsum deposited by evaporating ground waters since the flat came into existence. It is extensively cross-bedded (Pl. XIII) and consists of gypsum crystals rounded by wind wear. On the west side there are many coarse, angular crystal fragments, but farther east the wind-driven sands are smaller and better rounded. The eolian origin of the older parts of the formation is obscured by the solution and redeposition that is constantly taking place and that tends to convert the rounded sand grains into a crystalline mass. When dry the formation is in some localities nearly as white as snow, but in many places it has a slightly gray or cream color due to impurities. At night its whiteness gives it a distinct glow. Its purity where it is best developed is shown by the following analysis by Dr. W. J. Gies:[1]

Analysis of white sands, Tularosa Basin, N. Mex.

	Per cent.
CaO	30.8
SO_3	44.2
SiO_2	2.7
$Al_2O_3+Fe_2O_3$	0.4
H_2O	20.8
Other constituents (by difference)	1.1
	100.0
Gypsum ($CaSO_4,2H_2O$)	95.8

Toward the north the gypsum sand gradually gives way to quartz sand, the diminution in gypsum sand being obviously due to the fact that the bedded gypsum formation from which the gypsum sand is derived disappears toward the north. Deposits of impure gypsum sand and dust have been formed by the wind over large but indefinite tracts, especially east and south of the main body of wind-blown gypsum. They may represent an older epoch of wind work or only a less vigorous phase of the present wind activity.

WIND-DEPOSITED QUARTZ SAND.

In addition to the gypsum sands the basin contains extensive areas of wind-deposited quartz sand. The large area immediately north of the white sands consists of dunes of ordinary yellowish sand, probably derived largely from the disintegration of Cretaceous sandstones and brought approximately into its present position by

[1] MacDougal, D. T., Botanical features of North American deserts: Carnegie Institution of Washington Pub. 99, p. 16, 1908.

southwest storm winds acting upon the lake that once covered the lowlands. The southern dune area, surrounding the Jarilla Mountains, is larger than the northern one, but less definite and with smaller and more isolated dunes. It is in contrast with the northern area in having sand of reddish instead of yellowish color.

SALINE DEPOSITS.

Deposits of sodium chloride (common salt) and sodium sulphate (locally but erroneously called "soda") are found in certain low places. Thin crusts of sodium chloride occur on the small northern alkali flats, in certain localities along Salt Creek, and in some of the arroyos and small flats east of the white sands. Sodium sulphate has been found in considerable quantities underlying the southern part of the large alkali flat in the vicinity of the Eddy prospect (Pl. II, in pocket), and in the southern embayment of this flat. Thin crusts of magnesium sulphate (?) were observed in the arroyo on sec. 9, T. 15 S., R. 9 E.

These very soluble deposits were in part formed when the ancient lake dried up and yielded the salts that remained longest in solution. In part they were formed, and are still being formed, by the evaporation of mineralized ground waters that reach the surface through springs and capillary action. The latter process is to some extent a process of reconcentration.

CALICHE.

Caliche, or the lime hardpan that lies immediately below the soil, is most extensively developed in the southern part of the basin and in the extreme northern part. It is seen in railroad cuts and other exposures south of the Jarilla Mountains and becomes very thick and hard in the region south of Tularosa Basin. It is also abundant on the divide between this basin and the Estancia and Pinos Wells basins. The wells in the vicinity of Carrizozo generally penetrate, at depths of 25 to 50 feet, a flesh-colored hardpan, composed chiefly of clay and calcium carbonate and probably representing a buried caliche. The large amount of limestone in the formations that have been disintegrated to form the valley fill makes it probable that much calcium carbonate is present in the valley fill and that it forms the cement in the hard layers penetrated by the drill. Such a layer is reported in the section of the Alamogordo test well at the depth of 125 feet. (See fig. 11.)

QUATERNARY BASALT.

Character and distribution.—Tularosa Basin includes two beds of lava, which, though not of the same age, were both formed during the Quaternary period and are much younger than the Tertiary lavas already described. (See pp. 34–40.) The areas covered by these beds and their relation to other formations are shown in Plates IX (p. 42) and XVII (p. 54). Both beds form thin sheets, probably less than 100 feet in average thickness, but in the vicinity of the craters they are several hundred feet thick.

Both beds consist of basalt of the same general appearance and no doubt of similar composition. They are predominantly black, but locally reddish or brownish. Gray cinders composed of very light spongy lava cover the volcanic cones and lie in heaps a short distance northeast of the younger cone. (See fig. 5, p. 38.) They were evidently produced by gas or vapor that was erupted with the lava and that expanded suddenly when it reached the surface where the pressure was removed. The bulk of the lava flowed some distance before solidifying, lost most of its gas, and became relatively compact, though its vesicular texture, especially near the surface, shows that it cooled before all of the gas bubbles had escaped. The lava that was most violently ejected, however, cooled while still inflated by the gas, and fell to the surface near the crater in solidified fragments or cinders.

Weathering and other changes.—In many places the younger basalt has a shining black surface apparently untouched by the weather, but commonly the original surface is pitted by weathering, the material having been disintegrated and removed to the depth of a fraction of an inch. The older basalt has few fresh surfaces and is much more extensively disintegrated than the younger, although its disintegration does not generally extend far below the surface. The cinder deposits of the older formation appear practically as fresh as those of the younger.

The younger bed has no soil except in the crevices of the rock, and the soil found in these crevices was chiefly deposited by the wind, although it is in small part derived from the disintegrated lava itself. This meager soil supports various desert bushes and in the northern part many small sturdy pines and cedars. The older bed is in most places covered by a thin layer of pebbly soil produced by the weathering of the formation.

The younger basalt has nowhere been touched by stream erosion, the volcanic cone and cinder mounds being as smooth and symmetrical as when they were formed and the bed in general being so jagged and having so many fissures that the water does not flow over it. On the older basalt short gullies have been cut at a number of places. (See p. 38.)

Arroyos have been formed at certain places along the margins of both beds by the flood waters, but they are more extensively developed along the older than along the younger bed. Considerable sedimentation has also taken place along the margin of both beds. Near the north end of the younger bed a well passed through about 15 feet of unconsolidated sediments and then penetrated several feet of basalt. At the lower crossing the lava is largely silted over, and advantage has been taken of this condition in constructing the crossing. Along the margins of the older bed there has been much more sedimentation, and a considerable part of its surface has become entirely concealed by débris washed over it.

Age.—The younger lava flowed out upon the main body of valley fill and is clearly of less age than all except the most recently deposited parts of the fill. This fact and the evidences of age already given prove that it was erupted either in Recent time or very near the close of the Pleistocene epoch.

The older lava has been in existence several times as long as the younger. It is not directly related to the main body of valley fill but its close conformity to the existing topography and the other evidences that have been given prove pretty conclusively that it is much younger than the basin itself and much younger than the oldest valley fill. It was probably erupted late in the Pleistocene epoch.

Both beds of basalt are very much younger than the Tertiary igneous rocks, the latter having been erupted before the present topography came into existence and having suffered a relatively enormous amount of weathering and erosion. The age of the younger basalt is at least several hundred years, but in all probability not more than a few thousand years; the age of the older basalt is probably at least a few thousand years and is perhaps several tens of thousands of years; the age of the Tertiary eruptives is probably not less than several hundred thousand years and may be several millions of years.

STRUCTURE.

FAULTS.

Distribution.—The pre-Quaternary rocks have been extensively deformed, the deformation being expressed chiefly in a series of great faults. In various places the strata have been bent or folded without breaking, but in the major deformations they were broken into huge blocks which were tilted and displaced with reference to each other. Most of the principal faults of the region have a general north-south trend, but in some parts the trend is northwest or northeast or even approaching due east and west.

San Andreas-Sacramento section.—The steep west side of the Sacramento Mountains and the equally steep east side of the San Andreas Mountains are no doubt two immense fault scarps (Pl. XVII, p. 54). In the Sacramento Mountains the strata dip gently toward the east, whereas in the San Andreas Mountains essentially the same strata dip somewhat more steeply toward the west. In each range the edges of the beds, several thousand feet thick, are exposed on the side facing the desert, but in the intervening space occupied by the desert the entire thick rock series has disappeared. It was conceived by Herrick[1] that the formations were bent into a huge but gentle arch whose limbs were formed by the strata of the opposite ranges and whose keystone was in the position now occupied by the desert, as shown by the dotted lines in figure 18. According to this conception the strata broke along two parallel lines, allowing the keystone to drop and thereby producing the low desert and the two fault scarps that face each other. Herrick at first supposed that the keystone had dropped only to the level of the desert plain, but he afterward realized that it must have dropped much lower and that it is now deeply covered with débris. The fault on the east side

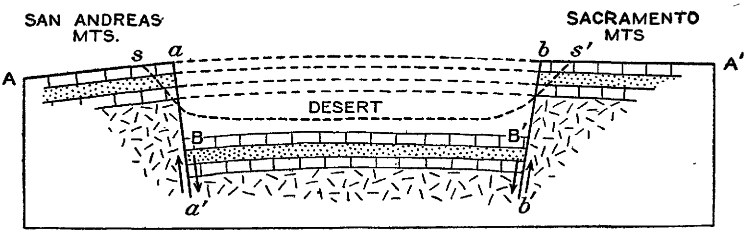


FIGURE 18.—Diagram showing hypothetical structure of the San Andreas-Sacramento section. AA', including the broken lines, shows original structure of the arch; BB', present position of the keystone part of the arch; *aa'* and *bb'*, fault planes. Arrows show direction of movement when faulting took place; *ss'*, present surface.

was not a single break but slipping seems to have occurred along at least two or three fault planes. The limestone buttes, from Cerrito Tularosa to the Two Buttes of the Tres Hermanos group (Pls. I and II, in pocket), in which the upper beds of the Manzano group are exposed, furnish some tangible evidence that the vanished rock strata do indeed lie beneath the desert sediments, but the deep wells near Alamogordo and Dog Canyon show that they have in general become buried to great depths since the faulting took place. The buttes also indicate that the arch itself was broken and faulted.

Oscuro-Sierra Blanca section.—North of the Sacramento and San Andreas ranges the earth's crust was broken into a number of blocks, which, like the Sacramento block, dip toward the east and expose their broken edges on their west sides (Pl. XVII, p. 54). The fractures occurred along parallel lines having a general north-south

[1] Lake Otero, an ancient salt lake basin in southeastern New Mexico: Am. Geology, vol. 34, pp. 175–179, 1904.

trend, and the present structure was apparently produced by the east side of each block slipping downward along the fault plane produced by the fracture. These blocks are smaller than the Sacramento block and the displacement of most of them is less, but their dip is generally greater, being in many places about 20° and locally much more.

The two major fault blocks west of the lava beds are formed by the Little Burro and Oscuro ranges, each of which is probably itself broken into several smaller blocks, among which there has been some displacement. It is not obvious, without more careful study of the stratigraphy, to what extent the hogbacks on the east sides of these ranges are fault scarps or to what extent they were developed by the erosion of alternately hard and soft strata. The displacements were not great enough to prevent the general succession from older to younger beds in the direction of the dip, but they introduce uncertainty as to the actual thickness of the series because it is not always evident whether the strata that outcrop in parallel ridges are similar beds resting stratigraphically on each other or the same beds whose outcrops are repeated by faulting. The occurrence of slickensides at Estey indicates faulting in that vicinity.

The largest Cretaceous escarpments east of the lava beds, such as Phillips Hills, Godfrey Hills, and Willow Hill, are believed to be the upthrow sides of fault blocks. Slickensides were observed in the escarpment of Willow Hill and in the escarpment north of Coyote.

Northern section.—In much of the northern part of Tularosa Basin the formations lie nearly horizontal and have apparently not been greatly faulted or otherwise deformed. This is true of a great part of the hill country west of the lava beds, the Chupadera Plateau, the plain east of the plateau, and the Mesa Jumanes. Gentle dips observed in small outcrops are here not significant of the general structure because of the undermining and sinking of the strata where the gypsum beds have been dissolved. The escarpment at the east edge of the Chupadera Plateau and the hill country is probably due to deformation. Steep dips were observed near the margin, but they are not everywhere in the same direction. In one locality west of Gran Quivira there is a westward dip of about 45°; in the large canyon 5 miles north of the Cerros Prietos the dip is toward the east, but changes within a short distance from only a few degrees to nearly 45°, and near the big cave on the west side of the younger lava bed (Pl. VI, p. 26) the dip changes abruptly from practically zero to fully 50° east. These acute dips seem to be local, the general position of the beds throughout the region being nearly horizontal.

Age.—The principal faulting occurred after the Cretaceous strata had been deposited. Keyes has reported a structural unconformity between the Carboniferous and Cretaceous rocks in the Chupadera Plateau, and it is possible that such structural unconformity may exist in Tularosa Basin, indicating deformation during the interval between the Carboniferous and Mesozoic periods of sedimentation. In general, however, the Carboniferous rocks appear to show no greater deformation than the Mesozoic, and it seems certain that any deformation between the two periods was gentle as compared with that following the Cretaceous period.

UNCONFORMITIES.

The two great unconformities of the region are at the base of the Paleozoic sediments and at the base of the valley fill. The Paleozoic sediments were deposited on a granite surface that had been worn nearly level. The edge of this ancient surface can at present be seen just below the sedimentary beds in the San Andreas, Little Burro, and Oscuro ranges. If these beds were restored to the horizontal position in which they must have been deposited the underlying granite surface would be nearly level in the region where it is now exposed. The valley fill was deposited on a surface that had been made exceedingly irregular by faulting and subsequent erosion.

VOLCANIC STRUCTURES.

The volcanic structures include dikes, sills, batholiths, lava beds, and volcanic cones. The Tertiary volcanic activity is probably closely related in time and cause to the post-Cretaceous faulting. Some of the intrusive sills appear to have been faulted with the sedimentary beds between which they lie and therefore to be older than the faulting movements, but the eruption of the batholithic bodies on the east side of the basin no doubt caused extensive deformation that was practically contemporaneous with the volcanism. The two flows of Quaternary basalt and their volcanic cones, all much younger than the principal faults, appear to have been erupted along a fracture plane that produced a zone of weakness through which the lava escaped.

GEOLOGIC HISTORY.

PRE-CARBONIFEROUS EROSION.

The deposition of the Paleozoic sediments was preceded by a long era of erosion, during which rocks of great thickness were removed, the deep-seated granite was exposed, and the region was worn down to a nearly level country.

The granite must have been originally covered by other rocks because it can be formed only at great depths. There is nothing in this region to indicate the nature of the rocks that lay above the granite and were worn away during the period of erosion, but in the regions both north and south they appear to have consisted in part of clastic sediments now hardened into quartzite.

At the close of the long period of erosion the ocean encroached upon the region from the south. The area near El Paso was submerged as early as the Cambrian period, when sandy sediments were laid down there, and it was also under water in the Ordovician and Silurian periods, when limestones were formed, but it is not known to have received any sediments during the Devonian period. The sea may have extended into a part of the area covered by Tularosa Basin at certain times in the Cambrian, Ordovician, Silurian, or Devonian, but there is as yet no proof of submergence during any of these periods.

CARBONIFEROUS SEDIMENTATION.

The first known submergence of the area now occupied by Tularosa Basin took place in the Mississippian epoch of the Carboniferous period, when the sea covered at least the eastern part of the region as far north as Alamogordo, and crinoids and other limestone-producing organisms flourished in its clear waters.

After the Mississippian epoch came the Pennsylvanian, during which the entire region was submerged and covered with thousands of feet of marine sediments. In the first part of the Pennsylvanian epoch the conditions seem to have been in general such as are normally found in the sea, and limestones, sandstones, marls, and shales of ordinary types were formed. Only locally swampy conditions prevailed, forming peat bogs, the remnants of which exist to-day as thin coal seams. Later the conditions changed in such a manner that great quantities of red sandstone and shale with some gypsum were deposited, the sediments apparently coming from the north. Toward the close of this long epoch limestone, sandstone, and shale of less striking colors were formed, but great quantities of gypsum were also deposited. It is generally believed that gypsum beds have been formed in basins whose waters were partly or wholly cut off from the ocean and subjected to great concentration, and that red beds associated with gypsum indicate aridity. The many alternations in the different kinds of deposits within the Pennsylvanian series give some conception of the great number of physical changes that the region must have undergone during this epoch.

POST-CARBONIFEROUS EROSION.

Near the close of the Carboniferous period the region apparently emerged from the sea, and from the absence or very meager representation of Triassic, Jurassic, and Lower Cretaceous formations the inference may be drawn that it probably remained dry land during most of the Mesozoic era prior to the Upper Cretaceous. According to Keyes there was some deformation and volcanic activity in the Chupadera Plateau during this interval of emergence, but for the region as a whole there was probably only a gentle uplift that added this part of the State to the continental area and subjected it to moderate erosion.

CRETACEOUS SEDIMENTATION.

During at least the later half of the Cretaceous period a part of the region, and possibly all of it, was once more submerged and covered with sediments. The sea of this period was for the most part shallow and muddy, and hence shales and sandstones were chiefly formed, and subaerial deposition probably also took place. Temporarily the waters cleared to such an extent that few sediments were deposited except those derived from the remains of lime-secreting organisms, and at these times limestones were formed. Swamp conditions were characteristic of parts of the period, and here, as elsewhere in the West, coal was formed in Cretaceous time.

POST-CRETACEOUS VOLCANISM, DEFORMATION, EROSION, AND NONMARINE SEDIMENTATION.

After the deposition of the Cretaceous sediments some notable events took place. The region was raised above the water, the rocks were broken and faulted, and great quantities of lava were intruded into or beneath the sedimentary beds and in some places were perhaps thrown out upon the surface. As a result mountains were formed and the basin began to assume its character as a definite physiographic feature. The faulting movements were probably continued intermittently during a long time, perhaps during the entire Tertiary period and practically to the present.

So soon as the land emerged from the sea it was subjected to weathering and erosion, and when the deformation had progressed far enough to produce mountains the erosive activity was intensified. During this period of erosion, extending from the Cretaceous period to the present time, immense quantities of Cretaceous and Carboniferous sediments and of igneous rock were removed. At certain stages the basin may have had a true drainage outlet toward the south, but there is no clue as to the amount of rock waste carried out of the region by streams. A vast quantity of débris has, however, accumulated in the depression presumably formed by the sinking of the great earth block between the Sacramento and San Andreas mountains and on some higher ground. The erosion, transportation, and deposition of so much material must have occupied a long time, and it is not improbable that the oldest valley fill was formed before the beginning of the Quaternary period. The accumulation of the valley fill implies more or less aridity, for in regions having humid climate the drainage is generally vigorous enough to sweep away most of the débris produced by weathering.

Several lines of evidence indicate that at one or more periods in the past the basin held a body of water, but this evidence is too indefinite to warrant statements as to the depth and extent of these water bodies. That the last lake disappeared by evaporation is shown by the gypsum, salt, and sodium sulphate which it left behind.

Since the lake disappeared several changes have taken place. The wind has formed the depressions occupied by the alkali flats, and has deposited the excavated material in dunes, chiefly of gypsum sand. After the alkali-flat depressions came into existence the flood waters eroded the arroyos directly tributary to these depressions. The mid-slope arroyos are older and were formed before the white sands were well developed, possibly while the lake existed. The last eruption of basalt was probably postlacustrine; the earlier eruption probably occurred while the lake existed, or before.

The following changes are taking place at the present time: (1) Weathering on the mountains, buttes, and lava beds; (2) stream erosion on the mountains, buttes, older lava bed, upper parts of the stream-built slopes, and areas near the alkali flats; (3) stream deposition on the lower parts of the slopes, on the borders of the lava beds, and to some extent in the mid-slope arroyos and the alkali flats; (4) wind erosion at the margins of the alkali-flat depressions and in other localities; (5) eastward migration of the white sands and quartz sands; (6) the formation of sink holes as a result of the solution and removal of gypsum by ground water; and (7) the precipitation of gypsum and other soluble minerals through the evaporation of ground water on the alkali flats, the floors of the mid-slope and low-level arroyos and other wet areas.

PRECIPITATION.

RECORDS.

Rainfall observations were begun at Fort Bliss, near El Paso, in August, 1850, and were continued, with interruptions, until 1861. They were resumed after the Civil War and were continued, with some interruptions, until the close of 1876. In July, 1878, a weather station was established at El Paso, and the observations since that date furnish a complete record covering a period of over 30 years.

Observations were begun at Fort Stanton in January, 1856, and nearly complete records exist for 34 out of the 56 years which elapsed between that date and January, 1912. The principal interruptions were from 1861 to 1868, 1873 to 1881, and 1896 to 1899, inclusive.

Observations were made at Whiteoaks from 1896 to 1901, and again in 1905 and 1906. They were begun at Alamogordo and Cloudcroft soon after the founding of these towns, and were continued until the present time, giving a nearly complete record of 11 years for Alamogordo and 9 years for Cloudcroft. The records of these two points are of sufficient length to be of great value, especially if they are interpreted in connection with the longer records for El Paso and Fort Stanton.

Since July, 1909, observations have been regularly made at most of the stations of the El Paso & Southwestern Railroad between El Paso and Tucumcari. The data obtained from this series of observations are already valuable, and the records will in a few years become much more valuable if the observations are continued.

Precipitation (in inches) at stations in and near Tularosa Basin, N. Mex.

Alamogordo (altitude, 4,338 feet).

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1901	0.15	1.35	0.35	0.41	0.22	0.38	1.47	1.14	1.18	2.59	2.13	0.10	11.47
1902	T.	.16	.22	.00	T.	.17	1.38	3.39	.53	.65	.15	.60	7.25
1903	.30	1.00	.40	T.	.48	1.30	.83	1.48	1.16	.00	.00	T.	6.95
1904	.50	.10	.00	.00	T.	.13	.81	2.01	2.10	2.38	.17	.75	8.95
1905	1.02	2.45	1.85	3.34	T.	1.84	2.88	.41	1.78	.34	2.75	.86	19.52
1906	.85	.74	.26	.99	.27	T.	.72	1.91	.42	.43	2.22	2.35	11.16
1907	1.45	.07	T.	.35	.23	.78	.93	3.74	1.74	.84	.75	T.	10.88
1908	1.15	.30	.42	1.29	.08	.13	4.30	3.06	.26	.19	.83	T.	12.11
1909	.95	T.	1.00	.00	.00	.17	.62	1.88	1.14	.13	.02	.94	6.85
1910	.40	.00	.20	.12	.04	1.00	.99	4.05	T.	.70	1.10	.05	8.65
1911	.21	1.96	.62	.84	.94	.54	2.75	.59	2.31	1.46	.18	.29	12.69
Average	.63	.74	.48	.67	.21	.59	1.61	2.15	1.15	.88	.94	.54	10.59

Ancho (altitude, 6,112 feet).

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1909	......	......	......	......	......	......	3.00	0.80	0.70	0.19	0.10	1.37	......
1910	0.07	0.00	T.	T.	0.00	0.15	.95	2.28	.00	.15	.15	.21	3.96
1911	.31	.74	0.56	1.15	.02	1.18	4.11	2.16	.94	1.04	T.	.62	12.83

Carrizozo (altitude, 5,429 feet).

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1908	......	......	......	......	......	0.76	2.98	2.20	0.20	0.35	0.65	0.30	......
1909	0.40	0.51	1.37	0.00	T.	1.01	2.58	2.67	.26	.10	.00	.75	9.65
1910	.50	T.	.00	.35	T.	.26	.28	2.51	.13	.60	.05	.00	4.68
1911	T.	1.23	.40	1.13	T.	.70	3.61	1.04	1.90	.69	.02	.44	11.16

Cloudcroft (altitude, 8,650 feet).

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1902	1.23	0.50	1.45	......	......	......	......	......	2.26	0.14	1.31	2.00	......
1903	.99	4.60	.90	0.15	1.20	4.01	0.66	2.98	1.85	.50	.00	.28	18.12
1904	.85	.10	T.	.50	.60	1.63	4.23	3.69	6.16	4.37	.55	1.36	24.04
1905	3.20	4.05	2.12	3.35	.00	1.12	2.87	1.85	4.54	.99	5.69	2.54	32.32
1906	1.00	1.72	1.47	1.60	1.17	T.	3.35	3.36	5.44	1.29	3.55	4.73	28.68
1907	6.32	.43	1.50	.83	1.82	1.80	4.50	3.86	1.44	4.55	4.00	.21	31.26
1908	1.96	2.00	1.00	.53	.07	.00	2.68	7.61	.39	.25	.80	.10	17.39
1909	1.10	2.40	2.10	.00	.00	1.30	4.69	3.34	2.77	.52	.20	.55	18.97
1910	.90	T.	.30	.27	.10	1.84	2.71	7.31	.88	.68	.15	.75	15.89
1911	.20	3.11	.85	.40	T.	1.22	6.06	1.06	3.99	1.80	.33	1.39	20.41
Average	1.47	1.89	1.16	.85	.55	1.43	3.53	3.90	2.90	1.46	1.56	1.34	22.29

Precipitation (in inches) at stations in and near Tularosa Basin, N. Mex.—Con.

Corona (altitude, 6,666 feet).

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1909	......	......	......	......	......	......	2.93	3.35	1.63	1.29	0.25	1.08	......
1910	0.53	1.62	0.35	T.	0.12	0.61	1.40	2.59	.50	.65	.50	.05	8.92
1911	.21	1.63	.99	1.98	.48	1.48	......	.60	1.00	.83	.39	1.08	......

Coyote (altitude, 5,800 feet).

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1909	......	......	......	......	......	......	1.10	2.99	0.34	0.33	0.10	1.62	......
1910	0.29	0.32	0.20	0.24	0.22	1.70	.86	3.03	.15	.49	1.04	.20	8.74
1911	.28	.79	.51	.63	.26	.61	5.38	2.42	2.49	1.20	.04	.82	12.43

Duran (altitude, 6,272 feet).

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1908	......	......	......	......	......	......	......	5.49	0.68	0.10	1.30	0.03	......
1909	0.19	0.27	2.24	0.02	0.36	0.99	0.64	2.81	.50	1.12	.15	.40	9.69
1910	T.	.47	T.	T.	T.	.76	2.36	2.61	.30	.79	.50	T.	7.79
1911	.22	2.05	.85	1.37	.33	2.15	7.68	......	1.28	.45	.72	.66	......

El Paso, Tex.[1] (altitude, 3,762 feet).

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1850	......	......	......	......	......	......	......	0.70	0.05	0.60	4.60	1.10	......
1851	0.00	0.90	0.00	0.00	0.70	0.02	1.05	2.49	......	......	......	......	......
1852-53	......	......	......	......	......	......	......	......	......	......	......	......	......
1854	......	......	......	......	......	......	.10	5.71	3.70	1.54	.00	.50	......
1855	.00	.00	......	.00	......	.05	.16	1.12	7.22	1.05	1.25	.00	......
1856	.33	5.55	2.02	.00	.00	.58	2.20	3.38	7.00	.00	.75	.00	21.81
1857	.00	.50	.00	......	.00	.63	1.52	3.73	4.15	2.87	.07	......	......
1858	.25	.15	.06	.00	.00	.19	1.52	2.42	.40	.00	.01	.00	5.00
1859	.10	.10	.00	.01	.01	.03	1.60	.22	1.11	.70	.95	.00	4.83
1860	T.	.24	.00	.01	.00	.30	.53	.08	.18	......	.20	.45	......
1861	.40	.00	......	......	......	......	......	......	......	......	......	......	......
1862-1864	......	......	......	......	......	......	......	......	......	......	......	......	......
1865	......	......	......	......	......	......	......	......	......	......	......	.40	......
1866	.00	.00	......	T.	......	......	......	......	1.45	.00	.15	.11	......
1867	.04	.19	.24	.00	.05	.00	.47	.17	1.29	.30	.02	.07	2.84
1868	.47	.17	.05	......	......	......	......	......	......	......	......	......	......
1869	......	......	......	.00	.40	1.30	.26	5.14	T.	.58	.24	.00	......
1870	.10	......	.00	......	.00	.04	1.43	4.01	.00	.05	T.	.60	......
1871	.59	.00	.20	T.	.33	1.54	1.20	.82	2.64	.01	.00	.28	7.61
1872	1.00	.00	T.	.00	.05	1.83	2.72	.04	.58	.32	.06	1.08	7.68
1873	.64	.00	.30	.36	.07	1.34	.56	.98	.50	.00	1.02	.00	5.77
1874	.37	.34	.06	.52	.00	.26	.50	.96	1.08	1.38	.54	1.23	7.24
1875	.00	.88	.10	.08	T.	.80	1.80	.92	1.87	.00	.00	.03	6.48
1876	.21	.00	.00	T.	T.	.50	T.	4.74	3.76	.00	.25	.00	9.46
1877	......	......	......	......	......	......	......	......	......	......	......	......	......
1878	......	......	......	......	......	......	1.25	2.55	.66	1.02	.66	.11	......
1879	1.57	.83	.18	.07	.00	.08	2.47	.35	.04	.95	.01	.26	6.81
1880	1.01	T.	.30	.10	.00	.00	6.54	3.60	.80	.47	.02	1.53	14.37
1881	.35	.24	.01	.22	1.83	.02	8.18	3.15	1.44	1.45	.50	.78	18.17
1882	.64	.78	.38	.00	.10	.43	1.26	2.82	.40	.00	1.46	.00	8.27
1883	.10	.40	2.09	.10	.02	.04	2.84	1.34	2.51	2.03	.61	.84	12.92
1884	.55	.84	.33	.91	T.	.11	.46	3.98	3.68	5.15	.22	2.07	18.30
1885	.12	.03	.34	.04	1.27	2.63	1.06	.46	.22	.46	.31	.37	7.31
1886	.31	.44	.28	T.	.01	1.03	1.62	1.85	1.16	.80	.52	.04	8.06
1887	.03	.15	.32	.09	.13	.34	.73	1.68	.94	.78	.56	1.01	6.76
1888	.32	1.51	.95	.74	.15	.42	1.39	1.32	.49	1.13	1.32	.05	9.79
1889	.76	.18	.67	.04	.00	.28	1.59	.04	2.64	.35	.55	.00	7.10
1890	.72	.02	.01	.06	T.	.63	.95	3.25	1.81	.41	.35	.28	8.49
1891	.27	.09	.16	.00	.38	.40	.06	.13	.23	T.	T.	.50	2.22
1892	1.25	.57	.30	.11	T.	T.	1.14	.07	.12	.22	.93	.61	5.32
1893	.02	.52	.31	.00	2.28	T.	2.08	3.15	2.08	T.	.02	.42	10.88
1894	.33	.29	.13	.01	.01	.01	1.40	.64	.40	.39	.00	.63	4.24
1895	.65	.17	.05	T.	2.11	.21	2.48	2.01	.28	.88	1.05	.31	10.20
1896	1.63	.14	T.	T.	T.	.60	2.73	1.09	1.48	2.02	.04	.06	9.79
1897	.54	.00	.05	.14	.46	2.17	2.89	2.57	2.73	.77	T.	.09	12.41
1898	.25	.04	.43	.81	.01	.46	1.46	1.00	.50	T.	.16	1.04	6.16

[1] Fort Bliss till December, 1876.

Precipitation (in inches) at stations in and near Tularosa Basin, N. Mex.—Con.

El Paso, Tex.—Continued.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1899	0.06	0.03	0.23	0.88	T.	0.61	3.08	0.91	0.64	0.01	0.64	0.21	7.30
1900	.11	.43	.26	.02	.41	.27	2.38	.43	2.18	1.23	.23	T.	7.95
1901	.35	.68	.47	.47	.05	.39	1.05	.34	.82	2.98	1.05	.03	8.68
1902	.57	.01	.00	.00	T.	.01	3.27	2.85	1.86	.31	.49	.78	10.15
1903	.61	1.09	.15	.54	.29	2.50	1.19	1.73	3.52	.00	.00	.01	11.63
1904	T.	.01	.00	.00	.06	.54	.59	2.24	3.50	3.51	.01	.84	11.30
1905	.86	1.88	1.46	1.38	.03	2.12	2.55	.53	2.29	1.28	2.40	1.02	17.80
1906	.87	1.37	.01	.40	.90	T.	2.02	4.10	1.18	.44	2.50	1.20	14.99
1907	.42	T.	T.	.07	.10	.76	.35	2.50	.96	2.52	.73	T.	8.41
1908	.10	.26	.35	.88	.01	.00	2.07	2.55	T.	.12	.45	.15	6.94
1909	.04	.16	.77	.00	T.	.05	1.62	.51	.60	.02	T.	.56	4.33
1910	.21	.10	T.	T.	T.	1.35	.60	1.18	.24	.02	.03	.30	4.03
1911	.36	.96	.43	.47	.39	2.36	3.43	.45	1.00	.43	.35	.24	10.87
Average	.40	.46	.30	.20	.27	.62	1.69	1.82	1.54	.81	.54	.43	9.08

Fort Stanton (altitude, 6,231 feet).

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1856	0.50	0.58	1.59	0.24	0.26	0.68	1.99	3.62	2.81	0.19	2.14	2.21	16.81
1857	.67	.97	.17	.62	.69	1.27	4.88	9.24	6.14	2.59	.87	.59	28.70
1858	.65	.12	1.47	.31	.70	2.00	3.49	8.09	.74	.47	.24	.48	18.76
1859	.09	.53	1.00	.30	.20	3.19	3.30	6.93	3.77	2.60	.25	1.65	23.81
1860	.39	3.55	.08	1.41	T.	1.03	1.50	2.87	.78	.08	.75	1.21	13.65
1861	1.76	.50	......	T.	3.14	3.38	4.23	......	......	......	......	......	......
1862	......	......	......	......	......	......	......	......	......	......	......	......	......
1863	......	......	......	......	......	......	......	......	......	......	......	......	......
1864	......	......	......	......	......	......	......	......	1.14	......	......	......	......
1865	......	......	......	......	......	......	......	......	......	......	......	......	......
1866	......	......	......	......	......	......	......	......	1.15	......	......	......	......
1867	......	......	......	......	......	......	......	1.50	.50	......	......	......	......
1868	......	......	......	......	......	......	......	......	1.02	......	.39	.62	......
1869	.49	1.36	1.18	2.75	4.17	3.70	1.44	2.45	.05	.88	.42	3.92	22.81
1870	.00	.00	2.20	.22	.18	2.08	4.45	4.70	.94	2.84	.00	.36	17.97
1871	1.68	.07	4.28	.00	.65	.14	5.80	1.13	2.10	1.50	.15	3.00	20.50
1872	.66	.63	.37	.66	.00	2.29	4.78	3.19	3.27	3.02	3.54	2.34	23.75
1873-1880	......	......	......	......	......	......	......	......	......	......	......	......	......
1881	......	......	......	......	......	......	......	1.05	2.65	2.59	.66	.35	......
1882	.95	.30	.26	.22	T.	.50	.56	1.87	.70	.00	1.21	.21	6.78
1883	.00	.00	......	.00	T.	.10	.95	4.10	......	......	......	......	......
1884	1.20	.40	.70	.30	1.73	2.11	2.48	6.98	3.21	2.65	.30	1.44	23.50
1885	.72	.63	.62	.50	.62	1.35	3.17	2.57	1.36	.18	.50	.35	12.57
1886	.36	.17	.50	1.50	.10	1.61	4.71	5.45	4.29	1.32	.15	.08	20.24
1887	.01	.11	.25	.04	.72	2.50	2.59	3.49	4.21	1.75	.17	.93	16.77
1888	.22	1.09	2.82	1.69	.25	.88	1.60	4.51	1.16	2.14	1.53	.15	18.04
1889	1.33	.39	.86	.24	.17	2.51	2.36	.89	2.76	1.90	1.04	.04	14.49
1890	.37	.08	.12	.57	.00	1.05	1.92	2.93	1.52	.40	1.85	1.06	11.87
1891	1.00	1.66	.98	.02	2.83	2.37	1.30	1.65	1.33	.12	.19	1.23	14.68
1892	.56	.36	1.15	.27	.11	.45	2.87	1.41	.32	1.76	.65	1.43	11.34
1893	.75	1.60	.11	.00	.72	.45	3.57	4.74	3.47	.04	.20	.15	15.80
1894	.00	.61	.27	.96	1.02	1.07	1.35	4.88	.15	1.46	T.	.37	12.14
1895	.47	1.02	.11	T.	1.06	1.45	6.03	1.61	.65	.78	1.24	.05	14.47
1896	......	......	......	......	......	......	......	......	......	......	......	......	......
1897	......	......	......	......	......	......	......	......	......	......	......	......	......
1898	......	......	......	......	......	......	......	......	......	......	......	......	......
1899	......	......	......	......	......	......	......	......	......	......	......	......	......
1900	1.00	.25	.48	.90	1.09	1.63	1.98	2.18	6.06	1.43	.40	.36	17.76
1901	.10	2.00	.50	.90	.64	1.34	3.25	1.85	2.00	1.76	2.85	.95	18.14
1902	.05	.38	.22	.00	1.88	.24	2.28	1.87	.48	1.81	.16	.57	9.94
1903	.36	.75	.17	.20	.38	3.41	.62	1.55	1.55	.48	.00	.05	9.52
1904	.02	.10	.03	.15	.14	1.50	2.87	2.92	6.06	2.68	.08	.35	16.90
1905	.40	1.32	1.75	2.04	T.	2.79	5.62	2.12	T.	.50	4.25	1.80	22.59
1906	.35	.35	T.	1.40	.02	.25	4.38	4.34	1.95	1.45	.86	1.68	17.03
1907	.25	.52	T.	.15	.20	3.35	2.74	4.58	1.85	2.64	.99	02	17.29
1908	.15	.60	.15	1.15	.48	.19	2.49	6.46	1.32	.05	.75	T.	13.79
1909	.18	.20	2.02	.00	.20	.67	3.28	3.54	.59	.82	T.	.25	11.75
1910	.10	.37	.35	.44	.18	2.85	1.57	4.57	.90	.56	.77	.23	12.89
1911	.15	1.82	.80	1.99	.75	3.11	5.62	1.83	1.50	2.28	.16	.47	20.48
Average	.49	.71	.81	.62	.70	1.66	3.01	3.53	1.94	1.36	.79	.85	16.47

Precipitation (in inches) at stations in and near Tularosa Basin, N. Mex.—Con.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Newman (altitude, 3,989 feet).													
1909	......	......	......	......	......	......	0.47	0.69	1.69	0.60	T.	0.63	....
1910	T.	0.10	T.	T.	T.	1.45	.29	1.32	.37	.00	.75	.45	4.73
1911	0.18	1.77	1.55	1.74	T.	.90	2.91	.48	.27	.31	.10	......	....
Gallinas (altitude, 6,635 feet).													
1909	......	......	......	......	......	......	1.76	2.47	0.56	0.97	0.16	0.60	....
1910	0.49	0.65	0.30	0.47	0.10	1.14	.62	1.03	T.	1.71	.72	.30	7.53
1911	.20	2.00	.48	1.71	.00	1.82	3.40	1.85	1.94	1.03	.21	1.09	15.73
Tularosa (altitude, 4,436 feet).													
1908	......	......	......	0.58	0.06	0.01	1.82	5.25	0.22	0.27	0.65	0.04	....
1909	0.12	0.24	1.03	T.	T.	.22	1.85	.99	1.22	.09	.03	.19	5.98
1910	.28	.00	.31	.24	.03	.97	.41	2.47	.21	.52	.16	.08	5.68
1911	.22	1.62	.78	......	......	......	......	......	......	......	.00	.25	....
Oscuro (altitude, 5,016 feet).													
1909	0.10	0.21	1.03	0.00	0.05	0.52	2.11	1.35	0.47	0.15	0.01	0.28	6.28
1910	.33	.01	T.	.10	.16	.27	.54	1.54	.08	1.01	.75	.26	5.05
1911	.22	1.96	.80	.76	.42	.97	4.83	.83	2.62	.86	.11	.08	14.46
Orogrande (altitude, 4,171 feet).													
1909	......	......	......	......	......	......	0.17	0.12	0.08	0.04	0.00	0.82	....
1910	T.	T.	0.01	T.	T.	1.68	.30	1.11	.25	.20	.60	.05	4.20
1911	0.32	1.62	1.24	0.55	0.54	.97	3.70	.62	1.10	.74	.07	.45	11.92
Tecolote (altitude, 6,539 feet).													
1909	......	......	......	......	......	......	3.35	2.42	0.53	1.15	0.11	0.25	....
1910	0.58	0.84	0.42	0.37	0.01	1.45	.15	3.95	.44	.42	1.15	.37	10.15
1911	.23	2.03	.85	1.68	.65	.68	4.37	2.35	2.49	.89	.16	.75	17.13
Three Rivers (altitude, 4,559 feet).													
1909	......	......	......	......	......	......	1.32	0.73	0.44	0.11	T.	0.18	....
1910	0.20	T.	0.09	0.32	0.32	0.65	.09	1.65	.13	.63	0.66	.02	4.76
1911	.22	1.87	.33	.62	.08	1.18	2.52	.45	2.62	.87	T.	.29	11.05
Torrance (altitude, 6,433 feet).													
1909	......	......	......	......	......	......	3.14	3.85	0.80	0.20	0.85	......	....
1910	T.	0.89	0.10	0.10	T.	0.05	.52	4.14	.11	.39	.50	0.40	7.20
1911	0.19	2.84	.05	1.22	0.04	1.08	11.54	2.30	1.99	.88	.42	.96	23.51

Precipitation (in inches) at stations in and near Tularosa Basin, N. Mex.—Con.

Whiteoaks (altitude, 6,470 feet).

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1896	......	......	......	......	T.	0.45	2.01	2.22	1.17	4.01	0.34	1.12	......
1897	2.32	0.55	1.21	0.45	1.27	1.84	1.78	2.28	2.85	.99	.06	.78	16.38
1898	2.21	.41	1.32	1.04	.00	5.21	5.60	3.54	1.24	.75	.25	.90	22.47
1899	.90	.50	.80	.05	.00	.69	5.53	1.72	.82	T.	1.25	1.10	14.36
1900	1.05	.65	.70	1.66	1.51	.77	1.67	1.10	3.99	1.56	.30	1.15	16.11
1901	1.52	2.53	.67	1.14	1.68	1.35	......	......	......	......	......	......	......
1902	......	......	......	......	......	......	......	......	......	......	......	......	......
1903	......	......	......	......	......	......	......	......	......	......	......	......	......
1904	......	......	......	......	......	......	......	......	......	......	......	......	......
1905	.50	1.61	2.18	4.97	.01	2.23	2.47	1.85	1.32	.47	4.13	2.50	24.24
1906	.64	.43	.30	1.62	.21	.19	2.11	2.82	1.51	1.73	1.62	1.80	14.98
1907	......	......	......	......	......	......	......	......	......	......	......	......	......
Average	1.31	.95	1.03	1.56	.58	1.59	3.02	2.22	1.84	1.36	1.28	1.34	18.08

AVERAGE PRECIPITATION.

In the following table are given the average amounts of precipitation at the stations having records of sufficient length to make the averages of much value:

Averages of precipitation, in inches, at stations in and near Tularosa Basin, N. Mex.

Station.	Length of record.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
	Years.													
Alamogordo	11	0.63	0.74	0.48	0.67	0.21	0.59	1.61	2.15	1.15	0.88	0.94	0.54	10.59
Cloudcroft	9	1.47	1.89	1.16	.85	.55	1.43	3.53	3.90	2.90	1.46	1.56	1.34	22.29
El Paso	43	.40	.46	.30	.20	.27	.62	1.69	1.82	1.54	.81	.54	.43	9.08
Fort Stanton	34	.49	.71	.81	.62	.70	1.66	3.01	3.53	1.94	1.36	.79	.85	16.47
Whiteoaks	6	1.31	.95	1.03	1.56	.58	1.59	3.02	2.22	1.84	1.36	1.28	1.34	18.08

El Paso and Fort Stanton have the longest records, and for this reason their averages are the most reliable. Since the averages for the different stations are based on the records for different years, these averages are not strictly comparable. Thus, the annual average for Whiteoaks is higher than that for Fort Stanton, although during the years that observations were made at both places slightly more rain fell at Fort Stanton than at Whiteoaks. In other words, the period during which observations were made at Whiteoaks was probably a period of more than normal rainfall. If, in order to compare Alamogordo, Cloudcroft, El Paso, and Fort Stanton, their records are considered for the nine years during which observations were made at all four points, it is found that their annual averages are, respectively, 10.86 inches, 22.29 inches, 10.03 inches, and 15.80 inches. These averages, when compared with those given in the table above, indicate that the precipitation of the last nine years was slightly above normal at El Paso and slightly below normal at

Fort Stanton, but they indicate much more conclusively that the records at Alamogordo and Cloudcroft are long enough to be fairly representative. The data at hand establish the facts that at both El Paso and Alamogordo the normal precipitation is not far from 10 inches a year, that at Cloudcroft it is about twice this amount, and that at Fort Stanton and Whiteoaks it is intermediate.

DISTRIBUTION FROM YEAR TO YEAR.

Although the average annual precipitation at the same point does not appear to differ greatly for periods of 10 or more years, there are radical differences in the amounts of precipitation in different years. In the 6-year record for Whiteoaks the annual precipitation ranges between 14.36 and 24.24 inches; in the 9-year record for Cloudcroft it ranges between 15.89 and 32.32 inches; in the 11-year record for Alamogordo it ranges between 6.85 and 19.52 inches; in the 34-year record for Fort Stanton it ranges between 6.78 and 28.70 inches; and in the 43-year record for El Paso it ranges between 2.22 and 21.81 inches.

The year of greatest precipitation recorded at El Paso or Fort Bliss was 1856, and other years of exceptionally heavy rainfall in that locality were 1880, 1881, 1884, 1905, and 1906. The year of greatest precipitation recorded at Fort Stanton was 1857, and other years of exceptionally heavy rainfall were 1859, 1869, 1872, 1884, and 1905. So far as the records for these stations show, the two wettest years in the last three decades were 1884 and 1905. The records for Whiteoaks, Alamogordo, and Cloudcroft also indicate unusually heavy precipitation in 1905.

The year of least precipitation recorded at El Paso or Fort Bliss was 1891, and other very dry years were 1858, 1859, 1867, 1894, 1909, and 1910. The year of least precipitation recorded at Fort Stanton was 1882, at Alamogordo it was 1909, and at Cloudcroft it was 1910.

The continuous record of the annual precipitation at El Paso for the last 33 years, as plotted in figure 19, clearly shows that the fluctuations from year to year are very great and very irregular. Thus, the record for 1911 and preceding years gives no basis for predicting whether 1912 is to be a wet year, a dry year, or a year of normal rainfall. There is no doubt some tendency for wet years and dry years to occur in groups, but even this indefinite rule has distinct exceptions.

The character of the precipitation curve for the decade from 1901 to 1910 is well shown by four nearly complete records that agree in essentials. A conspicuously humid period marked the middle of the decade, and this humid period was preceded and followed by periods of great drought. In 1911 the rainfall was for the first time in several years somewhat above normal.

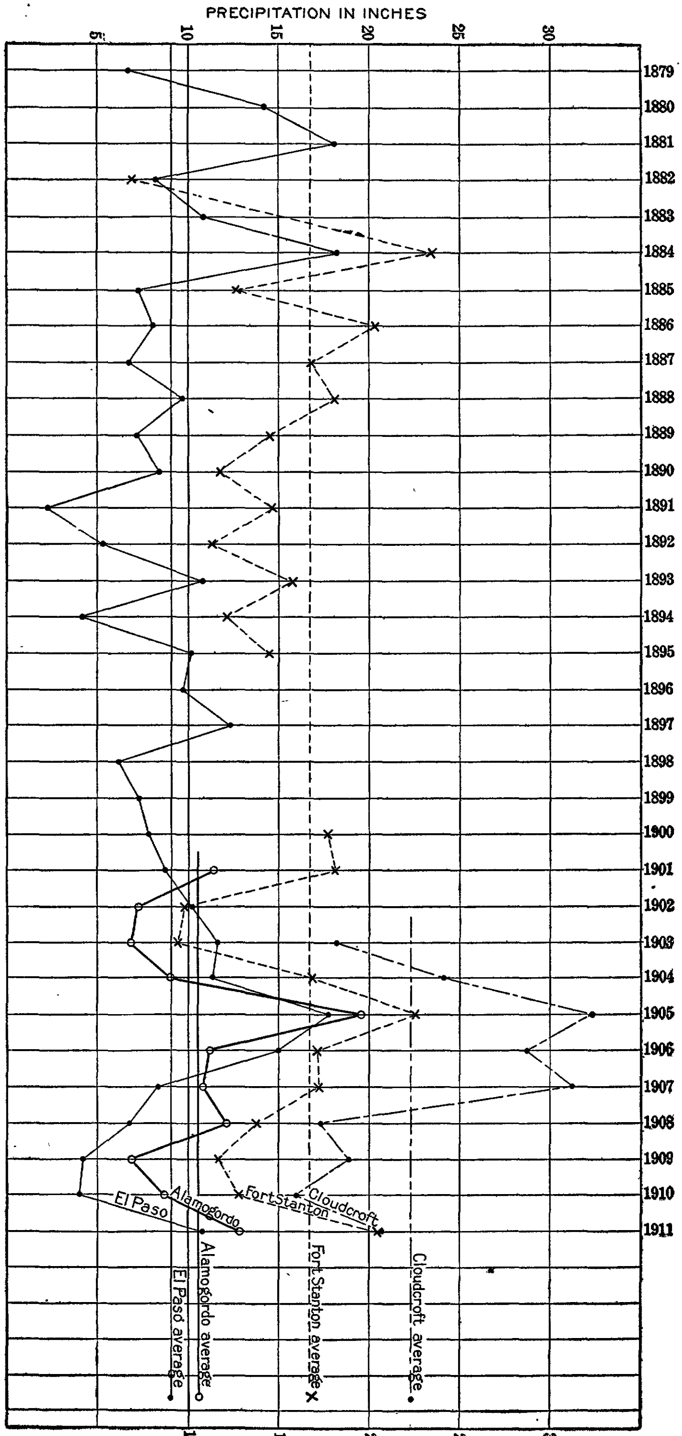


FIGURE 19.—Diagram showing annual precipitation at stations in or near Tularosa Basin.

SEASONAL DISTRIBUTION.

The principal rainy season in Tularosa Basin is in midsummer, generally beginning near the close of June or in the first half of July and continuing into September. From 55 to 60 per cent of the precipitation occurs in the months of June, July, August, and September and from 35 to 40 per cent in the months of July and August.

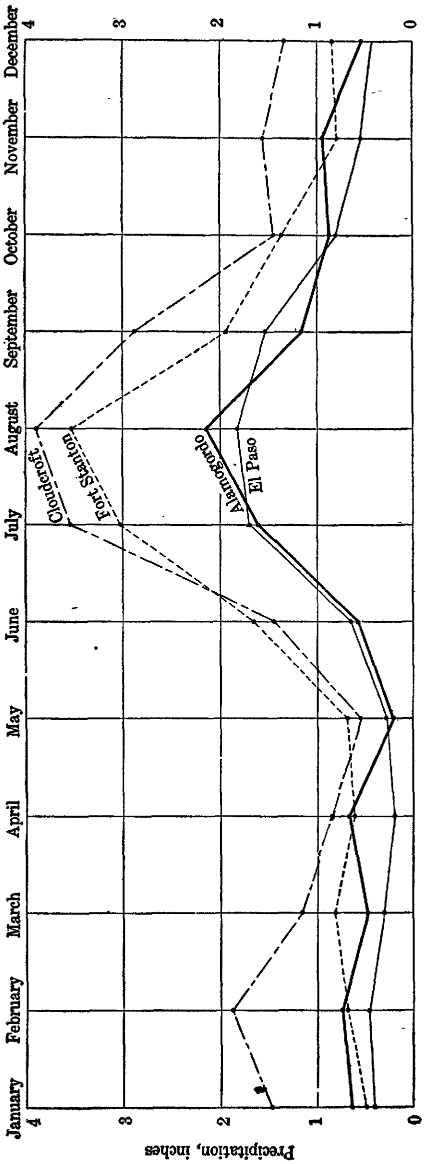


FIGURE 20.—Diagram showing average monthly precipitation at stations in or near Tularosa Basin.

The driest season is in the spring. Only a little over 10 per cent of the precipitation occurs in the months of March, April, and May, the average amount at El Paso and Alamogordo for this entire period of three months being only about 1 inch. The month with least precipitation is May. At El Paso out of 48 years for which there is a record there were 24 years in which practically no rain fell in May and only 4 years in which the rainfall during this month amounted to 1 inch. At Alamogordo there have in the last 11 years been 4 years in which no rain fell in the month of May and no year in which the rainfall amounted to as much as 1 inch, the average being about one-fifth of an inch.

During the late fall and winter months there are occasional rains and snows, which together contribute about one-third of the total precipitation.

Tularosa Basin lies outside of the track of most of the continental, cyclonic storms that control the climatic conditions farther north. Its winter precipitation is partly produced by these storms, but its summer rains are local and are produced by ascending currents of hot air which precipitate their moisture when they become chilled at the higher altitudes. Precipitation of this kind consists typically of sudden, heavy showers that are of short duration and occur at irregular intervals.

The precipitation of this region, like that of desert regions in general, is characterized not only by its average scarcity but also by its great irregularity. Much more rain falls in some years than in others, and much more falls in some seasons than in others. The so-called rainy season is not uniformly humid but generally includes several heavy downpours, between which may intervene periods of severe drought. Conversely, even the driest seasons may at infrequent intervals experience violent and heavy rainstorms. (See figs. 20 and 21.)

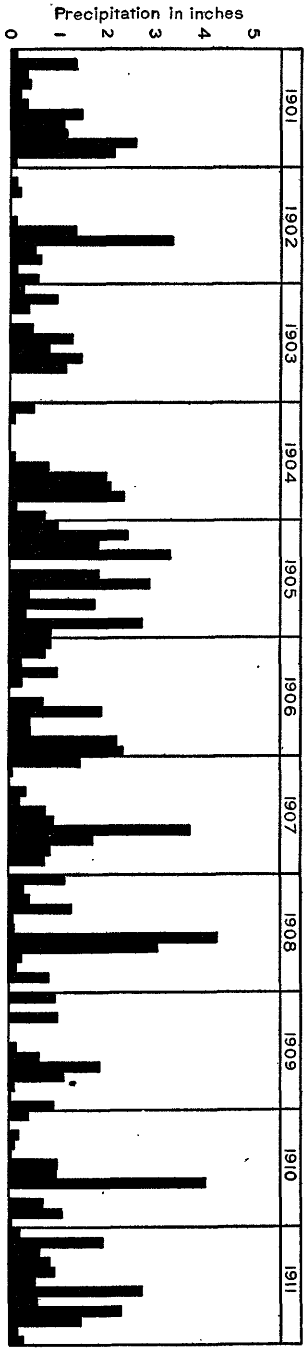


FIGURE 21.—Diagram showing monthly precipitation at Alamogordo, N. Mex.

GEOGRAPHIC DISTRIBUTION.

The precipitation is irregularly distributed in space as well as in time. It is on an average much greater on the high mountains than on the low plain, and for a given season it may be much greater in one locality than in another similarly situated. The fall and winter rains and snows are likely to be more or less general, but many of the sudden summer showers are very local.

The irregularities in the distribution of average precipitation are due mainly to topographic irregularities. An area of several thousand square miles in the midst of a flat region such as the Great Plains will have nearly the same average precipitation in all parts, but an area of equal size with a diversified topography such as that of Tularosa Basin is likely to have radical local differences in the average amount of precipitation.

In general the precipitation increases with the altitude, but altitude is not the only controlling factor, and any curve or formula expressing the relation between altitude and precipitation can at best be only approximate or of very local application. The precipitation is probably greater at a given level on one side of a range than on the opposite side; it is probably greater at a given level on a large, lofty range than on a small, low range; and it is probably greater at a given level near a mountain range than far out on the desert.

In the vicinity of Alamogordo, at the base of the Sacramento Mountains, 4,338 feet above sea level, the average annual precipitation is 10.59 inches; at Cloudcroft, only 13 miles away, but near the crest of the range and 8,650 feet above sea level, the average is 22.29 inches, or more than double the average at Alamogordo. At Fort Stanton, situated on the mesa at the intermediate altitude of 6,231 feet, the average is 16.47 inches; and at Whiteoaks, situated at an estimated altitude of 6,470 feet, the average is about the same as at Fort Stanton. (See fig. 2.)

In the following table are given the records of monthly and total precipitation for one year at 13 stations maintained by the State engineer in the drainage area of La Luz and Fresnal creeks (fig. 22), and in figure 23 is shown, by means of a curve, the relation of precipitation to altitude in this drainage area as exhibited by these records. In figure 24 is reproduced a similar diagram prepared by G. E. P. Smith, of the Arizona Experiment Station, giving two curves for southeastern Arizona.[1]

Precipitation in thedrainage areas of La Luz and Fresnal creeks Sept. 1, 1911, to Aug. 31, 1912.

[Data furnished by State engineer of New Mexico.]

Station No.	Location.	Elevation above sea level.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Total first period.
		Feet.							*Inches.*
1	Ranger station	4,950	0.65	1.17	0.10	0.80	Trace.	....	2.72
2	Springer	6,550	2.53	1.16	.14	1.11	Trace.	0.76	5.70
3	Malcolm	6,260	2.38	1.57	.13	1.08	Trace.	.72	5.88
4	Carl	6,650	1.52	1.61	.15	1.37	Trace.	1.03	5.68
5	Garcia	6,100	1.12	1.33	.15	1.06	Trace.	.74	4.40
6	High Rolls	6,550	2.12	2.03	.00	.74	Trace.	.39	5.28
7	Snow	7,240	.78	1.61	.00	1.57	Trace.	.80	4.76
8	Cowgar	7,340	....	2.16	.00	1.29	Trace.	.78	4.23
9	Walker	7,165	.38	2.05	.00	1.76	Trace.	.74	4.93
10	Nelson	7,300	.46	1.54	.00	1.76	Trace.	.75	4.51
11	Cloudcroft	9,000	3.99	1.80	.33	1.39	.06	1.42	8.99
12	Alamogordo	4,338	2.00	1.25	.14	.38	.00	.71	4.48
13	1 mile north of Alamogordo	4,430	2.31	1.46	.18	.29	.04	.61	4.89

[1] Water resources of Rillito Valley, Ariz.: Arizona Agr. Exper. Sta. Bull. 64, fig. 9, 1910.

Precipitation in the drainage areas of La Luz and Fresnal creeks Sept. 1, 1911, to Aug. 31, 1912—Continued.

Station No.	Location.	Mar.	April.	May.	June.	July.	Aug.	Total second period.	Total Sept. 1, 1911, to Aug. 31, 1912.
								Inches.	*Inches.*
1	Ranger station	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
2	Springer	1.28	1.06	0.11	2.02	2.14	4.04	10.65	16.35
3	Malcolm	1.93	.72	.05	.94	1.96	3.02	8.62	14.50
4	Carl	1.29	.91	.14	1.49	2.55	4.68	11.06	16.74
5	Garcia	.99	.75	.10	1.16	2.31	3.52	8.83	13.23
6	High Rolls	1.67	1.06	.23	2.16	2.95	3.70	11.77	17.05
7	Snow	1.89	1.15	.26	2.54	2.45	3.79	12.08	16.84
8	Cowgar	1.98	1.42	.39	2.09	2.74	4.99	13.61	17.84
9	Walker	2.09	1.22	.28	2.33	2.72	5.19	13.83	18.76
10	Nelson	2.11	1.30	.31	2.42	2.80	5.28	14.22	18.73
11	Cloudcroft	.42	.59	.30	3.10	4.07	6.95	15.43	24.42
12	Alamogordo	.47	.50	.17	.55	.15	4.31	6.15	10.63
13	1 mile north of Alamogordo	.47	.56	.14	.46	.22	4.11	5.96	10.85

a No record.

There are no data for determining what part of the entire precipitation of Tularosa Basin falls within the ascertained range between Alamogordo and Cloudcroft. If the precipitation is anywhere greater than at Cloudcroft it is over only small areas, such as Sierra Blanca Peak. On the other hand, in the interior of the desert the precipitation may be considerably less than at Alamogordo, although there are almost no records that throw light on this point. The available records seem to show that the precipitation is less at El Paso, Newman, and Orogrande than it is at Alamogordo, but the difference does not appear to be great. The timber on the mountains on the west side of the basin indicates that the rainfall is greater on these mountains than in the valley but less than on the Sacramento Mountains and the Sierra Blanca. A belt of timber along the top of the Chupadera escarpment shows that the edge of this plateau also intercepts more rain than the plain.

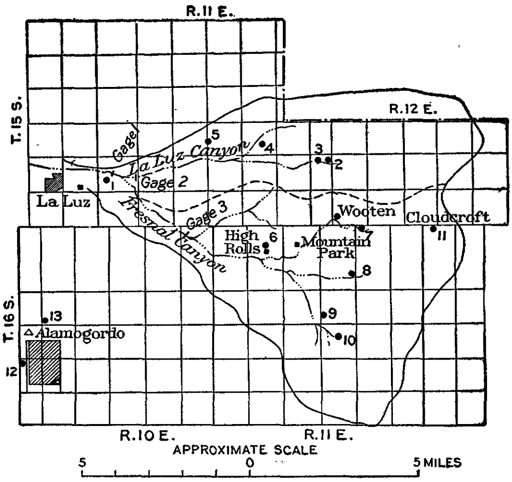


FIGURE 22.—Map of drainage areas of La Luz and Fresnal creeks, showing location of rain gages and automatic stream gages for investigations by the State engineer.

The curves in figure 25, although based on a short period, show pretty conclusively that the precipitation increases somewhat toward the north. This increase corresponds to an increase in altitude, but altitude is probably not the only influencing condition. In going northward from the interior of the desert to the Mesa Jumanes several changes in vegetation are observed which probably signify some increase in humidity, the desert brush giving way to grass and finally to clumps of cedar and other small trees. The abundance of trees near the north end of the younger lava bed and their complete absence farther south may also be related to differences in rainfall.

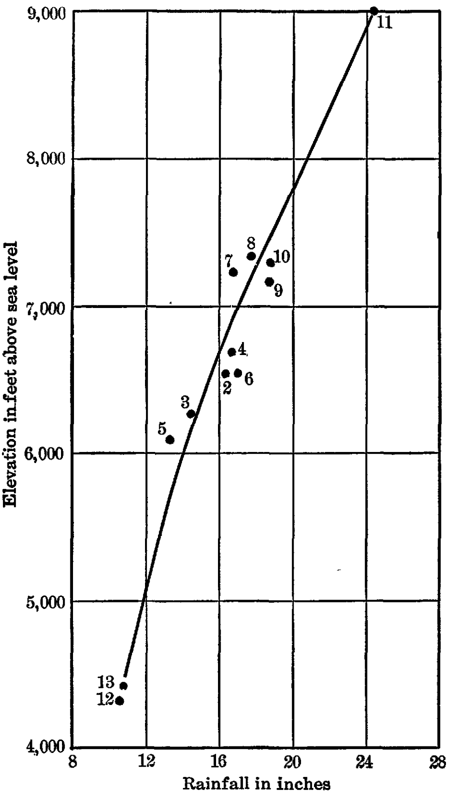


FIGURE 23.—Diagram showing relation of precipitation to altitude in drainage areas of La Luz and Fresnal creeks, September 1, 1911, to August 31, 1912. Data furnished by State engineer of New Mexico.

The records of precipitation, character of vegetation, and other considerations warrant the following summary statement: In the interior of the plain south of the younger lava bed the average annual precipitation is probably less than 10 inches; near the margins of the plain it is approximately 10 inches; in the mountain chain on the east side it increases with the altitude, and near the crests of the highest ranges it exceeds 20 inches; in the mountain chain on the west side it also increases with the altitude but is on an average less than in the mountains on the east side; on the plain north of the lava beds, on the Chupadera Plateau, and on the Mesa Jumanes it is greater than on the low plain south of the lava and probably ranges from about 10 to 15 inches.

RELATION TO AGRICULTURE AND WATER SUPPLIES.

On the arable tracts near the top of the Sacramento Mountains, where the average precipitation is 20 inches or more, agriculture is successfully practiced without irrigation, large yields and a good quality of hardy cereals, such as oats, being obtained. On the intermediate levels, where precipitation is between 15 and 20 inches, some success is also had with dry farming.

In the vicinities of Alamogordo and Carrizozo dry farming has been pretty extensively tried in the last decade, but, as in other parts of the Southwest where the average precipitation is not much over 10 inches, it has, on the whole, been unsuccessful, although in favorable years good yields of certain crops, especially forage plants, have in some localities been obtained. The preponderance of summer rainfall is to some extent an advantage, but the deficiency of

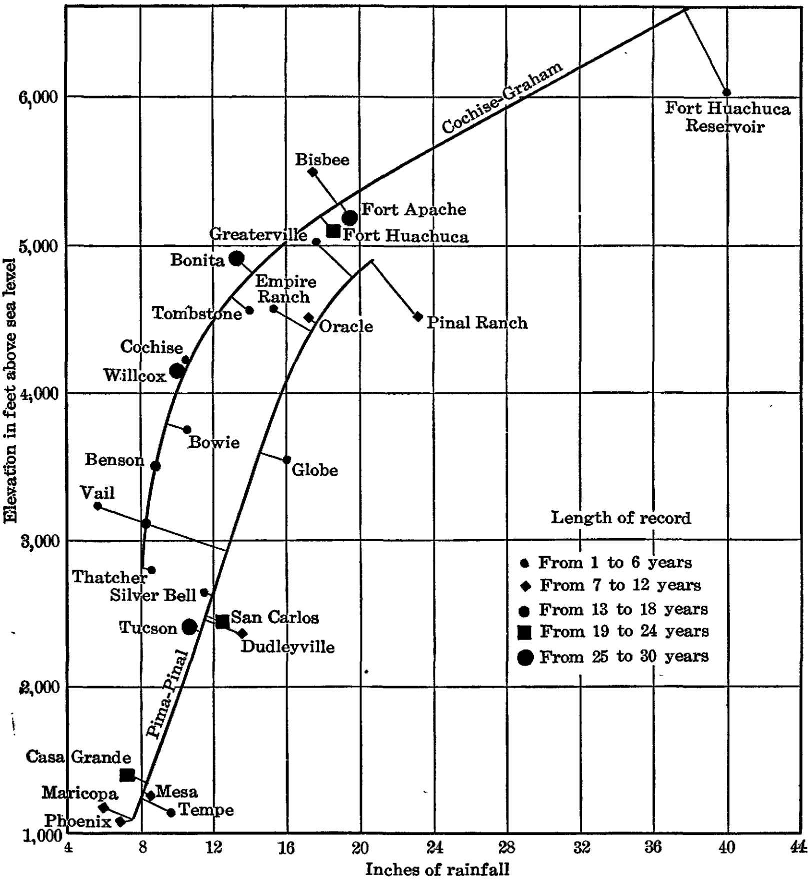


FIGURE 24.—Diagram showing relation of precipitation to altitude in southeastern Arizona. The upper curve applies to Cochise and Graham counties; the lower one to Pima and Pinal counties. After G. E. P. Smith.

rain in the spring and its general irregularity are serious handicaps to dry farming. In regions farther north in the United States, where a larger proportion of the rain falls in the winter and spring, considerable success has been attained by conserving the moisture of two years for the raising of a single crop, preferably a winter cereal, but in southern New Mexico this method is less feasible and the best success is had with quickly maturing summer crops.

The irregularities in rainfall produce irregularities not only in the moisture contributed directly to the soil but also in the flow of the streams, causing great quantities of water to be discharged at irregular intervals from a large number of canyons that are normally dry. To increase the agricultural production of the region it is necessary to supply more evenly to crops the water that is furnished so irregularly by the rainfall and resulting streams. Measures for accomplishing this conservation are (1) proper tillage to hold the moisture in the soil for a short time (which by itself has proved inadequate in this region), (2) construction of reservoirs to hold flood waters until needed, and (3) recovery of underground waters that are stored by natural processes and are generally as available in seasons of drought as in wet weather. The fact that a supply drawn from wells is available when water is most needed gives this kind of supply a peculiar value in supplementing rainfall and flood waters. (See section on irrigation, pp. 206–222.)

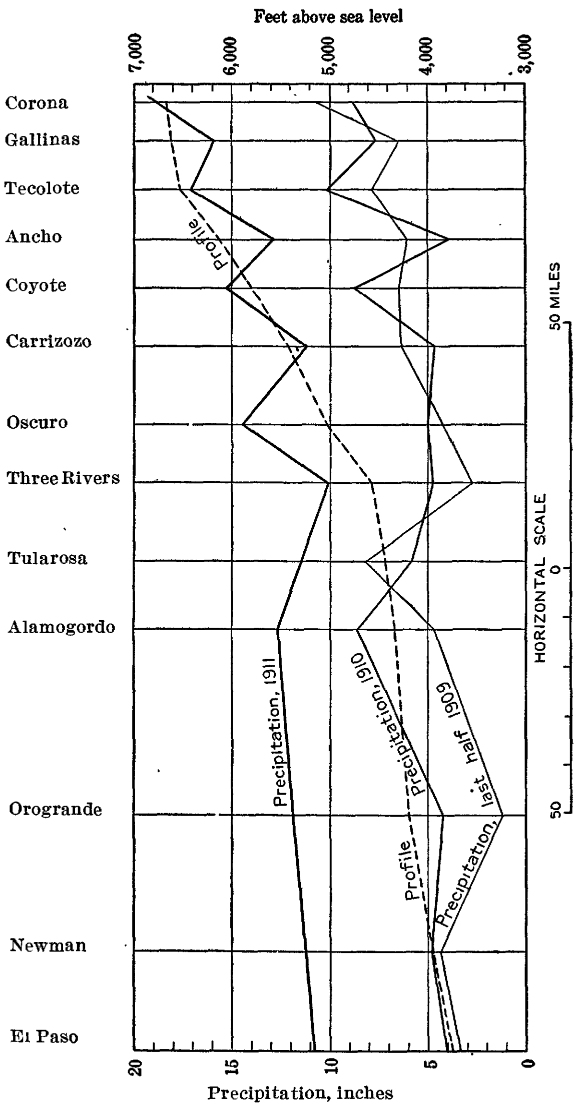


FIGURE 25.—Diagram showing increase in precipitation from El Paso, Tex., to Corona, N. Mex.

WATER IN VALLEY FILL.

AREA AND PROBLEMS.

The principal water problem in the area underlain by the thick deposit of valley fill,[1] which extends from the Rio Grande, in Texas, northward to the Phillips Hills on the east side of the lava and nearly to the upper crossing on the west side (Pl. XVII), concerns the development of supplies adequate in quantity and quality for irrigation. Supplies sufficient in quantity for domestic use and for stock can be obtained practically everywhere, although in some parts it is difficult to find water that is of sufficiently good quality for domestic use or even for stock, and in the southern part there is some difficulty in satisfactorily finishing wells in sand beds.

SOURCES OF WATER.

GENERAL CIRCULATION.

The general circulation of water is, for convenience, shown graphically in figure 26. The atmosphere holds a certain amount of water

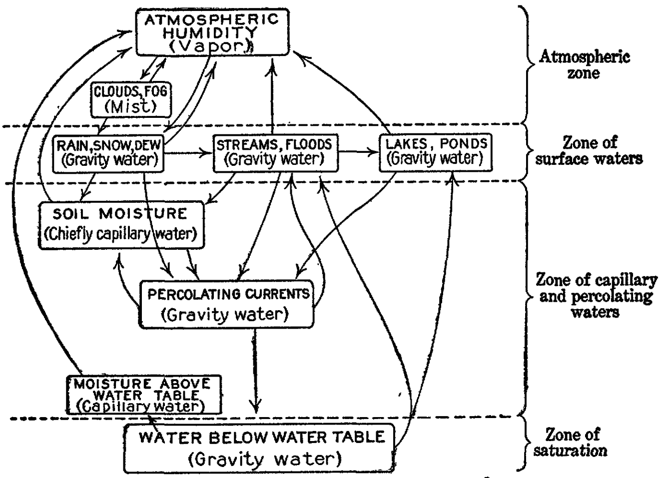


FIGURE 26.—Diagram showing water zones and general circulation of water.

in the invisible, gaseous state, which, under certain conditions, is in part thrown into the liquid state and forms dew or collects in minute drops whose weight is so slight that they are held in suspension in the air, forming clouds or fog. If these minute drops become sufficiently abundant they coalesce and fall as rain, or if the temperature is low they crystallize and fall as snow.

[1] The water in the thin mantle of débris that covers the bedrock farther north is discussed in connection with the water of the rock formation, pp. 138–175.

As is represented in the diagram, the rain and snow are disposed of in several ways. A part is returned to the atmosphere by evaporation; a part runs off in streams and temporary floods; a part is absorbed by the capillary pores of the ground and becomes soil moisture; and a part percolates into pores and crevices and is drawn downward by gravity. The streams and floods likewise lose water by evaporation, by capillary absorption, and by percolation. If their volume is not all dissipated in these ways the surplus is eventually discharged into some depression in the surface known as a pond, lake, or alkali flat. This surplus is gradually disposed of by evaporation, or, in some cases, by percolation or capillary absorption.

The moisture in the soil is largely returned to the atmosphere by direct evaporation or by the transpiration of plants, but in part it feeds the currents of water that are percolating to the ground-water level or becomes disseminated through minute capillary pores. It must also be assumed that the percolating waters are partly absorbed on their way from the surface to the zone of saturation by the capillary pores of the materials that form the walls of the passages through which these waters find their way.

Since the present investigation concerns especially the supply below the water table—that is, in the zone of saturation—the problem of accessions to and losses from this supply is important. This problem involves so many complex factors that even an approximate solution is not possible with the data that could be obtained, but certain considerations will nevertheless throw light on the magnitude of the quantities involved.

The waters of Tularosa Basin are of course not wholly isolated. The atmosphere carries water both into and out from the basin, and some ground water probably enters the basin, as in the Sacramento Mountains, and some leaves the basin, as at the south end.

ZONES OF PRECIPITATION, RUN-OFF, AND PERCOLATION.

In regard to precipitation, surface run-off, and underground percolation, Tularosa Basin can be divided into several zones, as follows: (1) The high mountains, which have heavy precipitation (about 17.5 to 25 inches), heavy flood discharge, and a small perennial stream flow; (2) the low mountains and the lower parts of the high mountains, which have intermediate precipitation (about 12.5 to 17.5 inches), heavy flood discharge, and little or no perennial stream flow; (3) the upper gravelly parts of the stream-built slopes, which have probably only a little more precipitation than the interior desert plain (about 10 to 12.5 inches), little run-off, and heavy percolation; (4) the areas of dense adobe soil, which have nearly the minimum precipitation, considerable run-off, a rather small amount of capillary absorption, and little or no percolation; (5) the interior gypseous plain, which has minimum precipitation, little run-off, considerable capillary absorption, and considerable percolation through sink holes; (6) the areas of gypsum sands and quartz sands, which have minimum precipitation, little or no run-off, and great capacity for absorption and percolation; (7) the lava beds (particularly the younger bed), which have nearly minimum precipitation, little or no run-off, and probably heavy percolation; and (8) the alkali flats, which have minimum precipitation, no run-off, little absorption or percolation, and maximum evaporation.

MOUNTAIN AREAS.

The parts of the Sacramento Mountains and the Sierra Blanca lying west of the divide cover somewhat more than one-tenth of the total area of Tularosa Basin. They receive a heavier precipitation than other parts of the basin, and are the only areas that give rise to permanent streams.

Within the mountains the Rinconada drainage area comprises about 85 square miles, the Tularosa about 165 square miles, the La Luz and Fresnal together about 75 square miles, and the small drainage areas between the Tularosa and La Luz and south of the Fresnal together about 200 square miles. The entire west side of the Sacramento Mountains (inclusive of all of the Rinconada drainage area, a part of which rises in the Sierra Blanca, and exclusive of the low mountainous area south of the main range) covers about 525 square miles. It has a maximum altitude of over 9,000 feet above sea level, or 5,000 feet above the desert plain, and an average altitude of somewhat more than 7,000 feet above sea level, or 3,000 feet above the desert plain. Its average annual precipitation is probably not less than 18 inches, and the total water supply that it receives as rain or snow is estimated to average about one-half million acre-feet a year, or 700 second-feet. The stream discharge, exclusive of flood discharge, is less than 5 per cent of the precipitation, and most of this amount is delivered by springs.

The Three Rivers drainage area, which includes the highest part of the Sierra Blanca, comprises about 100 square miles and exhibits a greater diversity of physical conditions than the drainage areas of the Sacramento Mountains, containing as it does the lofty Sierra Blanca Peak and also much land that is nearly desert. The total quantity of water that falls in an average year on the Three Rivers and other areas of the Sierra Blanca draining into Tularosa Basin no doubt exceeds 100,000 acre-feet.

The total area of the other mountain regions draining into Tularosa Basin is nearly as great as that of the combined Sacramento and

Sierra Blanca areas. Their precipitation is distinctly lighter than that of the high parts of these two ranges, but the total quantity of water that they receive as rain or snow in an average year must amount to several hundred thousand acre-feet.

The flood discharge of the mountain regions is difficult to estimate, but appears to be great. On account of the brief duration of the floods, however, there is perhaps some tendency to overestimate the aggregate amount of flood water. According to the estimates of the State engineer of New Mexico, based on gage readings, the flood discharge of La Luz and Fresnal creeks from March 1 to August 31, 1912, was only an insignificant percentage of the precipitation on the drainage area, but this region affords such a diversity of conditions that much more data would be required to form an adequate basis for generalization. The following table shows the distribution of floods in the period during which observations were made:

Estimated flood discharge of La Luz and Fresnal creeks from Mar. 1 to Aug. 31, 1912.[1]

	Acre-feet.
Apr. 5	3.36
July 10	6.77
14	5.21
16	1.24
18	92.35
28	4.42
Aug. 4	.66
15	5.60
16	4.50
17	37.20
19	------
21	19.38
24	47.44
30	9.50
	238.08

ZONE OF GRAVELLY SEDIMENTS.

The upper parts of the débris slopes adjacent to the mountains are sufficiently gravelly to allow ready downward percolation, although they are not so pervious as similar slopes where red clay and silt are less abundant. The streams and freshets discharged from the mountains generally cross the gravelly zone in definite high-level arroyos cut into the slopes, but in some places they spread over the general surface. In either case they lose much water that percolates down to the zone of saturation and replenishes the main

[1] Data furnished by State engineer of New Mexico. Measurements were made below the junction of the two streams (Gage No. 1, in fig. 22).

underground supply. The rain that falls on the upper parts of the slopes also contributes to the underground store.

The large area of plains and bench lands east, north, and west of the lava beds contributes water to the valley fill. A part of the northern run-off which comes down on both sides of the younger lava bed in streamways formed since the lava was extruded and a part of that which enters the porous sediments overlying the rocks no doubt reach the main body of water in the valley fill. However, much of the northern water enters the rock formations, large gypsum sink holes in the Pennsylvanian rocks receiving practically the entire drainage of some arroyos. Moreover, some of the flood waters on the west side of the lava reach Salt Creek and flow into the large alkali flat to which this creek drains, without passing below the surface.

ZONE OF DENSE ADOBE.

The middle zone of the stream-built slopes is largely covered with dense abode that is too impervious to allow percolation. To a great extent this zone lies below the high-level arroyos and above the mid-slope arroyos, and consequently the flood waters spread over it more than over the parts of the slopes above or below it. This spreading of flood waters over the adobe soil is fortunate in so far as irrigation with flood waters is concerned, but it is of little consequence in making contributions to the underground supply. The rain that falls on this zone also largely runs off over the surface. It is so slowly absorbed by the action of capillarity that even after a heavy rainfall and several hours of flooding the ground at a depth of a few inches may be found dry. The amount that percolates to the ground-water level in the areas of dense adobe is probably negligible.

THE GYPSEOUS PLAIN AND THE MID-SLOPE ARROYOS.

The gypseous soil of the extensive interior plain absorbs water more freely than does the adobe. Aside from the mid-slope arroyos, which convey waters gathered almost exclusively from higher levels, the gypseous plain has little run-off, although it receives an average rainfall of about 10 inches and also considerable flood water from higher levels. The alkali present in this soil, however, seems to indicate that there is little general downward seepage to depths of more than a few feet. Apparently the water that reaches this plain is disposed of chiefly by (1) percolation through sink holes to the water table and (2) capillary absorption followed by evaporation.

The floors of the arroyos are covered with adobe which renders them relatively impervious, but in the gypseous banks of the arroyos many sink holes have developed that receive large quantities of flood water, much of which probably reaches the water table. The northern mid-slope arroyos extend to the sand areas, but the southern disappear some distance from the sand, their waters being lost either by spreading over the general surface of the plain or by running into sink holes.

AREAS OF GYPSUM SANDS AND QUARTZ SANDS.

The gypsum sands, the quartz sands north of the gypsum sands, and the extensive sandy tracts in the southern part of the basin are so porous that they readily absorb such rainfall as they receive, and their pores are of sufficient size to allow the water to percolate to the floor on which they rest. The further percolation depends on the character of the underlying material, which below the gypsum sands and northern quartz sands is bedded gypsum or gypseous clay, and below the southern sands is loam or caliche. The percolating waters reaching the bottom of the sands are protected from evaporation and are in a favorable position to percolate farther downward unless the material is wholly impenetrable. Under such conditions of moisture even the caliche softens and no doubt allows some slow percolation.

The northern arroyos extend to the gypsum or quartz sands where they are either blocked by the sand dunes and form small temporary lakes, as the arroyo in the center of T. 14 S., R. 8 E., and the one ending near the southern margin of T. 16 S., R. 8 E., or else persevere some distance into the sands, as the Three Rivers arroyo and the arroyo that passes north of the Cerrito Tularosa. In either case the sands absorb the flood waters that have not been received by the gravels nor by the sink holes and have not been dissipated in other ways.

LAVA BEDS.

The older lava bed sheds some water, as is proved by the gullies that have been formed in it, but the younger lava is so extensively broken and so nearly devoid of any soil cover that it has practically no run-off. Out of approximately 75,000 acre-feet a year, or 100 second-feet, of rain that falls on the younger lava, a part is returned by evaporation, but a larger part, it is believed, percolates underground. Flood waters are also thrown against both sides of the younger lava bed and make some contribution to the underground supply. Malpais Spring and the adjacent wet lands are fed from this supply and give evidence of its importance.

ALKALI FLATS.

The alkali flats are the lowest areas to which the flood waters can flow. Since they are without drainage outlets and since the ground under them is saturated nearly or quite to the surface the flood waters that reach these flats can in general escape only by evaporation. They make no contribution to the underground supply.

The flood waters from the east do not reach the alkali flats because they are blocked by the intervening broad belt of gypsum and quartz sands, and those in the southern part of the basin do not reach the flats because the surface does not slope northward. Waters from far north on the west side of the younger lava bed, however, drain southward and to some extent reach the alkali flats, whereas the floods shed from the mountains west of the flats are carried quickly over the relatively short, steep slope and are in part discharged upon the large flat.

SUMMARY.

The water of the valley fill is derived chiefly by percolation through (1) the upper, porous zone of the débris slopes and the plains and bench lands east and north of the lava beds, (2) the sink holes in the interior gypseous plain and the gypseous banks of the mid-slope arroyos, (3) the gypsum sands and quartz sands, and (4) the lava beds. The quantity of water added to the underground store in the valley fill is no doubt great, aggregating probably more than 100,000 and possibly several hundred thousand acre-feet a year, but a large part is added below the zone of soil suitable for agriculture and may therefore not be available for irrigation.

OCCURRENCE OF WATER.

The water stored in the valley fill occurs in (1) the pore spaces of the sand and gravel deposits, (2) the smaller pores of the clayey and gypseous materials that comprise the bulk of the valley fill, and (3) the more or less open solution channels in the gypseous material.

The sand and gravel deposits are the most important sources of water. They are not as a rule continuous strata of uniform thickness that can be correlated over large areas, but are commonly irregular, lenticular masses that are found at different depths and in different amounts in adjacent localities. This irregular relation is shown to exist in the vicinity of El Paso by the sections of the numerous wells that were sunk within a few hundred feet of each other at the city waterworks (fig. 15, p. 68) and is less definitely indicated by the records of the wells throughout Tularosa Basin. Over most of the area between the Sacramento and San Andreas mountains there are several gravelly or sandy water-bearing beds within 200 or 300 feet of the surface, but in a few localities such beds are absent or very poorly developed. At greater depths the proportion of sand and gravel is apparently still smaller. Opposite the Organ Mountains and farther south the amount of sand is distinctly greater, reaching an aggregate maximum thickness of about 150 feet to the depth reached by some of the El Paso waterworks wells. There is some reason to expect that where the débris was supplied by the igneous and Cretaceous formations of the Sierra Blanca there is also more water-bearing sand and gravel.

The sand and gravel deposits are apparently not well assorted, clayey and silty materials being in many places mixed with the coarser materials. In the vicinity of El Paso the water-bearing beds have less clay, but generally contain sand grains of various sizes. In many places there appears to be no sharp distinction between the clayey gravel that is more or less water-bearing and the gravelly clay that is only slightly pervious. Much of the clay, however, especially that at considerable depths, is too dense to yield any water. There is much water in the pores of the less compact portions of the clayey and gypseous materials which is in general yielded too slowly to be utilized by drilled wells but which is in part recovered through dug wells that do not tap any sand or gravel bed. This water forms a reserve supply that will be slowly surrendered to the water-bearing formations drawn upon by drilled wells.

Some water is also found in solution channels in the gypseous material comparable to the solution channels commonly found in limestones. These channels, probably fed largely by sink holes, give some support to the popular belief in "veins" and "streams" of underground water. They are not generally hollow, but are at least partly filled with porous materials.

WATER TABLE.

SIGNIFICANCE.

The water table is the upper surface of the zone of saturation; that is, the surface below which all the spaces not occupied by earth are filled with water. A well sunk into the zone of saturation is, like other void spaces, filled with water to the level of the water table. If, however, an impervious formation protrudes into the upper part of the zone of saturation, the well does not receive water until it has been sunk to the bottom of the impervious formation, when the water will enter the well and rise to a static level that may be regarded as the water table at that point.

The water table is in few places a level surface, but it has much more gentle slopes and less pronounced irregularities than the land surface. A knowledge of its elevation and topography gives information in regard to the source, movement, and disposal of the underground water, and in areas with little development gives a basis for forecasting the depth to water. It also gives a basis for future estimates of the effects of heavy pumping. A knowledge of the position of the water table relative to the land surface is important in its bearing on the cost of drilling and pumping, the quantity of underground water returned to the atmosphere, and the accumulation of alkali in the soil.

The data obtained in regard to the elevation of the water table and its depth below the surface are given in the list of wells on pages 268–299. In most wells the bench mark to which measurements are referred is indicated by three notches cut into the wood of the well platform or curb, but in a few wells it is the top of the iron casing. For most of the wells the altitude of the bench mark was instrumentally determined.

FORM.

The form and elevation of the water table in the principal shallow-water area of Tularosa Basin is shown by 25-foot contours in Plate II (in pocket). In this area the water table forms an asymmetric trough whose axis is near the west side and descends toward the south. In the area shown in Plate II the water table is an even surface with few irregularities, but its slope ranges from about 50 feet to the mile in some localities on the east side to less than 5 feet to the mile on parts of the large alkali flat. In the regions north, west, and east of the area mapped the water table stands higher above sea level, and from all three directions it slopes toward the principal shallow-water area.

South of the area shown in Plate II (in pocket) the water table continues to descend but apparently not at a uniform rate. At the old Pelman wells, now owned by W. H. McNew, in the SW. ¼ sec. 5, T. 19 S., R. 7 E., it is 3,922 feet above sea level; in the dug well at the McNew ranch, 2½ miles west of the old Pelman ranch, NW. ¼ sec. 12, T. 19 S., R. 6 E., it is 3,918 feet; and at the south end of the southernmost alkali flat it is slightly less than 3,900 feet. In the wells at the Hitt ranch and at Newman station, both near the Texas State line and almost 50 miles south of the McNew wells and the alkali flats, it is somewhat more than 3,700 feet above sea level, and in the wells in the vicinity of Fort Bliss it is nearly at the same level or only slightly above the bed of the Rio Grande at El Paso. The average descent from the south end of the alkali flats to the Texas line is about 4 feet to the mile, but a large part of this descent seems to occur between the alkali flats and Bennett's ranch, and between Coe's north ranch and Coe's home ranch. (See Pl. I, in pocket.) No doubt the water table also slopes toward the east.

For some miles south of Dog Canyon the water table has only a gentle southward slope, but near Orogrande it seems to drop rapidly. In the abandoned railroad well at Orogrande the water level is, according to the record of the railroad company, only 3,695 feet above sea level, or about 25 feet below the water level in the Newman wells. In the abandoned Benton well, 5 miles northeast of Orogrande, the water level was found to be between 3,600 and 3,650 feet above sea level, which is the lowest water level found in Tularosa Basin, and considerably lower than the Rio Grande at El Paso.

RELATION TO LAND SURFACE.

Tularosa Basin contains one large shallow-water tract in the area of valley fill, which extends from a short distance north of the south end of the younger lava bed to a short distance south of the south end of the alkali flats and gypsum sands (Pl. II, in pocket). In addition to this large tract it contains a number of smaller shallow-water tracts, most of which lie east and north of the Phillips Hills or in the valley of Three Rivers, and are described in connection with the water in the Cretaceous rocks (pp. 138–157).

The following table gives the estimated areas of land having specified depths to the water table in the large shallow-water tract:

Areas (in square miles) having certain specified depths to the water table in the large shallow-water tract of Tularosa Basin.

Depths to water table, in feet.	Area, exclusive of lava bed, alkali flats, quartz sands, and gypsum sands (Pl. II, in pocket).	Total area.
	Square miles.	*Square miles.*
Less than 25	250	570
25 to 50	310	620
50 to 100	360	430
Less than 50	560	1,190
Less than 100	920	1,620

The position of the areas with different depths to water is shown for the most part on the large map, Plate II (in pocket). Water will probably be found less than 50 feet from the surface on the west side of the lava bed over an area extending north beyond the Mound Springs and west to Gililland's ranch, and less than 100 feet on both sides of the lava bed to within a few miles of the lower crossing. Water will also be found less than 100 feet from the surface over a belt of land extending south of the area shown in Plate II to a line running with a general east-west direction through T. 20 S.

Both the land surface and the water table slope from the mountain areas on the opposite sides of the basin toward the low central area occupied by the alkali flats, but the slope of the land surface is steeper than that of the water table, and consequently the two surfaces gradually approach each other. Near the mountains the depth to water is generally much more than 100 feet, but it decreases toward the low central area. Hence the areas having different depths to water, shown in Plate II, form roughly parallel or concentric belts around the low interior.

On the alkali flats the water table nearly coincides with the land surface, the depth to water being everywhere small and generally not more than a few feet. On the large dune area, including both gypsum and quartz sands, the depth to water differs locally because of the irregularities of the surface. In some places in the dune area the water table is practically at the surface, over a large part of the area it is between 25 and 50 feet below the surface, and in a few places it is more than 50 feet below the surface. The water table is at practically the same level below the mid-slope arroyos as below the intervening areas, and consequently the depth to water is less, and the 25-foot limit extends up the arroyos for several miles, as is shown in Plate II.

On account of the overfilling of the underground reservoir (p. 107) the water table is necessarily near the land surface over considerable areas, regardless of details of topography or structure within the basin. Several agencies have, however, been instrumental in bringing it to the surface in specific localities. The wind has planed the large tracts occupied by the alkali flats practically to the water table and has made possible the erosion of Salt Creek valley below the water table, so that this creek receives a seepage of ground water amounting to about one-half second-foot (Pl. VIII, *C*). The surface waters have in some places cut down the mid-slope arroyos so near to the water table that these arroyos contain springs and pools whose surfaces coincide with the ground-water level. At certain places the arroyos are flooded annually by the periodic rise of the ground-water level above the levels of the arroyo floors. The ground waters have formed sink holes in the gypseous soil, which in some places extend below the water table and contain pools of what is virtually ground water, such as the pool 2 miles southwest of Shoemaker's flowing well (Pl. XVIII, *B*) and the pool $1\frac{1}{2}$ miles north of that well.

South of the white sands the depth to water increases, although the land surface is nearly level. At Bennett's ranch it is about 130 feet. Thence southward for about 20 miles on the nearly level plain it is generally between 120 and 150 feet. Farther south the land surface rises and the water table descends, with the result that at Coe's home ranch, at the Hitt ranch (on the Texas line), and at intervening points the depth to water exceeds 300 feet.

Southward from Dog Canyon station for 15 miles or more the depth to water increases very gradually. At Oliver Lee's valley well (about sec. 2, T. 21 S., R. 9 E.) the depth is only 103 feet. South of Lee's well, however, the depth increases rapidly, although the surface rises only slightly. At the Benton well, situated about 5 miles northeast of Orogrande, on the general level of the plain and considerably below the railroad at Orogrande, the depth to water is 407 feet. From Fleck's home ranch and Orogrande westward to the vicinity of the Cox wells the depth to water probably decreases gradually. From Orogrande southwestward along the railroad to Newman station (on the Texas line) it probably also decreases gradually, ranging from nearly 400 feet on the plain south of Orogrande to somewhat less than 300 feet in the vicinity of Newman. South of Newman and the Hitt ranch the depth to water continues to decrease until at Fort Bliss, on the upland overlooking the Rio Grande valley, it is less than 200 feet.

FLUCTUATIONS.

The water table is not a stationary surface, but rises and falls gradually as a result of variations in the rate at which the underground supply is withdrawn and replenished. In Tularosa Basin the principal controlling factors are no doubt rainfall and evaporation, but in regions where the ground water is extensively used the quantity withdrawn by man becomes an important factor. If enough data can be obtained before important irrigation developments are made to establish the relation of fluctuations of the water table to fluctuations in rainfall, these data will be valuable as a basis for estimating the effects of pumping if in the future ground water is withdrawn on an extensive scale. The data thus far obtained are too fragmentary and cover too brief a period to establish this relation, but they give some information that is of value. The following table gives the results of monthly measurements, voluntarily made by Mr. A. K. Gore and Mr. Simeon Bowden, in two wells near Alamogordo. In addition to these observations a few successive measurements have been made in several other wells.

Monthly fluctuations of water level in two wells near Alamogordo, N. Mex.

Year and month.	Well of A. K. Gore.		Well of Simeon Bowden.	
	Day of month.	Depth to water level below bench mark.	Day of month.	Depth to water level below bench mark.
1911.		*Feet.*		*Feet.*
September	16	79.9	11	23.7
October	3	79.5	17	22.8
November	3	79.7	1	22.9
December	1	79.0	1	22.9
1912.				
January	1	78.8	1	22.9
February	1	78.8	2	22.8
March	3	78.7	6	22.9
April	2	78.8	1	22.2
May	2	78.7	1	22.5
June	2	78.6	6	22.5
July	4	78.7	1	23.5
August	1	78.9	1	23.7
September	4	78.7	1	[a] 19.7
December	6	78.9		
1913.				
January			12	[a] 18.5

[a] Well drilled deeper, giving higher artesian head.

These measurements show only small fluctuations. During a period of one year the range in Gore's well was 1.3 feet and the range in Bowden's well 1.5 feet. From these and other measurements it appears that the water level generally declines in the summer and does not rise again until several months after the summer rains. The principal rise of ground water in the arroyos takes place in the spring before evaporation becomes intense. The springs in the valley of Three Rivers have the largest flow in May and June.

In the vicinity of Alamogordo the water level is said to have risen considerably in the last decade owing to the irrigation water that has been brought there from La Luz, Fresnal, and Alamo creeks since the railroad was built. Such rise is indicated by the sharp deflection of the water-table contours at Alamogordo where the water is applied.

That the water table had generally gone down during the dry series of years prior to 1911 and had not yet recovered itself in the fall of that year is indicated by the fact that in many of the wells measured in the fall of 1911 the water stood several feet lower than the level at which it was reported to have stood when the wells were sunk.

DISPOSAL OF WATER.

Ground-water developments differ from mining developments in that they depend on a resource which does not become permanently exhausted, but is constantly replenished. If the underground supply in this region were not replenished it could be seriously depleted in a comparatively few years by moderately extensive pumping. Irrigation developments should not be planned on a scale to deplete the supply, but rather on a scale to utilize the annual contributions to the supply, which if not used by man form a surplus that is disposed of by nature. In order to gain some notion of the quantity annually available for pumping from wells, consideration should be given to both the annual increment from rainfall and subsequent run-off, and to the annual loss or surplus disposed of by nature. (See fig. 26.) Except as the storage changes with the fluctuations of the water table, the surplus disposed of is equal to the annual increment, and an estimate of either gives an estimate of the available annual supply.

Beneath the principal areas of intake the water table is elevated, beneath the principal areas of loss it is depressed. On account of these differences in level the ground water moves from the former to the latter. A map, such as Plate II (in pocket), which shows the topography of the water table, shows also the direction of movement of ground water, because the water always flows down the slope, or at right angles to the contours. The grade of the water table is the expression of a delicate adjustment between the gain and loss of water on the one hand and the resistance of the formations to the movement of water on the other.

Water in the valley fill of Tularosa Basin is lost mainly by return to the atmosphere, but also, at least in the southern part, by underground seepage to other regions. Return to the atmosphere occurs where the zone of saturation touches the land surface and its water flows out in springs, and also where this zone is so near the surface that its water rises by capillarity to the surface (fig. 26). The zone of saturation is held up to the level where it overflows through springs and capillary pores by the new supplies that are constantly being added to the underground reservoir and borne toward the areas of loss. If these new supplies were stopped the loss of water would gradually draw down the water table to a level from which the springs would no longer flow and the capillary water would no longer rise within reach of the atmosphere.

The springs in the valley fill are of two kinds, both of which are found where the water table is near the surface. One kind is caused by abrupt irregularities in the land surface whereby the zone of saturation is exposed; the other kind occurs where there are no such irregularities and where the water is apparently brought to the surface by artesian pressure. Examples of the first kind are the springs along Salt Creek, in the mid-slope arroyos, and on the alkali flats near their margins. Malpais Spring also belongs in a sense to this class. Examples of the second kind are the Mound Springs and some of the salt springs on the east side of the white sands. (See pp. 52, 123.) The salt spring near the limestone mound in the SW. ¼ sec. 28, T. 17 S., R. 8 E., probably results in part from the structure of the rock. The aggregate flow of the springs in the valley fill is not great; including Malpais Spring it probably does not average 10 second-feet.

Observation made in the lower parts of Tularosa Basin indicate that the height to which water is lifted above the water table by capillarity differs with the character of the fill, but is in many places about 8 feet. The alkali flats were examined in a number of widely separated localities, in almost all of which the water table was found to be not more than a few feet below the surface, and in one locality it was found only 6 inches below the surface. That ground water was returning to the atmosphere in these localities was indicated by the wet condition of the soil from the surface down to the water level. Wet areas, with the water table only a few feet below the surface, were also found in the vicinity of Malpais Spring, in the valley of Salt Creek, in the lower parts of the mid-slope arroyos, and in certain depressions in the dune areas. Altogether, ground water is probably evaporating over 150 to 200 square miles.

C. H. Lee[1] found that in Owens Valley, Cal., where the conditions are more or less comparable to those in Tularosa Basin, although the rainfall is probably less and the character of the soil and vegetation is somewhat different, the annual evaporation was about 35 inches where the average depth to the water table was 2.5 feet, about 27.9 inches where it was 3.5 feet, and about 14.1 inches where it was 5.5 feet. Although close comparisons are not possible it appears probable that the average rate of evaporation on the wet lands of Tularosa Basin is between 1 and 2 feet a year. If the area of evaporation is 175 square miles and the average rate of evaporation is 1 foot a year, ground water is being returned to the atmosphere from this area at the rate of about 150 second-feet, or 110,000 acre-feet a year. A part of the ground water disposed of by evaporation is received in the dune areas and other low tracts and could probably not be recovered for the irrigation of the good soil at higher levels.

South of the alkali flats the water table slopes southeastward, and the water no doubt moves slowly in that direction. The remarkably low water levels east of the Jarilla Mountains seem to indicate that the ground water is drained away rather than replenished by the broken Carboniferous rocks that outcrop in the low, barren ridges in that region. It has been supposed that an underground barrier extends from the Jarilla to the Organ Mountains, separating the mineralized waters of Tularosa Basin from the relatively soft waters of

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

Hueco Basin, but there is no topographic or geologic evidence of such a barrier, and it does not seem to be required by the differences in the quality of the water, nor indeed would it account for the differences in quality as shown by the analyses given in this paper. (See pp. 124–133.) The water under the plain extending between the alkali flats and El Paso is no doubt supplied chiefly from the San Andreas, Organ, and Franklin ranges, and moves in general away from these mountains. Moreover, the low water levels in the Jarilla Mountain region tend to prevent the spread of the highly mineralized waters of that region. There is no reason for supposing that in the absence of a rock barrier a current would move from the flats to El Paso or that any of the water in Tularosa Basin would ever reach Fort Bliss. The comparatively small amount of northern mineralized water that probably reaches the middle and eastern parts of the Hueco Basin is no doubt widely disseminated and greatly diluted by the purer waters of more local sources. A barrier separating the two kinds of water would have to pass north of Bennett's and Lee's wells and yet remain some distance west and south of the Jarilla Mountains. To postulate such a barrier would seem to involve untenable assumptions.

YIELD OF WELLS.

In the following paragraphs are given, in geographic order from north to south, some of the principal data on the yield of wells which end in the valley fill and which were in existence in 1911–12. Data in regard to the yield of wells ending in the rock formations are given on pages 138–175, and additional data in regard to all classes of wells will be found in the tables, pages 268–299.

WELLS NORTH OF JARILLA MOUNTAINS.

Otis wells.—At the dwelling on the farm of Isaac Otis, SW. ¼ sec. 8, T. 14 S., R. 9 E., there is a well consisting of a dug hole 3½ feet in diameter and 24 feet deep and a drilled hole 6 inches in diameter extending from the bottom of the dug hole to a depth 58 feet below the surface. The dug hole is uncased; the drilled part has heavy iron casing, the lower 10 feet of which is perforated with round holes three-eighths of an inch in diameter. The principal supply is obtained from sand and gravel in the lowest 10 feet. The original water level was about 20 feet below the surface, but when the basal sand bed was struck the water rose within 8 feet of the surface. In a test covering 1½ hours the well was pumped at the rate of 260 gallons a minute and the water level was thereby drawn down from 8.0 feet below the bench mark, its normal level, to 16.5 feet below the same datum, or a distance of 8.5 feet. The yield was therefore a little over 30 gallons a minute for each foot of drawdown. In an earlier test, 15 hours long, the pump is reported to have thrown 270 gallons a minute, but the drawdown was somewhat greater.

Another well, on the farm of Mr. Otis, situated in the NE. ¼ sec. 17, T. 14 S., R. 8 E., is 8 inches in diameter and 68 feet deep and also ends in a sandy bed near the bottom. It is said to be cased to a depth of about 58 feet in a manner similar to that of the well at the house. It is pumped with a deep-well pump, the cylinder of which is 40 feet below the surface and has 10 feet of suction pipe. In a test covering nearly an hour the pump first delivered 70 gallons and the water was drawn down from its normal level, 17 feet below the top of the casing, to 28.1 feet below, and later the rate of pumping was increased to 100 gallons a minute and the water level was consequently lowered to 31.5 feet below top of casing. The yield of this well is therefore between 6 and 7 gallons a minute for each foot of drawdown. A large quantity of red clay and grit was pumped up with the water.

Hill wells.—On the Hill farm, NW. ¼ sec. 13, T. 14 S., R. 8 E., there is a system of 3 dug wells about 4 feet in diameter and nearly 40 feet deep, connected by about 50 feet of tunnels 3 feet wide and 6 feet high. The entire system is uncased and receives water from small crevices and gravelly seams about 28 feet below the surface. It is pumped with a vertical centrifugal pump which has a capacity of over 100 gallons a minute and quickly reduces the accumulated supply when operated. Before the third well was connected the rate of infiltration was only about 20 gallons a minute, but with the present system the yield is estimated by one of the owners to be about 75 gallons a minute. A drilled well 158 feet deep failed to find water but ended in a white plastic material designated "lava ash" by the driller.

Votaw well.—On the farm of M. W. Votaw, NE. ¼ sec. 14, T. 14 S., R. 9 E., there is a well consisting of a dug hole 3½ feet in diameter and 96 feet deep, and a 9-inch drilled hole extending from the bottom of the dug part to a level 116 feet below the surface. The dug part is uncased; the drilled part was first finished with perforated casing but later with a rather fine brass screen. The water level is 94.8 feet below the bench mark, or 92 feet below the surface, and the well ends in a sandy deposit that furnishes most of the supply. A deep-well pump is operated at 70 gallons a minute, and, according to the owner, has been operated at this rate for 24 hours continuously. The drawdown was not measured but can not be more than about 20 feet; according to observations of the owner it is only 4½ feet.

Purday well.—On the farm of H. W. Purday, NE. ¼ sec. 28, T. 14 S., R. 9 E., there is a dug well 35 feet deep with a water level 31.2 feet below the bench mark, or 29 feet below the surface. This well has been pumped with a deep-well pump at the rate of about 10 gallons a minute for many hours without emptying the well.

Larsen wells.—On the farm of F. C. Larsen, NW. ¼ sec. 4, T. 16 S., R. 9 E., there are two wells, both 100 feet deep, one lined with 6-inch and the other with 7-inch casing. Both are pumped with deep-well pumps, one of which is propelled by a windmill and the other by a gasoline engine. They pass through three recognized water beds about 55, 85, and 95 feet, respectively, below the surface, but the normal water level when measured in the fall of 1911 was about 63 feet below the surface. The owner reports that he pumps a little over 20 gallons a minute with the windmill and from 60 to 75 gallons a minute with the gasoline engine.

Morgan well.—On the farm of C. W. Morgan, NW. ¼ sec. 23, T. 16 S., R. 9 E., there is a drilled well 160 feet deep, cased with sheet metal that is perforated below the water level. This well is 9 inches in diameter to the depth of 80 feet and 5 inches from that depth to the bottom. It is pumped with a deep-well pump, the cylinder of which is 74 feet below the surface, or about 20 feet below the water level, and has no suction pipe. The pump is operated at 40 gallons a minute without affecting the supply. The drawdown could not be measured but is apparently less than 20 feet.

Carl wells.—At the ice plant of George Carl, a short distance southwest of the depot at Alamogordo, three 10-inch wells with heavy iron casings are connected and pumped simultaneously by means of a horizontal centrifugal pump 18 feet below the surface. The three wells are arranged in a north-south line. The middle and north wells are 186 feet deep and are 18 feet apart; the south well is only 80 feet deep and is 20 feet from the middle well. The 80-foot well ends in a gravelly bed about 5 feet thick; and the 186-foot wells end in a gravelly bed 5 to 7 feet thick (fig. 11, p. 64). The middle well is finished with a 20-foot strainer having large oblong openings, this type of strainer being in use to some extent in the Rio Grande valley;[1] the other two wells have perforated casings. The combined capacity of the 3 wells is 375 gallons a minute when the water level is drawn down about 19 feet, or about 20 gallons per foot of drawdown. Most of the water is said to be furnished by the 186-foot well with coarse strainer and comparatively little by the 80-foot well.

Another well at the ice plant is 186 feet deep and is pumped independently by a vertical centrifugal pump. Its yield was not measured, but is estimated by the owner to be about two-fifths of the combined yield of the other three wells.

Wertane well.—On the farm of Mrs. Wertane, NE. ¼ sec. 35, T. 16 S., R. 9 E., there is a drilled well similar in depth and construc-

[1] Slichter, C. S., Observations on the ground waters of Rio Grande valley: U. S. Geol. Survey Water-Supply Paper 141, Pl. II *B*, 1905.

tion to the deep wells of George Carl, by whom it was sunk. It is pumped by means of a deep-well pump so attached that the drawdown could not be measured, but the yield is apparently similar to that of Mr. Carl's wells.

Bowden well.—On the farm of Simeon Bowden, NW. ¼ sec. 3, T. 17 S., R. 9 E., there is a well which in 1911 consisted of a dug hole 42½ feet deep and a 7-inch hole extending from the bottom of the dug part to a total depth of about 70 feet. The 7-inch hole was lined with heavy iron casing that extended to the depth of 66½ feet and was perforated in the lower 5 feet. The water level was 23.7 feet below the bench mark. The water was reported to enter chiefly from a 6-foot bed of sand and gravel near the bottom, but also in the dug part below the water level. The well was pumped with a vertical centrifugal pump that was 35 feet below the surface, and had a 21-foot suction pipe extending to a depth of 35 feet below the surface. When the pump was operated it delivered about 100 gallons a minute until the water stored in the dug part was exhausted; the yield then diminished rapidly and was soon inadequate to keep the pump primed. The permanent capacity with a drawdown of 35 feet was probably less than 40 gallons a minute. In 1912 the well was sunk to the so-called third stratum, which is an 8-foot bed of fine gravel between the depths of 130 and 140 feet. The water from this bed rose to 19.7 feet below the bench mark, and is reported by the owner to yield about 60 gallons a minute with a drawdown of 14 feet, or about 4 gallons for each foot of drawdown.

Aple well.—On the farm of Benjamin Aple, S. ½ sec. 35, T. 16 S., R. 9 E., there is a drilled well that has been pumped with a deep-well pump at a reported rate of about 60 gallons a minute. This report was not, however, verified.

Loomas well.—On the farm of Mr. Loomas, SW. ¼ sec. 34, T. 16 S., R. 9 E., a well 67 feet deep is reported to be pumped at the rate of about 30 gallons a minute.

Pierce well.—A well drilled in 1912 on the farm of R. H. Pierce, about 2 miles east of Simeon Bowden's plant, is said to tap the third water bed and to furnish about 60 gallons a minute.

Patty well.—On the farm of H. F. Patty, NE. ¼ sec. 15, T. 17 S., R. 9 E., there is a well consisting of a dug hole 35 feet deep, walled with lumber, and a 7-inch hole with heavy iron casing extending from the bottom of the dug hole to a total depth of 59 feet. The water-bearing beds are reported to consist mainly of a 6-foot layer of sand near the bottom of the dug part and a 9-foot layer of sand and gravel at the bottom of the drilled part. The lower 17 feet of casing are perforated with holes seven-sixteenths of an inch in diameter. The water is lifted with a vertical centrifugal pump which is near the bottom of the dug part and has a suction pipe 14 feet long extending into the drilled part. The normal water level is 31.2 feet below the bench mark, and the bottom of the suction pipe is about 18 feet below the water level. The owner reported a yield of 185 gallons a minute during a run of several hours, with a drawdown of about 10 feet. On the day the well was tested, however, the yield was irregular, averaging only a little over 100 gallons a minute, and was eventually interrupted apparently by clay caving and clogging the intake.

Camp well.—On the farm of Mrs. S. D. Camp, at Dog Canyon station, there is a well consisting of a dug hole 8 feet square and 50 feet deep, and a drilled hole 6 inches in diameter extending from the bottom of the dug hole to a level 160 feet below the surface. The dug hole is walled with lumber below the water level, which is here 38 feet below the surface; the drilled hole is cased with No. 18 galvanized sheet iron, perforated throughout with slits one-eighth inch wide and 18 inches long. Water was found in three sandy beds lying, respectively, between depths of about 38 and 58 feet, between depths of 76 and 84 feet, and below the depth of 158 feet. Mr. Camp, who drilled the well and followed the excellent plan of testing each bed before drilling to the next, furnished the following data: The tests were made with a vertical centrifugal pump set at the bottom of the dug hole, but a deep-well pump was later installed in its stead. When the well was 58 feet deep it was pumped for several hours at 70 gallons a minute and the water level was drawn down 12 feet, the yield therefore being about 6 gallons a minute for every foot of drawdown. When the well had been sunk through the second water bed it was pumped at 100 gallons a minute. After it had been sunk to 160 feet and the perforated casing had been inserted it was pumped by means of the centrifugal pump with suction pipe extending to 70 feet below the surface, or 32 feet below the water level, and yielded 144 gallons a minute with a drawdown of 12 feet, or about 12 gallons for every foot of drawdown.

Summary.—The data given in the preceding paragraphs show that the wells which have been tested yield from small to medium amounts of water and that there are great differences in the capacities of different wells in the same locality. For example, the first Otis well has a larger specific capacity than any of the wells investigated; that is, it yields a larger quantity of water for each foot that the water level is drawn down, yet in the same locality wells have been drilled that yield very little. In connection with these data it should be stated, on the one hand, that they represent the most successful wells rather than the average wells, and, on the other hand, that they represent various methods of drilling and finishing, some of which are ill adapted to the existing conditions, and that better average yields could have been obtained in the wells described if the best methods had been uniformly used.

WELLS SOUTH OF JARILLA MOUNTAINS.

Since the water-bearing beds in the valley fill of the southern part of Tularosa Basin and the adjacent region to the south differ from those in the valley fill of the rest of the basin they should be considered separately. On account of the great depth to the water table irrigation with ground water is not feasible in this region, but good tests have been made by the El Paso & Southwestern Railroad Co., the Southern Pacific Co., the United States War Department, and especially by the city of El Paso.

Railroad wells at Newman.—The two railroad wells at Newman station are 320 feet deep and are in sand below the water level, which is at a depth of 272 feet. (See fig. 14.) They are finished with 6-inch heavy iron casings, at the bottom of which are 5½-inch Cook strainers 12 feet long. The tested capacity of each of these wells with the pump cylinder at the bottom of the wells is reported to be 75,000 gallons in 24 hours, or about 50 gallons a minute.

El Paso & Southwestern Railroad wells at Fort Bliss.—Two wells were drilled by the El Paso & Southwestern Railroad Co. at Fort Bliss, both of which are 8 inches in diameter and are reported to be in sand and gravel below the water level. The south well is said to be 410 feet deep, to have a normal water level 190 feet below the surface, and to have been tested, with the pump cylinder 400 feet below the surface, at the rate of 30,000 gallons in 24 hours, or 20 gallons a minute. The north well is reported to be 249 feet deep, to have a water level 169 feet below the surface, and to have been tested with the pump cylinder 245 feet below the surface at the rate of 80,000 gallons in 24 hours, or somewhat more than 50 gallons a minute.

Army post wells at Fort Bliss.—Two wells supplying the Army post at Fort Bliss are 8 inches in diameter and respectively 313 and 319 feet deep. When they were investigated by C. S. Slichter[1] in 1904 they furnished from 52,000 to 86,000 gallons a day.

Southern Pacific Co.'s wells at Fort Bliss.—At the pumping station of the Southern Pacific Co. Slichter reports four 8-inch wells, 270 feet deep and finished with No. 6 Cook strainers 7 inches in diameter and 20 feet long. He reports the maximum combined yield of these wells to be only 150,000 gallons in 24 hours, or about 100 gallons a minute.[2]

El Paso waterworks wells.—At the pumping plant of the El Paso waterworks, immediately northeast of Fort Bliss, 28 wells were

[1] Slichter, C. S., Observations on the ground waters of Rio Grande Valley: U. S. Geol. Survey Water-Supply Paper 141, pp. 17–18, 1905.

[2] Idem, p. 17.

drilled prior to December, 1912, and others were at that time being put down. The relative locations of these wells and their distances from each other are shown in figure 27.

Twenty-three of the 28 wells were in use in December, 1912, of which 9 (Nos. 3, 4, 8, 9, 10, 12, 13, 14, and 15) are between 500 and 600 feet deep and 14 (No. 7 and Nos. 16 to 28, inclusive) are 600 feet deep. The other 5 wells (Nos. 1, 2, 5, 6, and 11) had been abandoned. Well No. 5 was drilled to the depth of 2,285 feet, its section to a depth of 1,560 feet being given in figure 13 (p. 66). The wells pass through numerous irregular beds of rather clean but fine sand

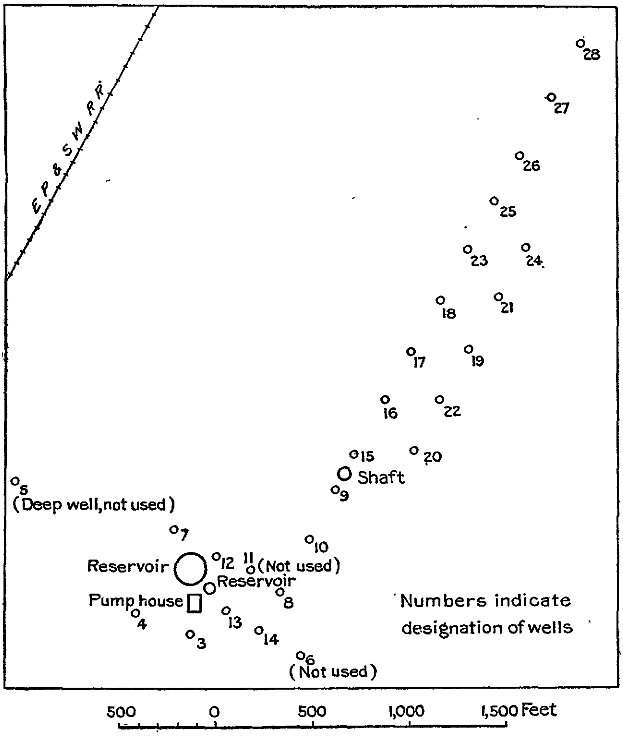


FIGURE 27.—Map showing pumping plant and wells of El Paso waterworks.

interstratified with layers of clay, as is shown in figure 32 (p. 146). They are cased with 8-inch standard iron pipe that is perforated where it passes through water-bearing beds with slits about 10 inches long and one-half inch wide. The water is lifted out of the wells by means of compressed air (fig. 28), the air pipe in the 600-foot wells extending about 440 feet below the surface, or about 250 feet below the water level.

The 23 wells in use supply the consumption of El Paso, which averages about 4,000,000 gallons a day but reaches a maximum of about 5,250,000 gallons a day. The maximum capacity of these wells with the appliances in use is estimated at 6,000,000 gallons a day, which would be an average yield per well of about 260,000 gallons a day, or 175 gallons a minute. The 9 old wells, when tested, yielded about 1,000,000 gallons in 12 hours with a lowering of the water level to nearly 250 feet below the surface. This is an average yield per well of about 155 gallons a minute, or less than 3 gallons a minute for each foot of drawdown.

It appears that in 1905, when the first wells were sunk, the water level was about 177 feet below the surface, but that it now stands about 193 feet below the surface in the new wells before they are pumped. When all the wells are in use the water in the shaft (fig. 27) stands about 210 feet below the surface, and when all except No. 9 are in use it stands 206 feet below. When pumping stopped in all wells for 19 hours the water in the shaft rose to a level 197 feet below the surface. Much of the depression of the water level in the vicinity of the wells is temporary; that is, it is the lowering which is necessary to make the water flow toward the wells. In order to ascertain the permanent effect of the withdrawal of water on the water table, and hence on the available supply, it would be necessary to make observations of depth to water in several wells at different distances from the pumping plant at regular intervals (preferably once every month) during a period of at least several years.

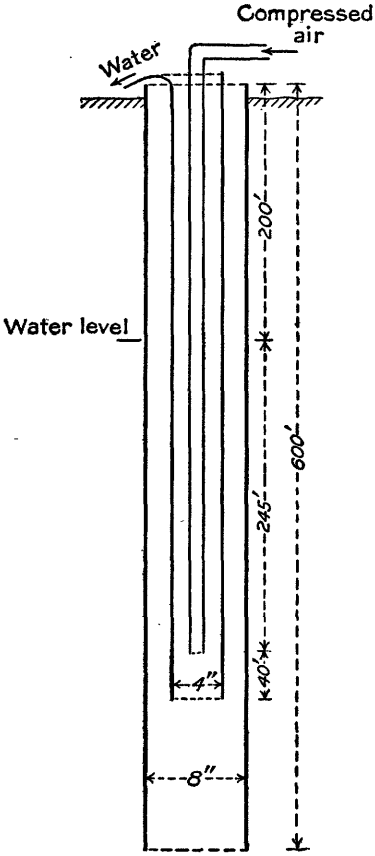


FIGURE 28.—Diagram of typical El Paso waterworks well, showing air lift. The water level indicated is the approximate level when the well is not in use.

In 1905, when the present pumping plant on the upland was installed, the quantity of water withdrawn amounted to about 1,500,000 gallons a day; in 1912 it amounted to about 4,000,000 gallons, or 12.3 acre-feet a day, or to about 4,500 acre-feet a year. In other terms, it amounted to about $2\frac{1}{4}$ second-feet in 1905 and to somewhat over 6 second-feet in 1912. If the consumption has increased at a uniform rate the total quantity withdrawn in the 7 years from 1905 to 1912 amounts to approximately 22,000 acre-feet, which is equivalent to a depth of about 35 feet of water over 1 square mile, or 1 foot of water over a township.

METHODS OF CONSTRUCTING WELLS.

DRILLING, BORING, AND DIGGING.[1]

The valley fill is easily penetrated, and, except near the mountains where bowlders are encountered, it presents few difficulties in sinking wells.

Most of the domestic wells are dug a short distance below the water table and are about 3½ feet in diameter. Some shallow wells have also been bored with augers propelled by hand. Where the water level is far below the surface, however, or where sinking to considerable distances below the water level has been necessary in order to obtain larger supplies or water that is less mineralized, machines propelled by horsepower, steam, or gasoline have been used.

The machine most commonly used for sinking these deeper wells is the portable standard rig with percussion drill attached to a cable, the drill being withdrawn at intervals and the drillings removed by means of a bailer or sand bucket. A machine of this type is among the most reliable for exploration work, especially where deep drilling is involved, and it is also well adapted for drilling through deposits containing bowlders or hard layers. By its use water-bearing beds are generally detected, even though their yield is not great.

A machine of another type also used is the rotary hydraulic rig, in which a stream of water is forced downward through hollow iron drill-rods, the material being loosened by the combined action of the rotating drill and the constant jet of water and removed from the well by the current of water that is forced up outside of the drill rod. This machine is adapted for rapid work in unconsolidated sediments that are free of bowlders and hard layers. It is successfully used in beds of caving sand because muddy water can be injected which shuts out the sand by puddling and because the water in the well exerts an outward pressure. It is likely to give bad results if used by careless or inexperienced drillers, because weak water-bearing beds are not easily recognized and are liable to be shut out by the clay wall that is formed, with the result that these sources of water may never be developed. Stronger water-bearing beds are recognized by the character of the drillings and by the fact that the water pumped into the well tends to escape.

A rather inexpensive machine auger, generally propelled by one or more horses that walk around the machine, has been used to a

[1] See also Bowman, Isaiah, Well-drilling methods: U. S. Geol. Survey Water-Supply Paper 257, 1911.

small extent in this region. It is extensively used in the glacial drift of Minnesota and Iowa, but is rarely found in the West. It can be employed for making holes of various sizes, but is often used for rather large holes—18 inches and more in diameter. It is well adapted for rapid work in making comparatively shallow wells in unconsolidated deposits that do not contain bowlders, but its speed and efficiency diminish rapidly with increase in depth, and it is not very successful in penetrating hard layers. When sand that caves readily is encountered, the casing must be driven in advance and the hole cleaned with a sand pump. With the auger, as with the percussion drill, weak water-bearing beds can easily be detected. In California augers propelled by hand or by gasoline engines are in use for boring holes generally 7 to 12 inches in diameter. They are advantageously used to depths of 150 feet and have gone to depths of about 300 feet. They are not adapted for boring through hard formations or through deposits containing rocks more than about 3 inches in diameter, but they could be successfully used in much of the valley fill of this region.

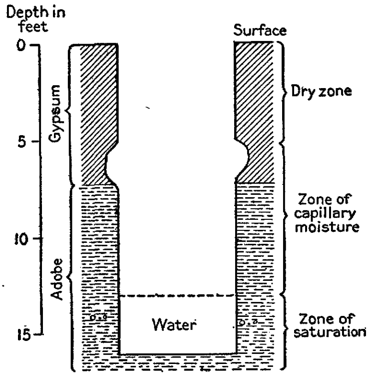


FIGURE 29.—Section of dug well showing zone of caving due to moist gypsum.

Where the materials are soft and largely water bearing, holes are sometimes sunk by means of sand pumps or bailers only, but this method is not practicable in most localities. The mud-scow method, which is extensively used in California, could be successfully used in this region, but requires a rather expensive outfit.[1]

CASING.

Dug wells are frequently left uncased, except below the water level, where they are usually walled with lumber. Some wells are also cased above that level as far as the earth is moist, or at other horizons where there is material that caves readily. Figure 29 shows a shallow well in which the zone of capillary moisture extends up through the adobe and a short distance into the overlying gypsum. Since the moist gypsum caves more freely than the moist adobe or the dry gypsum, there is an horizon of caving material between the

[1] Slichter, C. S., Field measurements of the rate of movement of underground water: U. S. Geol. Survey Water-Supply Paper 140, pp. 98–103, 1905; also, Observations on the ground waters of Rio Grande valley: Water-Supply Paper 141, 1905.

surface and the water level. In some wells the wooden casing is blackened, perhaps by the reduction of sulphates in the water, and the water at the same time acquires a disagreeable taste. If these wells are used for domestic supplies, casings of stone, brick, or tile are preferable to wooden casings below the water level.

Bored and drilled wells are generally cased with standard iron pipe, standard screw casing, or sheet iron or steel ranging in thickness from about No. 12 gage to a very thin plate. Some bored and drilled wells are left uncased, but these are liable to deteriorate rapidly because of caving and consequent filling of the wells with sediments. The heavy iron casings are the least liable to accidents and the most reliable where beds of mineralized water are to be shut out. Generally, however, a moderately heavy sheet casing, which costs less, can be inserted and will give satisfactory service. The double stovepipe casing, which is extensively used in California, is less expensive than the standard pipe or screw casing and is more convenient where the casing follows the drill. It does not buckle as readily as the single sheet-iron casing and is more nearly watertight.[1]

When the hydraulic method is used the casing is generally not inserted until the drilling is completed. When an auger or percussion drill is used the casing is often allowed to follow the auger or drill in order to prevent caving, an expansion bit being used in some rigs. When the hole is made with a sand pump, bailer, or mud scow it is necessary to sink the casing as fast as the hole is excavated.

FINISHING.

Although it is easy to drill or bore into the valley fill, it requires skill to finish wells in this material in such a manner as to develop the largest possible yields. Much of the failure in the past appears to have been due to improper methods of finishing. The water-bearing material is poorly assorted and consists largely of gravel with a sandy or clayey matrix which yields water slowly. Every effort must be made to remove this matrix in order to develop around the well a bed of clean porous gravel that will transmit water freely. If the clayey material is not removed, slow seepage will take place over only the small intake area offered by the walls of the well, but if it is cleaned out for some distance in all directions from the well, this seepage will take place over the much larger intake area offered by the resulting gravel bed surrounding the well, and the flow into the well will be correspondingly increased. The transporting power

[1] Slichter, C. S., Field measurements of the rate of movement of underground water: U. S. Geol. Survey Water-Supply Paper 140, 1905; also, Observations on the ground waters of Rio Grande valley: U. S. Geol. Survey Water-Supply Paper 141, 1905.

of a current of water increases rapidly with increased velocity. Hence, when the yield of a well has been somewhat increased by the cleaning process, the current toward the intake of the well becomes swifter, and consequently carries out more fine sediments. The cleaning can be done first with a bailer or sand pump and later by pumping as hard as possible. If the well fills with fine sediments, these should be removed with the bailer or sand pump, and pumping should be resumed until the water becomes clear and no more sediments can be brought out. The air lift is best adapted for cleaning wells, but the centrifugal pump will also give good results.

Where much material is removed, there is some danger that the clay from higher levels will slump and thereby shut out the water. The formation of a void and consequent slumping can in large measure be prevented by driving the casing into the upper part only of the water-bearing deposit and then introducing gravel into the bottom of the well as rapidly as room is made for it by the removal of fine sediments. After the cleaning is finished, it may be advisable to drive the casing into the gravel bed and to perforate it near the bottom. Where the sediments are all fine, a porous bed, resulting in an increased yield, can also often be produced around the intake of the well by introducing gravel through the inside of the casing. In exceptional localities, where the water-bearing bed is near the surface and where the entire section consists of unconsolidated sand, the cleaning can be continued until the sand caves from the top down, and gravel can then be introduced through the resulting cavities on the outside of the casing. This method has been used in the Rio Grande valley with excellent results, but will find little application in Tularosa Basin. It may, however, be possible to devise practicable methods of introducing gravel on the outside. The hole could, for instance, be drilled large enough for the insertion of a 12-inch heavy iron casing, ending in the upper part of the water-bearing bed. A 6-inch casing, perforated near the bottom with holes one-fourth to one-half inch in width or diameter, could be inserted inside the 12-inch casing and driven to the bottom of the water-bearing bed. The sand and clay could then be pumped up through the 6-inch casing and fine gravel could be poured down between the two casings. After the gravel screen had been satisfactorily developed, the 12-inch casing could be withdrawn and used in drilling other wells of the same kind. (See fig. 30.)

If a well ending in a gravelly bed of the valley fill in Tularosa Basin is thoroughly cleaned, it will not as a rule require a fine strainer. A very coarse strainer was used with good success in one of Mr. Carl's wells, and most of the other wells with relatively large yields have perforated casings. The perforations can be made after the casing is inserted[1] or before it is put into the well; if before, care must be taken lest the perforations become clogged with adobe and do not admit the water. Where gravel is introduced the water can be admitted at the open end of the casing without perforations, or the casing can be sunk through the gravel screen and the water admitted through perforations.

Most of the wells ending in the sandy beds in Hueco Basin and the southern part of Tularosa Basin are finished with fine strainers, but the wells at the El Paso waterworks are finished with casings that are perforated at all water horizons with slits 10 inches long and about one-half inch wide. It is estimated by the engineer in charge that when the air lift is applied to a new well a carload or more of sand is removed before the water clears sufficiently to be used. These wells are undoubtedly more satisfactory than they

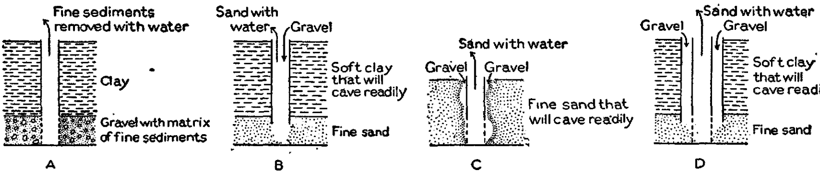


FIGURE 30.—Diagrammatic well sections showing methods of developing gravel screens. A, Method applicable where water-bearing bed consists of gravel with matrix of finer sediments, especially if there is a roof of hardpan that will not readily cave. B, Method applicable where water-bearing bed contains no coarse material or where roof consists of soft material that will cave readily. C, Method applicable where water-bearing bed is near the surface and the overlying material consists entirely of unconsolidated sediments that will cave readily. D, Method applicable where conditions are the same as in B.

would be if the sand that is removed were held in place by strainers of fine mesh.

In the first Otis well the water is admitted through circular perforations three-eighths inch in diameter. At first this well did not supply the pump, and much mud and sand were lifted with the water, but after two days' pumping the water cleared and the yield was greatly increased. When the test was made, the capacity of the well far exceeded the capacity of the pump.

ARTESIAN HEAD.

At the time the investigation was made there were no flowing wells in the region except two situated on the floor of a broad arroyo on the farm of D. W. Shoemaker, NE. ¼ sec. 1, T. 15 S., R. 8 E., about 8 miles southwest of the village of Tularosa and 1 mile northwest of Cerrito Tularosa. These wells are only a few feet apart,

[1] Slichter, C. S., The California or "stove-pipe" method of well construction; in Contributions to the hydrology of eastern United States, by M. L. Fuller and others: U. S. Geol. Survey Water-Supply Paper 110, pp. 34, 35, 1904. The same information is given in Water-Supply Papers 257 and 277.

are respectively 2 inches and one-half inch in diameter, and are reported by the owner to be about 40 feet deep. The 2-inch well discharges a little less than 3 gallons per minute at an elevation 9 feet above the surface, 15 feet above the normal water table, and 4,137 feet above sea level. The smaller well yields much less. (See Pl. XVIII, *B*, p. 158.)

Three deep test wells have been sunk into the valley fill. One of these, drilled in 1905 and 1906 in the NE. ¼ sec. 26, T. 16 S., R. 9 E., a short distance west of Alamogordo, was 1,004 feet deep (fig. 11, p. 64); the other two, drilled in 1910 in the NE. ¼ sec. 14, T. 18 S., R. 9 E., a little north of Dog Canyon station, were, respectively, 1,235 feet and 1,800 feet deep. (See fig. 12, p. 65.) In the Alamogordo well the water stands 35 feet below the surface, or at nearly the same level as the water table in that locality. In the 1,235-foot well at Dog Canyon, which was cased only to 150 feet, the water is reported to have stood within 18 feet of the surface, or about 20 feet above the water table, when the greatest depth was reached. In the 1,800-foot well, which is said to have been cased to 1,200 feet, the head is not known, but it was not sufficient to bring the water to the surface.

Many of the wells in the region extend far below the water table and tap the second or third water-bearing bed. In most of these wells the water is under sufficient head to rise a few feet above the water table and in several it rises more than 10 feet above the water table. At the Otis well, in the SW. ¼ sec. 8, T. 14 S., R. 9 E., the water table is about 20 feet below the surface, but the water from the bottom of the well, 58 feet deep, rose within 8 feet of the surface, and in another well in the same vicinity it rose still nearer the surface. In a well in the NE. ¼ sec. 3, T. 17 S., R. 9 E., the first water was struck at 22 feet and stood at that level, but water struck at depths of 80 feet and 125 feet is reported to have risen within 10 feet of the surface, and it stood about 14 feet below the surface in the fall of 1911. Other examples of this condition could be given. On the other hand, some of the deeper wells do not appear to have any higher head than the shallow wells in the vicinity in which they are located. Where there are perched bodies of water, as is apparently the case in the shallow-water tracts southeast of Three Rivers station, the water level would be much lower in deep wells than it is in the existing shallow wells.

In the Mound Springs (Pl. XVI) and in several springs and water holes east of the white sands the water rises a number of feet above the surface and to a greater height above the water table (p. 53). This artesian head seems to show that the water comes from considerable depths and rises through openings made in some way by nature. It must be regarded as a favorable indication in so far as prospects for flowing wells in these localities are concerned.

Flowing wells can probably be obtained over a part of the area in which the depth to water is less than 25 feet. The prospects are best in especially depressed localities, such as the lower parts of the mid-slope arroyos, but it is possible that flows will also be obtained in other tracts, such as the shallow-water belt extending from the Chosa Spring to a point some distance south of the Lomitas Springs. It is, however, not probable that flowing wells will ever be an important source of irrigation supplies, because they are likely to be obtained chiefly on alkali land, and their yield is likely to be small and to diminish if much water is drawn from other wells in the same locality. Wells intended for irrigation should be sunk with a view to developing pump supplies, and even if flows are struck it will generally be advisable to install pumps and thereby obtain larger, more dependable, and more elastic supplies than the natural flows are likely to furnish.

QUALITY OF WATER.

QUANTITY OF DISSOLVED SOLIDS.

The mineral character of the waters from the wells, springs, and streams in Tularosa Basin and adjacent areas is shown by the analyses given on pages 268–305. Most of these analyses were made in the laboratories of the New Mexico Agricultural Experiment Station, under the supervision of Dr. R. F. Hare, but a few were obtained from the El Paso & Southwestern Railroad Co. and from other sources. About 115 of these analyses represent waters in the valley fill, exclusive of the thin deposits of waste overlying Cretaceous, Carboniferous, and igneous rocks in the areas east, west, and north of the lava beds. (See Pl. XVII.)

In the area north of a line passing a short distance south of the white sands, and in an indefinitely known area surrounding the Jarilla Mountains, practically all of the water of the valley fill is heavily loaded with dissolved mineral matter; south of this line, except in the area surrounding the Jarilla Mountains, the water of the valley fill, so far as it has been investigated, contains only moderate amounts of mineral matter. In the following discussion these three areas are recognized and called, respectively, the northern area, the Jarilla Mountain area, and the southern area. The northern area is assumed to extend to the middle of the tier of townships numbered 19 S. The southern area includes the region extending from this line to El Paso, except the indefinite area surrounding the Jarilla Mountains. The recognition of the Jarilla Mountain area as distinct from the northern area is rather arbitrary. The analyses given in this report include about 100 samples from the valley fill of the northern area, 11 samples from the valley fill of the southern area, and 2 samples from the valley fill of the Jarilla Mountain area. Other waters from the valley fill near the Jarilla Mountains are, however, known to be mineralized. The samples from the northern area range in total dissolved solids from 752 to 259,000 parts per million, and those from the southern area from 292 to 630 parts. Exclusive of the specially concentrated waters, such as are found on the alkali flats, the average of total dissolved solids is 3,673 parts per million in the northern area, 4,217 parts in the Jarilla Mountain area, and only 421 parts in the southern area. The following table also shows the heavy mineralization of the waters of the northern area and the Jarilla Mountain area, and the comparatively light mineralization of the waters of the southern area:

Number of samples from the different groups of water of the valley fill having specified quantities of total dissolved solids.

Parts per million.	Number of analyses.		
	Northern area.	Jarilla Mountain area.	Southern area.
Less than 200	0	0	0
200 to 500	0	0	6
500 to 1,000	4	0	5
1,000 to 2,000	16	0	0
2,000 to 3,000	20	1	0
3,000 to 5,000	28	0	0
More than 5,000	22	1	0

CHARACTER OF DISSOLVED SOLIDS.

The dissolved solids consist chiefly of basic and acid radicles, the most abundant basic radicles being calcium (Ca), magnesium (Mg), and sodium (Na), the most abundant acid radicles the bicarbonate (HCO_3), carbonate (CO_3), sulphate (SO_4), and chloride (Cl). Only the constituents that occur most abundantly are included in the analyses given in this paper. In most of the samples, calcium and magnesium were the only bases determined in the laboratory, the quantities of sodium and potassium having been calculated, but in a few the sodium and potassium were separated and the quantity of each was experimentally determined, the amounts of potassium in these samples being shown in the table on page 129. The bicarbonates, carbonates, sulphates, and chlorides were determined in all of the samples, but the bicarbonates and carbonates are reported together as carbonates.

The radicles are for the most part disassociated when dissolved in water, but they are derived from compounds in which the basic and acid radicles are combined, and if through evaporation or other cause they are precipitated from the water they will again form compounds. In the tables (pp. 268–305) the dissolved solids are expressed in two forms; first, as radicles, and second, as combinations of these radicles. The first form of expression gives the fundamental data and is the only form in which water analyses are generally published by the United States Geological Survey; the second form is passing into disuse because of the hypothetical assumptions that it involves, but is retained in this joint report by the New Mexico Agricultural Experiment Station because of the utility it is believed to have in the interpretation of the fundamental data. (See pp. 265–267.)

The following tables give a general view of the quantities of the more important constituents dissolved in the water of the valley fill:

Average quantities of the principal dissolved constituents of the waters of the valley fill in the northern and southern areas.

	Parts per million.		Percentage.	
	Northern area.	Southern area.	Northern area.	Southern area.
Calcium (Ca)	362	45	9.7	10.9
Magnesium (Mg)	179	21	4.8	5.1
Sodium and potassium (Na+K)	541	73	14.5	17.7
Carbonate (CO_3)	119	108	3.1	26.2
Sulphate (SO_4)	1,725	104	46.2	25.3
Chlorine (Cl)	808	60	21.7	14.8

Number of water samples from the valley fill having specified quantities of dissolved mineral constituents.

Parts per million.	Calcium (Ca).		Magnesium (Mg).		Sodium and potassium (Na+K).		Carbonate radicle (CO_3).		Sulphate radicle (SO_4).		Chlorine (Cl).	
	Northern area.	Southern area.	Northern area.	Southern area.	Northern area.	Southern area.	Northern area.	Southern area.	Northern area.	Southern area.	Northern area.	Southern area.
Less than 100	3	10	24	10	6	7	23	4	0	7	2	10
100 to 200	20	0	46	0	22	4	65	5	0	3	20	1
200 to 500	49	0	22	0	37	0	6	0	10	1	32	0
500 to 1,000	26	0	2	0	13	0	0	0	24	0	21	0
1,000 to 2,000	0	0	0	0	10	0	1	0	35	0	8	0
More than 2,000	0	0	4	0	10	0	0	0	29	0	15	0

CALCIUM.

In the samples from the northern area the calcium content ranges from less than 100 to 755 parts per million, and averages 362 parts. In only 3 of these samples are there less than 100 parts. In about one-fourth there are less than 200 parts, in about one-half there are between 200 and 500 parts, and in about one-fourth there are over 500 parts. In the samples from the southern area the calcium content ranges from 32 to 77 parts, and averages 45 parts, or about one-eighth as much as in the northern area. In the two samples from the Jarilla Mountain area the average amount of calcium is 250 parts.

The calcium in the ground waters has been derived from both limestone (calcium carbonate) and gypsum (calcium sulphate). Calcium carbonate is abundant in both the northern and southern areas; calcium sulphate is very abundant in the northern area, but rare in the southern area. Calcium carbonate is almost insoluble except in the presence of carbonic acid, and the amount dissolved by the water is therefore limited by the supply of available carbonic acid rather than by the supply of calcareous material. Since carbonic acid is not abundant in the soil of the arid regions, where vegetation is scanty, the amount of calcium that the water derives from the calcareous material in these regions is rather definitely limited and is generally not large. Calcium sulphate is more soluble than calcium carbonate and its solubility does not depend, as does that of calcium carbonate, on the presence of carbonic acid, but it is not nearly so soluble as the sodium compounds and some of the magnesium compounds.

The foregoing tables show that the waters of the northern and southern areas are nearly alike in their carbonate contents, but differ vastly in their sulphate contents. They indicate that the amounts of calcium carbonate dissolved in the two areas does not differ greatly and that these amounts are determined in general by the supply of available carbonic acid rather than by the supply of calcareous material, which occurs in great excess in both areas. They also indicate that large amounts of gypsum are dissolved in the northern area and only very small amounts in the southern area, and that the difference in the supply of gypsum accounts chiefly for the difference in the calcium contents of the two groups of water.

At the temperatures of the ground in this region calcium sulphate in the form of gypsum is soluble in pure water to the extent of about 2,000 parts per million,[1] but it is much more soluble in solutions of sodium chloride and other salts. The calcium sulphate of 37 of the samples from the northern area, as estimated from determination of calcium and sulphate, ranges between 1,000 and 2,000 parts per million, and that of 7 samples (including those from Salt Creek) exceeds 2,000 parts, the highest recorded being 2,597 parts. The calcium sulphate of the two samples from the Jarilla Mountain area is estimated at 148 and 1,154 parts per million, respectively.

[1] Seidell, A., Solubilities of inorganic and organic substances, p. 97, D. Van Nostrand Co., 1907.

MAGNESIUM.

In the samples from the northern area the magnesium content ranges from 29 to 33,773 parts per million; if the specially concentrated samples are excluded, it ranges from 29 to 751 parts and averages 179 parts. In the samples from the southern area it ranges from 10 to 57 parts and averages 21 parts. In the two samples from the Jarilla Mountain area it averages 170 parts. In the northern area nearly one-half of the samples contain between 100 and 200 parts of magnesium, about one-fourth contain less than 100 parts, and a little over one-fourth contain more than 200 parts. In the southern area they all contain less than 100 parts.

The source of the magnesium has not been so definitely traced as that of the calcium, but it is probably derived chiefly from magnesium carbonate associated with calcium carbonate and from magnesium sulphate associated with calcium sulphate. Most of the samples contain less magnesium than calcium, the average in both northern and southern areas being only about one-half as great. In several highly concentrated samples, however, the ratio is reversed, the amount of calcium being very small and that of magnesium very great. The large amount of magnesium in the concentrated waters is no doubt due chiefly to the great solubility of magnesium sulphate, and the small amount of calcium in the same waters is probably due to the precipitation of calcium carbonate in the strong solution of magnesium sulphate.

A shallow ground-water pool, without discharge, in the mid-slope arroyo on sec. 9, T. 15 S., R. 9 E., contained water of a brownish color, probably produced by the action of the dissolved salts on vegetable matter, and was covered with a thin crust of precipitated salts locally called "ice." This water was found to contain 33,773 parts per million of magnesium and 122,573 parts of the sulphate radicle, but no calcium. If account is taken of the water of crystallization, about two-thirds of the total solids may be regarded as magnesium sulphate. As the pool does not discharge it is not probable that the concentrated solution exists in sufficient quantity to be of much commercial value.

SODIUM AND POTASSIUM.

In the samples from the northern area the amount of sodium and potassium together ranges from 36 to 98,000 parts per million. If the specially concentrated samples are excluded it ranges from 36 to 3,383 parts, and averages 541 parts. In the samples from the southern area it ranges from 49 to 113 parts, and averages 73 parts. In the two samples from the Jarilla Mountain area it averages 848 parts. In the northern area only 6 samples contain less than 100 parts, whereas 70 contain over 200 parts, 32 over 500 parts, and 20 over 1,000 parts.

In 17 of the analyses given in the table the sodium and potassium are reported separately. All but two of these analyses represent waters that were derived directly or indirectly from the valley fill. Several of them are taken from the report on the potash investigation of this region, made by the United States Bureau of Soils;[1] several were made in connection with the present investigation; and several were obtained from other sources. In the following table the data furnished by these analyses relative to sodium and potassium are assembled. These data indicate that the quantities of potassium are small in comparison with the large amounts of sodium and total solids; they are therefore unfavorable to the prospects of recovering potassium for commercial use.

Potassium in the waters of Tularosa Basin, compared with sodium and total solids.[a]

	Sodium (Na), parts per million.	Potassium (K).		Source of analyses.
		Parts per million.	Per cent of total solids.	
WELLS.				
SE. ¼ sec. 8, T. 13 S., R. 8 E	424	18	0.4	Experiment station.
NW. ¼ sec. 13, T. 14 S., R. 8 E	509	17	.4	Do.
SW. ¼ sec. 7, T. 14 S., R. 9 E	700	22	.4	Do.
SW. ¼ sec. 26, T. 16 S., R. 9 E	410	Trace.	Very small.	Bureau of Soils.
Army post well at Fort Bliss	51	6.4	2.0	Experiment station.
El Paso waterworks well No. 18	55	7	2.2	El Paso Water Department.
El Paso Milling Co. well	94	9	2.5	Do.
SPRINGS.				
Alkali flat (north end)	98,800	Trace.	Very small.	Bureau of Soils.
Do	75,000	1,200	.4	Do.
Malpais Spring	732	16	.3	Experiment station.
Sulphur Spring at Agency	44	4.3	.4	Indian Office.
Pool in arroyo, sec. 9, T. 15 S., R. 9 E	17,854	851	.3	Experiment station.
Salt Spring	3,620	Trace.	Very small.	Bureau of Soils.
Alkali flat (south end)	18,800	Trace.	Very small.	Do.
STREAMS.				
Tularosa River at Agency	44	4.3	.7	Indian Office.
Fresnal Creek	96	5.5	.5	Railroad Co.
Salt Creek	7,000	Trace.	Very small.	Bureau of Soils.

[a] For further data in regard to the waters in this list see the complete tables, pp. 268–305. For data in regard to potassium, phosphates, and nitrates in the soil see pp. 179–180.

In the waters of the northern area the sodium is no doubt derived chiefly from the sodium chloride and sodium sulphate associated with the gypsum of the Carboniferous rocks and valley fill. In the southern area, where the gypsiferous rocks do not occur, there is evidently much less sodium chloride and sodium sulphate in the for-

[1] Free, E. E., An investigation of the Otero Basin, N. Mex., for potash salts: U. S. Dept. Agr. Bur. Soils Circ. 61, 1912.

mations and consequently much less sodium in the water. The sodium derived from the disintegration of igneous and other crystalline rocks chiefly forms the carbonate, but where gypsum is present in sufficient quantity the gypsum reacts with the sodium carbonate, forming sodium sulphate. In the northern area the amount of sodium derived from the disintegration of the igneous rocks is wholly negligible, but in the southern area, where there is more igneous rock and much less sodium available from other sources, the sodium derived from the igneous rocks is apparently discernable in the excess of sodium over the chloride and sulphate radicles in some of the waters. This excess seems to show that some of the water in the southern area has not come into contact with enough gypsum to neutralize the small amount of sodium carbonate resulting from the disintegration of the igneous rocks.

Throughout most of the region sodium chloride is the most abundant sodium salt, but in certain localities sodium sulphate predominates greatly. In the southern part of the large alkali flat there are sodium sulphate deposits of sufficient purity and extent to be of commercial value. (See analysis A42, pp. 310–311.)

In both the northern and the southern areas the average sodium content is approximately one and one-half times that of calcium and three times that of magnesium. Because of the great solubility of the sodium salts, however, the range in the content of sodium is great, and certain samples contain very large amounts of this constituent. The water in the lower part of Salt Creek contains as much sodium and as much common salt as sea water, and several samples obtained on or near the alkali flats contain much more than sea water. Some of this water has been used for the production of common salt on a small scale and it may in the future prove valuable for salt production on a larger scale.

ACID RADICLES.

The acid radicles found in the water have been incidentally discussed in connection with the bases.

The bicarbonate and carbonate radicles, which are both reported in the analyses as carbonates, are derived in part from calcium carbonate and magnesium carbonate in the limestones and other formations, and in part from carbonic acid of atmospheric origin. On account of the limits of their solubility they rarely occur in large quantities. Expressed as the carbonate radicle, they range in the northern area, with one exception, between 30 and 312 parts and average 119 parts. In the southern area they range between 54 and 795 parts and average 108 parts.

The sulphate radicle, which is derived chiefly from the abundant deposits of gypsum, is generally found in large quantities in the waters of the northern but in much smaller quantities in those of the southern area. In the northern area it ranges between 241 and 122,573 parts per million; exclusive of the specially concentrated samples, it ranges between 241 and 9,379 parts and averages 1,725 parts. In the southern area it ranges between 30 and 250 parts and averages 104 parts. In the samples from the Jarilla Mountain area the sulphate radicle averages 1,494 parts.

Chlorine, which is derived chiefly from sodium chloride, is likewise very abundant in the northern area but present in only moderate quantities in the southern area. In the northern area it ranges between 55 and 186,200 parts per million; excluding from consideration the specially concentrated samples, it ranges between 55 and 9,400 parts, and averages 808 parts. In the southern area it ranges between 13 and 193 parts, and averages 60 parts. In the Jarilla Mountain area it averages 1,043 parts. Nearly one-half of the samples from the northern area contain over 500 parts of chlorine and only about one-fourth contain less than 200 parts.

RELATION OF DISSOLVED SOLIDS TO DERIVATIVE ROCKS.

The high mineralization of the waters of the northern area and the Jarilla Mountain area is due primarily to the soluble constituents, chiefly gypsum and common salt, in the upper Pennsylvanian rocks (Manzano group) so abundant in this region. The smaller mineral content of the waters of the southern area is due (1) to the greater abundance of igneous and other crystalline rocks, which furnish but little soluble matter, (2) to the smaller amount of soluble matter in the Pennsylvanian rocks of the southern area,[1] and probably (3) to the absence in some localities of the Manzano rocks on the Tularosa side of the mountain divides. More detailed stratigraphic studies will probably show that the relatively small mineral content of the well waters in the part of the southern area that extends north of the Jarilla Mountains is due to the absence of gypsiferous beds of the Pennsylvanian series in the mountains adjacent to this part of the southern area, and that the high mineralization of the waters near the Jarilla Mountains is due to the presence of such beds in these mountains.

The underground waters of the central part and perhaps of the eastern part of Estancia Valley are comparable in their contents of chlorine and sulphate with those of the northern area of Tularosa

[1] Richardson, G. B., U. S. Geol. Survey Geol. Atlas, El Paso folio (No. 166), 1909.

Basin, but the waters underlying the extensive west slope of that valley contain much less of these constituents and are comparable with the waters of the southern area. In 34 samples collected from an area including all but the lowest part of the west slope of Estancia Valley the chlorine ranges from 7 to 25 parts and averages only 16 parts per million. This west slope is largely adjacent to mountains composed of metamorphic rocks and Carboniferous rocks that are older than the principal gypsiferous horizons. The large amount of chlorine in the central area of Estancia Valley indicates that some of the bordering rock formations (probably certain of the gypsiferous beds of the Manzano group) are salt-bearing. It is, however, remarkable that in several highly gypseous well waters obtained near the gypsum ledge of the Mesa Jumanes the chlorine content is only 25 parts or less.[1]

RELATION OF DISSOLVED SOLIDS TO DEPTH OF THE WATER TABLE.

The following table shows the highest, lowest, and average amounts of total solids and also of chlorine for specified depths to the water table. It is based on the analyses of well waters in the northern area of valley fill, the waters south of the middle of T. 19 S. not being included.

Relation of total dissolved solids and chlorine to depth of water table, in samples from wells in valley fill north of the middle of T. 19 S., Rs. 4 to 10 E.

Depth to water table in feet.	Number of analyses.	Total solids, parts per million.			Chlorine (Cl), parts per million.		
		Lowest.	Highest.	Average.	Lowest.	Highest.	Average.
Less than 25	18	1,670	15,600	4,371	144	2,858	591
25 to 50	30	1,324	11,640	4,058	104	3,412	717
50 to 100	25	752	11,092	3,406	55	4,457	850
More than 100	6	502	4,267	2,017	160	683	303

In areas where a rather definite relation exists between the quality of the water and the depth to the water table, a knowledge of such relation is of much practical value. The above data shows that the average mineral content of the waters in the valley fill decreases with increasing depth to the water table but that these differences are so small as compared with the differences in the specific samples which enter into the averages that they are of little practical assistance in predicting the quality of water where no analysis has been made. They show no decrease in the average chlorine content.

[1] Meinzer, O. E., Geology and water resources of Estancia Valley, N. Mex.: U. S. Geol. Survey Water-Supply Paper 275, pp. 48 to 51 and Pl. XI, 1911.

RELATION OF DISSOLVED SOLIDS TO DEPTH OF WATER-BEARING BEDS.

It is important to know to what extent the water of the deeper water-bearing beds is better than the first water encountered in sinking a well. The following list includes all valley-fill wells that have been investigated which extend 50 feet or more below the water table. Nearly all of these end in the second or third water-bearing bed. In many of the wells it was not possible to ascertain how effectually the first water was cased out, but in nearly all wells most of the water is no doubt drawn from the deeper beds.

Mineral character of water in wells extending more than 50 feet below the water table, and comparison with average water in the valley fill (north of middle of T. 19 S., Rs. 4 to 10 E.).

Location.			Depth of well.	Depth to water table.	Parts per million.	
Township (south).	Range (east).	Section.			Total solids.	Chlorine (Cl).
			Feet.	*Feet.*		
9	8	5	252	180	3,341	324
14	9	7	180	18	5,500	807
15	9	24	140	85	2,632	479
15	10	31	138	86	1,883	417
16	4	36	120	65	6,100	2,001
16	9	23	160	54	3,060	669
16	9	25	186	20	1,680	270
16	9	25	95	33	5,540	357
16	9	26	80	24	....	700
16	9	33	122	....	3,360	315
16	9	35	200	....	2,240	496
17	9	2	80	....	3,288	465
17	9	4	130	28	2,476	510
17	9	3	135	....	2,584	....
17	9	8	100	24	4,740	620
17	9	23	85	30	2,140	244
18	9	13	103	41	1,804	199
Average for wells extending more than 50 feet below water table					3,273	555
Average for all samples from the valley fill of northern area					3,673	808

This table indicates that the average water from the deeper water-bearing beds is less mineralized than that from the first water-bearing bed, but it does not indicate that the average difference is great or that it amounts to as much as the differences between the waters of similar wells in the same locality. In some localities, as on the farm of C. W. Morgan, NW. ¼ sec. 23, T. 16 S., R. 9 E., the second water is more highly mineralized than the first, but more commonly the deep water is better than the first. Advantage should be taken of such difference wherever it exists.

No analysis was made of the water in the deep test wells near Dog Canyon, but Mr. S. D. Camp, who assisted in drilling one of these wells, reports that the first water was gypseous, the water at 76 and 160 feet was good, the water at 288 and 565 feet was of fair quality but somewhat inferior to that higher up, and the water at 890 and 1,200 feet was salty. (See fig. 12.)

EFFECTS OF DISSOLVED SOLIDS ON USE OF WATER.

DRINKING AND CULINARY USE.

The effects of specific quantities of mineral substances dissolved in water upon the health of persons who drink the water are not well understood. There are wide differences in the effects of the same water on different persons, and many of the supposed effects, both curative and injurious, are no doubt imaginary rather than real. It sometimes happens that virtually the same water is in one community avoided as unfit to drink and in another prized for its medicinal properties. 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 may at first object to a certain water because of the taste given by its mineral matter, but the same person after drinking the water for some time may become unable to detect any taste in it and may even prefer it to less mineralized water.

Any classification based on total solids alone is unsatisfactory because the different constituents do not have the same effects, and hence much depends on the proportions of these constituents. The calcium salts are less objectionable in water used for drinking than the same amounts of the sodium salts, and the different sodium salts are not equally objectionable. The older authorities on drinking waters for England and the eastern part of the United States fixed 570 parts per million as the extreme limit of mineral content.[1] This limit would exclude all of the waters from the northern area of valley fill that were examined. MacDougal, 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.[2] In Tularosa Basin, where many of the waters are practically saturated with calcium sulphate, the limits are possibly even higher than those given by MacDougal. Waters ranging up to 2,000 parts of total solids are generally considered satisfactory for drinking, and where the proportion of calcium is especially high and that of chlorine especially low, waters containing 2,500 parts, or even more, may be considered satisfactory. The more gypseous waters

[1] Hare, R. F., and Mitchell, S. R., Composition of some New Mexico waters: New Mexico Agr. Exper. Sta. Bull. 83, p. 8, 1912.

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

ranging between 2,500 and 4,000 parts of total solids are considered potable although of inferior quality, but other waters that fall between these limits but are richer in sodium chloride are avoided for drinking. A few waters ranging between 4,000 and 5,000 parts are used for drinking, but waters containing more than 5,000 parts are almost never used by human beings except in need. The water from the Point of Sands well is commonly used by travelers for drinking. It contains 4,804 parts of total solids, but it is practically saturated with gypsum and contains only 188 parts of chlorine. The water from the North Lucero ranch is so unpalatable that it was refused even by thirsty horses that were accustomed to drinking desert water. It contains only 3,019 parts of total solids, but 1,541 parts consist of chlorine. The water from the drilled well on McNew's ranch southwest of the Point of Sands is considered satisfactory. It contains 3,044 parts of total solids and only 139 parts of chlorine, but it contains 2,009 parts of the sulphate radicle, over one-half of which is calculated as magnesium sulphate or sodium sulphate. The waters from the Mound Springs and Malpais Spring are very unpalatable, but are drunk by human beings when absolutely necessary. They contain approximately 5,000 parts of total solids, and although they are practically saturated with calcium sulphate they contain also much chlorine. The Malpais Spring water is worse than the Mound Springs water because it contains even more chlorine. The water of a spring on the alkali flat where cattle were seen drinking contains 9,413 parts of total solids.

Water that contains 250 to 300 parts per million of chlorine in the form of common salt has a slightly salty taste, and water containing larger amounts is correspondingly more salty. The following generalizations can be made for the waters of Tularosa Basin whose analyses are given in this paper, except those in which the sulphates of sodium or magnesium are relatively abundant. Waters containing less than 300 parts of chlorine are considered good; those containing between 300 and 600 parts are considered rather poor, but are used for drinking and for culinary purposes; those containing between 600 and 1,000 parts are considered bad, but are used to some extent for drinking and cooking in cases of necessity; those containing between 1,000 and 2,000 parts are almost entirely avoided by man, but are used for live-stock supplies where no other water is available. The water of Malpais Spring, which contains 1,130 parts of chlorine, is very unpalatable and is rarely drunk by human beings, although it is given to horses. The water from the well of James Gililland, which contains 3,412 parts of chlorine, is given to live stock when necessary, but so far as possible it is diluted with flood waters before it is used even for a stock supply. The water from the spring on the alkali flat where cattle were seen drinking was found on analysis to contain 3,348 parts of chlorine. Water containing over 1,000 parts of chlorine should, however, be given to horses with caution, especially if they are accustomed to good water, or if they are hot and thirsty. Numerous small fish live in Salt Creek in a locality where the water was found to contain 13,295 parts of chlorine.

About 400 parts of the sulphate radicle in the form of sodium sulphate, or glauber salt, are perceptible to the taste. Waters still richer in this constituent are salty and bitter. Magnesium sulphate, or epsom salt, is also perceptible when present in considerable quantities. Both glauber salt and epsom salt are laxative, and waters containing several hundred parts per million of these salts are prized by some persons for their medicinal properties. Nearly all of the waters of Tularosa Basin except those in the southern area are rich in sulphates. Calcium sulphate generally predominates, but in most samples the sulphate radicle is in excess of the calcium and was probably derived from magnesium sulphate and sodium sulphate.

LAUNDRY AND TOILET USE.

Because the waters of the northern area and the Jarilla Mountain area are all very rich in calcium and magnesium they are also very hard. Because the calcium and magnesium are derived chiefly from the sulphates these waters can not be softened by boiling or by treating with lime, but they can be softened by adding soda in sufficient quantities. When they are used with soap some of the calcium and magnesium are precipitated and form a thick curd. Since the waters of the southern area contain only moderate amounts of calcium and magnesium, they are only moderately hard, and in comparison with the northern waters seem very soft.

BOILER USE.

The waters of the northern area and the Jarilla Mountain area are all poor boiler waters and most of them are entirely unfit for steam making. Because of their very large content of calcium and magnesium they deposit great quantities of scale, and because the magnesium is deposited chiefly as an oxide and the calcium as a sulphate the scale is hard. Because these waters are also rich in sodium they foam readily. Moreover, attempts to soften them and thereby to remove the scale would introduce more sodium and would therefore make the foaming tendency still worse. Because magnesium as well as the sulphate and chloride radicles are generally abundant and the carbonate content is small these waters are also likely to be corrosive.

The waters of the southern area are much more satisfactory and are used extensively in locomotive and other boilers. Because their contents of calcium and magnesium are not large, while their content of carbonate is considerable, they will form only moderate amounts of a rather soft scale and are not likely to be corrosive. Because their sodium content is not large they are not likely to cause trouble by foaming.

IRRIGATION USE.

Plants can endure a larger amount of dissolved mineral matter than animals, but the soil solution on which they subsist is generally more concentrated than the water applied in irrigation, for the reason that some of the alkali in the soil goes into solution. Moreover, the 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 the soil has good drainage, the alkali can from time to time be washed out, and highly mineralized waters can be successfully used for irrigation. If, on the other hand, the drainage is poor, even water of low mineral content may eventually cause the accumulation of alkali. It should be understood that 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 calcium constituents of the water are not injurious to plants. Because of their low solubility they do not form a large part of the mineral content of concentrated soil solutions. The injury to plants is caused by the sodium salts, and perhaps, to a much less extent, by the soluble magnesium salts. Among the sodium salts, the carbonate, or so-called black alkali, is most injurious, the sulphate is least injurious, and the chloride is intermediate. In the waters of the valley fill of the northern area there is no sodium carbonate, but there are generally large amounts of sodium chloride and also important amounts of sodium sulphate and magnesium sulphate. The chlorides and sulphates of sodium and magnesium are together called white alkali.

For water of the type found in the valley fill of the northern area and throughout almost the entire irrigable area of Tularosa Basin the following generalizations, based on experience in other regions, can be made: Water that contains less than 100 parts per million of chlorine and less than 400 parts of total white alkali can be used indefinitely without injury to crops on soil not impregnated with alkali from other sources. Water that contains between 100 and 300 parts of chlorine and less than 1,000 parts of total white alkali can be successfully used on soil that does not contain excessive alkali from other sources and has fair drainage, provided precautions are taken to prevent accumulation of alkali. Water containing between 300 and 1,000 parts of chlorine or more than 1,000 parts of total white alkali is poor for irrigation and can probably be used successfully only where effective drainage to remove alkali is possible. Water containing more than 1,000 parts of chlorine is of very doubtful value for irrigation, although it has been used successfully in a few places exceptionally well drained. In other words, water that contains enough salt to be perceptible to the taste can be used successfully from year to year only if precautions are taken to remove the alkali that will tend to accumulate in the soil, and water that is so salty that it is disagreeable to the taste is worthless for irrigation unless exceptionally good drainage is provided.

Out of about 100 samples of water from the valley fill in the northern area, 2 contain less than 100 parts of chlorine, 37 contain between 100 and 300 parts, and 37 contain between 300 and 1,000 parts. It is obvious that in using these waters for irrigation precautions must be taken to prevent accumulations of alkali. In the areas where flood waters can occasionally be obtained the best method will probably be to use the ground waters in connection with flood waters. The ground waters can be used sparingly when necessary and can be conserved by dry-farming methods of cultivation; the flood waters can be used whenever they are available and in as large quantities as possible in order to wash the accumulated alkali out of the soil. The imperviousness of much of the soil introduces another difficulty and may make it more feasible to wash the alkali from the surface than to leach it downward.

Much of the water can probably not be used successfully on land that is poorly drained and does not receive floods. It is difficult, however, to fix limits. The water of Pecos River, which contains about 5,000 parts per million of total solids and has the same general character as the ground water of the valley fill in the northern area of Tularosa Basin, is being used successfully in southern New Mexico for growing many crops. Only about one-fourth of the samples in the northern area contain more than 5,000 parts per million, the average being 3,673 parts. (See p. 125; for quality of Cretaceous and Carboniferous waters see pp. 154, 173.)

WATER IN CRETACEOUS ROCKS AND OVERLYING SEDIMENTS.

AREA AND PROBLEMS.

Rocks of the Cretaceous system (described on pp. 60–62) occur over most of the area between the younger lava and the eastern mountains, either at the surface or beneath a thin mantle of rock débris (Pl. XVII), and their stratigraphy and structure are such that they produce a series of rock barriers that impound the ground waters. Many wells have been sunk in the Cretaceous area, some of them entering the rocks and others ending in the overlying mantle of unconsolidated sediments, and nearly all obtaining sufficient water for domestic use and stock supply. In quality the waters differ widely, some being truly soft and some too highly mineralized for drinking. The principal problems in this area relate to the development of supplies for irrigation, but in certain localities water that is good enough for domestic use is needed. Data in regard to springs, infiltration ditches, and wells are presented first, and are followed by discussion of the general conditions and prospects.

SPRINGS.

The Cretaceous area contains numerous springs, in which respect it is in contrast with most of the Carboniferous area. Thus in the Cretaceous region between Three Rivers and Whiteoaks water issues from the ground at many places, but in the Carboniferous area of similar topography lying farther north almost no springs are found. None of the springs in the Cretaceous, however, compare in volume with the copious streams that escape from the Carboniferous limestones in the Sacramento Mountains.

Among the springs in the Cretaceous area are Nogal Spring, Carrizozo (or McDonald's) Spring, Upper Coyote Spring, Upper Willow Spring, Chaves Spring, Lower Coyote Springs, Lower Willow Springs, Jakes Spring, Milagro Spring, and the numerous springs along Three Rivers. (See Pl. VI.) The principal data in regard to these springs are tabulated on pages 300–301 and in the list of watering places on pages 249–264. Some of them, such as Nogal Spring, Lower Coyote Springs, and Milagro Spring, are associated with rock outcrops; others, such as Carrizozo Spring, issue from the débris mantle and are not near any rock outcrop; but all of them are probably produced by rock ledges which form dams that impound the underflow.

Nearly all of the springs yield a permanent though small flow and are reliable watering places for range stock and travelers. The springs along Three Rivers together furnish enough water to irrigate considerable land (see p. 208), and Carrizozo Spring is used to water a small tract. A few others, such as Milagro Spring, are of sufficient size to irrigate very small fields, but most of them are too weak to be of any practical value for irrigation.

INFILTRATION DITCHES.

Where the ground water is impounded by a rock barrier it is brought near the surface, the water level being much higher above than below the barrier. If the barrier extends practically to the surface, the water overflowing from the underground reservoir may appear in the form of a spring; otherwise it may seep across the barrier and sink to a great depth without coming to the surface. In certain localities, where the surface has considerable slope, it is possible to conduct water by gravity from an underground reservoir to the surface of the land at a point where the surface is lower than the water level in the reservoir. This can be accomplished by means of ditches or tunnels which tap the ground water and which by having slighter grades than the surface of the land, gradually lead the water to the surface; or it can be accomplished by means of siphons which draw water out of wells situated behind the barriers, delivering it at the surface farther down the slope, where the surface of the ground is lower than the water level in the wells. (See fig. 31.) Since the Cretaceous rocks include a series of barriers (p. 153), they give rise to conditions that make possible infiltration ditches and siphons, the conditions being especially favorable in the localities where the barriers form escarpments as shown in figure 31.

One of the most successful infiltration ditches, at the I Bar X ranch, SW. ¼ sec. 30, T. 9 S., R. 10 E., 6 miles east of Oscuro, is an open ditch, about one-eighth mile long, 6 feet wide at the bottom, and 15 feet deep at its upper end. This ditch was excavated out of rock waste consisting of granitic gravel, and apparently does not touch

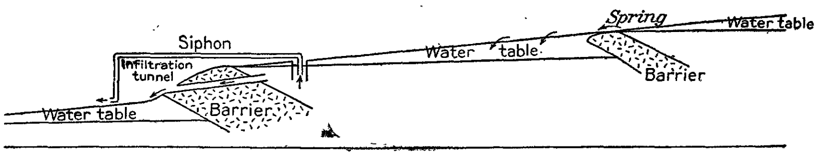


FIGURE 31.—Diagrammatic section showing relation of underground barriers to the water table in the Cretaceous area.

bed rock at any point. It is supplied by seepage from the gravel near the bottom and delivers about 60 gallons per minute of good water. (See analysis, pp. 300–301.) As shown on the map (Pl. VI, p. 26), this ditch is situated on the débris slope several hundred feet above the water level of the wells and springs nearer the railroad. It is less than one-half mile north of the point of the Godfrey Hills, and about the same distance south of a small rock butte, a position indicating that the conditions of shallow water in this locality may be produced by the damming of the underflow by impervious rock ledges.

At Jake's section house, on the railroad, in the NW. ¼ sec. 10, T. 9 S., R. 9 E. (Pl. VI, p. 26), there is a small west-facing escarpment of yellow Cretaceous sandstone, into which a tunnel has been run a distance of over 100 feet. Water of good quality seeps and drips into the tunnel and is discharged at its mouth in a tiny stream amounting to only about 3 gallons a minute. The supply from which this tunnel and Jakes Spring, about one-half mile farther south, are fed is apparently held by an underground barrier from descending to the level of the much lower ground west of the railroad.

About 3 miles south of Jake's section house, NE. ¼ sec. 28, T. 9 S., R. 9 E., on a sloping surface far above the dry arroyo a short distance northwest, there is a shallow excavation in similar yellow sandstone which is nearly filled with ground water that could be brought to the surface by a gravity device. The water in this locality is evidently also held up by some underground structure.

Milagro Hill forms an effective ground-water barrier. Near the south end of the hill flood waters have cut into the igneous rocks a notch through which some of the impounded ground water escapes, forming Milagro Spring. In this vicinity the water level drops abruptly, being much higher east of the igneous sill or dike than west of it. In a shallow well sunk by Dr. G. Ranniger near the northeast corner of the SW. ¼ sec. 32, T. 9 S., R. 9 E., at the south end of Milagro Hill, water was found so near the surface that it was possible to conduct it by means of a siphon to the house at the foot of the escarpment. The siphon was used for some time, but because it filled with air and required frequent priming, it was abandoned and a windmill was used instead. In the hope of tapping the impounded water and obtaining an irrigation supply, Dr. Ranniger also extended a tunnel a considerable distance into the rock, but with the work done in 1911 only a small seep had been developed.

Several gravity devices are in use in the drainage basin of Three Rivers. At the ranch house of Senator A. B. Fall, in sec. 25, T. 11 S., R. 9 E., an infiltration ditch is in successful operation, producing a small but valuable supply. Along the Carrizozo road, sec. 13, T. 10 S., R. 9 E., a short ditch and pipe-line system, heading on the upstream side of an outcrop of igneous rock that blocks the underflow, produces a supply of hardly more than 1 gallon per minute. The shallow water at this latter point is also shown by a well situated near the bank of the arroyo a few rods above the ditch, in which the water stands only 5½ feet below the level of the stream channel. (See pp. 300–301.)

WELLS.

WELLS NEAR NORTH END OF YOUNGER LAVA BED.

Several wells have been sunk to depths of a few hundred feet in the vicinity of the north end of the younger lava bed. A few of these obtained small supplies of water, but others were unsuccessful.

A well belonging to J. B. French is situated in the rincon at the northwestern extremity of the younger lava bed, about 5,500 feet above sea level. A 6-inch hole drilled to a depth of 208 feet, passed through 15 feet of soil and clay, then through 3 or 4 feet of basalt, then through clay, sandy shale, and finally dense blue shale that persisted to the bottom. A small amount of water struck in a joint or seam between the depths of 88 and 105 feet, rose within 57 feet of the surface. To increase the yield a hole 4 feet in diameter was sunk to a depth of 102 feet and connected with the drilled hole, which was plugged at that level. The present yield of the combination well is reported to be 6 gallons per minute.

The well of John Pramberg is situated near the center of sec. 2, T. 7 S., R. 10 E., about 5,400 feet above sea level (Pl. VI, p. 26). It was dug to 50 feet and drilled from this depth through "soapstone" to a level 128 feet below the surface, where it entered sand that furnishes a small amount of water. It is not certain whether the shale and "soapstone" of the French and Pramberg wells belong to the Cretaceous, to the Carboniferous, or to an intermediate rock system, but the soft black-alkali water in the Pramberg (analysis, p. 270) indicates that the formation is probably Cretaceous. The water in the French well is of the hard, gypseous type found in the Carboniferous rocks and also in the upper beds of the Cretaceous system. (See pp. 268, 269.)

Between Pramberg's well and the north end of the younger lava bed there was at one time a rather deep well that is said to have yielded freely. Later another hole was drilled in the same locality to a reported depth of about 500 feet. This well is said to have struck seeps at depths of 90 and 220 feet, the water rising to a level 80 feet below the surface, but the yield was only about 200 gallons a day. Another well was drilled by Gallacher Bros. about 1½ miles east-southeast of Indian Tank (Pl. I, in pocket) and scarcely more than 5,500 feet above sea level. It was sunk to about 400 feet, passed through sandstone, shale, and perhaps other formations, and encountered a seep at the depth of 330 feet. The water is said to have risen considerably, but the yield was very small.

WELLS ON THE NOGAL ARROYO SLOPE.

Nogal Arroyo heads in the northern part of the Sierra Blanca, passes through the gap between that range and Tucson Mountain, and drains in a westward or northwestward direction to the younger lava bed, where its flood waters are impounded or flow southward along the edge of the lava. It is joined by an arroyo that emerges through the gap between Tucson and Carrizo mountains and by other storm-water courses (Pl. VI, p. 26). The region drained by this arroyo is a smooth waste-covered slope with isolated outcrops of Cretaceous beds and associated igneous rocks, the Cretaceous beds commonly dipping eastward (fig. 15, p. 68). The average thickness of the rock waste is probably not great. Several score of wells have been sunk on this slope, but most of them are shallow, and although the mantle of waste is in many places thin, only a few of the wells have reached bedrock.

Upstream from Walnut station Nogal Arroyo crosses numerous rock outcrops that produce conditions of shallow water. The ground water appears in springs at several points and is tapped by shallow wells that yield rather generous supplies of water of fair quality. (See analyses, p. 276.) A typical well of this vicinity is the dug well on the ranch of Joseph Vega, 1½ miles upstream from Walnut, which has a water level 31 feet below the surface, only slightly below the arroyo level, and more than 100 feet above the valley at Walnut. A good well was at one time in use at the power plant of the Vera Cruz mine, situated in the valley at the south end of Tucson Mountain, near Vera Cruz station and only a short distance above Walnut. No definite information was obtainable in regard to this old well. According to some reports it is only 50 to 85 feet deep, but according to others it was drilled deeper. The water rose practically to the surface and the supply was abundant, although the rate of pumping is not known.

In the vicinity of Walnut the arroyo passes through a valley about one-fourth mile wide in which the depth to water is less than 25 feet, but on both sides of this valley the land rises and the depth to water is greater. Two dug wells situated near the arroyo about one-third mile below Walnut have a water level 23 feet below the surface, or 6,043 feet above sea level. They are pumped with windmills and are said to yield an abundant supply of satisfactory water.

Farther downstream the water table remains near the surface along the arroyo, but exhibits some irregularities. In the first 2 miles below Walnut its depth increases gradually until it is nearly 50 feet below the surface, but in the next 5 miles its depth gradually decreases, being 47 feet in a well in the NW. ¼ sec. 12, 41 feet in a well in the SW. ¼ sec. 3, and 17 feet in a well in the NW. ¼ sec. 32 (Pl. VI). The dug well of Joseph George, NE. ¼ sec. 13, T. 8 S., R. 11 E., extends chiefly through clayey material, but ends at a depth of 52 feet in water-bearing gravel from which the water rises to a level 48 feet below the surface. The well is pumped by a windmill which at times of strong wind lifts 12 gallons per minute and fills a 50,000-gallon reservoir in 3 or 4 days. The dug well of Antonio Vega, in the NE. ¼ sec. 13, T. 8 S., R. 12 E., is 45 feet deep, has a water level 41 feet below the surface, and also furnishes water of fairly good quality. (Analysis, pp. 274–275.) Other wells in this vicinity are of the same character as the George and Vega wells, but none have been severely tested.

Several wells drilled along the branch arroyo that heads north of Tucson Mountain are deeper and reveal a considerable thickness of rock waste. In a few wells the water stands about 100 feet below the surface, but the depth to the water table decreases near the mountain. The well of Fred. La Lone, in the SW. ¼ sec. 1, T. 8 S., R. 11 E., is 106 feet deep, passes through 90 feet of clayey deposits, ends in 16 feet of sand and gravel, and has a water level 99 feet below the surface. In the well of F. J. Bright, near the southeast corner of the NE. ¼ sec. 1, in the same township, the water level is 102 feet below the surface. A well situated one-half mile east of Bright's well was dug through clay and bowlders to a depth of 76 feet and its water level is 72 feet below the surface, but the supply is so small that it is easily depleted by a windmill.

Below the shallow-water tract in the vicinity of sec. 32, T. 7 S., R. 11 E., the water table appears to drop abruptly to nearly 100 feet below the surface, and then gradually to reapproach the surface until on the west side of the railroad springs break out in the arroyos. West of these springs, in the vicinity of the lava, the depth to the water table is somewhat greater although generally less than 50 feet. In a belt extending several miles north of Nogal Arroyo (Pl. VI, p. 26) there are several dug wells which are generally less than 100 feet deep, do not reach far below the water level, and have not been severely tested.

SHALLOW WELLS IN THE VICINITY OF CARRIZOZO.

The slope on which Carrizozo is situated drains in part into Nogal Arroyo and in part to the edge of the lava through smaller draws farther south. It is underlain by eastward-dipping Cretaceous beds which in most localities are covered with a thin layer of rock waste. Many wells have been sunk in this vicinity, but they are nearly all less than 100 feet deep and only a few of them enter bedrock. As a rule, they are dug through clayey material into a flesh-colored calcareous hardpan. Most of them are pumped either by hand or by small windmills. They have not been adequately tested, but their yield is probably small. Since many of them extend only a slight distance below the normal water level they are likely to fail in dry seasons when the water level descends.

A dug well in the NW. ¼ sec. 8, T. 8 S., R. 11 E., 119 feet deep, ends in 9 feet of sandstone, which contains water that is not under pressure. The well of A. C. Wingfield, on the east side of Carrizozo, also enters sandstone. The drilled well of Mrs. M. L. Millican, in the NW. ¼ sec. 23, T. 8 S., R. 10 E., which is 127 feet deep, is reported to pass in succession through 60 feet of "concrete," 20 feet of pale yellow clay, 10 feet of blue clay, 10 feet of yellow and brown sandstone, 23 feet of blue "soapstone," 1 foot of "hard rock," and 3 feet of soft sandstone. The strata below the depth of 90 feet are probably Cretaceous. A little water was struck in the concrete and somewhat more in the sandstones, but the yield is not sufficient to supply the windmill that is used in pumping the well. The water stands about 80 feet below the surface. It is hard, but otherwise of satisfactory quality. (Analysis, pp. 274–275.)

The water from the shallow wells in the village of Carrizozo is used for live stock, but most of it is too highly mineralized to be desirable for drinking or domestic purposes. The water from many of the farm wells is much better. (See pp. 154–155 and analyses, pp. 270–279.)

CARRIZOZO RAILROAD WELLS.

Several wells were drilled at Carrizozo by the railroad company, the deepest of which was 1,125 feet. The sections of three of these wells, as reported by three different drillers (fig. 32), do not agree closely and are probably inaccurate in many details, but they furnish evidence that Cretaceous formations were entered between the depths of 50 and 100 feet and persisted throughout most of the rest of the distance penetrated. These formations consist chiefly of alternating beds of soft shale and sandstone, most of the water being found in the sandstone.

Well No. 2, completed in 1903, found water at 41 feet but was carried to a depth of 161 feet where it ended in sandstone. It was drilled 12⅝ inches in diameter and was provided with 40 feet of 9⅝-inch casing. The water level is reported to be 35 feet below the surface, or 5,405 feet above sea level. With the cylinder set 60 feet below the surface the well was pumped at the rate of 50,000 gallons in 24 hours, or about 35 gallons a minute. The water is hard but of much better quality than the water in the shallow wells at Carrizozo. (See analysis, pp. 272, 273.)

Well No. 1, drilled in 1901 to a depth of 895 feet, is 12 to 8½ inches in diameter and was finished with 40 feet of 10-inch and 300 feet of 7⅝-inch casing, both strings of casing being hung from the top. The well was drilled through numerous beds of sand and sandstone and ends in a thick deposit of sand. The water level in the completed well is reported at 90 feet below the surface. With the cylinder 400 feet below the surface the well was pumped at the rate of 75,000 gallons in 24 hours, or approximately 50 gallons a minute. According to the analyses (p. 272) the water is of entirely different character from that in the 161-foot well (No. 2). It contains little calcium or magnesium but much sodium together with the sulphate, chloride, and carbonate or bicarbonate radicles. It is a soft, saline, black-alkali water, which may produce a mild cathartic effect. In boilers it may foam but will not form much scale.

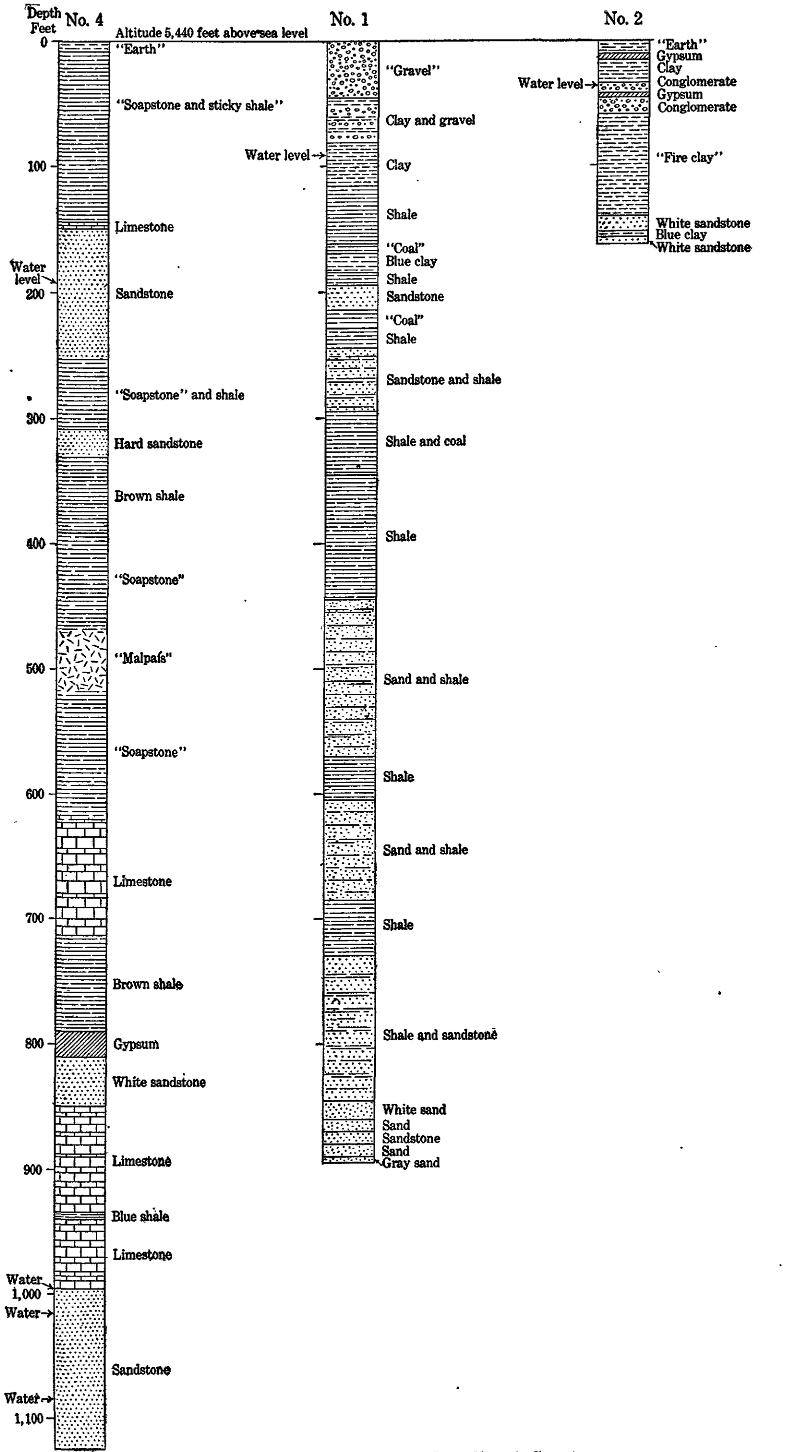


FIGURE 32.—Sections of railroad wells at Carrizozo.

The 1,125-foot well, known as No. 4 and drilled in 1906, is 17 to 10 inches in diameter and has 110 feet of 12-inch casing and 924 feet of 10-inch casing extending from the top. It was drilled through muck shale and sandstone and ends in a thick bed of water-bearing sandstone. A 50-foot layer of igneous rock was reported at about 500 feet and thick beds of limestone at greater depths. The water level in the completed well is reported to be 193 feet below the surface, and the tested capacity is reported at 75,000 gallons in 24 hours, or an average of about 50 gallons a minute. An air lift was used in this well, the air pipe extending to a depth of 1,005 feet. The water is of the same type as that in the 161-foot well (No. 2), but contains only about one-half as much mineral matter. (See analysis, p. 272.)

WELLS IN THE VICINITY OF POLLY.

The land in the vicinity of Polly forms a sloping plain which is underlain by Cretaceous beds that outcrop in certain ridges but are in most places covered with rock waste. A number of wells have been sunk on this plain, a few of which end in unconsolidated sediments, but most of which had to be drilled some distance into bedrock in order to obtain water.

The well of A. F. Roselle, NE. ¼ sec. 19, T. 8 S., R. 10 E., which is 6 inches in diameter and uncased, was sunk to a depth of 170 feet, the drill passing in succession through 70 feet of clayey deposits, 10 feet of yellow sandstone, 15 feet of blue clay, and 75 feet of yellow sandstone. Hard but otherwise good water was struck at a depth of about 160 feet and rose to a level 128 feet below the surface. (See analysis, p. 274.) The yield has not been tested.

The well of D. L. Bryon, SW. ¼ sec. 19, T. 8 S., R. 10 E., which is 6 inches in diameter and cased to the bottom, appears to end above bedrock at a depth of 163 feet. The water, which is rather highly mineralized but is used for drinking, stands about 123 feet below the surface and is believed to be ample in quantity to supply a pump operated by a windmill.

The drilled well of M. W. Beagle, NE. ¼ sec. 25, T. 8 S., R. 9 E., which is 115 feet deep and in which the water stands 105 feet below the surface, is reported to end in gravel but to yield only a small supply.

WELLS AT WHITEOAKS.

The village of Whiteoaks was not visited, but a number of dug and bored wells are reported in that vicinity, ranging from about 60 to 240 feet in depth. The ground water is so highly mineralized that rain water collected in cisterns is commonly used for drinking and for domestic supply.

SHALLOW WELLS IN THE VICINITY OF OSCURO.

The Oscuro settlement is situated on a plain that slopes from the Godfrey Hills toward the younger lava bed with an average grade of approximately 100 feet per mile, but is separated from the lava bed by the Phillips Hills and Bull Gap Ridge, and is partly divided into an upper and a lower portion by Milagro Hill. It is underlain by eastward-dipping Cretaceous strata and by dikes and sills of igneous rock that are imperfectly concealed by a veneer of stream-deposited rock waste. Nearly 40 wells have been sunk on this slope, some of which are shown on the map forming Plate VI (p. 26). A few of these wells end in the unconsolidated sediments, but most of them have been drilled into bedrock and derive their supplies from Cretaceous sandstones. If it were not for the dams produced by the impervious igneous and sedimentary beds the ground waters would be drained to much lower levels and it would probably be as difficult to obtain wells in this region as on the Carboniferous uplands north of Carrizozo. The underground dams produce irregularities in the water table; but since many of them are entirely concealed by rock waste, there may be nothing on the smooth, evenly inclined surface to suggest such irregularities.

The well of George Castle, NE. ¼ sec. 21, T. 9 S., R. 9 E., is 7 inches in diameter and 175 feet deep and is cased only near the top. The water normally stands about 30 feet below the surface and is said to be lowered to a level 48 feet below the surface when the well is pumped at the rate of 50 gallons a minute. The plant was not seen in operation, but a test of 90 gallons a minute for several hours' continuous pumping is reported.

The well of A. Gschwind, NW. ¼ sec. 28, T. 9 S., R. 9 E., is 7 inches in diameter and 130 feet deep, and below the depth of 10 feet passes through alternating beds of sandstone and blue shale. Water was struck in sandstone at depths of 80 feet, 96 feet, and 115 feet, the water from the lowest level rising within 70 feet of the surface. The well is reported by the owner to have been pumped 56 hours continuously at the rate of 18 gallons a minute and 4 hours continuously at 25 gallons a minute without noticeable effect on the supply. As shown by the analysis (p. 276), the water is hard but of good quality for irrigation.

Two wells, respectively 67 and 108 feet deep, have been drilled on the farm of E. F. Jones, SE. ¼ sec. 31, T. 9 S., R. 9 E., one-half mile east of Oscuro. In the 67-foot well, which is 8 inches in diameter and cased to a depth of 20 feet, water struck at 42 feet rose to a level 35 feet below the surface, or about 150 feet above the water level in the wells at Oscuro. At first the well showed signs of weakening when the pump was operated at 25 gallons per minute, but recently it is reported to have been pumped for several hours at this rate with the cylinder only 2 feet below the water level. The 108-foot well, which is 7 inches in diameter, is situated near the 67-foot well, but apparently does not tap the same supply. Water is reported to have been struck in it at 97 feet and to have risen within 33 feet of the surface, but the quantity is so small that even with the cylinder 70 feet and the end of the suction pipe 90 feet below the surface the well will not continuously supply the windmill by which it is pumped. The water is of satisfactory quality for irrigation, as is shown by the analysis (pp. 276–279).

The well of Robert Young, SE. ¼ sec. 5, T. 10 S., R. 9 E., which is 158 feet deep and cased to a depth of 130 feet, has been pumped at a rate of a little over 20 gallons a minute. Since the cylinder is set in the casing the water level could not be ascertained, but it is probably about 80 feet below the surface. As shown by the analysis (p. 278), the water is mineralized to an extent that is unusual in wells in this vicinity, but comparable to that of the shallow water in Carrizozo.

The well of Anthony Borovansky, NE. ¼ sec. 9, T. 10 S., R. 9 E., which is 8 inches in diameter and 171 feet deep, passes through about 40 feet of gravel and clay and then through layers of shale, sandstone, and igneous rock, receiving water at depths of 134, 160, and 165 feet. The water rose to a level 108 feet below the surface, which is somewhat below the water level east of Milagro Spring, but approximately 140 feet above that in the Jones wells and nearly 300 feet above that in the wells at Oscuro.

The well of E. G. Raffety, situated on the west side of the railroad in the village of Oscuro, had reached a depth of about 200 feet at the time the region was visited in 1911, and was cased to a depth of 70 feet, the principal supply of water coming from 135 feet. The water stood 99 feet below the surface, or about 4,905 feet above sea level. The yield had not been tested. As is shown by the analysis (p. 276), the water belongs to the soft Cretaceous type.

OSCURO RAILROAD WELLS.

The two wells at Oscuro, respectively 489 and 965 feet deep, are among the few railroad wells in this part of the State that are still used for locomotive supplies. As in the Carrizozo wells, the materials penetrated were somewhat differently interpreted by the different drillers, but the reported sections, as given in figure 33, agree in showing a series consisting chiefly of alternating beds of soft shale and sandstone that probably belong entirely to the Cretaceous system.

The 489-foot well, completed in 1903, was drilled 10 inches to 7½ inches in diameter and cased to a depth of 136 feet with 7⅝-inch pipe. Water was found at 275 feet and no doubt at other horizons, and is reported to stand at a level 128 feet below the surface, or 4,890 feet above sea level. With the cylinder set 352 feet below the surface the well was pumped at a rate of 100,000 gallons in 24 hours, or an average of nearly 70 gallons a minute, but according to J. H. Kimmons, who is in charge of the plant, the maximum yield is at present less. As shown by the analysis (p. 276), the water is of the same type as that in the 895-foot well at Carrizozo, though its total mineral content is only about one-half as great. It is soft, black-alkali water that will not deposit much scale, but tends to foam somewhat in boilers.

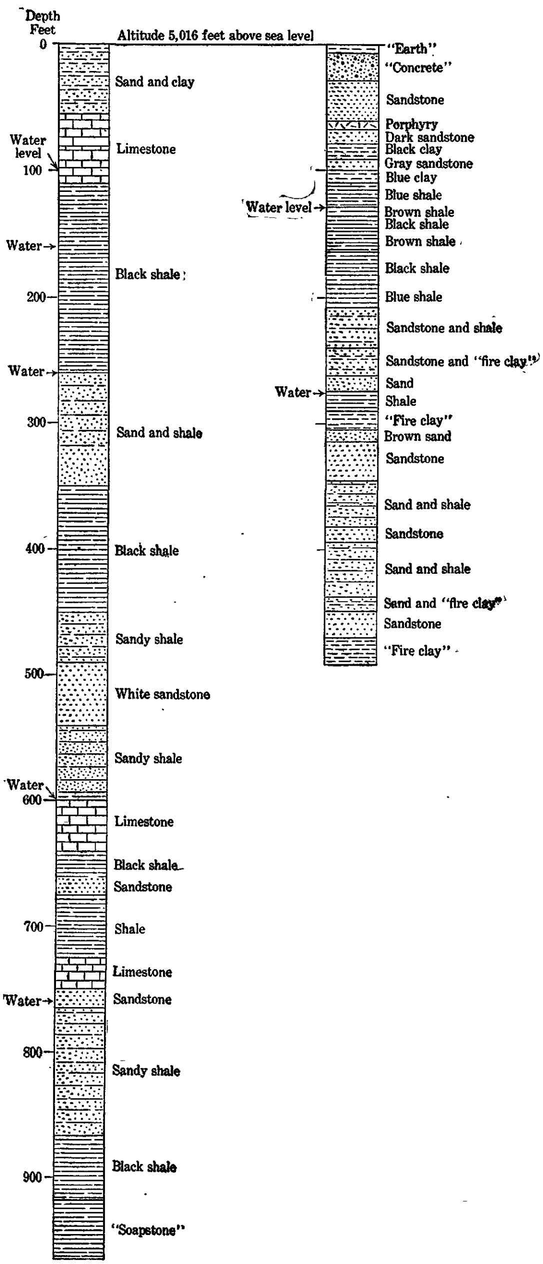


FIGURE 33.—Sections of railroad wells at Oscuro.

The 965-foot well, drilled in 1906, has a bore ranging from 16 to 10 inches in diameter, and two strings of casings both hung from the top, one 13 inches in diameter and 55 feet long, the other 10 inches in diameter and 490 feet long. Water was struck at various levels, as is shown in Plate XXI, but the largest supply is said to come from the sandstone at 750 feet. The water level in the completed well is about 100 feet below the surface, but the water from the 750-foot bed is reported to have risen within 60 feet of the surface. With the pump cylinder set at a depth of 650 feet, the tested capacity of the well is 100,000 gallons in 24 hours. At present the two wells are usually pumped at a combined rate of 115 gallons a minute. The water is soft and is charged with hydrogen sulphide, the sulphureted supply coming mainly from the 750-foot horizon. (See analysis, p. 276.)

WELLS IN THREE RIVERS VALLEY.

Shallow water is found in a large part of the open valley drained by the different branches of Three Rivers above the Palisades and along the main stream to within a short distance of Three Rivers station. A number of shallow wells have been sunk in this valley, most of which have been used only for domestic or live-stock supply, and have therefore not been severely tested. As in the other Cretaceous areas, the underflow is repeatedly returned to the surface by the rock formations that act as barriers. In certain localities, where water is found in coarse sediments above bedrock, supplies adequate for irrigation can probably be developed. As shown by the analysis (p. 278), the water is as a rule not very highly mineralized and is of good quality for irrigation.

Several wells recently sunk on the ranch of Senator A. B. Fall have been given rather severe tests. A well in the NE. $\frac{1}{4}$ sec. 13, T. 11 S., R. $9\frac{1}{2}$ E., consists of a vertical shaft and a horizontal tunnel, both walled with timber. The shaft is 50 feet deep and has a cross section 5 feet square; the tunnel is 100 feet long and connects with the shaft at the 33-foot level. The material excavated consists of coarse stream deposits with numerous bowlders. The water level is 8 feet below the surface and is said not to have changed materially in dry seasons. Pumping with a centrifugal pump at the rate of 500 gallons a minute is reported to have lowered the water to the level of the tunnel, 33 feet below the surface. In a later test only 300 gallons a minute were obtained, but it was not certain whether this diminution was due to decreased supply or to an imperfect condition of the pump. Senator Fall states that after pumping the well for several days the water stood 2 or 3 feet below its former level and did not recover its normal position for some days.

Another well, 5 by 5 feet in cross section and 50 feet deep, was sunk at a point several hundred feet from the well just described. Its water level is 8 feet below the surface and it is reported to have been tested at the rate of 150 gallons a minute. A large hole excavated in the same locality was originally intended as a reservoir, but ground water was struck near the surface and the hole was therefore extended about 15 feet below the water level and is to be used as a source of supply. It has been pumped at the rate of 150 gallons a minute.

Five wells, each 10 inches in diameter and 100 feet deep, have been drilled at Senator Fall's ranch house, E. ½ sec. 25, T. 11 S., R. 9 E. One is centrally located and the others are 30 feet from it, one in each cardinal direction of the compass. The central well has a dug pit 22 feet deep and is to contain a centrifugal pump that will draw simultaneously from all the wells. This well and three of the other wells struck water at 22 feet, penetrated a bed of gravel at 48 feet from which the water rose within 14 feet of the surface, and below the gravel passed through weathered shale that also bears some water. They had not been tested at the time the region was visited except that one of them had been bailed at a rate of about 15 gallons a minute. A striking example of the irregular occurrence of the ground waters in this area is afforded by the fact that the fifth well failed to find gravel, yields a very small supply, and has a water level 38 feet below the surface.

WATER-BEARING CAPACITY OF ROCKS.

The Cretaceous rocks consist chiefly of alternating beds of shale and sandstone. The shales yield little water; the sandstones furnish supplies adequate for ordinary purposes to nearly all wells that have been drilled into them, but their capacity for irrigation supplies has not been fully tested. The railroad wells at Carrizozo were given only moderate tests, and there is no record as to the effect of these tests on the water level. The data in regard to the railroad wells at Oscuro are likewise indefinite, but in the 489-foot well the water level appears to be greatly lowered by even a slow rate of pumping. According to the reported tests Castle's well yields about 3 gallons a minute for every foot that the water level is lowered and Jones's 67-foot well yields somewhat more, but some of the farm wells yield less. Developments thus far made indicate that only small or moderate irrigation supplies can be obtained from wells deriving water from Cretaceous sandstones.

Since the Cretaceous beds have steep dips, are in some places broken by faults, and contain irregular bodies of intrusive rock largely concealed by rock waste, different strata will be penetrated by the drill in different localities and the section that will be encountered can not be accurately predicted. Over most of the area, however, beds of water-bearing sandstone will be found within the first few hundred feet of the surface, and if the water is not cased out the yield of wells will probably be somewhat proportional to the thickness of sandstone penetrated.

The existence of deep water-bearing sandstones along the railroad and farther east is indicated by outcrops and deep-well sections, but their yield would probably not be much greater than that of the sandstones nearer the surface. The shales encountered near the north end of the younger lava bed are probably older than the sandstones near the surface in the vicinity of Carrizozo and Oscuro. Whether they are underlain by water-bearing beds is not certain, but the conditions would seem to warrant further prospecting.

In some parts of the Cretaceous area the rock waste above the bedrock is dry or too thin or clayey to furnish more than a meager supply, but in other parts, such as the Three Rivers Valley and the upper reaches of the Nogal Arroyo slope, it is sufficiently coarse and porous to furnish valuable irrigation supplies.

WATER LEVELS AND ARTESIAN HEAD.

The conditions determining the water levels in the Cretaceous area have already been alluded to and can be briefly summarized as follows: The ground water is derived chiefly from the mountains on the east side of the basin and moves westward or southwestward in the general direction of the surface slope (Pl. VI, p. 26). The Cretaceous rocks consist of alternating pervious and impervious sedimentary strata that dip toward the mountains and are intruded by masses of impervious igneous rock. The impervious beds form a series of underground dams that follow the strike of the rocks and lie athwart the course in which the ground water is moving. The ground water has adjusted itself to these dams in much the same manner as the water of a stream adjusts itself to artificial dams or natural barriers in the course of the stream. Like a vast stream of exceedingly slow motion it descends through the pervious strata from the mountains to the lowlands in reaches and rapids. Back of each dam the water is impounded in a reservoir composed of porous beds and the water table has only a slight gradient, but at the dam the reservoir overflows and the water cascades, as it were, to a lower level, where it is impounded in the same manner by the next dam in the series. Some of the barriers are visible at the surface but most of them are concealed beneath a smooth plain, and their presence can only be inferred from the irregularities in the water table that are discerned when wells are sunk (fig. 31, p. 140).

The numerous irregularities of the water table make it impossible to predict confidently the depth to water in any locality where there are no springs or wells. The water table has, however, been found to be less than 100 feet below the surface over large parts of the Cretaceous area (Pl. VI, p. 26), and it probably occurs at less than this depth in most of the area except on the mountains, the large ridges and hills, and the upper parts of the débris slopes bordering the mountains.

The total area of land in which the depth to the water table is less than 50 feet is difficult to estimate but appears to be approximately 60 square miles. The largest tract is formed by the Nogal

Arroyo slope, the region about Carrizozo, and the adjacent bottom lands near the younger lava bed, and the tract next in size is in the valley of Three Rivers. Between these two tracts there are many smaller areas in which the water stands less than 50 feet below the surface.

Nearly a score of small, detached, and widely scattered tracts are known in which the depth to the water table is less than 25 feet and others no doubt remain undiscovered. Their combined area, though not certainly determined, probably does not exceed 20 square miles. The largest shallow-water tracts are in the vicinity of Carrizozo and in the valley of Three Rivers.

The Cretaceous strata dip in the wrong direction to produce artesian conditions. In the deep well at Oscuro the water from the depth of 750 feet is said to have been under greater head than that from beds lying near the surface, but the water in the completed well does not stand above the normal water level of that locality. In the wells at Carrizozo the head varies inversely with the depth, the water standing farthest below the surface in the deepest wells. Such decrease in head is probably due to the structure of the rocks, as may be seen by inspection of figure 31 (p. 140). A well drilled a short distance above the spring shown in this figure would have a high-water level until it reached the bottom of the ledge that forms the barrier, but it would then communicate with the body of water below the barrier and its water level would accordingly drop.

QUALITY OF WATER.

The water from most of the springs and wells of moderate depth is hard but of good quality for irrigation and fairly satisfactory for drinking and household use, but the water from the wells in certain localities, notably the immediate vicinity of Carrizozo, is too highly mineralized for drinking or household use and of doubtful character for irrigation.

The waters from the two railroad wells at Oscuro, Raffety's well at Oscuro, Braunstein's well southeast of Oscuro, the 895-foot railroad well at Carrizozo, and Pramberg's well north of Carrizozo differ in character from other waters found in this region. They are all soft, black-alkali waters, containing much sodium but little calcium or magnesium. They appear to come from the middle and lower parts of the Cretaceous deposits and are probably typical of much of the deeper Cretaceous water. The Oscuro waters are good for drinking, cooking, and washing and are fairly satisfactory for irrigation and for steam making, although they have a tendency to foam in locomotive boilers. The Carrizozo water is so rich in the sodium salts that it is undesirable except for laundry and toilet use, for which it is well adapted by reason of its softness.

The water from the 1,125-foot well at Carrizozo is of the hard gypseous type and probably comes in part from Carboniferous rocks beneath the Cretaceous. The water from the 161-foot railroad well at Carrizozo is also of the hard gypseous type, but is much better either for domestic use or for irrigation than any of the water that was analyzed from shallow wells in the village.

PROSPECTS.

The supply of ground water in the Cretaceous area is not large and the cost of developing and pumping this supply for irrigation will be rather heavy, but the conditions in many localities are such that if intensive methods are employed rather heavy costs for water can be borne by the farmer. (See pp. 210–223.) Since the cost both of sinking wells and of pumping increases with the depth to the water table, the most favorable localities for obtaining supplies for irrigation are where the water is near the surface, and developments should first be made in these localities. It seems probable that on a large proportion of the 250 quarter sections, more or less, in which water is within 50 feet of the surface, adequate supplies can be obtained to irrigate sparingly at least 10 to 20 acres. After a farmer has procured enough water on his land to render it self-supporting, he can from time to time add to his supply by sinking new wells.

Where the material to be penetrated consists of rock waste that contains many bowlders it may be necessary to sink wells by digging, but in general irrigation supplies will be more effectively and economically obtained by drilling. Portable, cable, percussion drilling machines capable of sinking 6-inch or 8-inch holes to depths of several hundred feet are well adapted for this purpose. Much of the work, especially in rock, can be done without casing, and if reasonable precautions are taken to keep the hole straight the drilling should proceed rapidly and with few mishaps. In any locality where shallow water is known to exist a test well should be sunk to a depth of several hundred feet, but deep drilling for irrigation supplies is not advisable. The driller sinking such a well should note the depth, thickness, and character of each water-bearing bed that is penetrated and especially the changes in the water level as the drilling proceeds. Pumping tests should also be made at successive depths. Since a single well will generally yield only a small supply for irrigation it will commonly be advisable to drill a series of wells. Proper observations made when the first well is sunk will generally serve as a guide for future drilling. If in the first well the yield was not considerably increased or if the head was lowered by the last part of the drilling it may be advisable to finish the other wells at less depth.

A series of wells can be pumped by different methods. If the water table is near the surface of the ground and above the rock surface, a hole a few feet in diameter can be sunk to the water level or a little deeper, and this hole can be connected at the bottom with the other wells by means of tunnels or open ditches. A centrifugal pump, driven by gasoline engine or other power, can then be installed at the bottom of the dug hole and can be connected with suction pipes extending into the different wells. Such an installation is rather expensive because of the cost of the tunnels, but it affords a relatively inexpensive and satisfactory method of pumping. Another method is to put a deep-well cylinder pump into each well and to operate these pumps either separately or from a single source of power. The cylinder pumps have a fairly high efficiency if kept in good repair but they require considerable attention. To have a small gasoline engine at each pump would be expensive both for installation and for operation; to have a single larger engine mechanically connected with all of the pumps would probably be more economical if great care were taken to prevent undue loss of energy in transmission. Where the supply must be obtained from a group of wells not easily connected and each yielding a relatively small amount of water windmills can be used to special advantage, one mill being set over each well. To avoid serious interference, the wells should be at least 30 feet and preferably 50 to 100 feet apart.

Infiltration ditches and tunnels can be constructed in many localities, and may in some places give good results, but these devices are generally expensive and are rarely under sufficient head to produce much water. Generally more water can be developed with the same expenditure by drilling wells. Before beginning the construction of such a ditch one or more shallow test wells should be sunk in the locality from which the supply is to be drawn in order to ascertain the thickness of the barrier, the available head and the water-bearing capacity of the formation in which the supply is to be developed. The lower part of a ditch passes above the water level and will lose by seepage unless it is made waterproof. The flow may be so small and the seepage so great that no water will reach the mouth of the ditch.

Deep drilling may be undertaken for the purpose of obtaining softer water than is furnished by the shallow beds, but deep prospecting for flowing water or other irrigation supplies seems inadvisable. At Carrizozo better water could be obtained by drilling even moderate depths into the sandstone.

WATER IN CARBONIFEROUS ROCKS AND OVERLYING SEDIMENTS.

AREA AND PROBLEMS.

Carboniferous rocks, several thousand feet thick, underlie almost the entire northern plateau section of Tularosa Basin, and comprise the largest parts of most of the mountain ranges (Pl. XVII). They also underlie portions of the Chupadera Plateau and the Mesa Jumanes outside of this basin, occur in the mountains west of Estancia Valley, and form the extensive upland that is bordered on the west by Tularosa Basin and the Estancia Valley and on the east by the Pecos Valley. Since these vast upland areas are in large part destitute of streams, the question of obtaining water for domestic, live stock, and railroad supplies from the Carboniferous rocks has for years been one of vital importance. Failure to find adequate supplies has left large parts of the region uninhabited and has made necessary the hauling of water for great distances, as along the Belen cut-off of the Atchison, Topeka & Santa Fe Railway, or the construction of costly pipe lines, as along the El Paso & Southwestern Railroad. (See p. 224.)

The problem involves both the quantity and quality of water. Many rather deep holes have been drilled without finding any water or without finding enough to be of practical value, and there is general uncertainty whether the absence of water is due to imperviousness of the rock or to a low water level. Most of the water that has been found is so hard that it is undesirable for domestic or locomotive use and in a few wells it is salty.

In the following pages the detailed data in regard to the principal springs and wells are given first, after which the general conditions and prospects are considered. The discussion is not restricted to Tularosa Basin, but covers the entire plateau region of central New Mexico, which in regard to underground waters may be considered a unit. The well sections given in Plate XIX and figures 34 to 39 are compiled from drillers' logs and are probably inaccurate in many details.

SPRINGS.

The Carboniferous rocks give rise to large springs in the Sacramento Mountains and to a number of smaller ones in the San Andreas Mountains, but to only a few weak, widely separated seeps or springs in the Jicarilla, Gallinas, and Oscuro ranges and the Chupadera Plateau. They also give rise to large springs in the Manzano Mountains, west of Estancia Valley. The plain north of the lava beds is wholly destitute of springs, and the extensive Carboniferous uplands northeast of Tularosa Basin are also without springs except at a few of the isolated rock outcrops such as the sandstone ledges at Williams's ranch northwest of Vaughn.

The largest springs in the Sacramento Mountains are those that supply Tularosa River, the principal ones being situated at the head of the stream, about 4 miles above the Mescalero Indian Agency, at a point in the main canyon three-fourths of a mile above the agency, and at a point in the North Canyon about one-half mile above the agency. According to measurements made by H. F. Robinson, engineer of the Indian Service, during 1906, these three groups of springs furnish more than one-half of the water of Tularosa River, or about 5,000 gallons per minute. At the largest springs the water flows from definite solution passages in the limestone. According to Mr. Carroll, formerly superintendent of the agency, the records of stream flow show that there are practically no seasonal fluctuations in the discharge of the springs and only slight fluctuations from year to year, but that in spite of deficiency in precipitation, there has been a gradual increase in flow from 1906 to 1911 amounting to 1 or 2 second-feet. These springs are supplied from the water that falls as rain and snow on the Sacramento Mountains at higher levels, percolates through the ground, collects in the void spaces of limestone, and is fed to the springs through more or less definite channels. The underground reservoir is probably large and deep and the amount of water stored in it so great that its water level and the consequent yield of the springs is only slightly affected by fluctuations in precipitation. In a deep-seated underground water system the effects of fluctuations are transmitted with great lag and it therefore seems possible that the increase in the discharge of the springs may follow from the heavy precipitation preceding the dry years.

The springs a short distance above the agency have deposited great quantities of calcareous material across the valley, thereby impounding the drainage and producing a peat bog of considerable extent (Pl. XVIII, *A*). Seepage from the bog, escaping through the travertine dam, gives rise to a small spring that has a strong odor of hydrogen sulphide and has deposited in its channel a beautiful coat of white sulphur, obviously derived from the vegetable matter of the bog.

WELLS.

WELLS IN THE TRANSMALPAIS HILLS.

The hill country west of the younger lava bed contains no wells except Phillips's well, several miles southwest of the Cerros Prietos, Lee's well, near the upper crossing, and several abandoned holes. There are, however, a few shallow wells farther west, in the foothills of the Oscuro Mountains.

A. VALLEY OF TULAROSA RIVER, SHOWING AGGRADATION PRODUCED BY TRAVERTINE DAM.

B. SHOEMAKER'S FLOWING WELL, WITH CERRITO TULAROSA IN BACKGROUND.

A well recently drilled by E. E. Phillips in a draw west of the old lava bed and about 8 miles west-southwest of Duck Lake (Pl. I, in pocket), is 732 feet deep, 6 inches to 4½ inches in diameter, and cased to the bottom. According to the driller's log, it passes through sandstone, limestone, and shale, as shown in figure 34, and ends in a bed of "quicksand" and gravel. The strata are probably all Carboniferous, and at the surface are seen to dip southeastward. A little water was struck at about 300 and 500 feet below the surface, but the first supply of any consequence was found in the sandy bed at the bottom. The water rises but slightly above the top of this bed and apparently does not stand higher than 5,100 feet above sea level, or distinctly below the water level in French's well and the wells at Carrizozo. In October, 1911, a pump had not yet been installed, and the yield of the well was not definitely known.

A well belonging to James Lee is situated on the west side of the younger lava bed, a short distance north of the upper crossing, on ground approximately 4,900 feet above sea level (Pl. I, in pocket). It is 152 feet deep, the upper 104 feet being a dug hole, and the remaining 48 feet a 6-inch drilled hole. It is reported to pass through gypsum, limestone, and "blue granite," and to end in sand, from which the principal supply is derived. The water stands about 90 feet below the surface, and the yield has been tested by pumping for 12 hours at the rate of about 5 gallons a minute.

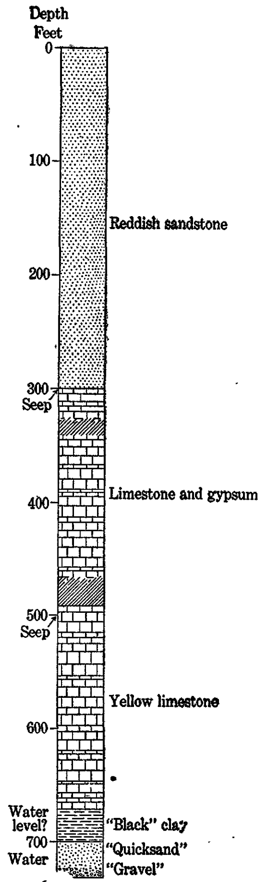


FIGURE 34.—Section of E. E. Phillips's well, west of Duck Lake.

A well was drilled near the west margin of the younger lava bed, about 4 miles south of Duck Lake (Pl. VI, p. 26), and at a somewhat lower level. It was carried to a depth of 235 feet, and at 210 feet is reported to have struck salt water that rose within 50 or 60 feet of the surface.

WELLS IN THE OSCURO FOOTHILLS.

Two dug wells, about 50 feet deep, are situated in an open draw on the ranch of Thomas McDonald, in Mockingbird Gap (Pl. I, in pocket), and extend through red detrital material overlying Carboniferous red beds. In November, 1911, they were filled with water within 21 feet of the surface, and they are reported to yield a permanent and rather plentiful supply. The accumulation of shallow water, which is known to exist along the draw for some distance above the wells, is apparently produced by impervious red beds that border the valley east of the wells and partly inclose it, the general depth to water in this region no doubt being great.

A drilled well 30 feet deep at the ranch of A. C. Mills, on sec. 13, T. 9 S., R. 6 E (Pl. I, in pocket), encountered water at 20 feet and near the bottom, and is reported to have been tested at the rate of 13 gallons a minute. Like the McDonald wells, it is situated near a stream course that leads southeastward and is in a region where the rocks dip in a general easterly direction. In the vicinity of this well the valley is crossed by an outcrop of limestone and shale beds tilted into an almost vertical position. The conditions favoring shallow water are local, the underflow of the dry run apparently being impounded by the rock ledges.

Several shallow wells at the Schole ranches, some miles north of Estey, were not visited, but are no doubt also dependent on relatively local conditions for their supplies. At the Red Canyon ranch the water stands so high that it is led to the surface by gravity.

A dry hole several hundred feet deep is said to have been drilled at Estey. At that point, as in other parts of the foothills east of the Oscuro Range, the ground water follows the eastward dip of the rocks to the lower levels of the basin, except as it is held by some special structure.

ANCHO RAILROAD WELLS.

A group of successful wells, formerly used for railroad supply, have been drilled in Ancho Arroyo, about 2 miles upstream from the village of Ancho. Heavy beds of limestone and gypsum having the characteristic appearance of the Carboniferous rocks of this region outcrop in the vicinity of Ancho. Near the village they lie almost horizontal, but farther upstream they dip eastward. The outcropping formations in the vicinity of the wells are yellow, red, and drab sandstones and shales with a steep northeastward dip. Between Ancho and the wells a quartz diorite dike cuts the sedimentary beds and extends across the arroyo. The sections of three of the wells of this group are shown in figure 35. The upper few hundred feet of rocks penetrated consists of shales and sandstones of uncertain age, but the deeper beds, reached in the 855-foot well, consist of gypsum, red clay, and red sandstone that undoubtedly belong to the Carboniferous system.

The well known as No. 5, completed in December, 1903, is 215 feet deep and is cased with $9\frac{5}{8}$-inch pipe from top to bottom. The first water was struck in sandstone at 134 feet, and the water level in the completed well is reported at 128 feet below the surface. With the

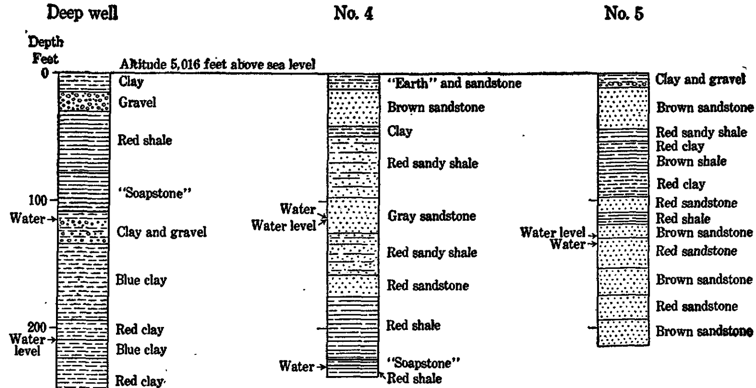
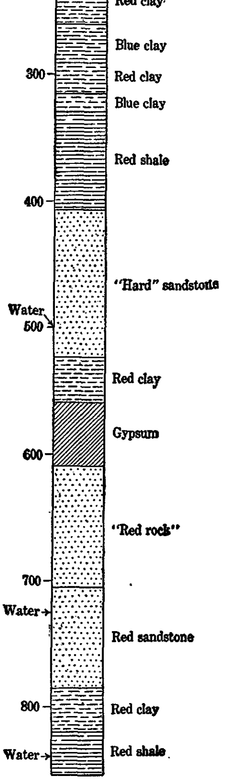



FIGURE 35.—Sections of railroad wells near Anchc.

pump cylinder near the bottom, the well has been tested at 29,000 gallons in 24 hours. or about 20 gallons a minute.

Well No. 4, completed in November, 1903, is 238 feet deep and has 220 feet of 7⅝-inch casing, of which 160 feet is perforated. The water level is reported at 114 feet below the surface, and the tested capacity, with pump cylinder 214 feet below the surface, at 63,000 gallons in 24 hours, or about 44 gallons a minute.

The 855-foot well, completed in January, 1907, and provided with 712 feet of 6⅝-inch casing, has a water level about 210 feet below the surface. No definite test has been made, but with the cylinder 650 feet below the surface the yield is fairly abundant.

The water tapped by these wells, especially the shallower ones, is more or less local in occurrence, as in the Cretaceous area. The water from the Jicarilla Mountains, in which the arroyo heads, is apparently prevented from sinking or percolating downstream by the impervious shale beds, which alternate with porous beds and which, by dipping in an upstream direction, form a series of underground dams. The dike some distance below the wells may also have a part in holding the ground water. It is significant that the head of the water in the shallow beds is higher than that of the deeper ones. In well No. 1, which is one of the shallowest, the water level was found in November, 1911, to be only 97 feet below the surface; in the deep wells on the same day a 165-foot tape failed to reach water. As nearly as could be ascertained the head ranges between about 6,000 and 6,100 feet above sea level.

Two analyses reported by the railroad company are given in the table (p. 268), one of water from the shallow wells and the other of water from the deep well. These analyses do not differ greatly from each other, and both indicate water of only moderate permanent hardness.

WELLS WEST OF ANCHO.

Many holes several hundred feet deep have been drilled on the plain west of Ancho. Most of them were abandoned without obtaining a supply, but a few struck water and have made successful wells. Water does not occur at concordant levels in different localities. Comparatively deep, dry holes are found not far from shallower wells containing water, although there may be nothing at the surface to indicate a difference. The irregularity in the occurrence of the ground water appears to be due to rock structures, such as dikes and dipping sedimentary beds, which in certain places hold the water that would otherwise sink to great depths, but these structures are so generally concealed that they can rarely if ever be used as guides in drilling.

A 6-inch drilled well on the old J. B. French ranch, 6 miles southwest of Ancho and nearly a mile west of the railroad (Pl. I, in pocket), is 166 feet deep, and ends in white sandstone. The water was struck about 160 feet below the surface and rose to a level of about 154 feet below the surface, or about 5,600 feet above sea level. The well has recently been pumped at 22 gallons a minute.

A 6-inch drilled well 150 feet deep is situated on the Horace French ranch, about one-half mile east of Largo switch (between Ancho and Coyote, Pl. I, in pocket), where the surface altitude is about 5,950. The well is cased to the bottom, and its maximum yield is reported to be 8 gallons a minute. Between this well and the railroad, at nearly the same elevation, a dry hole several hundred feet deep was at one time drilled.

Two drilled wells are situated at Warden's ranch, sec. 17, T. 4 S., R. 11 E., approximately 6,000 feet above sea level. One well is at the bottom of a rather deep depression; the other is near the edge of this depression on ground about 25 feet higher. Both wells pass through red sandstone and shale and through gray limestone. The lower well is reported as 196 feet deep, with water level 135 feet below the surface, maximum yield 25 gallons a minute; the upper well is said to be 232 feet deep, with water level 215 feet below the surface, and tested capacity 40 gallons a minute. As in the Ancho railroad wells, the lower head is found in the deeper well.

Two drilled wells are in use on the ranch of James Cooper, situated between the J. B. French ranch and Warden's ranch, about 6,000 feet above sea level. Their yield was not ascertained, but one of them is reported to fail in dry seasons.

WELLS NEAR GRAN QUIVIRA.

Several shallow wells have been sunk at Dow's ranch about a mile west of the ruins of Gran Quivira. (See Pl. I.) They are situated approximately 6,400 feet above sea level in a small sand-covered basin that seems to have no outlet. The well at present in use was dug to a depth of about 80 feet through clay and gravel and was cased with cedar logs. It is said to yield only a few barrels of water in a day. In October, 1911, its water level was 73 feet below the surface. Another dug well, similarly cased, is situated one-eighth mile farther south and on ground 8 feet lower. It is only 24 feet deep, and its water level is 23 feet below the surface or 40 feet above the water level in the first well. The water tapped by these wells is apparently a small perched supply far above the general water table and is not so heavily mineralized as most of the water from the Carboniferous rocks. According to an indefinite report a hole about 800 feet deep was drilled on the upland north of Gran Quivira without finding water.

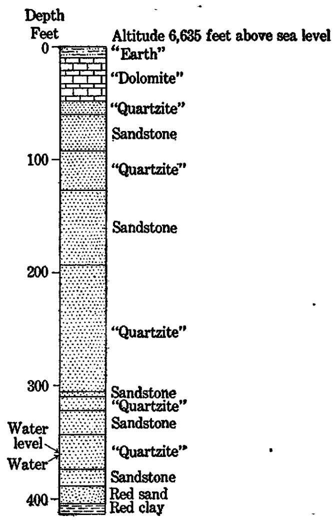


FIGURE 36.—Section of railroad well at Gallinas.

GALLINAS RAILROAD WELL.

A 10-inch uncased well, 414 feet deep, was drilled at the station of Gallinas in 1903. It passed through a great thickness of sandstone, as is shown in figure 36, and found water at a level 360 feet below the surface, or 6,275 feet above the sea, at which level the water stood in the completed well. The tested capacity is 100,000 gallons in 24 hours, or nearly 70 gallons a minute. The analysis (p. 268) shows that the water is so strongly gypseous that it could not well be used in boilers without softening, although it would be satisfactory for stock use.

WELLS BETWEEN GALLINAS AND VAUGHN.

A well 850 feet deep was drilled by the railroad company in 1904 at Varney switch, near milepost 199, between Corona and Torrance. As shown in Plate XIX, the formations through which the well passes are largely limestone, gypsum, and red shale near the top, but include sandstones at greater depths. The well was finished with 637 feet of 10-inch casing, of which 64 feet is perforated. The water level in the well is 357 feet below the surface, or 6,100 feet above the sea. The pump cylinder was placed 550 feet below the surface, and the well was pumped at the rate of 100,000 gallons in 24 hours, or about 70 gallons a minute.

A well 1,139 feet deep, drilled at Duran by the railroad company in 1906, passes through characteristic Carboniferous rocks, including red shale, limestone, gypsum, and some sandstone, as is shown in Plate XIX. Water is reported to have been struck at 500 feet and in several sandstones farther down and to have risen to a level 310 feet below the surface, or about 5,960 feet above the sea. With 8-inch casing inserted to the depth of 873 feet and the pump cylinder set 700 feet below the surface, the well was tested at 100,000 gallons in 24 hours, or about 70 gallons a minute.

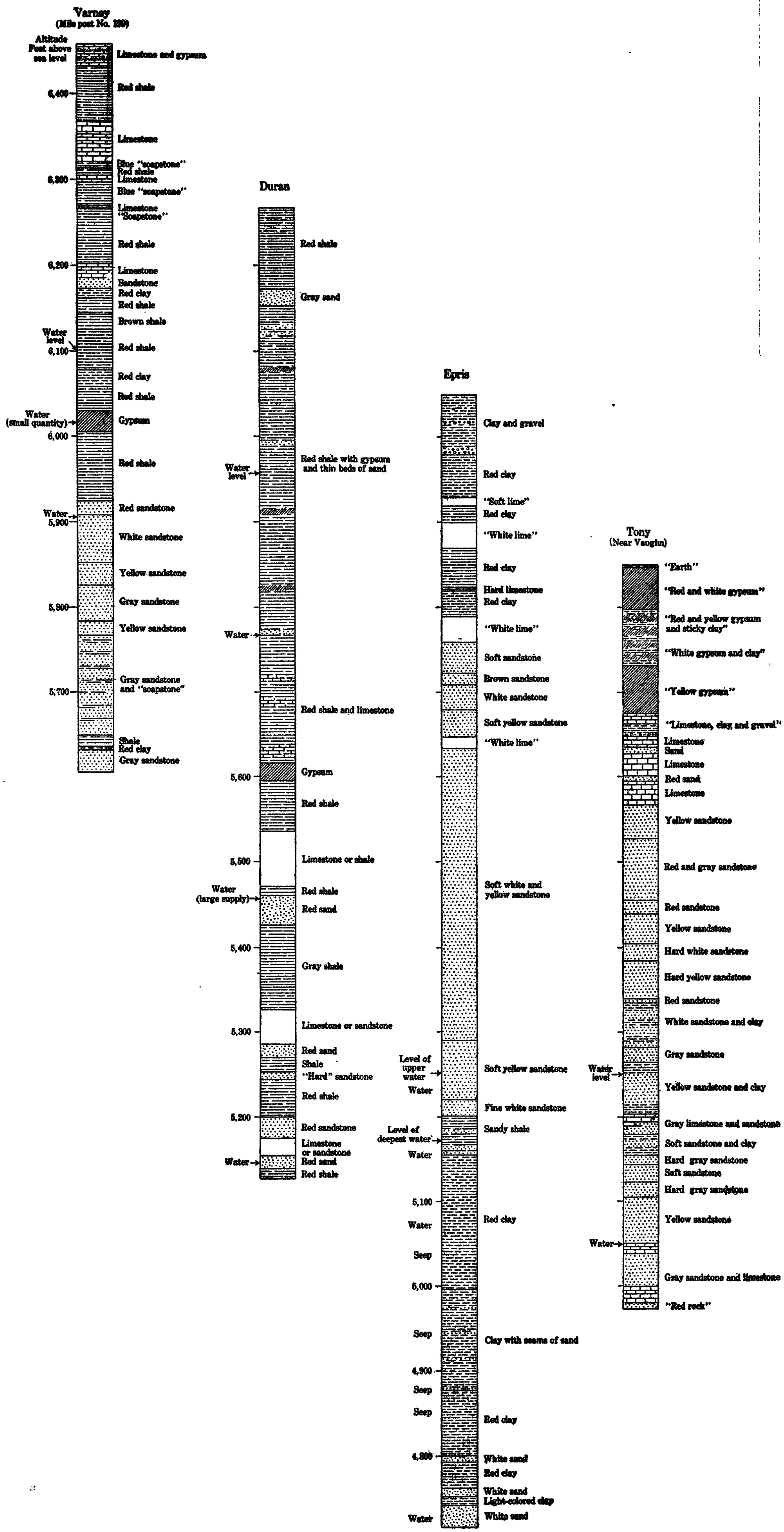
At Cedarvale there is a well 298 feet deep in which the water level is 174 feet below the surface, or about 6,250 feet above the sea, and other wells have been drilled on homesteads in that vicinity. In the vicinity of Torrance there are also a few wells. In the Pinos Wells and Encino basins shallow wells obtain water, and on the uplands between these basins and north and west of the latter, wells drilled into rock obtain water a moderate depths.[1] East of the El Paso & Southwestern Railroad, however, and in the region about Vaughn there has been little success in drilling for water.

As shown in the analysis given on page 304, the water in the Varney well is very gypseous but not otherwise excessively mineralized. Although unfit for boiler supplies, it can safely be used for watering live stock. The water in the Duran well, as shown by the analysis, is also very gypseous and in addition contains a large amount of sodium.

WELLS IN THE VICINITY OF VAUGHN.

Deep wells have been drilled in the vicinity of Vaughn by both railroad companies and by the municipality. The sections of two of the El Paso & Southwestern Railroad wells are given in Plate XIX. One of these, situated at Tony, or the Vaughn passing track,

[1] For further information on the wells in and near Encino and Pinos Wells basins see Geology and water resources of Estancia Valley and adjacent parts of central New Mexico: U. S. Geol. Survey Water-Supply Paper 275, 1911.



SECTIONS OF RAILROAD WELLS AT VARNEY, DURAN, AND VAUGHN, N. MEX.

Based on driller's logs (?).

is about 870 feet deep; the other, situated at Epris, a short distance south of Vaughn, is 1,355 feet deep.

The 870-foot well, completed in March, 1906, is from 17 to 8 inches in diameter and is cased to a depth of 767 feet with 8-inch pipe. The pump cylinder was placed 840 feet below the surface, and in February, 1907, the well was tested at the rate of 12½ gallons a minute. The section includes large amounts of sandstone. The first water is reported at about 800 feet. In this well or a well of about the same depth at the same place the head is reported 600 feet below the surface, or about 5,250 feet above sea level, and the rate of pumping about 10 gallons a minute.

In the 1,355-foot well at Epris, which was completed in June, 1906, water was found as follows: A small amount at 820 feet, a supply of about 7 gallons a minute at 829 feet, other small supplies at 900 feet and 980 feet, and seeps of brine at several depths below 1,000 feet. According to the data furnished by the railroad company, the 829-foot water rose to a level 800 feet below the surface, or 5,250 feet above the sea, the 980-foot water to 900 feet below the surface, and the water from the sandstone near the bottom to 880 feet below the surface.

The water struck in these wells probably represents the permanent body of ground water underlying the plateau. Wells of less depth at Vaughn have failed to find water, and the sink holes near the town are unfavorable for the accumulation of shallow supplies. Small bodies of comparatively shallow water occur in certain localities, as at Monroe Williams's ranch, 8 miles north-northwest of Vaughn, where there is a seepage out of sandstone, and on sec. 1 or 2, T. 3 N., R. 16 E., where a well 218 feet is reported. Such shallow supplies have, however, been found only rarely, and except where they form springs their location can not be determined by surface indications.

The water from the Tony wells is very gypseous, but contains only a small amount of common salt. (See analysis, p. 304.) The 829-foot water in the Epris well is of the same character, being reported to contain 2,807 parts per million of total solids, of which 2,678 parts are incrustants. The waters found below 1,000 feet are of a different type, in that they are not only very hard, but also very salty. The water from the 1,330-foot level was found by the railroad chemist to contain 240,000 parts per million, or 24 per cent, of total solids—a concentration about seven times that of sea water and greater than the average concentration of the water of Great Salt Lake. Most of this immense mineral load consists of the readily soluble sodium salts, but calcium and magnesium are also present in great quantities as is shown by the fact that the incrustants are reported to be more than 11,000 parts per million, or about four times as high as in the strongly gypseous water from the 829-foot level.

RAILROAD WELLS AT PASTURA.

Two wells, respectively 341 and 857 feet deep, were drilled at Pastura railroad station. (See fig. 1.) The shallow well drilled in July, 1906, is 14 to 10 inches in diameter and is cased to a depth of only 100 feet. The materials penetrated consist largely of limestone and gypsum, but include a thick bed of sandstone near the bottom. (See fig. 37.) Water was reported in limestone at 200 feet and in gypsum at 290 feet, the head being 150 feet below the surface, or 5,135 feet above sea level. With the pump cylinder set 336 feet below the surface the well was tested at 100,000 gallons in 24 hours, or about 70 gallons a minute.

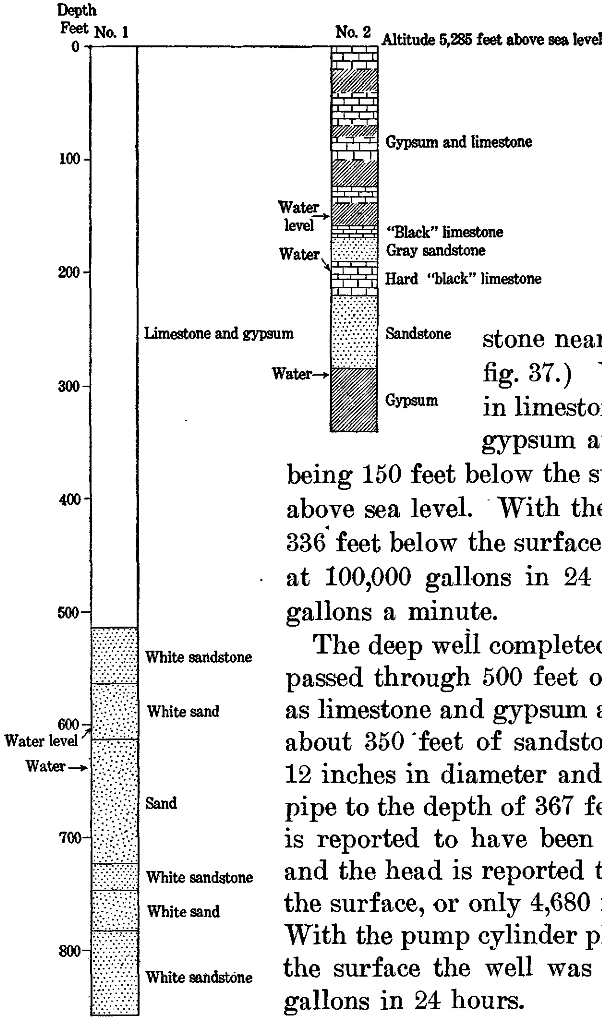


FIGURE 37.—Sections of railroad wells at Pastura.

The deep well completed in February, 1904, passed through 500 feet of material reported as limestone and gypsum and then penetrated about 350 feet of sandstone. It was drilled 12 inches in diameter and cased with 10-inch pipe to the depth of 367 feet. The first water is reported to have been struck at 638 feet, and the head is reported to be 603 feet below the surface, or only 4,680 feet above sea level. With the pump cylinder placed 777 feet below the surface the well was pumped at 100,000 gallons in 24 hours.

The analyses given on page 304 show that the waters in the two wells are alike in containing great quantities of gypsum, but only moderate amounts of the sodium salts. The shallow water is a little more highly mineralized than the deep water.

WELLS NEAR PECOS RIVER.

From the high region forming the eastern border of the Encino and Pinos Wells basins to the brink of the Pecos River valley, a distance of 50 to 75 miles, the plateau descends over 2,000 feet. In a zone several miles wide, bordering the Pecos Valley, wells have been obtained by drilling to moderate depths, but between this zone and the El Paso & Southwestern Railroad there are very few wells of any kind.

A well drilled at Ricardo (see fig. 1, p. 12) by the Atchison, Topeka & Santa Fe Railway Co. to a depth of at least 863 feet passed through sandstone, limestone, red shale, and gypsum, as shown in figure 38. It encountered a little water at about 150 feet and more substantial supplies at 200 feet, 250 feet, 295 feet, and probably other depths. The water level in the well is about 200 feet below the surface, or 4,190 feet above the sea (fig. 41, p. 172). The 200-foot water-bearing bed yielded 6 gallons a minute, and the 250-foot bed 8 gallons, and when the well was 420 feet deep it was pumped at 20 gallons a minute. Tests were made by the railroad chemists of the mineral content of the water at various levels. A sample obtained at the depth of 300 feet contained 3,770 parts per million of dissolved solids, and one at 510 feet contained 6,185 parts, both samples being especially rich in calcium and magnesium salts. Water from the 595-foot bed is reported, however, to contain only 323 parts per million of total solids.

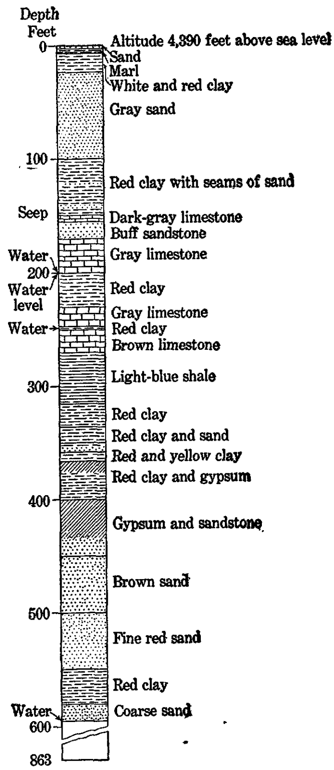


FIGURE 38.—Section of railroad well at Ricardo.

At Agudo (see fig. 1, p. 12) a well 208 feet deep yields a small supply of fairly good water that stands about 155 feet below the surface, or a little less than 4,100 feet above the sea (fig. 41, p. 172). One-half mile east of this station is a well that furnishes a large supply of satisfactory water that is reported to stand 196 feet below the surface. Other wells south of the Atchison, Topeka & Santa Fe Railway are as follows: SW. ¼ sec. 28, T. 2 N., R. 26 E., a well with a depth of 80 feet to the water level; SE. ¼ sec. 6, T. 1 N., R. 26 E., a well with a generous supply of fairly good water standing 140 feet below the surface;

NW. ¼ sec. 1, T. 1 N., R. 25 E., a well with a small supply standing 110 feet below the surface; SE. ¼ sec. 12, T. 1 N., R. 25 E., a well 178 feet deep with a small supply of water standing 168 feet below the surface; SW. ¼ sec. 18, T. 1 N., R. 26 E., a well 172 feet deep with a generous supply 152 feet below the surface; W. ½ sec. 32, T. 1 N., R. 25 E., a well 120 feet deep with good water that stands 109 feet below the surface and is yielded freely; NW. ¼ sec. 32, T. 2 N., R. 25 E., a well with a good supply of satisfactory water standing 164 feet below the surface; and NW. ¼ sec. 31, T. 2 N., R. 25 E., a well 225 feet deep. The water in most of the wells that have been mentioned is considered fairly good, but some very hard water has been struck in this vicinity.

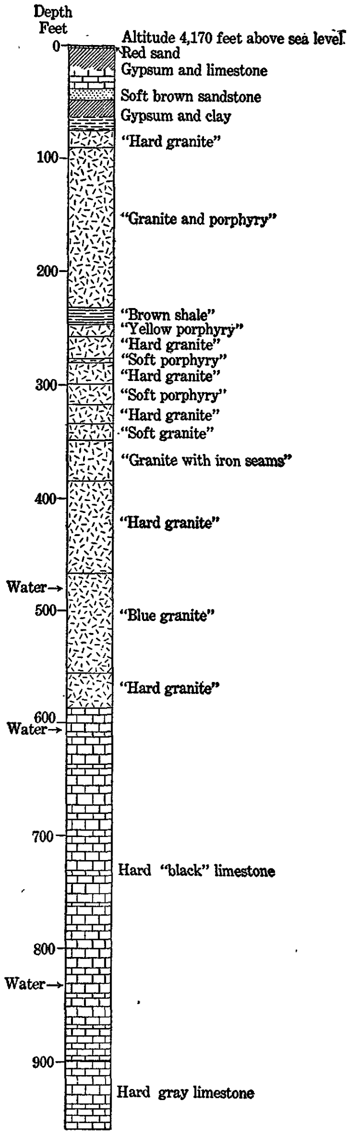


FIGURE 39.—Section of railroad well at Orogrande.

WELLS IN THE JARILLA MOUNTAINS.

A well was drilled in 1902 at Orogrande railroad station to a depth of 960 feet. As shown in figure 39, it passes through a great thickness of granitic rocks, and in the lower part through nearly 400 feet of limestone that is probably of Carboniferous age. It is 16 to 8 inches in diameter and has 8-inch casing from the top to a depth of 806 feet. Saline water was struck at various levels below 480 feet (analysis, p. 298), but the head and yield were not reported.

In Lucy Flat, near the south margin of sec. 3, T. 22 S., R. 8 E., where the surface altitude is about 4,555 feet above sea level, a shaft was sunk to a depth of 250 feet and a drill hole to a depth of 160 feet from the bottom of this shaft. The upper 235 feet of the section consists of nearly horizontal beds of limestone and shale, below which granite is reported to the depth reached by the drill hole. The granite outcrops on both east and west sides of the shaft and seems to form an impervious basin which holds the water that percolates through the limestone and shale. Water was struck a few feet above the granite and at present stands about 150 feet below the surface. Pumping at the rate of about 175,000 gallons a day was required when work was done in the mine. According to the analysis (p. 298), the water is not too heavily mineralized for domestic use although it contains much more mineral matter than the Orogrande pipe-line water. The underlying granite yielded no water.

WATER-BEARING CAPACITY OF THE ROCKS.

In the Tularosa Basin the Carboniferous rocks, except for a small thickness of Mississippian, are referred to the Pennsylvanian series and consist of limestone, sandstone, shale, and gypsum (pp. 57–60). To the east, near Pecos River, a considerable thickness of younger Carboniferous rocks, of Permian age, is found. The lower part of the Pennsylvanian series consists chiefly of limestone, but includes also considerable sandstone and shale; the middle part consists largely of shale and dense red sandstone; the upper part includes sandstone, gypsum, and limestone, with only minor amounts of shale. The shales, the dense red sandstones, and some of the more compact limestones are impervious or nearly so, but most of the Pennsylvanian rocks appear to be of sufficiently open texture to carry water. The yellow sandstones that belong to the upper part of the series are more or less porous. The limestones contain not only joints and small solution passages, but also many large caverns and sink holes, which show that these rocks are penetrated by descending waters. It must be concluded from a study of the Carboniferous formations as seen in their outcrops that the difficulties in finding water in these formations are not entirely due to compactness of the rocks. The system includes impervious members, some of which may be several hundred feet thick, but most of the strata are more or less porous or fissured and have the appearance of water-bearing rocks.

This conclusion is supported by some of the data in regard to the yield of springs and wells. The largest springs in the Sacramento Mountains issue from limestones of the Manzano group. All of the wells in the Carboniferous reported by the El Paso & Southwestern Railroad, which as a rule are deeper than the wells sunk by the stockmen, found some water, and a number of them are reported to have been tested at the rate of 100,000 gallons a day. Moreover, the strongest artesian wells in the Pecos Valley are supplied from limestones, which, although representing a somewhat higher horizon than the limestones of Tularosa Basin, are apparently of the same general character.

WATER LEVELS AND ARTESIAN HEAD.

Head produced by Sacramento Mountains.—The structure of the Carboniferous rocks in the Sacramento Mountains is favorable for producing artesian conditions in the Pecos Valley, but unfavorable for producing them in Tularosa Basin. The strata dip eastward at a small angle, but slope somewhat more steeply than the surface of the highland on the east side of the range. Consequently beds that outcrop on the highland pass gradually to some distance beneath the surface as they extend eastward, and in the vicinity of Roswell and Artesia their water is under sufficient head to rise above the valley level when tapped by wells.[1] On the steep west flank of the range, however, the edges of the formations are exposed, and the ground water that does not follow the eastward dip of the bedding planes escapes at these exposed edges in the form of springs. The Carboniferous strata that lie beneath the desert plain of Tularosa Basin are severed from the equivalent strata in the mountains by faults having several thousand feet of displacement, and they can not form an artesian system with the mountain strata. (See fig. 18, p. 75.)

Head produced by San Andreas Mountains.—The structure of the San Andreas Range is similar to that of the Sacramento Mountains and indicates the absence of any artesian connection between the Carboniferous strata of that range and strata underlying the desert plain. The artesian prospects in the Jornada del Muerto lying west of the San Andreas Range are discussed by W. T. Lee in a report on the water resources of the Rio Grande valley in New Mexico.[2]

Head produced by Oscuro Mountains.—The structure of the Oscuro Mountains and adjacent parts conforms more closely than that of the Sacramento and San Andreas ranges to the requirements for an artesian system within Tularosa Basin, in so much as beds outcropping in the mountains pass eastward beneath the surface of the lower lands in a manner somewhat comparable to the beds beneath the Pecos Valley. However, the strata dip more steeply and are more faulted, and there appears to be more opportunity for the water to escape to lower levels than in the Pecos artesian system. The low head of water shown by the wells sunk in the Carboniferous area west and north of the lava beds practically dispels all hope of obtaining flows in this area.

Water pockets.—The wells drilled in the Carboniferous area of Tularosa Basin west and north of the lava beds and on the extensive Carboniferous plateau north and east of this basin show that

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[1] Fisher, C. A., Preliminary report on the geology and underground waters of the Roswell artesian area, New Mexico: U. S. Geol. Survey Water-Supply Paper 158, 1906.

[2] U. S. Geol. Survey Water-Supply Paper 188, p. 39, 1907.

throughout most of the region the fundamental water table is far below the surface. In certain localities, however, permanent supplies of water are found at much higher levels than are general in the region, these perched supplies apparently being prevented from sinking by impervious structures that form underground basins or reservoirs. In some places the ground water is dammed by dikes of igneous rock but more commonly it is held up by strata of shale, compact limestone, or other impervious sediments. The sedimentary strata, by dipping at a steep angle, may form a barrier athwart the course of the underflow following some drainage line, or by lying nearly horizontal may form a floor which checks the direct descent of the water.

Perched supplies were found in the wells at Thomas McDonald's ranch, Mills's ranch, the Schole ranches, and Gran Quivira, at the 300-foot and 500-foot levels in Phillips's well, in some or all of the Ancho railroad wells and the ranch wells west of Ancho, in the few comparatively shallow wells in the vicinities of Torrance and Vaughn, and in the shallow railroad well at Pastura. (See fig. 40.) Perched bodies of water probably also feed certain seeps such as Chupadera Spring and the spring at Williams's ranch, northwest of Vaughn. To some extent the large, elevated shallow-water bodies, such as are found in the Pinos Wells, Encino, and Estancia basins, may be perched (fig. 41). The ground water in the vicinity of Cedarvale, for instance, is adjusted to the water level of Estancia Valley, but it is apparently perched with reference to the fundamental water level of the plateau.

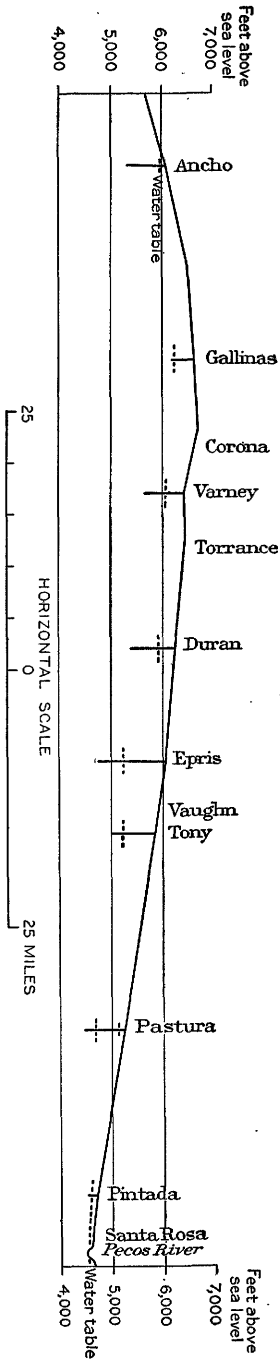

FIGURE 40.—Section from Ancho to Santa Rosa showing water table. Dotted lines indicate level of water in wells.

The supplies that have been developed by tapping elevated water pockets are generally permanent and reliable and consequently of

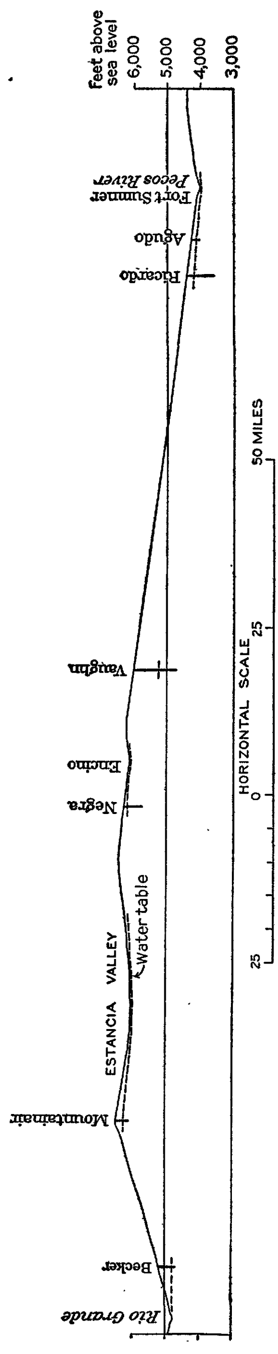

FIGURE 41.—Section from Rio Grande to Pecos River, along Belen cut-off, showing water table. Dotted lines indicate level of water in wells.

great economic value. The drilling that has been done in this region, however, shows that these pockets are local and that in a well sunk at random the chances are against finding shallow water. In some localities there are surface indications of ground water, such as seeps or vegetation of certain kinds, and in others the structure of the rocks is shown in outcrops to be favorable for the accumulation of shallow supplies, but over most of the region there is nothing at the surface that can be used as a clue to the conditions of the ground water.

Fundamental water table in the plateau region.—On account of the numerous failures in drilling, many of the ranch owners doubt whether any continuous body of ground water exists even at great depths below the plateau. The deep wells sunk by the railroad company prove rather conclusively, however, that there is a plane below which the pervious formations are saturated, although this plane is far from the surface. Figure 40 shows the profile along the El Paso & Southwestern Railroad from Ancho to Santa Rosa and the water level in the deep wells drilled between these points; figure 41 shows the profile between the Rio Grande and Pecos River along the Belen cut-off and the water levels along that line. At Vaughn the water level is about 5,200 feet above the sea, or 600 to 900 feet below the surface; in the vicinity of Fort Sumner, in the Pecos Valley, it is about 4,000 feet above the sea, or nearly at the river level. If these levels represent the fundamental water table, then this table descends 1,200 feet between Vaughn and Fort Sumner, or has an average slope of over 20 feet to the mile. It will probably be encountered in the region between the El Paso & Southwestern Railroad and the Pecos River wherever the drilling is carried to sufficient depth. The correlations of some of the ascertained water levels remain uncertain. For instance, the deep-seated water at Duran apparently rises to a level nearly 800 feet above the level of the deep water at Epris. On the Chupadera Plateau probably no wells would obtain water until they reached great depths unless by chance they found a perched water pocket. Even in the canyons of this plateau the depth to the fundamental water table is probably great.

QUALITY OF WATER.

The mineral character of the Carboniferous waters is shown by the analyses given in the tables on pages 268–305. The analyses (pp. 300–303) of the spring waters at the Mescalero Agency, in James Canyon, in Alamo Canyon, and in the Sacramento River valley show that the spring waters from the limestones of the Manzano group in the Sacramento Mountains contain only small amounts of mineral matter, but the other analyses show that practically all well waters derived from the Carboniferous rocks are highly mineralized. Probably all of the wells enter older and more gypseous formations than those giving rise to the springs in the Sacramento Mountains. These well waters are all rich in calcium and the sulphate radicle derived from gypsum, some being much richer than others, and they are also generally rich in magnesium. In their content of sodium and chlorine they differ greatly, some samples, such as the water from the Gallinas railroad well, containing only small amounts of either of these constituents, and others, such as the 1,330-foot water at Epris, being nearly concentrated brines. It should be noted, however, that only a small proportion of the Carboniferous waters thus far discovered are salty. The evidence at hand indicates that although some salt deposits occur in the Carboniferous rocks, such deposits are not abundant and salt is not found in considerable amounts in all of the gypsum deposits.

As the Carboniferous well waters are rich in calcium and magnesium, they are hard and deposit large amounts of scale when used in boilers. Some of the waters, especially those from shallow sources, are fairly satisfactory for domestic use and for drinking, but many are either undesirable or wholly unfit for these uses. In addition to their great hardness the more highly mineralized waters are so heavily loaded with sulphates and chlorides that they are unpalatable and may have a cathartic effect. So unsatisfactory were the supplies from the railroad wells for use in locomotives, even after they had been treated, that these wells have been generally abandoned. It is important, however, to understand that with a few exceptions, such as the deep water at Epris, the Carboniferous supplies are not undesirable for watering live stock. Nearly all of the supplies from the railroad wells could have been used for this purpose.

PROSPECTS.

The chances of finding bodies of ground water at shallow depths on the plateaus of central New Mexico underlain by Carboniferous rocks are so poor that except where there are definite indications of water it is not advisable for any one to undertake drilling unless he is prepared to sink to the level where the fundamental water table may be expected. If the site chosen is as low as possible a fair test will usually be made by sinking 1,000 feet, and in many localities water will be struck before reaching this depth. (Figs. 40 and 41.) If it happens, however, that a thick impervious formation occurs at the horizon where the water table would normally be encountered, the hole must be carried to an unusual depth before water is found (fig. 42).

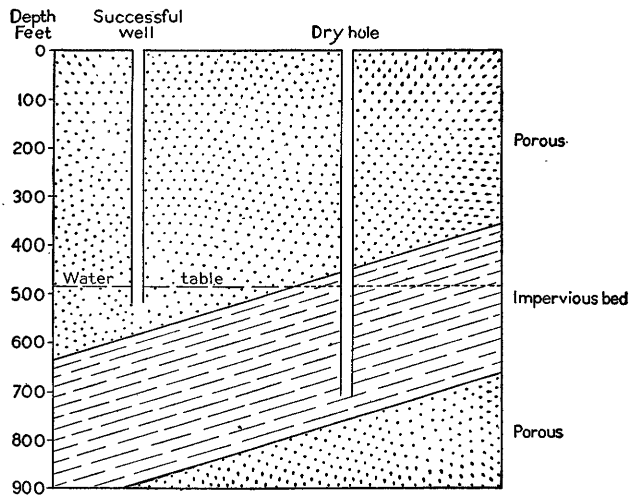

FIGURE 42.—Hypothetical section to explain dry holes of great depth on the central plateaus of New Mexico.

The expense of drilling to the necessary depths is so considerable and the water is as a rule so highly mineralized that further drilling is in general not advisable except to obtain supplies for live stock. There are some chances of failure to find satisfactory supplies even for this purpose, but there is reason to expect that in most localities an adequate quantity of water good enough for stock use can be developed by deep drilling, and in view of the lack of watering places and the value of the region for grazing further prospecting for deep supplies would seem to be justified. The work can best be done with a standard portable cable percussion rig designed to drill at least 1,000 feet. Because of the scarcity of water and its poor quality for boiler feed a gasoline engine is preferable to a steam engine for producing power to operate the drill. Drilling in the Carboniferous rocks is not difficult, except where the formations dip at a steep angle, thereby tending to deflect the drill and throw the hole out of alignment. Casing will not be required unless caving materials are encountered or the water is found in incoherent sand that requires a strainer. Where the water remains several hundred feet below the surface it is necessary to install deep-well pumps of special strength, and the expense for operation and repairs will be considerable. A gasoline engine will be best adapted for generating the power for pumping. A permanent derrick should be built over the well so that when the pump needs repairs it can be lifted by means of the engine used in pumping.

Where shallow water is known to exist, supplies large enough for a ranch can generally be developed. At Gran Quivira the amount of water is no doubt small, yet it is not improbable that by sinking shafts and extending tunnels below the water level a supply sufficient for watering large flocks of sheep could be obtained.

In some of the valleys of the Sacramento Mountains additional supplies for irrigation could possibly be developed by drilling wells, and in a few other shallow-water tracts, such as those at Thomas McDonald's ranch and A. C. Mills's ranch, sufficient water could be obtained to irrigate gardens and small orchards.

WATER IN IGNEOUS ROCKS.

In many places where igneous rocks are associated with sedimentary beds they form impervious basins that impound ground water or barriers that bring it to the surface, many examples of which are furnished in the Cretaceous areas and some in the Carboniferous areas of this region. Where igneous rocks lie at the surface small supplies of water containing but little mineral matter are likely to be found in the weathered zone near the surface. In such places the water table generally fluctuates with the rainfall, and the yield of springs is variable.

The deeper parts of the igneous bodies are generally barren of water or contain only small supplies along the veins and fracture planes. Exceptionally, however, as in the deep well near Jicarilla, open veins are struck that yield water freely. The Jicarilla well is situated at a high altitude in the mountains east of the settlement, and penetrates granitic rock to a depth of 402 feet, where it is reported to have struck a cavity from which the water rose under pressure. According to reports the well was pumped for 48 hours, with the cylinder about 100 feet below the surface, at a rate of 150 gallons a minute. The water is conducted through a small pipe line to the village of Jicarilla, where it forms practically the only supply. As shown by the analysis (p. 268), this water contains only moderate amounts of mineral matter.

SOIL AND NATIVE VEGETATION IN RELATION TO WATER SUPPLIES.

TYPES OF SOIL.

The soils that are more or less suitable for agriculture can be grouped as (1) the red adobe soils, (2) the gypseous soils, (3) the more ordinary loam soils (east and north of the lava beds, in the southern part of the basin, in the mountain valleys, and in some other localities), and (4) the sandy soils (in the southern part of the basin and in other localities). The soils that produce more or less desert vegetation but are practically worthless for agriculture can be grouped as (1) the gravelly and bowldery deposits, (2) the quartz sands of the dune areas, (3) the gypsum sands, (4) the alkali clays, and (5) the waste in the crevices of the lava beds.

The red adobe soils are typically developed on the slopes adjacent to the Sacramento Mountains, but are found on all the slopes adjacent to ranges formed of Carboniferous rocks. (See the detailed descriptions on pp. 199–206.) They consist of a matrix of clay and included coarser particles. The proportion of clay is not the same in different localities, but is generally large enough to give the soil plasticity and the other attributes of a clay loam. As a rule the adobe at the higher levels contains the largest proportion of silt, grit, and gravel, and the adobe at the lower levels is the heaviest and most clayey. The red soil that was deposited along the margins of the younger lava bed, on the floors of the mid-slope arroyos, and in the undrained depressions of the gypseous plain is as a rule less firmly compacted than the older deposits and becomes very miry when wet.

The adobe soils can in general be made very productive with proper irrigation and cultivation, as has been proved in the areas under irrigation. They become miry when wet and bake when dry, although the gypsum and calcareous material that they contain makes them more friable than other clay soils of the same constituency. They require much cultivation, but if properly tilled will hold the soil moisture well. When they are wet cultivation tends to puddle them and thus destroy their tilth. Like most desert soils, they do not contain much humus or other nitrogenous matter. The application of manure and the raising of crops, especially nitrogen-producing crops, such as alfalfa, will improve these soils, both by supplying them with nitrogenous matter and by making them more mellow and porous.

The gypseous soils occur in the interior of the basin, chiefly on the east side between the adobe soils and the white sands, and in the areas north and south of the alkali flats. (See the detailed description on pp. 199–206.) These soils are pale in color and loose, powdery, or crystalline in texture. In their content of gypsum they range from gypseous loam that blends imperceptibly with the red adobe to nearly pure gypsum, the proportion of gypsum increasing in general toward the interior of the basin. The upper layer of soil, a foot or more in thickness, is generally somewhat clayey and gray or brownish in color. It is underlain by a light cream-colored subsoil that is generally 5 feet or more in thickness and consists largely of gypsum and calcium carbonate. This subsoil gradually gives place downward to red clay or adobe. In many localities adobe has been washed over the gypseous formation with the result that there is an adobe soil and a gypsum subsoil. (See fig. 43, p. 187.) The subsoil in the Schofield section (fig. 17, p. 70) contains 60 per cent of calcium sulphate and 12½ per cent of calcium carbonate.

Where the gypseous soils are not clayey they will allow irrigation waters to seep through them rather readily, and, because of their soluble character, they are likely to develop underground passages through which much water may run to waste. Crops will germinate in gypseous soil, but the general experience seems to be that they do not thrive after they are up—a condition which may, however, be due to the absence of plant food or to the abundance of alkali rather than to the properties of the gypsum itself. The gypseous soils probably do not have the natural fertility of the adobe, and developments should therefore be made with great caution on the areas underlain by them. Like the adobe, they are poor in nitrogenous matter. They generally contain some alkali, and in many places their alkali content is rather large.

The region lying east and north of the Phillips Hills and also extending some distance south of these hills (Pl. I, in pocket) is underlain in general by gray loam soils that are more sandy and porous than the red adobe. They appear to be good soils of the desert type and will probably prove productive where they are adequately watered. Except very locally, these soils contain little or no alkali, but they contain considerable gypsum and calcium carbonate.

In the southern part of the basin and in the adjacent area to the south, the soils range in texture from true loam, through all grades of sandy loam, to sand that is too nearly destitute of fine particles to be utilized for agriculture. Even where it is not sandy the loam is generally less heavy and clayed than the typical red adobe. South of the Jarilla Mountains and Cox windmills (Pl. I, in pocket), there is little gypsum, and, except locally, almost no alkali. Where they are not too sandy the soils of this southern area are no doubt fertile, and would yield well if watered. However, the caliche, or lime hardpan, is more developed here than in other parts of the basin, and because it lies near the surface it must be reckoned with in any agricultural undertaking.

Over a large but indefinite area extending on both sides of the railroad from the Texas line to a point beyond the Jarilla Mountains the soil is in general very sandy, but throughout the area there are small, comparatively level tracts of good soil.

The east boundary of the sand-dune area north of the white sands (Pl. II, in pocket) is definite, but the west boundary is very indefinite. Most of this area contains clean quartz sand, or, in the southern part, quartz sand mixed with gypsum sand, but there are certain small tracts of arable land.

RELATION OF SOILS TO DERIVATIVE ROCKS.

The red adobe soils are derived from the red beds of the Pennsylvanian series. They are not found in typical form in the area east and north of the Phillips Hills because the mountains that supply débris to that area do not contain much Pennsylvanian rock, nor in the southern part of the basin where the Pennsylvanian rocks are either absent or do not include red beds. The crystalline rocks and Cretaceous sandstones produced soils that are more porous and sandy. The gypseous soils are derived from gypsum beds and disseminated gypsum in the Pennsylvanian rocks.

RELATION OF SOILS TO CIRCULATION OF WATER.

The great difference in solubility between the gypsum beds in the Pennsylvanian series and the materials of the red beds in the same series has produced a segregation which has given rise to the adobe and gypsum soils. The red sediments were carried in suspension by streams and flood waters and by waves and lake currents; the gypsum was in large part dissolved and accumulated in the ancient lake, on the bed of which it was deposited when the water became concentrated. It is also deposited in low places by evaporating ground waters.

The differences in the texture of the adobe and other loam soils found at different levels on the débris slopes are chiefly due to the sorting action of the streams and flood waters. The coarsest materials were as a rule deposited first by the waters flowing from the mountains, and the finest particles were carried farthest into the interior.

The existence of adobe soils overlying gypsum subsoils is for the most part due to the recent deposition of adobe by flood waters upon gypsum beds formed earlier by lake or wind.

The gypseous and calcareous hardpans formed near the surface are probably the result of the slow work of rain and flood waters that seep into the soil and transport the gypsum and calcium carbonate through a small vertical range. The alkalies in the soil are also the product of circulating waters.

RELATION OF SOILS TO DEPTH OF WATER TABLE.

In the large shallow-water area shown in Plate II (in pocket), the belt in which the depth to the water table is 50 to 100 feet coincides most nearly with the zone of adobe soil. Most of the belt in which the depth to the water table is less than 50 feet, exclusive of the alkali flats and dune areas, is on the interior plain of gypseous soil, but it includes some good adobe soil near its outer margin and in the upper parts of the mid-slope arroyos. In the small shallow-water tracts east and north of the Phillips Hills the soil appears to be generally of satisfactory quality. Unfortunately much of the best soil lies in the southern part of the basin where the depth to water is several hundred feet and where underground supplies can therefore not be economically lifted for irrigation.

PLANT FOODS IN THE SOIL.

A few analyses made to determine the amount of nitrogen, potash, and phosphoric acid in the soil are reported in the table on page 180. The following statements are based on these analyses and on other investigations made by Dr. Hare.

Nitrogen, which was determined by the Kjeldahl method modified to include nitrates, was found to be generally deficient, as was to be expected in a region where all forms of life are scarce, the deficiency being due to the arid climate and the overstocking of the range. The soils are in poor tilth and need deep cultivation, manuring, and the plowing in of green crops, preferably alfalfa, in order that they may be "opened up" for the freer passage of air and water and the addition of the much needed nitrogen-bearing humus.

The phosphoric acid shown by the analyses is that which is soluble in strong hydrochloric acid. The amount compares fairly well with that usually found in soils of average fertility. In view of the fact that the phosphorus may not all be in an available form, however, the use of phosphate fertilizers may be beneficial.

The potash reported in the table is only that portion which is soluble in water and therefore serves as a plant food. The amounts differ greatly in the different samples. Though the soils of this basin probably contain enough potash for the needs of crops, it is remarkable how little they contain of this constituent as compared with their large content of soda and other soluble salts.

Potash, phosphoric acid, and nitrogen in soils of Tularosa Basin.

Location.	Per cent of total soil.		
	Potash (K_2O).	Phosphoric acid (P_2O_5).	Nitrogen (N).
T. 14 S., R. 8 E., sec. 13	0.32		
T. 13 S., R. 9 E., sec. 32, 2 miles northwest of Lomitas ranch		0.28	
T. 13 S., R. 8 E., sec. 2, 2 miles east of Chosa ranch		.29	
T. 13 S., R. 9 E., sec. 11, 1 mile east of Temporal		.22	
T. 13 S., R. 9 E., sec. 20, peach orchard of Al Gray		.32	0.11
T. 12 S., R. 8 E., sec. 10, 7 miles east of Three Rivers		.32	.06
T. 14 S., R. 9 E., sec. 14, Votaw's peach orchard		.13	.05
T. 15 S., R. 9 E., sec. 13:			
Top scrapings	.10	.065	.112
First foot	.15	.12	.098
T. 15 S., R. 9 E., sec. 13, one-half mile from above (first foot)	.145	.16	.063
T. 15 S., R. 9 E., sec. —:			
Surface soil	Trace.	.12	.077
First foot	Trace.	.08	.035
First 6 inches	Trace.	.21	.077
T. 15 S., R. 9 E., sec. 14:			
First foot	.36	.11	.028
Second foot	Trace.	.11	.014
T. 15 S., R. 9 E., sec. —, 2 miles from above:			
Surface soil	.135	.24	.196
First foot	.42	.27	.147
Second foot	.37	.18	.077
T. 15 S., R. 9 E., sec. —, near above, surface soil	.05	.12	.08

ALKALI IN THE SOIL.

KINDS OF ALKALI.

The readily soluble constituents of soils are commonly, though rather inaccurately, called alkalies. When present in small amounts these constituents are valuable plant foods and give fertility to the soil, but when present in large amounts they injure vegetation or may prevent its growth. The soluble constituents most commonly found in abundance are sodium chloride, sodium sulphate, magnesium sulphate, sodium bicarbonate, and sodium carbonate. Sodium chloride (common salt), sodium sulphate (glauber salt), and magnesium sulphate (epsom salt) are usually called white alkali, because they produce white crusts; whereas sodium bicarbonate (baking soda) and sodium carbonate (washing soda), although also white salts, are called black alkali, because they react on vegetable matter in such a manner as to produce a black or brown stain. The amount of alkali that cultivated plants can endure depends on the kind of alkali, the kind of plants, the kind of soil, the methods of cultivation and irrigation, and other factors. Black alkali is more injurious to plants than white alkali, and among the common white alkalies sodium chloride is more injurious than sodium sulphate. Black alkali when present in sufficient quantity corrodes the bark where it concentrates near the surface, thus girdling the plants. It also injures the tilth of the soil. The other soluble salts do not corrode but if present in large quantities they also injure vegetation. In general crops do not thrive in soils having more than 0.05 to 0.20 per cent of sodium carbonate, 0.25 to 0.50 per cent of sodium chloride, or 0.50 to 1.00 per cent of sodium sulphate. The amount of alkali present in a virgin soil is, however, of less importance than the conditions that determine whether the alkali will accumulate or disappear when the land is irrigated and cultivated. If the drainage is good and the soil is porous, the alkali, even though present in large quantities, can be readily disposed of by leaching it downward through the soil. If, on the other hand, the water table is raised by irrigation within capillary reach of the atmosphere, the upward-moving ground water will accumulate alkali near the surface, and soils that originally contained little alkali may become worthless. (See pp. 187–193.)

Calcium sulphate (gypsum) and calcium carbonate (limestone) are much less soluble than the so-called alkalies, but where they are present in the soil they are to some extent dissolved by the soil waters. They are not known to be injurious in soluble form to plant life. Since calcium sulphate tends to react with sodium carbonate, producing calcium carbonate and sodium sulphate, a gypseous soil will not contain injurious amounts of ordinary black alkali.

ALKALI ANALYSES.

The table on pages 306–311 gives the analyses of the water-soluble constituents of 78 samples of soil taken at 35 critical points in the large shallow-water belt of Tularosa Basin, all samples being collected within the area where injurious amounts of alkali were suspected from the appearance of the soil or vegetation and therefore chiefly within the zone of gypseous soil. They were obtained in Tps. 11, 12, 13, 14, 15, 16, 17, 18, and 19 S., Rs. 5, 6, 7, 8, and 9 E., all located in Otero County except five in western Socorro County and one from western Dona Ana County. Except where the boring was stopped by hardpan or some other obstacle, samples were generally taken of the soil to a depth of 5 feet, one analysis being made of the soil within 1 foot of the surface and another analysis of the soil below the depth of 1 foot. The analyses show the constituents of the soils that went into solution when the samples were leached with water. (See methods of analysis, p. 265.)

SULPHATES.

The analyses show large amounts of sulphates and only very small amounts of carbonates or bicarbonates. They also show large amounts of calcium—a constituent which is not abundant in the soil solutions of most regions. The sulphates are generally above 0.50 per cent and range up to 2.45 per cent, not including the sample taken at Eddy's prospect (analysis A42, p. 310), which consists chiefly of sodium sulphate. The calcium content is generally over 0.10 per cent and ranges up to 0.40 per cent, not including several special samples in which it is greater. There is generally less magnesium than calcium, but it ranges up to 0.37 per cent in ordinary samples and is also higher in the special samples. The samples were all taken from soils that are somewhat gypseous and most of them represent soils consisting in large part of gypsum. Obviously the greater part of the sulphates and nearly all of the calcium found in the solutions were derived from this gypsum. A part of the sulphates are derived from magnesium sulphate and sodium sulphate, but the computed amounts of sodium sulphate are generally not large, and many analyses show no excess of the sulphate radicle over what will combine with calcium and magnesium. Calcium sulphate was found in all of the soil samples. The computed quantities varied considerably, but exclusive of surface scrapings averaged 52.91 per cent of the total dissolved solids. In the samples in which the dissolved solids exceed 2 per cent the proportion of gypsum is, however, relatively small.

The analyses do not, however, show the total amount of gypsum in the soil, but merely the amount that passed into solution when the standard methods of leaching were applied in the laboratory. In the sample taken from the subsoil at H. W. Schofield's dug well (analysis A37), for example, the total calcium sulphate was found to be 60 per cent, but the dissolved portion shown by the regular alkali (analysis A37), for example, the total calcium sulphate was found to the extent of only about 0.20 per cent, the additional 1 per cent having gone into solution because the solubility of gypsum is increased by the presence of sodium chloride and other sodium salts and also because the amount of water used in leaching was in excess of the amount of soil.

The amounts of dissolved calcium sulphate as shown by the analyses are not an index to the total gypsum content, the amount of gypsum in nearly all samples being greater than the amount that could dissolve in the quantity of water used in leaching the sample. Since the dissolved calcium sulphate is probably harmless, the figure representing "total soluble solids" does not indicate so bad a soil as it would if all the dissolved substances were harmful, which is approximately true in many alkali soils. The analyses given in this paper emphasize the fact that the determination of total soluble solids, whether by electrolytic or gravimetric methods, does not furnish a reliable guide to conditions unless something is known of the character of the dissolved substances. In a gypseous soil the danger from alkali may not be so great as might be inferred from a determination of total solids alone.

Moreover it has been demonstrated by Kearney and Cameron[1] that gypsum has an ameliorating effect on alkali salts. These investigators found this effect to be much more marked on sulphates of magnesium and sodium than on the corresponding chlorides. They showed that it raised the concentration limit of magnesium sulphate endurable by plants about 480 times, and of sodium sulphate more than 60 times. The fact that plants grow in Tularosa Basin in amounts of toxic salts that are usually considered beyond the limits of tolerance is evidence in support of these results.

A theory advanced by O. Loew[2] in regard to the ratio of calcium and magnesium salts best suited to the growth of plants may also serve to explain the beneficial action of gypsum on these alkali salts, at least in so far as the magnesium salts are concerned. He believes that these two elements should exist in the soil in about the same ratio that they are utilized by the plants, which for most crops is about 1 of magnesium to 3 of calcium; and when an excess of either is present it results in injury to the plant. The ratio of available calcium and magnesium in the soils of Tularosa Basin is about 1 to 4, and certain plants, such as tobacco and grapes, that can utilize this excess of calcium should be well suited to these soils.

CARBONATES.

Since calcium carbonate and magnesium carbonate are nearly insoluble in water and relatively only slightly soluble even in the presence of the carbon dioxide of the soil, the presence of a considerable amount of carbonates or bicarbonates in a soil solution is usually regarded as an indication of the presence of the more soluble sodium carbonate, or sodium bicarbonate, which constitute the harmful black alkali. For the same reason the presence of a considerable amount of calcium in the soil solution may be regarded as an indication of calcium sulphate or calcium chloride. Since sodium carbonate and sodium bicarbonate act upon calcium sulphate and calcium chloride, precipitating the nearly insoluble calcium carbonate, all soil solutions are very poor either in calcium or in carbonates and bicarbonates, or else they are poor in all of these constituents. In other words, a black-alkali soil furnishes a solution that contains appreciable amounts of carbonates or bicarbonates but almost no calcium, whereas a white-alkali soil furnishes a solution that contains almost no carbonates or bicarbonates and may or may not con-

[1] U. S. Dept. Agr. Rept. 71, p. 55, 1902.
[2] Porto Rico Agr. Exper. Sta. Circ. 10, p. 6.

tain much calcium. The analyses of soils in Tularosa Basin invariably show only very small amounts of the carbonates or bicarbonates, which proves that none of the soils examined contain much black alkali, in the sense in which the term is commonly used. Several of the tests showed slight amounts of sodium carbonate, but the quantities are so small that they are practically negligible.

The carbonates shown by the analyses in no sense represent the total amount of calcareous material in the soil. The analysis of soluble constituents of the subsoil at H. W. Schofield's dug well (analysis A37, p. 310) shows only 0.01 per cent of carbonates, and hence not over 0.02 per cent of calcium carbonate, yet this subsoil was found to contain a total of 12.55 per cent of calcium carbonate. The dissolved calcium carbonate is not injurious, but, on the contrary, is known to have a beneficial effect on vegetation.

CHLORIDES.

Most of the chlorine found in soil solutions represents sodium chloride (common salt), which is the more harmful of the two principal white alkalies. A few analyses, however, showed an excess of chlorine over sodium, indicating the presence of magnesium chloride or calcium chloride. Where either of these salts was present it could be detected by the deliquescent character of the soil or of the water residue. The presence of magnesium chloride was verified by heating the residue above 100° C. and noting the loss of chlorine. In Tularosa Basin sodium chloride is the most dangerous alkali and its amount probably furnishes the best guide to the character of the soil in regard to alkali. Of the ordinary soil samples that were analyzed, about one-fourth contained over 0.50 per cent of sodium chloride to the depth that the boring was made, and somewhat more than one-half contained over 0.25 per cent. Nearly one-fourth of the total dissolved solids consists of sodium chloride.

SPECIAL TYPE OF BLACK ALKALI.

In certain localities in Tularosa Basin the soil has a black or brown appearance resembling the black-alkali spots produced by sodium carbonate. The darkest soil from two of these localities was analyzed—one on the farm of Hill Bros. (analysis A 22) and one on the farm of H. W. Schofield (analysis A 36). Both samples were characterized by the great abundance of chlorides and the presence in quantity of nitrates. In both, magnesium chloride and calcium chloride were present in addition to large amounts of sodium chloride, these three salts together with the nitrates and gypsum forming practically the entire soluble content. A sample of very concentrated brown water from a pool in one of the arroyos (analysis, p. 300) contained a large amount of sodium and chlorine, but was specially characterized by its great content of magnesium sulphate. The dark appearance is in part due to the moist condition of the soil produced by the calcium chloride and magnesium chloride, both of which have the property of attracting moisture, but in part it seems to be due to an actual stain, as is indicated by the brown color of the concentrated water sample.

The alkali in Tularosa Basin is similar to that in the Pecos Valley, which has been investigated by the United States Bureau of Soils and in regard to which the following statements are made:[1]

> In the Pecos Valley, N. Mex., it has been made very evident that the predominating feature is the contact of waters carrying considerable quantities of sodium chloride with the gypsum found abundantly in the soil, the gypsum, in fact, being in some places the main component of the soil. The sodium chloride, being so much more soluble, will be taken up long before the gypsum is appreciably affected, and we are therefore justified in regarding this problem as the action of aqueous solutions of sodium chloride upon gypsum ($CaSO_4.2H_2O$) or the dihydrate of calcium sulphate.
>
> In aqueous solutions a reaction takes place between gypsum and sodium chloride, which may be represented thus,
>
> $$CaSO_4+2NaCl \rightleftarrows Na_2SO_4+CaCl_2,$$
>
> part of the calcium and sulphions [sulphate radicle] of the sparingly soluble calcium sulphate being converted into calcium chloride and sodium sulphate, compounds much more soluble than gypsum. * * * In other words, the gypsum becomes more soluble on account of the presence of sodium chloride and the solution more concentrated with respect to the total salts dissolved. * * *
>
> The calcium chloride which has been washed down into the subsoil accumulates there in certain places, and then on prolonged drought is sometimes brought to the surface in very large amounts in spots of limited area. On account of its well-known and very great property of deliquescence it keeps the surface where it has accumulated quite damp, even during periods of protracted drought. This gives a darker appearance to the soil where the calcium chloride has accumulated than that of the surrounding drier areas where this salt has not accumulated, these darkened areas being locally known in the Pecos Valley as black alkali spots, although chemical examination shows them to be quite free from soluble carbonates.
>
> The interaction of calcium sulphate and sodium chloride is the predominating feature of the alkali in the Pecos Valley. It is modified to some extent by the presence of other salts, as the salts of magnesium, for example; but the latter are always present in much smaller quantities than are the calcium and sodium salts. Soluble carbonates are almost entirely absent and merit no attention in this area. As the Pecos area was the first of the gypsum-sodium chloride type to receive extended investigation by this bureau, it has been proposed to classify areas in which the interaction of gypsum and sodium chloride is the predominating feature under the heading "Pecos type."

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[1] Dorsey, C. W., Alkali soils of the United States: U. S. Dept. Agr. Bur. Soils Bull. 35, pp. 150–152, 1906.

RELATION OF ALKALI TO TYPES OF SOIL.

The porous upland soils and the adobe soils at the higher levels were not examined, but are without doubt nearly free of alkali. In some localities on the lowlands, however, the adobe contains harmful amounts of alkali. Sample A 2 was taken on the west side of the younger lava bed where the soil is red in color and includes enough clay to be exceedingly miry. Yet this sample, to a depth of 5 feet, contained 0.90 per cent of sodium chloride. Sample A 25, which was taken from soil consisting of adobe to a depth of 1½ feet, contained 0.30 per cent of sodium chloride in the first foot; sample A 34, consisting of adobe, contained 0.22 per cent of sodium chloride in the upper 4 feet; sample A 31, which was taken from a soil consisting of reddish clay loam to a depth of 3 feet, contained 0.77 per cent of sodium chloride in the first foot and 0.54 per cent in the second and third feet; and sample A 41, consisting in the upper part of adobe, contained 0.69 per cent of sodium chloride in the first foot and 0.58 per cent in the next 3 feet.

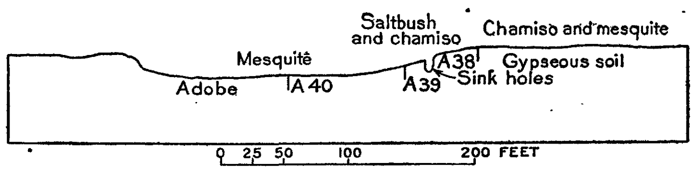

FIGURE 43.—Section across small arroyo showing relation of soil and vegetation to topography (NW. ¼ sec. 3, T. 17 S., R. 9 E.).

The sandy soils and dune sands are so porous that they have been leached wherever the percolating waters were free to circulate, but the depressions between the dunes contain some alkali. The sample at Black Lake, A 14, was taken from the floor on which the dunes rest and was found to contain 0.13 per cent of sodium chloride in the first foot and 0.40 per cent in the next 3 feet. The gypsum sands have also been leached to a certain extent, as is indicated by analysis A 28, which shows only a trace of sodium chloride and no sodium sulphate.

In the samples taken on the typical gypseous plain, well above the water level, the sodium chloride, to the depth that the boring was made, ranges from hardly more than a trace to somewhat over 0.50 per cent and averages about 0.25 per cent. The analyses of these samples show that a moderate amount of alkali is widely disseminated through the gypseous soil.

The alkali flats, the wet area adjacent to the south end of the younger lava bed, the lower parts of the mid-slope arroyos, and certain other localities are excessively impregnated with alkali. Examples of alkali spots on the general plain are furnished by analyses A 17 and A 35. (See pp. 306–311.)

Figure 43 is instructive in showing a certain distribution of alkali with reference to soil and topography in a locality where the water table is too low to affect the distribution. Sample A38 was taken on the typical gypseous plain and is probably representative of general conditions on that part of the plain. Sample A 40 was taken in a depression or arroyo and is representative of the red loam or adobe commonly forming the soil of these low places. Sample A38 was found to contain a moderate amount of alkali whereas A 40 is nearly free of alkali, and this difference is probably rather typical of these two soils where they are found in this topographic relation. Sample A 39 was taken from the gypseous soil at the margin of the depression and was found to contain more alkali than either of the others. It probably represents a local concentration.

RELATION OF ALKALI TO THE WATER LEVEL.

The alkalies in the soil are the soluble products of the weathering of the rocks from which the soil is derived. While the insoluble products, such as the grains of sand and clay, are carried in suspension or rolled over the ground by surface waters, the soluble products go into solution, are carried as readily by the slow underground seepage as by the surface streams, and are not generally deposited until the water evaporates.

The low shallow-water areas, where there are possibilities of recovering ground water for irrigation, are as a rule the areas in which evaporation has occurred in the past and is occurring at present, either from lakes or ponds or from returning ground waters. Therefore the problem of alkali is generally involved in projects for irrigation with ground waters.

The vertical distance through which ground water will rise by capillarity above the water table differs with the texture of the soil or other conditions, but at most points where observations were made it rises about 8 feet. Where the water table stands much more than 8 feet below the surface and the ground water is not brought within reach of the atmosphere by capillary action, there is merely a wet zone of dormant capillary water above the water table, but where the water table stands within about 8 feet of the surface the zone of capillary water is brought within reach of the atmosphere, evaporation takes place, and an upward capillary current is produced. This current carries soluble solids to the surface where they are deposited when the water evaporates. The analyses plotted in figures 44 and 45 represent as diverse conditions in regard to soil and topography as could be found within the area investigated for alkali, yet they show very plainly the effect of this capillary current. The samples derived from localities where the water table stood within 10 or 12 feet of the surface at the time observations were made are, with few exceptions, much richer in alkali than those taken where the depth to the water table is greater.

The recent experiments of C. H. Lee[1] showed that, so far as his investigations were carried, the rate of withdrawal of ground water by capillary action through a given soil under given conditions varies inversely with the depth, from the surface, where it is a maxi-

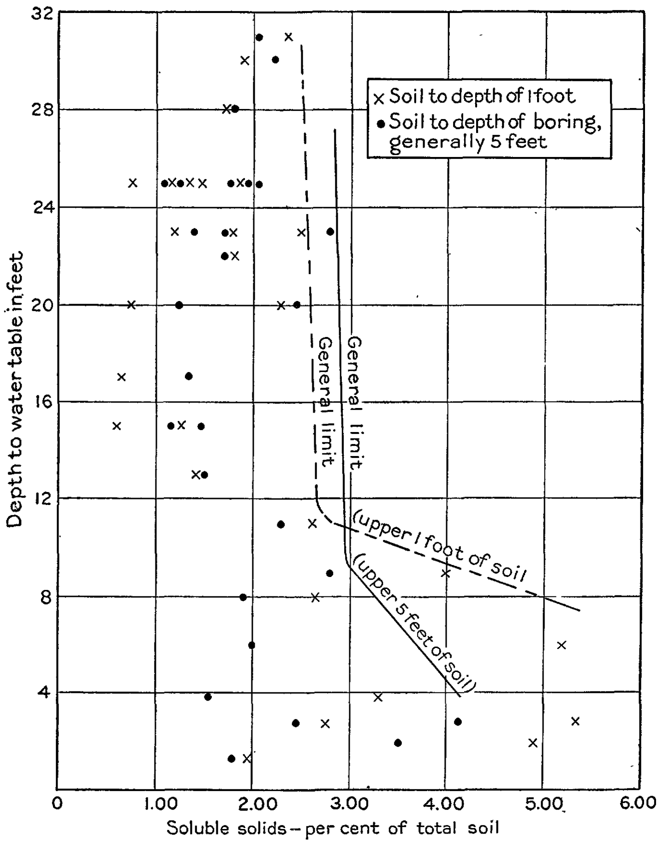

FIGURE 44.—Diagram showing relation of soluble solids (in soils analyzed) to depth of water table.

mum, to the depth of capillary range, where it becomes zero. For example, if the capillary range is 8 feet and the evaporation amounts to 40 inches a year where the water table is at the surface, the evaporation will, under the same conditions, amount to about 35 inches where the water table is 1 foot below the surface, 30 inches where the water table is 2 feet below the surface, and so on, to

[1] Lee, C. H., An intensive study of the water resources of a part of Owens Valley, California: U. S. Geol. Survey Water-Supply Paper 294, p. 59, 1912.

8 feet, at which depth evaporation ceases. The analyses plotted in figures 44 and 45 were taken under conditions too diverse to form the basis for any general rule; but it is nevertheless noteworthy that they conform in general with the rule based on Lee's observations, the average amounts of alkali within the capillary limits increasing gradually with decreasing depth of ground water. Although the broken right lines representing the general alkali limits are hardly required by the analyses plotted, they no doubt represent correctly the main relations of the distribution of alkali to the depth of ground water. They mean that wherever the water table is within about 12 feet of the surface the soil is liable to contain harmful amounts of alkali, and that the nearer the surface the ground water stands the greater is the danger from alkali.

In all of the samples taken in localities where the depth to water is less than 10 feet the alkali content was greater in the first foot of soil than farther down, a fact which shows that in these localities the alkali has in recent times been accumulating, the effect of the upward capillary current being greater than any downward leaching by rains or floods.

Although the alkali content is, as a rule, much greater where evaporation from ground water is taking place than elsewhere, yet the analyses show that sodium chloride and other alkalies are distributed in appreciable quantities over much of that part of the interior gypseous plain where the water table is at present too low to have any influence on surface conditions. (See figs. 44 and 45.) Over most of this area alkali is evidently not accumulating at present, and the alkali that is disseminated through the surface formation is a product of conditions that have ceased to exist. It was probably deposited from the concentrated waters of the ancient lake or from evaporating ground waters in the lake epoch or soon after, when the water table stood considerably higher than it stands at present. This ancient alkali may be regarded as probably Pleistocene, in distinction from the alkali in the wet places which is related to present processes and may be regarded as Recent. To some extent the Recent alkali accumulations represent an enrichment or reconcentration of more disseminated Pleistocene alkali.

In only exceptional localities is the ancient alkali concentrated in the upper part of the soil. Generally where the depth to the water table is more than 12 feet the first foot of soil contains less than the rest of the boring. (See figs. 44 and 45.) The presence of this alkali above the water table seems to indicate that since its deposition, perhaps several thousand years ago, there has not been enough general downward percolation of water from rains and floods to leach out the alkali. The deficiency of alkali in the first foot as compared with the next 4 feet seems to furnish some measure of the amount of leaching just as the excess in the first foot of the wet areas gives some measure of the preponderance of accumulation over leaching.

The gradual decrease of the average alkali content with increasing depth to water beyond the critical depth (figs. 44 and 45) is prob-

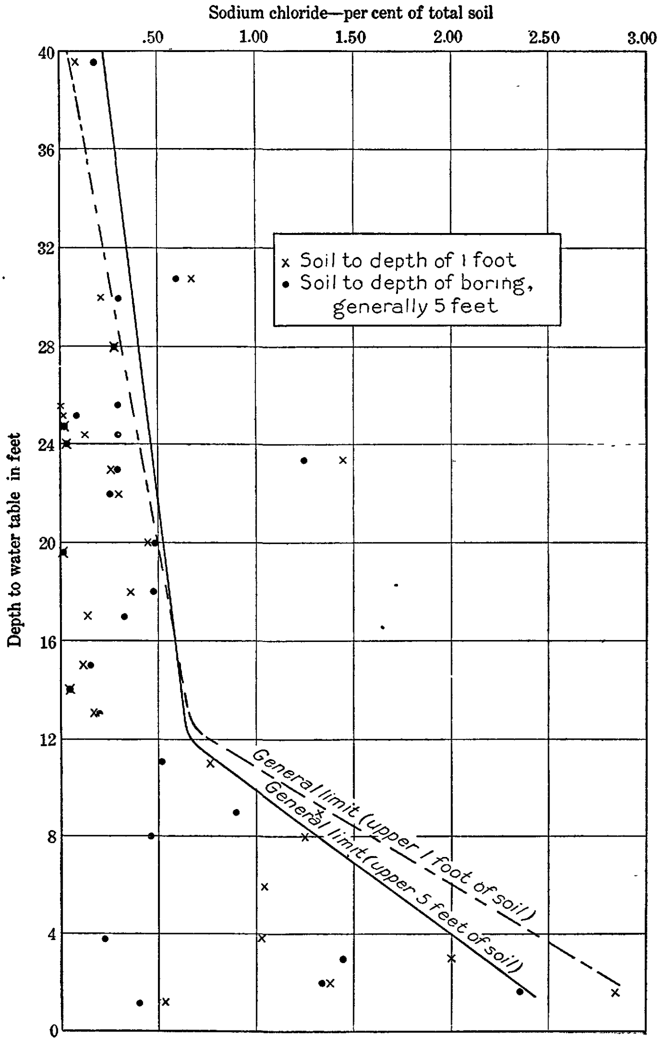

FIGURE 45.—Diagram showing relation of sodium chloride (in soils analyzed) to depth of water table.

ably related to fluctuations in ancient water levels. However, in certain localities where the surface is far above the water table there are heavy accumulations of alkali which seem to require special explanations (for example, analyses A 35 and A 41).

DISPOSAL OF ALKALI.

Whether the alkali content of the soil decreases or increases when the land is irrigated and cultivated depends on the character of the soil and topography, the position of the water table, the methods of irrigation and cultivation, and the crops raised. Heavy irrigation will be effective in removing alkali under certain conditions, but will accumulate it under other conditions. If the soil is porous and heavy applications of water are made, the alkali will be leached downward out of the soil. But if the ground water is within capillary reach of the atmosphere the alkali will be drawn back as soon as the irrigation ceases and evaporation begins. Moreover, if the drainage conditions are not good and heavy applications of water are made, the water table will be raised through accretions to the ground water from the irrigation supplies, and land which in its natural state was not affected by the rise of ground water may, through the elevation of the water table and consequent upward movement of capillary water, become seriously impregnated with alkali. Light irrigation will not supply much ground water, and hence is not so likely as is heavy irrigation to cause the accumulation of alkali through capillary rise of the ground water. Moreover, if light irrigations are followed by careful cultivation, evaporation will to a great extent be prevented, and the alkali will be drawn up but slowly. Light irrigation will not, however, be effective in disposing of any alkali.

In general, the best practice is to remove alkali by leaching it downward, and where the natural drainage is poor to construct drainage ditches through which the alkali-impregnated seepage waters can be permanently removed. In some places, however, artificial drainage is not practicable either because of the expense involved or because no outlet can be found at a sufficiently low level. Downward leaching is also difficult where the soil is dense and impervious.

Other methods of removing alkali are by washing or scraping it from the surface and by raising plants that take up alkali, these plants being removed from the land when they are harvested in order to remove the alkali.

Throughout most of the area in Tularosa Basin that has possibilities of irrigation from wells the ground water is not within capillary reach of the atmosphere. Since pumping will remove more water from the underground reservoir than it will return thereto, the water table will not be generally raised by this kind of irrigation, although it may be locally raised somewhat. But though with this kind of irrigation the alkali in the ground water will not commonly be brought into the soil by capillary rise, it will be introduced through the pumping and irrigation process. Since much of the ground water is heavily mineralized, and since much of the soil is either of the impervious adobe type or already contains considerable alkali, there is danger of accumulating alkali by irrigating with ground water.

Since pumped supplies must necessarily be sparingly used, and since much of the soil is relatively impervious, downward leaching with well waters will probably not be generally practicable. Sparing use of well waters and careful cultivation to prevent unnecessary evaporation will reduce alkali accumulation to a minimum. Where flood water can be led to an irrigated field it can be used as a corrective. By applying this water generously in times of freshets, as is often possible, the alkali can be leached downward through the more porous soil or possibly washed from the surface of the more impervious soil.

If the wet lands in the lower courses of the arroyos are irrigated with well waters their alkali content, already generally great, will be increased by both the capillary rise and the irrigation application of the ground water. Moreover, these lands lie so low that they could not well be effectively drained by artificial ditches, and the occasional floods would make the maintenance of drainage ditches difficult and expensive. To some extent these wet lands may eventually be utilized for agriculture by raising alkali-resistant and alkali-removing crops, by improving every opportunity to wash away alkali through the agency of floods, and by using the other precautionary methods that have been mentioned.

The wet land adjacent to the south end of the younger lava bed is of particular interest because of the large flow of water from Malpais Spring. This land lies at a sufficient elevation to be drained into either the small alkali flats 3 miles west of the spring or into Salt Creek, which is 5 miles west. The alkali flats could probably not dispose of more than 1 to 2 second-feet of water by evaporation from their surfaces, and this rate of disposal would not be adequate for the drainage of all the land in question that could be irrigated with the spring water. Salt Creek could, of course, dispose of all the water that would drain into it by carrying this water southward to the much larger flat into which it discharges.

A more feasible project and one that would involve less expense would be to lead the spring water through a ditch to the uplands adjacent to the flats or adjacent to the creek, where it could be used on soil containing less original alkali than the soil near the spring, and where a certain amount of drainage would occur naturally, where deeper drainage could be effected by means of shorter and less expensive ditches, and where only the water actually used would have to be disposed of.

In view, however, of the large amounts of alkali in the water of Malpais Spring (analysis, p. 300) and the inferior quality of soil in the region between this spring and Salt Creek, it is doubtful whether any reclamation project in this region would be wholly successful.

ZONES OF NATIVE VEGETATION.

Since the native plants are sensitive to differences in soil, moisture, and temperature, and since their distribution is controlled by the physical conditions constituting their environment, they form valuable guides in any study relating to the water supplies and irrigation possibilities of a region. In any given zone of vegetation there are generally several kinds of native plants growing together, but some one of these is likely to predominate or to be characteristic of that zone. In some places the boundaries between the different zones are quite distinct; in others they are very indefinite.

The following zones and areas of native vegetation are recognized in Tularosa Basin: (1) The lower barren zone, (2) the zone of alkali vegetation, (3) the chamiso zone, (4) the mesquite zone, (5) the creosote zone, (6) the grass-covered areas, (7) the area of true sagebrush, (8) the yucca groves, (9) the zone of foothill vegetation, (10) the forest zone, (11) the upper barren zone, (12) the white sands and adjacent quartz sands, and (13) the malpais.

The lower barren zone, which is destitute of vegetation, includes most of the area occupied by the alkali flats (Pl. II, in pocket), and covers approximately 150 square miles.

The zone of alkali vegetation includes marginal parts of the alkali flats, the valley of Salt Creek and vicinity of Salt Spring, a considerable area adjacent to the south end of the malpais, the lower parts of the mid-slope arroyos, and other small areas of alkali soil. Outside of the alkali flats it probably does not cover a total of more than one township of land. In this zone salt grass and alkali-resistant bushes, such as burro weed (*Allenrolfea occidentalis*), are dominant.

In the chamiso zone the dominant type is a species of Atriplex, known by the Mexicans as "chamiso," and often incorrectly called "sagebrush" by the English-speaking inhabitants of the region. This zone covers approximately 650 square miles and includes (1) most of the gypseous plain on the east side of the basin between the white sands and the mesquite zone (Pl. II, in pocket), (2) a portion of the plain south of the white sands extending from these sands to an indefinite boundary some miles south, (3) the gypseous plain north of the white sands and southwest of the malpais, in the vicinity of Salt Creek and the northern alkali flats, and (4) a narrow belt practically adjacent to the west margin of the large alkali flat. In some places on the west side of the basin chamiso intervenes between the mesquite and creosote zones (fig. 46), but such a relation is exceptional. Both the inner and outer boundaries of this zone are indefinite. The boundary between it and the zone of alkali vegetation is considered to pass through the localities where the chamiso and the alkali vegetation are equally abundant. Likewise the boundary between this zone and the mesquite zone is considered to pass through the localities where chamiso and mesquite are equally abundant.

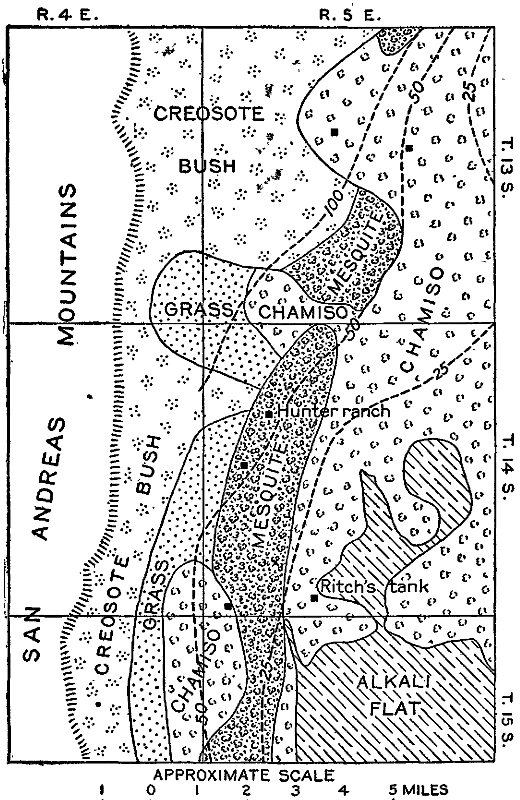

FIGURE 46.—Map of a part of the west slope of Tularosa Basin, showing zones of vegetation. Numbers indicate depth to water table, in feet.

The mesquite zone occupies the intermediate parts of the stream-built slopes and forms an irregular belt on each side of the valley (Pl. II, in pocket). Within the area covered by Plate II it occupies about 180 square miles, five-sixths of which is on the east side of the basin, but on both sides it extends north and south of the area mapped. Its outer boundary is in most places formed by the creosote zone and is generally more definite than the inner boundary, adjacent to the chamiso zone.

The creosote zone occupies a large part of the gravelly upper portion of the stream-built slopes and covers a greater total area than the mesquite zone. It is characterized by the so-called creosote bush, sometimes incorrectly called greasewood, but also contains a number of other desert bushes. Its inner boundary is generally rather definite. In most places it is adjacent to the mesquite zone but in some localities where mesquite is absent, as in an area between Tularosa and Temporal and in the vicinity of the Henderson ranch, it touches the chamiso zone, and in other localities it touches the grass-covered areas. Its upper boundary is either indefinite or coincides with the edge of the mountains

Small tracts of creosote bush are also found in the interior of the basin.

Grass with only small amounts of brush covers most of the area east and north of the lava beds and most of the southwestern part of the plain south of the white sands. It is also dominant over parts of the stream-built slopes in other localities, especially on the west side of the basin, as in the area shown in figure 46.

True sagebrush is absent, or very rare, except in the southeastern part of the basin, where a species of Artemisia different from species prevalent in the Northwest (probably *Artemisia filifolia*) forms the dominant vegetation over large areas. This sagebrush is found along the railroad, with certain interruptions, from some distance north of Turquoise station nearly to Hueco station.

Yucca is widely distributed, but does not constitute the dominant vegetation except in some localities in the southern part of the basin, where it occurs on the upper slopes in association with a number of desert bushes, and on the lowland plain in association with sagebrush, grass, mesquite, and chamiso. It is especially abundant along the railroad on both sides of Hueco.

The isolated hills, the low ranges, and the lower parts of the high ranges support a scattered growth of various desert bushes, such as creosote bush, ocatilla, century plant, Spanish bayonet, and yucca, and in some places small cedars or junipers. At greater altitudes the high ranges, especially those on the east side, support forests of large trees containing much valuable lumber. At Cloudcroft, 8,000 to 9,000 feet above sea level, there are yellow and other pines, spruce trees, maples, black locusts, quaking asps, and scrub oaks. Smaller pines, cedars, and large mountain junipers are abundant at the horizon of High Rolls, 6,000 to 7,000 feet above sea level. Small conifers are scattered over many parts of the northern plain and Mesa Jumanes and form ribbons of timber along some of the Cretaceous escarpments. Small trees also cover the east-facing scarp of the Chupadera Plateau. Sierra Blanca Peak, the culminating point of the rim of Tularosa Basin, 12,003 feet above sea level, is above the timber line and represents the upper barren zone.

The white sands and adjacent quartz sands and the younger lava bed may be regarded as special areas in so far as vegetation is concerned. Both support a scattered growth of desert vegetation, their floras being composed of various plants commonly found in this region. On the white sands chamiso, mesquite, sagebrush, yucca, and various grasses are common, and a few stunted cottonwood trees are found. The southern part of the malpais supports mesquite, chamiso, and other bushes that grow in the dust-filled crevices of the rock; the northern part, including the area within about 10 miles of the north end, supports these bushes and also a large number of small but sturdy conifers, chiefly cedars. The cedars are most abundant near the north end and gradually disappear southward.

RELATION OF VEGETATION TO SOIL.

The positions of the different zones of vegetation are determined by differences in soil, water supply, and temperature. Since all three of these factors everywhere exert an influence but are of very different relative importance in different localities, it is difficult to give proper value to the influence of each.

The mesquite and grass zones comprise the largest proportion of satisfactory soil, although some of the soil within these zones is not good and much fertile soil lies outside of them. The mesquite zone occupies an intermediate topographic position and does not generally extend up to soil that is too gravelly or bowldery for agriculture nor far into the interior where gypseous and alkali-impregnated soils prevail. Mesquite is, however, found in some places on gravelly soils and in many places on soil that is undesirably gypseous. It also extends down the arroyos to localities having dangerous amounts of alkali.

Chamiso is associated with the gypseous soil of the interior plain. This plant can endure the moderate amounts of alkali found in soil of this type, and it appears to be especially adapted to the gypsum areas, but it does not thrive in the strongly alkaline tracts. It is to be regarded as a warning of excessive gypsum rather than of excessive alkali.

Salt grass and the succulent alkali bushes are distinct warnings of alkali. Where they are dominant the soil certainly contains much alkali, and where they are found in association with chamiso, mesquite, or other plants they indicate an appreciable and perhaps an injurious amount of alkali. The absence of vegetation over most of the area covered by alkali flats seems to indicate that the soil of these flats contains too much alkali for even the most alkali-resistant plants.

The diagrams in figures 47 and 48 show the range of alkali in the different zones of vegetation, in so far as they are indicated by the analyses that were made. The actual range is no doubt greater for each zone. It should be noted that the diagrams do not indicate the amounts of alkali that can be endured by the different plants, but the amounts in which the different plants can exist as the dominant vegetation.

The creosote zone extends over the upper parts of the stream-built slopes where the soil is gravelly and full of bowlders, but it also includes much good soil. Most of the soil at present under irrigation lies within this zone.

The true sagebrush is definitely related to the sandy soil, its occurrence being nearly coextensive with the southern sand-covered area. A little scattered sagebrush is also found in the white sands.

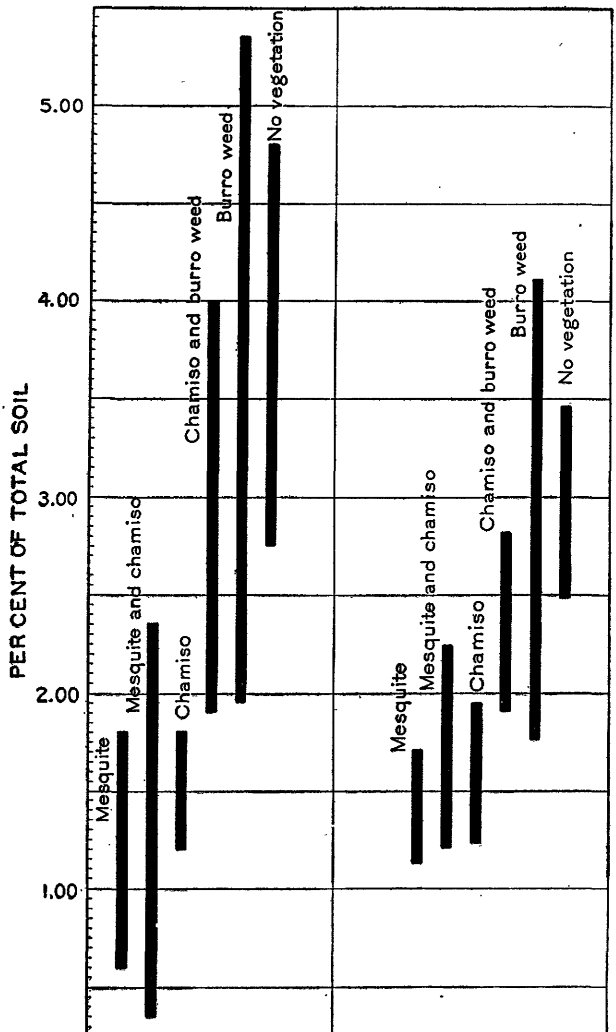

FIGURE 47.—Diagram showing range of dominant vegetation with regard to total soluble solids in soils analyzed.

RELATION OF VEGETATION TO WATER SUPPLIES.

The distribution of zones of vegetation is influenced by the amounts of rainfall and flood waters and by the depths to ground water.

The most obvious effects of the distribution of rainfall are (1) the desert types of the vegetation throughout most of the basin and (2) the forests in the high mountains. At Cloudcroft, where the average annual rainfall is 22 inches, large trees are abundant; at Alamogordo, where it is less than 11 inches, desert plants prevail. At intermediate levels and on the low mountain ranges there is an intermediate amount of rainfall, and consequently only a scattered growth of small trees. The trees and grass in the northern part of the basin are probably in part due to the somewhat greater rainfall and less evaporation there than in the central and southern desert areas. The trees on the Cretaceous scarps and on the scarp of the Chupadera Plateau probably result from the extra rainfall produced by these abrupt although low elevations.

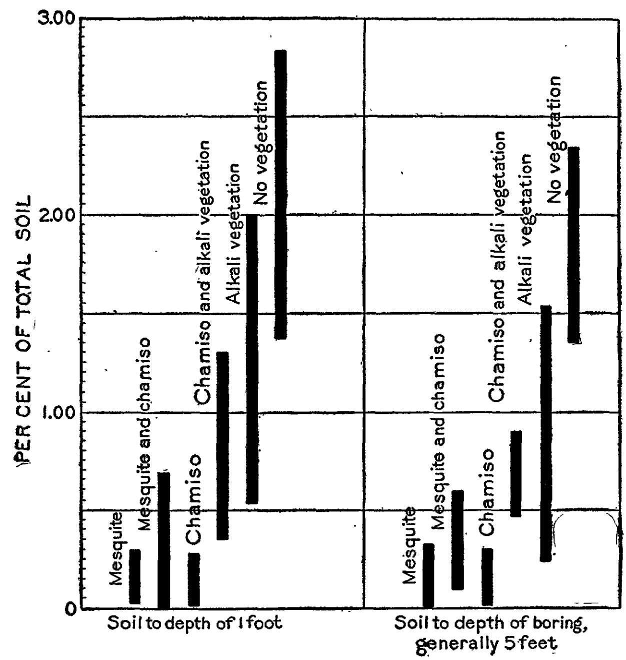

FIGURE 48.—Diagrams showing range of dominant vegetation with regard to sodium chloride in soils analyzed.

The arrangement of the principal zones of vegetation around the interior of the basin results largely from differences in soil, but partly from differences in water supply. The alkali plants in the wet areas utilize ground water, and it is possible that mesquite and chamiso also to some extent tap the underground supply. However, the maps (Pl. II, in pocket, and fig. 46) show that no very close relation exists between the boundaries of the mesquite and chamiso zones and the depths to water. The zones of vegetation do not maintain uniform widths, but are alternately wide and narrow. The sinuosities of their boundaries do not correspond in general to sinuosities of either surface contours or water-table contours, but are manifestly related to the mouths of the principal canyons. Since both the coarseness of the soil and the flood-water supply are also related to the mouths of the canyons, it is difficult to estimate to what extent each of these two controls the sinuosities.

The zones also show somewhat different relations on the opposite sides of the basin. On the west side both mesquite and creosote zones expand opposite the mouths of large canyons and contract or entirely disappear in the interstream localities. Opposite the mouths of canyons these two zones abut against each other, but in the interstream localities chamiso and grass occupy the areas not covered by mesquite or creosote. The dilations of the mesquite zone can be pretty confidently ascribed to the better water supply opposite the canyons; those of the creosote zone may be due largely to differences in the coarseness of the soil.

All of the zones are much wider on the east than on the west side because the streams on the east side are larger and have built broader and more gentle slopes. The mesquite zone is less interrupted and hugs the creosote zone more closely on the east side, probably because the flood-water supply is more abundant. As on the west side, it shows a tendency to widen in the areas opposite the mouths of large canyons, but such widening is to a great extent prevented through the down crowding of the creosote zone in these localities and through the withdrawal of flood waters by the mid-slope arroyos.

RELATION OF VEGETATION TO TEMPERATURE.

The existence of forests in the high mountains is due to the abundance of rain in those regions, but the vertical distribution of the different kinds of trees is due largely to decreasing temperature with increasing altitude (fig. 2, p. 14), as is shown by the fact that the kinds of trees found at higher altitudes correspond in a general way to the kinds found at higher latitudes. The upper barren zone is also a result of temperature control.

The differences in vegetation that can be observed in passing from the north to the south end of the basin are due in part to difference in rainfall and in part to differences in temperature. The latter are due to differences in both latitude and altitude. The greater abundance of yucca and cacti in the southern than in the northern part of the basin can be ascribed chiefly to differences in temperature.

DISTRIBUTION OF SOILS AND VEGETATION IN THE SHALLOW-WATER BELT.

The following detailed data on the distribution of soils and native vegetation within the area of shallow ground water are given because of their bearing on the problem of irrigation with well waters:

T. 10 S., Rs. 6 and 7 E.—The southeastern part of T. 10 S., R. 7 E., is covered with lava, and the northwestern part of T. 10 S., R. 6 E., is occupied by gravelly upland. A nearly level plain several miles wide runs parallel to the edge of the lava and is covered with loamy soil that apparently does not contain a great amount of alkali. The dominant vegetation is creosote bush.

T. 11 S., R. 6 E.—Along the east margin and near the southeast corner of the township there is low alkali land. Most of the rest of the township is occupied with mountains and a steep gravelly slope, but a narrow belt of better soil lies between the steep slope and the alkali land.

T. 11 S., R. 7 E.—The southeastern part of the township is covered with lava. The rest is a low nearly level plain, with reddish or brownish soil and pale gypseous subsoil. The amount of alkali apparently increases toward the south. (See analyses A 1 and A 2.) The vegetation is chiefly chamiso and grass. Some creosote bush grows in the northern part, and the succulent alkali bushes (*Allenrolfea occidentalis*) are found in the southern part.

T. 11 S., R. 8 E.—Most of the township is covered with lava, but the southeastern part consists of a gently sloping plain. The subsoil, which is gypseous and contains a small amount of alkali, is overlain, especially near the lava, by recently deposited reddish or brownish loam that is practically free of alkali. (See analysis A 3.) The vegetation consists of large but scattered mesquite, together with chamiso and grass.

T. 11 S., R. 9 E.—The northeastern part of the township is largely rocky and the soil throughout is rather gravelly. The southwestern part is a gently inclined, grass-covered plain.

T. 12 S., R. 5 E.—Most of the township is occupied by mountains and a steep gravelly slope, but the southeastern part is a gently inclined plain ranging from gravelly to gypseous loam. At the Jackson ranch the soil is somewhat sandy and gravelly, but apparently of satisfactory quality. Mesquite predominates for some distance northwest of this ranch, and chamiso between the ranch and Salt Creek.

T. 12 S., R. 6 E.—The soil of the northeastern part of the township contains much alkali and has an alkali vegetation. Alkali is also abundant along Salt Creek (analysis A 5). Much of the central and southern parts of the township lies considerably above Salt Creek and has soil that is gypseous, but does not contain excessive quantities of alkali (analysis A 4). It supports creosote bush, mesquite, and chamiso. Similar soil is found on the west side of the creek, becoming less gypseous toward the northeast corner. The vegetation consists of chamiso near the creek and of chamiso and mesquite farther west.

T. 12 S., R. 7 E.—The lava bed projects into the northern part of the township. The western half of the township, where it is not covered by lava, consists of wet alkali land, over much of which succulent bushes and salt grass prevail (analyses A 6 and A 7). The eastern half is chiefly covered with mesquite and contains less alkali. The southeast corner of the township is sandy. (See Pl. II, in pocket.)

The flow from Malpais Spring can not be successfully used for irrigation on the wet land near the lava unless that land is first drained. It could be led by gravity several miles southwest of the spring upon land that is gypseous, but contains less alkali and is considerably above the water table. (See p. 192.)

T. 12 S., R. 8 E.—The northwestern corner of the township is covered with lava; the southern and especially the southeastern part, comprising about one-half of the total area of the township, is sandy. (See Pl. II, in pocket.) Between the lava and sand there is a belt of loam soil 2 to 3 miles wide that is covered with mesquite and apparently does not contain injurious amounts of alkali. The soil of this belt is somewhat gravelly in the northeastern corner of the township and becomes more clayed toward the southwest.

T. 12 S., R. 9 E.—The eastern part of the township comprises rather gravelly creosote-covered land that lies high above the main body of ground water. The western part is covered principally with mesquite and grass and lies nearer the water table. Most of the western part contains fairly good loam soil, but in the southwest there is some sandy and possibly some alkali land. In the northeastern part of the township, and in parts of the township next east, there are small bodies of ground water lying above the main body. These will probably afford a supply to shallow wells for irrigation on a small scale.

T. 13 S., R. 5 E.—The northwestern part of the township is occupied by a steep gravelly slope; the southeastern by a nearly level plain considerably above the valley of Salt Creek. This plain, which extends from the east side of the township to some distance beyond the Henderson ranch, is covered for the most part with chamiso, and has a gypseous soil. In some places the surface is slightly undulating, and the depressions are filled with reddish clay soil. A belt of apparently good soil intervenes between the steep slope and the nearly level plain. In the southern part of the township this belt is largely covered with mesquite. (See Pl. II, in pocket, and fig. 42.)

T. 13 S., R. 6 E.—The valley of Salt Creek and the depressed flat in the southwestern part of the township contain a large amount of alkali (analysis A 12). The rest of the township is a plain at a distinctly higher level and with soil that contains much gypsum, but not excessive amounts of alkali (analyses A 10 and A 11). The southern and eastern parts have irregularities due to wind work. The predominant vegetation outside of the alkali flat is chamiso.

T. 13 S., R. 7 E.—The soil throughout the township is gypseous or sandy. The sand hills increase in prominence toward the east.

T. 13 S., R. 8 E.—Sand hills cover about one-half of the township, their eastern limit being shown on the map forming Plate II (in pocket). There are small tracts of nearly level loam soil within the sand-hill area, as at Black Lake ranch (analysis A 14). The eastern part of the township is a gypseous plain, most of which is covered with chamiso and contains only a moderate amount of alkali (analysis A 15).

T. 13 S., R. 9 E.—The eastern part of the township belongs to the high gravelly slope where the depth to water is great. Westward the soil becomes more clayey and then more gypseous. The soil on the southern part of the slope is of the red adobe type; north of Temporal it has a more ashy appearance. The shallowest water occurs in a belt passing through the Chosa, Gray, and Lomitas ranches. East of this belt the surface rises rather abruptly. The shallow-water belt locally contains injurious amounts of alkali (analysis A 17), but good crops of fruit have been grown at the Gray ranch and vegetables at the Lomitas ranch. This belt has the best prospects for artesian flows. The eastern part of the township is covered with creosote bush, the northwestern with mesquite, and the southwestern with chamiso.

T. 14 S., R. 5 E.—The best soil is in the western third of the township, where mesquite is the dominant vegetation. The northwestern part is a gypseous plain covered with chamiso. The southeastern part is occupied largely by alkali flats and wind deposits. (See Pl. II, in pocket, and fig. 46, p. 194.)

T. 14 S., R. 6 E.—An alkali flat and dune areas occupy most of the township. In the western part there is some level land but the soil is generally gypseous.

T. 14 S., R. 7 E.—Most of the township is occupied by dunes of quartz and gypsum sands.

T. 14 S., R. 8 E.—The western half of the township is occupied by quartz and gypsum sands; the eastern half by a gypseous plain, most of which is covered by chamiso. The plain is dissected by one large arroyo. The gypseous soil generally contains only moderate amounts of alkali, but in some spots the alkali content is large and the soil shows dark stains. (See analyses A 21, A 22, and A 23.)

T. 14 S., R. 9 E.—In general the eastern part of the township contains red adobe soil and the western part contains gypseous soil, the boundary between the two trending south-southeastward. The adobe increases in clay content toward the west but is not excessively gravelly along the east margin of the township except perhaps near the northeast corner. The arroyos and many irregular depressions in the gypseous plain are covered with red soil that is believed to be better for agriculture than the gypsum. The red soil areas diminish in importance toward the west side and especially toward the southwest corner of the township. A moderate amount of alkali occurs throughout most of the soil in the western part of the township (analyses A 25 and A 26). Somewhat greater amounts occur locally in the shallow-water belt passing through the Lomitas ranch and in the lower parts of the arroyos, but most of the soil of the arroyos in this township is probably not seriously impregnated with alkali.

T. 15 S., R. 5 E.—On the west side of the township there is a belt of loam soil covered with mesquite. Nearly all of the rest of the township is occupied by the large alkali flat.

T. 15 S., R. 6 E.—The southwestern part of the township is occupied by the large alkali flat, the rest chiefly by gypsum sands.

T. 15 S., R. 7 E.—Gypsum sands prevail throughout the township.

T. 15 S., R. 8 E.—The western two-thirds or more of the township is covered by gypsum sands. (See Pl. II, in pocket.) The eastern part, including about 10 square miles, is occupied by (1) the chamiso-covered gypseous plain, (2) the lower parts of several broad arroyos that dissect the plain, and (3) the conspicuous limestone ridge known as Cerrito Tularosa. The gypseous plain contains moderate amounts of alkali, as is shown by analyses A 23 and A 29. The arroyos, especially the northernmost one, have shallow water and more or less alkali near the surface. The soil of the bottom land at Shoemaker's well supports alkali bushes and shows alkali. The analysis (A 20) reveals the fact that the upper foot of this soil is heavily charged with sodium chloride, sodium sulphate, and magnesium sulphate, but that the next 5 feet contain only a moderate amount of magnesium sulphate, a small amount of sodium chloride, and practically no sodium sulphate. It is reported that good vegetables have been grown in this soil.

T. 15 S., R. 9 E.—The township comprises a gently sloping plain dissected in the northern part by broad mid-slope arroyos supplied from Tularosa River basin, and in the southeastern corner by similar arroyos supplied from the Fresnal and La Luz drainage basins. The upland soil ranges from red loam on the east to ashy gypseous material on the west. Mesquite covers the eastern part but westward gives way gradually to chamiso. The soil near the east margin appears to contain little if any alkali; the gypseous soil farther west contains moderate amounts of alkali (analysis A 29). In the northeastern part of this township and adjacent parts of the township next east conditions are favorable for irrigation with ground water in so far at least as soil and depth to water are concerned. The parts of the arroyos in which the depth to water is over 15 feet also present favorable conditions, but the parts in which water is very near the surface are liable to contain undesirable amounts of alkali.

T. 16 S., R. 4 E.—The western part of the township is mountainous, and east of the mountains there is a steep gravelly slope. The northeastern part of the township is occupied by the large alkali flat. Between the gravelly slope and the flat there is a narrow mesquite-covered belt of apparently good loam soil.

T. 16 S., R. 5 E.—The large alkali flat occupies nearly the entire township. There is a very small area of fairly good land in the southwest corner.

T. 16 S., Rs. 6 and 7 E.—White gypsum sands cover both townships.

T. 16 S., R. 8 E.—The gypsum sands extend only into the western tier of sections. The rest of the township is included in the nearly level chamiso-covered plain of gypseous soil through which pass several broad arroyos supplied from the Fresnal and La Luz drainage basins. The soil throughout practically the entire township is unsatisfactory. The upland soil contains undesirable amounts of gypsum; the arroyo soil contains undesirable amounts of alkali.

T. 16 S., R. 9 E.—In the northeast corner of the township the soil is a gravelly red loam. Southwestward it changes gradually into less gravelly loam, then into dense clay loam, then into gypseous loam, and finally, near the southwest corner, into impure gypsum. Near the northeast corner, covering approximately the more or less gravelly soil, the dominant vegetation is creosote bush. Southwest of the creosote zone, covering about one-half of the township and coinciding in general with the red loam soil, the dominant vegetation is mesquite. Farther southwest the mesquite very gradually becomes more scattered and stunted, and chamiso becomes the dominant type, indicating gypseous soil. The floors of the arroyos are generally covered with red loam, even where they pass through the region where the upland soil is gypseous. Alkali in moderate amounts is widely disseminated through much of the upland soil, except probably in the northeastern part. (See analyses A 32 and A 34.)

In the arroyos it occurs in undesirable amounts where the water table is near the surface but need not be feared where the depth to water is over 15 feet. (See analyses A 30, A 31, and A 33.)

T. 16 S., R. 10 E.—Most of the township is occupied by mountains and the adjacent, steep, gravelly slope, but red loam soil that is not excessively gravelly is found near the west margin. The mesquite zone originally extended into the west-central part of the township, covering an area of 3 or 4 square miles. The dominant native vegetation of the rest of the slope is creosote bush.

T. 17 S., R. 4 E.—Most of the township is occupied by mountains and the steep gravelly slope that borders the mountains on the east.

Baird's ranch is on the gravelly slope. In the northeastern and east-central parts of the township there is a mesquite-covered belt of apparently good though rather sandy soil.

T. 17 S., R. 5 E.—Most of the township is occupied by the large alkali flat, but west of the flat is a mesquite-covered belt of apparently good sandy or loamy soil.

T. 17 S., R. 6 E.—The township is occupied by the alkali flat and gypsum sands.

T. 17 S., R. 7 E.—All of the township is covered with gypsum sands except about 5 square miles in the southeastern part, which also have a very gypseous soil.

T. 17 S., R. 8 E.—Almost the entire township is occupied by a chamiso-covered plain with very gypseous and somewhat alkali-impregnated soil. There are one or more small alkali flats and a number of small dunes of gypseous material. The white sands encroach on the township only in the northwest corner. The mid-slope arroyos fade out in the northeastern part of the township.

T. 17 S., R. 9 E.—Most of the township contains gypseous, chamiso-covered soil, but red adobe occurs near the east margin and in numerous small arroyos and undrained depressions farther west. There are also intermediate soils of red clayey appearance but large content of gypsum. The mesquite zone is well developed near the east margin of the township but toward the west gives way gradually to chamiso. A moderate amount of alkali is widely disseminated (analyses A 37 and A 38), and in certain localities, even within 2 miles or less of the east boundary, it occurs in objectionable quantities (analyses A 35 and A 41) and may give the soil a dark stain (analyses A 35 and A 36). So far as investigated, the red soil in the arroyos and depressions contains less alkali than the adjacent gypseous soil. (Compare analyses A 38, A 39, and A 40.)

T. 17 S., R. 10 E.—Most of the township is occupied by mountains and the adjacent, steep, gravelly slope, but red loam soil that is not excessively gravelly is found near the west margin. It is covered partly with mesquite and partly with creosote bush. (See Pl. II, in pocket.)

T. 18 S., R. 5 E.—The central and western parts of the township are covered with alkali and gypsum sands. Along the west margin the slope is steep and the soil gravelly. Between the steep slope and the flat there is a narrow strip of land that is not very gravelly and does not contain much alkali. Most of the area west of the flat is covered with mesquite. (See Pl. II, in pocket.)

T. 18 S., R. 6 E.—The township is covered almost entirely with gypsum sands.

T. 18 S., R. 7 E.—The northwestern half of the township is covered with gypsum sands; the southeastern half is occupied by a gently undulating plain of gypseous soil.

T. 18 S., R. 8 E.—Most of the township contains gypseous soil but the amount of gypsum apparently decreases toward the southeast. Reddish quartz sand occurs in the southern part of the township, especially in the vicinity of the buttes.

T. 18 S., R. 9 E.—Most of the soil is gypseous, but the amount of gypsum decreases toward the east and also toward the south. Near the east margin of the township the soil is chiefly of the red adobe type and the dominant vegetation is mesquite.

T. 18 S., R. 10 E.—The eastern part of the township is covered with mountains and an adjacent short, steep, gravelly slope. The western part is a gently sloping plain which lies within the mesquite zone and in which the soil is adobe.

T. 19 S., R. 5 E. and farther south.—The southwestern part of the township is occupied by mountains and a steep gravelly slope; the northeastern part by an alkali flat and gypsum sands. In an intermediate position, not far from the alkali flat, there is a belt of good loam soil.

A meadow of level grass land and loam soil, less than a mile in average width, extends southward from the southwest corner of this township, through 5 or 6 townships, to Coe's ranch. It is bordered on the west by a steep gravelly slope and on the east by an undulating plain of wind-blown material that consists chiefly of gypsum to a point a short distance beyond Coe's two windmills (Pl. I, in pocket) and of reddish quartz sand farther south.

T. 19 S., R. 6 E.—Gypsum sand covers the northern part of the township and irregular deposits of gypsum and quartz sand occur over much of the remaining area. There are also many nearly level tracts of soil that do not contain much alkali (analysis A 43) although they may be somewhat gypseous or sandy. Chamiso is the dominant type of vegetation.

T. 19 S., R. 7 E.—The township is occupied by a gently undulating plain with loam soil that is generally gypseous in the northern part and more sandy in the southern part.

IRRIGATION.

STREAMS AND SPRINGS.

Sources of supply.—According to the United States census report, 6,346 acres were irrigated in Otero County in 1909 with water from springs and streams. This included nearly all of the irrigated land in Tularosa Basin and also some on the east slope of the Sacramento Mountains. The largest irrigation supply within this basin is furnished by Tularosa River; smaller supplies are furnished by La Luz Creek, Fresnal Creek, Alamo Canyon, and Three Rivers. Altogether only about 1 acre in 1,000 is under irrigation in Tularosa Basin.

Tularosa River.—Most of the water of Tularosa River rises on the Mescalero Apache Indian Reservation, the three principal sources being a group of springs about 4 miles above the agency, a group of springs in the main canyon about three-quarters of a mile above the agency, and a group of springs in the North Canyon about half a mile above the agency. (See Pl. III, in pocket.) Measurements made by H. F. Robinson, superintendent of irrigation, United States Indian Service, in 1906, when the water rights on the stream were adjudicated, showed that the normal flow passing Blazer's mill, 3 miles above the west line of the reservation, was about 11 second-feet, and that the accretions of water below this point, derived chiefly from springs, was about 8 second-feet. According to Mr. Carroll, formerly superintendent of the agency, the flow has increased slightly since 1906. It appears that in 1905 about 2,077 acres were irrigated with the Tularosa supply, of which 470 acres were on the Indian Reservation, 1,070 acres in the vicinity of Tularosa, and 537 acres along the stream between the reservation and the village. Since that time the acreage has been somewhat increased, and a part of the water formerly used farther upstream is now used at Tularosa. In 1911 it was estimated that about 1,700 acres were under irrigation in the vicinity of Tularosa. In addition to the irrigation from the main stream, about 160 acres are irrigated with water in Nogal Canyon.

At Tularosa the principal crop is alfalfa, which is in large part made into hay and shipped. Winter irrigation is practiced, and cattle are allowed to graze on some of the alfalfa fields until about March 1. Four crops are generally cut in a season. The land is irrigated 2 or 3 times for the first crop and usually only once for each of the later crops. The first crop is the heaviest and commonly yields 2 tons or more per acre. According to Mr. J. J. Sanders, a well-informed resident, a conservative estimate of the average yield for one year is 4½ tons per acre. No definite information is available as to the duty of the water, but it is believed that, exclusive of the winter water, this amount of alfalfa can be raised with 2 acre-feet, although, including wastage, more is commonly used. Alfalfa hay is estimated to be worth $7 to $8 per ton for feeding to stock, but nets more than $10 when shipped to other markets. Fruit is also grown to a considerable extent, but the industry has not yet been systematically developed. There seems to be no sufficient reason why, if adequate market facilities are acquired, the raising of fruit on a larger scale will not be profitable.

La Luz and Fresnal creeks.—According to measurements made by James A. French, State engineer of New Mexico, the discharge between March 1 and August 31, 1912, of all springs and seepages tributary to La Luz Creek (Pl. III, in pocket) amounted to 2,472 acre-feet, or an average of nearly 7 second-feet, and of all springs and seepages tributary to Fresnal Creek, to 1,973 acre-feet, or an average of $5\frac{1}{2}$ second-feet. It was found that during this period, exclusive of floods, approximately 955 acre-feet were discharged by La Luz Creek and 1,050 acre-feet by Fresnal Creek, both measured immediately above their junction. The average normal discharge of the two streams was therefore about $5\frac{1}{2}$ second-feet. Most of the rest of the water was diverted and used for irrigation on ranches situated above the junction of these streams, but some was lost by percolation into the ground and by evaporation.

The village of La Luz is entitled to 36 miner's inches, and the Alamogordo Improvement Co. to the rest of the water discharged by the two streams. The relative rights of the company and of the ranches along the streams was in litigation at the time this investigation was made. According to the measurements made by the State engineer, the water delivered between March 19 and August 31, 1912, exclusive of floods, was 317 acre-feet to the La Luz community ditch and 1,380 acre-feet, or an average of a little over 4 second-feet, to the main ditch of the Alamogordo Improvement Co.

According to the best information obtainable, nearly 160 acres are irrigated with water delivered to the La Luz community, and over twice this area is irrigated with the water of the Alamogordo Improvement Co. The latter is widely distributed, a part being used by the company and a part sold in small quantities to farmers and residents of Alamogordo. A part of the company's water is used east of La Luz but most of it is conveyed in a ditch to the vicinity of Alamogordo.

The crops raised and the agricultural methods employed are largely the same as those at Tularosa. Alfalfa is the leading product and fruit is second in importance. At La Luz alfalfa is grown in the orchards. The yield and prices of alfalfa are about the same as at Tularosa. The fruit industry is capable of further development.

Alamo Canyon.—The small water supply furnished by Alamo Canyon (Pl. III, in pocket), southeast of Alamogordo, is owned by the Alamogordo Improvement Co. and is described on page 226. It is used primarily for domestic and industrial purposes, but the surplus water is used, according to the superintendent of the company, for the irrigation of about 140 acres south of Alamogordo.

Three Rivers.—The water supply of Three Rivers is derived from a number of springs and seepages, the more important of which are shown in Plate VI (p. 26), and from small streams heading in the

Sierra Blanca and fed by melting snow until early summer. The flow of the springs fluctuates annually, being greatest in May and June, and is also affected by periods of wet and dry years. The mountain streams are perennial, but, owing largely to increased evaporation, their waters do not generally reach the Three Rivers valley later than May.

The total area under irrigation in this valley varies, according to Senator Fall, between about 900 and 1,200 acres, the acreage being greater in wet than in dry years. All of the irrigated land except about 240 acres is on the Tres Ritos ranch, owned by Senator Fall, where by careful use of the water the cultivated acreage has been increased in recent years. The principal products are alfalfa and apples and other fruit.

Storage projects.—The construction of reservoirs to store surface waters until needed for irrigation has been considered for nearly all of the larger drainage areas on the west side of the Sacramento Mountains and the Sierra Blanca, including the Rinconada. This phase of the water-supply problem was not included in the present investigation.

Isolated springs.—A small amount of irrigation is accomplished with isolated springs, such as Carrizozo Spring on the ranch of Gov. W. C. McDonald (sec. 26, T. 7 S., R. 10 E.), the infiltration ditch on the I Bar X ranch (sec. 30, T. 9 S., R. 10 E., and sec. 25, T. 9 S., R. 9 E.), the springs on the Lomitas ranch (SE. ¼ sec. 4, T. 14 S., R. 9 E.), and the sink-hole spring on the SW. ¼ sec. 25, T. 14 S., R. 8 E. Attempts have been made to irrigate with the water of Malpais Spring, and with water drained by gravity from the sink-hole pool 1½ miles southwest of the Cerrito Tularosa. Both projects were, however, abandoned, no doubt because of the excess of alkali in both water and soil. Irrigation with the water of Malpais Spring is discussed on page 192.

FLOOD WATERS.

The surface waters that result from heavy rains have been used to a considerable extent for irrigation by the settlers who have no other water rights and have produced some good results, especially in raising quickly maturing crops, such as cane, Milo maize, and Kafir corn. The aggregate quantity of these flood waters is large, they are chiefly available during the crop-growing season, and they can be led with comparatively little difficulty upon some of the best soil in the region. The greatest obstacle to their successful use is their extremely erratic occurrence, on account of which destructive droughts often intervene between irrigations.

Attempts made to store flood waters in shallow earth reservoirs on the gently sloping plains have not been very successful. Such reservoirs lose their water rapidly through percolation and evaporation, they tend to silt up, and their dams are likely to be washed out by heavy floods. Nevertheless they deserve further trial. They can be constructed, enlarged, and repaired without much expenditure of money by the farmers themselves at times when other work is not urgent. The danger of washouts can be partly overcome by building the reservoirs at points as far removed as possible from the course of the flood waters, so that they are not filled by sheet floods drained directly into them, but by definite ditches which tap the flood waters and by means of which the supply can be regulated. The danger of washouts can also be reduced by building protective dams above the reservoirs for the purpose of diverting the surplus water, and by making large and substantial spillways. The loss by percolation is difficult to overcome, largely because of the checking that occurs when the reservoirs are dry, but storage during any long period is not contemplated. The reservoirs will be valuable if they hold a considerable part of their water for two weeks or even a shorter time. Underground waters recovered through wells will, however, on the whole, form a more dependable and otherwise more satisfactory auxiliary supply than the flood waters stored in earth reservoirs.

WELLS.

DEVELOPMENTS.

In 1911–12 a few small pumping plants had been installed in the region, some of which furnished water for the irrigation of small tracts of vegetables, forage crops, alfalfa, and fruit trees. The total acreage irrigated with well waters was inconsiderable, and, with a few exceptions, the product amounted to but little. Pumping for irrigation was still in an early experimental stage. In addition to the pumping plants listed in the following table there are various small projects in which the water is supplied by windmills.

Irrigation pumping plants in Tularosa Basin investigated in 1911–12.

Location.				Owner.	Wells (see tables, pp. 268–305).	Pumps.	Power	Capacity per minute.[a]	Area irrigated.	Crops.
Quarter.	Section.	Township south.	Range east.							
								Gallons.	*Acres.*	
NE	13	8	9	Joseph George	Dug 52 feet	Deep-well cylinder	10-foot windmill	12	3	Orchard and vegetables.
SE	35	9	8	R. Richardson	Dug about 50 feet	2 deep-well cylinders.	Dutch windmill			
NE	21	9	9	George Castle	Drilled 175 feet	Deep-well cylinder	5-horsepower gasoline engine.	[b] 90		
NW	28	9	9	A. Gschwind	Drilled 130 feet	do	12-foot windmill	10 to 25	5	Vegetables.
SE	31	9	9	E. F. Jones	Drilled 67 feet	do	4½-horsepower gasoline engine.	[b] 25	3 (for this row and the next)	Orchard and vegetables.
SE	31	9	9	do	Drilled 108 feet	do	Windmill	Small		
SE	5	10	9	Robert Young	Drilled 158 feet	do	4½-horsepower gasoline engine.	20 to 25		Orchard.
NW	8	10	9	I. Braunstein	Drilled	do	16-foot windmill	Several	3	Orchard and corn.
NE	13	11	9½	A. B. Fall	Dug 50 feet with 100-foot tunnel.	Vertical centrifugal	Gasoline engine	300 to 500		
NW	13	14	8	A. J. Hill	3 dug holes, 40 feet, with infiltration galleries.	do	4-horsepower gasoline engine.	75 (?)	3	Vegetables, orchard and forage plants.
SW	8	14	9	Isaac Otis	Dug and drilled 58 feet.	do	13-horsepower gasoline engine.	270	20	Kafir corn.
NE	14	14	9	M. W. Votaw	Dug and drilled 116 feet.	do	7-horsepower gasoline engine.	70	9	Orchard, vegetables, etc.
NE	17	14	9	Isaac Otis	Drilled 68 feet	Deep-well cylinder	6-horsepower gasoline engine.		None	
NE	28	14	9	H. W. Purday	Dug 35 feet	do	Gasoline engine	10	Several	Vegetables, etc.
SE(?)	28	14	9	H. R. Douglas	do	do	3-horsepower gasoline engine	[b] 100	16 (for this row and the next)	Orchard, etc.
NE	33	14	9	A. L. Douglas			Gasoline engine			
NE	4	16	9	F. C. Larsen	Drilled 100 feet	Deep-well cylinder	5-horsepower gasoline engine.	75	(for this row and the next)	
NE	4	16	9	do	do	do	Windmill	20		
NW	23	16	9	C. W. Morgan	Drilled 160 feet	do	Electric motor	40	Several	Orchard, vegetables, etc.
NE	25	16	9	George Carl	2 drilled wells 186 feet; 1 drilled well 80 feet.	Horizontal centrifugal.	Steam engine	375	Several	Alfalfa, etc.
NE	25	16	9	do	Drilled 186 feet	Vertical centrifugal	12-horsepower gasoline engine.	[b] 150		
SW	34	16	9	Mr. Loomas	Drilled 67 feet		3-horsepower gasoline engine.	30		
NE	35	16	9	Mrs. Wertane	Drilled about 200 feet	Deep-well cylinder	Electric motor	[b] 150	Several	Vegetables, etc.
S	35	16	9	Benj. Aple	Drilled	do	do	[b] 60(?)	None	

[a] The capacity refers to the rate at which water can be supplied with the existing wells and equipment. In some plants it is limited by the yield of the wells, in others by the size of engine or pump.

[b] Approximate.

Irrigation pumping plants in Tularosa Basin investigated in 1911–12—Continued.

Location.				Owner.	Wells (see tables, pp. 268–305).	Pumps.	Power.	Capacity per minute.	Area irrigated.	Crops.
Quarter.	Section.	Township south.	Range east.							
								Gallons.	*Acres.*	
NW....	3	17	9	Simeon Bowden..	Dug and drilled 140 feet.	Vertical centrifugal....	5-horsepower gasoline engine.	*a* 40	2	Vegetables, etc.
NE....	15	17	9	H. F. Patty.......	Dug and drilled 59 feet.	.....do................	7-horsepower gasoline engine.	*a* 110	14	Milo maize, cane, and orchard.
NE....	26	17	9	J. S. Morgan......	Dug and bored 90 feet.	Deep-well cylinder....	Horsepower and gasoline engine.	....	....	
NE....	14	18	9	Mrs. S. D. Camp..	Dug and drilled 160 feet.	.....do................	Windmill and 5-horsepower engine.	144	....	

a Approximate.

IRRIGABLE AREAS.

The principal conditions that determine the boundaries of the areas in which irrigation with well water is an economic consideration are (1) depth to the water table, (2) quantity of water available, (3) quality of the water, (4) quality of the soil, (5) topography and drainage, and (6) availability of flood waters or other supplementary supplies. Thus the upper parts of the stream-built slopes on both sides of the basin are excluded because of the great depth to water in these elevated positions and also partly because of the gravelly character of their soil; the extensive plains with rich soil in the northern and southern parts of the basin are excluded because of the great depth to water and to some extent also because of the meagerness of the supplies; the wet lands south of the younger lava bed and in the lower parts of the arroyos are probably excluded because of the alkali in their soil and because of the poor drainage; and the extensive gypseous plains in the interior of the basin are probably also to a great extent excluded because of the unsatisfactory character of their soil.

The cost of pumping increases with the depth to the water table. The maximum depth from which it is economically practicable to lift ground waters for irrigation depends on a number of associated physical conditions, on the methods of agriculture, on the kind of crops, and on the ability and thrift of the farmer. Where the conditions are otherwise such as to make pumping for irrigation practicable, the lift does not generally become a limiting factor until the depth to the water table reaches about 50 feet; on the other hand the cost of lifting water from depths exceeding 100 feet is generally prohibitive, except where it is to be used on especially valuable crops.

The areas prospectively available for irrigation with well waters can be outlined as follows: (1) The shallow-water tracts in the Cretaceous area north of Three Rivers, including land adjacent to Nogal Arroyo and near Carrizozo and Oscuro and the surrounding country (Pl. VI, p. 26); (2) the shallow-water tracts in the valleys of the Sierra Blanca and Sacramento Mountains and adjacent foothills, especially in the valley of Three Rivers (Pl. VI); (3) a belt on the east side of the basin extending from the lower part of the younger lava bed to some distance south and southwest of Dog Canyon, limited on the north, east, and south by the depth to water (Pl. II, in pocket), and on the west by the alkali and gypsum in the soil (pp. 176–206); and (4) a narrow belt on the west side of the basin extending from the vicinity of Mound Springs to the meadow south of the white sands, limited on the north, west, and south by the depth to water (Pl. II) and on the east by the alkali and gypsum in the soil.

In the shallow-water tracts adjacent to Nogal Arroyo and in the neighborhood of Carrizozo and Oscuro the principal problems relate to the recovery of adequate quantities of water at costs that are not prohibitive. The soil is generally satisfactory and the drainage is as a rule good. Only locally, as in some of the shallow wells in the village of Carrizozo, is the water too highly mineralized to be used for irrigation, and even here satisfactory water can probably be obtained by drilling a short distance into the sandstone below the unconsolidated sediments. (See analyses, pp. 270–275.) As a rule large quantities can not be obtained, but in many places supplies can be developed that will be adequate for profitable irrigation if proper methods of agriculture are used. In some places such supplies can be obtained from the unconsolidated sediments resting on the bedrock; in others it will be necessary to drill some distance into the rock in order to tap the Cretaceous sandstones. Deep wells will generally tap lower sandstones that will yield water, but the additional supplies thus obtained will probably not warrant the cost of sinking these deep wells. The deeper Cretaceous waters contain some black alkali, but they are not likely to be injurious because this alkali will be neutralized by the gypsum in the soil. (See the section entitled "Water in Cretaceous rocks and overlying sediments," pp. 138–157, and the table of analyses, pp. 268–301.)

In the valleys of the Sierra Blanca and the Sacramento Mountains the problem consists chiefly in finding the localities where shallow water exists and developing in them supplies adequate for irrigation. The water in these valleys is nearly everywhere good enough for irrigation, and satisfactory soil on which to use it can generally be found. Many of these elevated shallow-water tracts are well located for raising fruit. Most of the water occurs in the unconsolidated sediments in localities where the character of the bedrock and the shape of the bedrock surface are such that the water does not readily drain away. Cretaceous shales and sandstones interspersed with eruptive rocks, such as underlie Three Rivers valley, are better adapted for holding shallow supplies than the Carboniferous limestones that largely underlie the valleys farther south. Where the unconsolidated rock waste is coarse and porous generous yields may be obtained. In general the supplies are largest and most dependable in the well-watered valleys, but supplies adequate for irrigation may also be found in valleys having no surface flow.

In the belt on the east side of the basin between the younger lava bed and the region near Dog Canyon the problem is not only to obtain sufficiently large supplies but to get combinations of water and soil that are suitable for irrigation. The first problem is discussed under the headings "Yield of wells" and "Methods of constructing wells" (pp. 110–122); the second, under "Quality of water" (pp. 124–138), and in the section on soil and vegetation (pp. 176–199). The differences in the quantity of ground water in this belt are local and can not be foretold from surface indications. The yield of wells will depend largely on the care and skill that is used in their construction. The analyses show that the differences in the quality of the water are also local. Since different strata encountered in the same well may yield water differing widely in mineralization, the quality of the supply can to some extent be regulated by casing out the worst waters. In general, the most favorable areas are the parts of the shallow-water belt that have adobe or other loam soils and receive flood waters. These areas are largely but not exclusively covered with mesquite. Some of the most promising tracts are the parts of the mid-slope arroyos in which the depth to water exceeds 15 feet. The lower parts of the arroyos, where the depth to water is less, generally have alkali soil. The chamiso-covered gypseous plain that lies west of the belt of adobe soil affords less favorable conditions and should not be developed until irrigation has proved successful in the most favored areas.

In the narrow belt on the west side of the basin, where the water is not too deep and the soil is not too poor for irrigation, the most serious problem relates to the quality of the water. Nearly all of the samples from that belt represent waters that are too highly mineralized for use in irrigation, but possibly water of somewhat better quality might be found by drilling to deeper strata. Unfortunately, south of the white sands, where the water is of satisfactory quality, the depth becomes too great for profitable pumping.

PUMPING APPLIANCES AND POWER.

The cost of pumping depends largely on the kind of pumps and power used, on the adjustments of the different parts to one another and to the wells that are pumped, on the condition in which the machinery is kept, and on the rate at which the pumps and engines are run. All these subjects are better understood by the mechanic than by the farmer, but the farmer who wishes to make a livelihood by irrigation with well waters must master them thoroughly by diligent study in so far as they relate to his own water supply. They are subjects of general application which can not be adequately discussed in this paper, but on which much valuable information has been published in reports listed below, which are arranged in chronologic order.

Reports on pumping appliances published by the United States Geological Survey.[1]

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.

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, Arizona: Water-Supply Paper 320, 1913. Also published as a bulletin of the Arizona Agricultural Experiment Station.

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

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 semi-arid West: Farmers' Bull. 394, 1910.

Reports on pumping appliances published by the New Mexico Agricultural Experiment Station.

Vernon, J. J., and Lester, F. E., Pumping for irrigation from wells: Bull. 45, 1903.

Vernon, J. J., Lester F. E., and McLallen, H. C., Pumping for irrigation: Bull. 53, 1904.

Vernon, J. J., Lovett, A. E., and Scott, J. M., The duty of well water and the cost and profit on irrigated crops in the Rio Grande Valley: Bull. 56, 1905.

Fleming, B. P., Small irrigation pumping plants: Bull. 71, 1909.

Fleming, B. P., and Stoneking, J. B., Tests of pumping plants in New Mexico, 1908–1909: Bull. 73, 1909.

Fleming, B. P., and Stoneking, J. B., Tests of centrifugal pumps: Bull. 77, 1911.

[1] 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.

Reports on pumping appliances published by the Arizona Agricultural Experiment Station.

Smith, G. E. P., Ground-water supply and irrigation in the Rillito Valley: Bull. 64, 1910.

Meinzer, O. E., Kelton, F. C., and Forbes, R. H., Geology and water resources of Sulphur Spring Valley, Arizona. (See above.)

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 have in their service engineers or expert mechanics who will assist farmers in planning installations suited to their particular needs.

In general, horizontal centrifugal pumps are best adapted for pumping water for irrigation. Vertical centrifugal pumps have an advantage where the water table is at a considerable distance below the surface or fluctuates greatly, but if these pumps are not carefully installed or are neglected they may develop great friction and consequently may have low efficiency. Deep-well cylinder pumps are used in a large proportion of the irrigation wells of this region. Their efficiency is rather high if they are kept in repair, but very low if their valves leak. They are better adapted for pumping small than large yields and are especially useful where a part or all of the water is pumped by windmills. Where they are operated by engines or electric motors they should be of the double-acting type. Air lifts are adapted for cleaning new wells with the purpose of obtaining larger yields, and they are convenient for lifting water under certain conditions, but their efficiency is too low to recommend them for irrigation use.

Most of the pumping plants thus far installed in Tularosa Basin are operated by windmills, gasoline engines, or electric motors, but horsepowers and steam engines are also in use.

A small but successful plant utilizing ground water was in operation in 1911 on the farm of A. Gschwind, northeast of Oscuro, where, by very sparing use of the water and very careful cultivation, about 5 acres of vegetables were grown by means of a supply pumped with a 12-foot steel windmill mounted on a 20-foot tower, the mill and tower together costing $80. The water level in the well is 70 feet below the surface. According to Mr. Gschwind the mill pumps about 12 gallons a minute with considerable regularity until the middle of June, after which there is less wind. The water is stored in an earth reservoir. Another successful windmill plant is that of Joseph George, east of Carrizozo, where 3 acres of productive orchard and a vegetable patch are irrigated with water pumped from a depth of about 50 feet by means of a 10-foot windmill, which, in a strong, steady wind, lifts about 12 gallons a minute and fills a cement-lined reservoir of 50,000-gallons capacity in three or four days. The orchard is generally given one or two irrigations per month.

In experiments made by P. E. Fuller, of the Department of Agriculture,[1] it was found that with a lift of 56 feet a 12-foot windmill would pump 1½ gallons a minute when the velocity of the wind was 6 miles per hour, 4½ gallons when the velocity was 8 miles, 8⅓ gallons when the velocity was 10 miles, 12 gallons when the velocity was 12 miles, and 22½ gallons when the velocity was 18 miles. It was also found that in one and one-half months, with an average wind velocity of about 13 miles per hour and a lift of 56 feet, a 12-foot back-geared windmill pumped 1¼ acre-feet, a 14-foot back-geared mill pumped a little over 2 acre-feet, and a 16-foot direct-stroke mill pumped about 2⅓ acre-feet.

Records were obtained by the Office of Experiment Stations, United States Department of Agriculture, in 1904 of the performance of 72 windmills at Garden City, Kans. It was found that these windmills irrigated from one-fourth to 7 acres each, at a cost of 75 cents to $6 per acre. The crops were worth $12 to $500 per acre, and included alfalfa, garden vegetables, fruit trees, sugar beets, corn, cane, and sweet potatoes.[2]

Windmills can be used to good advantage in connection with other power in small pumping plants or over wells of rather small yield. They should be allowed to run throughout the year, and the water that they pump outside of the crop-growing season should be put into the ground and conserved by proper tillage. Where a windmill is used, a reservoir of some kind is required.

Although horsepowers are probably not practicable for extensive use, they are worthy of consideration for supplemental irrigation in times of drought or as duplicate installations to be used in case of breakdowns in gasoline engines.

Where no electric current is available, internal-combustion engines burning gasoline, naphtha, distillate, crude oil, or some other fuel are best adapted for providing irrigation water in moderate quantities. In 14 tests made by C. S. Slichter[3] in the Rio Grande valley with 5 to 28 horsepower gasoline engines, where the cost of the gasoline ranged between 14 and 17 cents a gallon and the total lift between 24 and 46 feet, the cost of fuel for pumping 1 acre-foot ranged between $1.04 and $5.80, and the total cost of pumping 1 acre-foot (including labor, interest on investment, and depreciation), according to the estimates, ranged between $2.21 and $13.20 per acre-foot. In these tests the fuel cost for each foot that an acre-foot of water was lifted ranged between 3½ and 16½ cents and averaged about 8 cents.

[1] U. S. Dept. Agr. Yearbook for 1907.

[2] Idem. for 1905, p. 431.

[3] Observations on the ground water of Rio Grande valley: U. S. Geol. Survey Water Supply Paper 141, 1905, pp. 34, 35.

In the tests made in 1911 by F. C. Kelton, of the Arizona Agricultural Experiment Station, of 20 pumping plants in Sulphur Spring Valley, Ariz.,[1] the cost of the pumping plants, exclusive of wells and buildings, ranged from $40 to $104 per rated horsepower and averaged $66. The cost per useful horsepower averaged $290, but if an efficiency of 40 per cent were obtained (as there should be) the cost would be reduced to $165 per useful horsepower. The fuel cost per acre-foot of water pumped averaged $4.39, with distillate figured at 16½ cents per gallon in the northern part of the valley and at 17½ cents in the southern part, an addition of 5 per cent being made to the fuel cost as an allowance for losses by leakage and evaporation. The fuel cost of lifting an acre-foot through a distance of 1 foot ranged from 4.7 to 20.5 cents and averaged 11.2 cents. If the cost of lubricating oil is included the average is about 12 cents.

The motors in use in 1911 were supplied with current from the electric plant of the Alamogordo Improvement Co. at Alamogordo, at rates ranging between 3½ and 5 cents per kilowatt-hour. At C. W. Morgan's pumping plant, west of Alamogordo, where the lift is probably between 60 and 75 feet, an electric motor is used. Pumping at the rate of about 40 gallons a minute required 1.7 kilowatts. At 3.7 cents per kilowatt-hour the cost of power was about $8.50 per acre-foot of water, or between 11 and 14 cents for each foot that an acre-foot was lifted.

Possible sources of comparatively inexpensive power in Tularosa Basin are the streams in the Sierra Blanca and Sacramento Mountains and the coal in the Cretaceous formations. The water powers were not investigated, but it seems probable that their development to a certain extent would be practicable if the power could be locally utilized. Some investigation has been made by the United States Geological Survey of the coal deposits in the Capitan[2] and Whiteoaks[3] fields. These deposits appear to be adequate to supply a power plant of large dimensions. A power plant could be installed near the coal fields or the coal could be shipped by rail from Capitan to plants situated along the main railroad and nearer the shallow-water tracts. Coal could also be obtained from Dawson at moderate cost. Water suitable for steam making could no doubt be obtained from the railroad supply at Carrizozo, from wells at Oscuro, or from the public supply at Alamogordo. The installation of power plants should, however, be deferred until a much larger supply of well water has been developed, and until the well water has been used

[1] Meinzer, O. E., Kelton, F. C., and Forbes, R. H., Geology and water resources of Sulphur Spring Valley, Ariz.: U. S. Geol. Survey Water-Supply Paper 320, 1913.

[2] Campbell, M. R., Coal in the vicinity of Fort Stanton Reservation, Lincoln County, N. Mex.: U. S. Geol. Survey Bull. 316, pp. 431–434, 1907.

[3] Wegemann, Carroll H., Geology and coal resources of the Sierra Blanca coal field, New Mexico: U. S. Geol. Survey Bull. 541, pp. —, 1914.

long enough in practical agriculture or horticulture to demonstrate that the alkali of water and soil can be successfully handled and that irrigation with this supply is practicable under the conditions that exist in this basin.

STORAGE AND DISTRIBUTION.

In connection with small pumping plants it is desirable, if not necessary, to have at least small reservoirs. Cement-lined reservoirs are the most satisfactory, but earth reservoirs, which can be constructed at almost no cost except the labor of the farmers, are generally nearly water-tight if they are properly built and maintained and are not constructed of too porous soil. Adobe can be made water-tight, but gypsum may allow the water to escape. Reservoirs and ditches are likely to develop solution channels in soil that contains a considerable proportion of gypsum, even though it appears clayey, and they must therefore be watched carefully. Reservoirs should be well puddled and should not be allowed to become entirely dry lest cracks are formed which will provide outlets for the water. The following information and advice in regard to the construction of small earth reservoirs is given in a recent bulletin by P. E. Fuller:[1]

A means of storing water * * * should be resorted to in every instance where the flow is less than 600 gallons per minute. The reason for recommending a reservoir for flows up to this amount is that, with small streams used direct from the pumps, the loss in conveyance in ditches is excessive and the loss in the application of the water to the land is large, since a small stream will saturate a spot and a large amount of water will sink into the soil in this one place instead of spreading over a large area and moistening the surface. Further, much more labor is required to irrigate with a small stream than with a large one. * * *

If possible, a site should be chosen where the natural surface of the ground which will become the bottom of the reservoir is above the land to be irrigated, and if the highest land to be irrigated is some distance from the reservoir the bottom should be enough higher than the land to give a slope of at least 6 feet to the mile from the reservoir to the land.

All sod and vegetation should be removed from the site, as the decay of the roots will leave passage for seepage. In a circle midway between the outside and inside bank line plow a trench 2 feet wide and 1 foot deep, removing this dirt to the outside of the bank; fill in this trench with clay or with a clay and gravel mixture. After a part of the trench has been so filled add water, and thoroughly puddle so as to form a bond between the original walls of the trench and the material added; haul in additional clay material to this section of the trench until it projects above the original ground surface at least a foot and is yet a soft mass; then proceed to build the banks, puddling and tamping the new fill so as to thoroughly bind with the core of clay material. Proceed with the embankment until the first course to a depth of 6 inches has been completed around the entire inclosure, then add a second course of the same

[1] Fuller, P. E., The use of windmills in irrigation in the semiarid West: U. S. Dept. Agr. Farmers' Bull. 394, pp. 28–33, 1910.

thickness around the entire wall, allowing the teams to walk upon the top of the banks a distance of at least 20 feet each time a scraper is dumped, for in this way each course is well tamped as the work progresses. It would be far better if each course could be thoroughly wet down so as to puddle it or better to tamp the embankment; and even better results would be obtained if the clay core could be carried up with the work to the top of the bank, though this is not an easy matter and is not imperative if the material used in constructing the banks is of a clayey nature. It is well to allow the banks to settle under several rains or snows before the reservoir is filled.

The inside slope of the bank should be very gradual, so as to avoid erosion and cutting. The width of the top of the bank should be not less than 3 feet for a reservoir 4 feet deep, and 4 feet for one 5 feet deep. The slope of the outside of the embankment may be steeper, 1 to 1 if planted to grass, so as to avoid washing or cutting from rains.

Haul into the bottom a lining of clay or clay mixture several inches in excess of the depth of soil removed, and after distributing it evenly pump into the reservoir sufficient water to form a thick muck or paste and thoroughly puddle by keeping cattle or sheep in the reservoir for a least a week, and better for 30 days. Indeed, the entire success of the reservoir is dependent upon such puddling, and there can be no reason why, by placing a temporary fence around the inclosure, the cattle or sheep can not be fed and watered while so penned up for 30 days. It will, of course, be necessary to allow water to run into the reservoir in small quantities during the operation of puddling so as to maintain a soft puddle. After the work of puddling is completed the banks may be trimmed to line by shovel.

The inlet and outlet pipe should be put in place while the banks are being constructed, for in this manner a water-tight joint between the pipe and banks can be secured.

The loss from evaporation in the reservoir can be reduced effectually by the planting of bush willows or some similar low-bush tree profusely around the top of the banks, thereby breaking the wind. The cutting of banks from wave motion can be eliminated entirely in an earthen reservoir by floating a boom of old railroad ties or other timbers around the inner banks facing the direction of the prevailing wind, or, if desirable, around the entire reservoir. The ties should be held together at the ends by cleats securely nailed and the entire boom should be anchored in a line 3 feet from the banks.

AGRICULTURAL METHODS.

Agriculture depending wholly on rainfall has proved too uncertain to give promise of success, although quickly-maturing or drought-resistant crops have been raised in certain localities and in certain years with the moisture supplied by direct rainfall alone. Many crops that failed completely could have been matured by the aid of comparatively small amounts of irrigation water applied at the particular times when the damage by drought occurred. Agriculture depending on rainfall supplemented by flood waters has been somewhat more successful, but is also uncertain because the floods, like the rains, are irregular. Moreover, this kind of agriculture is restricted by the quantity and areal distribution of the floods.

Because of the limitations in regard to both quantity and quality of the underground supply and because of the cost of pumping, it is doubtful whether heavy irrigation, such as is commonly practiced in the Rio Grande valley and other irrigation districts, will be feasible, except very locally, in Tularosa Basin; but the sparing use of well water to supplement rainfall and flood waters contains more promise and should be given a thorough trial. That a small amount of well water properly applied in supplemental irrigation in connection with careful methods of farming will add greatly to the yield of certain crops has been shown in results obtained by R. H. Forbes and R. W. Clothier on one of the experimental farms of the Arizona Agricultural Station,[1] and also by a number of thrifty settlers in various parts of the Southwest. The value of such supplemental irrigation has been demonstrated for forage and other field crops, for vegetables, and for fruit.

The underground supply has the great advantage of being available whenever it is needed, provided only that the pumping plant is kept in repair so that breakdowns will not occur at critical times. It is contended by many engineers that, because of the interest on the investment and because of the deterioration (which is frequently assumed to be a fixed amount per annum regardless of the length of time a plant is in use during the year), a pumping plant in order to be profitable must be in operation a large part of the time. Although this contention has in general much merit, it is not necessarily applicable to the particular conditions existing in Tularosa Basin. With proper care the deterioration of the engine and pump should be more nearly proportional to the actual period of operation than to the period of installation. Moreover, the interest on the investment in a small plant is not a controlling factor. In times of drought a plant should be operated day and night at its full capacity. The extent to which pumping with gasoline engines or electric current outside of the crop-growing season will be profitable for the purpose of storing moisture in the soil can be determined only by experience, but pumping with windmills throughout the year for this purpose will no doubt be profitable. Stream waters that would otherwise be wasted can also be profitably applied to the soil outside of the crop-growing season and can be conserved by proper tillage.

The two important needs in Tularosa Basin are (1) the careful and intelligent sinking of wells for the purpose of developing more numerous and larger irrigation supplies, and (2) the establishing of an experimental farm for the purpose of evolving a system of agriculture adapted to the conditions in this region.

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[1] See Geology and water resources of Sulphur Spring Valley, Ariz.: U. S. Geol. Survey Water-Supply Paper 320, 1913. Also recent publications of Ariz. Agr. Exp. Sta., Tucson, Ariz.

RAILROAD AND PUBLIC SUPPLIES.

GENERAL CONDITIONS.

When the El Paso & Northeastern Railroad, which is now a part of the El Paso & Southwestern system, was built great difficulty was experienced in obtaining water that was fit to use in locomotives. Much expensive deep drilling was done along the railroad from El Paso to Tucumcari, but most of the wells extended into gypseous Carboniferous rocks or into sediments derived from these rocks, and yielded water of very poor quality. Good water was, however, obtained in wells at Fort Bliss and Newman from the valley fill of the southern area, and soft water satisfactory for boiler use although having some tendency to foam was obtained in wells at Oscuro from Cretaceous sandstones. For the other parts of the line the problem was eventually solved by constructing pipe lines at heavy cost to conduct pure mountain supplies to the railroad stations. Thus the supply at Orogrande is derived from the Sacramento River, the supply at Alamogordo from Alamo Canyon, and the supplies at Carrizozo and stations farther north from Bonita Creek. The problem of railroad supplies and public supplies has been practically identical, and a solution of the one has involved the solution of the other. The Alamogordo and Bonita systems were constructed by the railroad company; the Sacramento system was constructed by a smelter company but is now owned by the railroad company. The installation of these systems is a great achievement and demonstrates the practicability of conveying small supplies over long stretches of desert country.

As most of the people in the towns along the railroad use this water it is very important to protect the contributing drainage basins from pollution. Time was not available in the present investigation to make a sanitary survey of these basins, but it appeared that the conditions were in general sanitary and that with proper precautions the basins can be adequately protected. The water will not produce typhoid fever unless it is contaminated with the specific germs of this disease. Such contamination is caused only by the liquid and solid discharges of human beings. Safety therefore requires that no human discharges be deposited in any place where they could be washed into the water supply. The water may be clear and good to the taste and still contain deadly germs. A single case of typhoid fever in the mountains might produce an epidemic in the towns where the water is used. Storage in reservoirs will lessen but not remove the danger of infection.

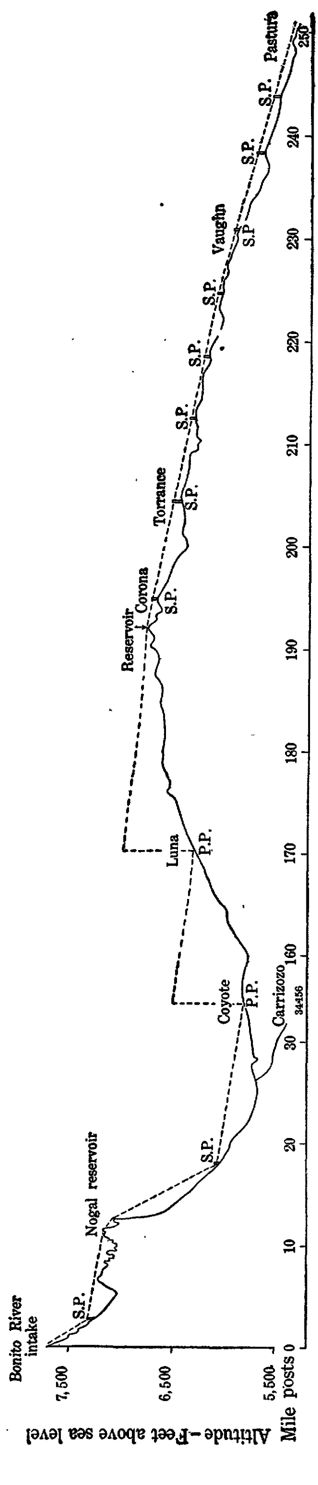

FIGURE 49.—Condensed profile of Bonita pipe line from Bonita Creek to Pastura, N. Mex. Adapted from J. L. Campbell, Am. Soc. Civil Eng. Trans., vol. 70, pl. 5, Dec., 1910. Dotted line represents hydraulic grade line when valves are open. S. P., standpipe; P. P., pumping plant. Pipe line reaches railroad at Coyote and parallels it on right of way to Pastura. Beginning at Coyote, the railroad mileposts are used.

BONITA PIPE-LINE SYSTEM.

The Bonita pipe-line system, which was designed to deliver at least 5 second-feet of water, is briefly described in the following quotations from a paper by J. L. Campbell:[1]

After the most thorough practicable treatment the well waters were still so bad that they caused violent foaming, low steam pressure, hard scaling, rapid destruction of boiler tubes, high coal and water consumption, extraordinary engine failures and repairs, small engine mileage, low train tonnage, excessive overtime, and a demoralized train service.

*   *   *   *   *

The writer [Mr. Campbell] was directed to find, if possible, a supply of good water, and his efforts proved successful. The pure water now in use has eliminated the adverse conditions before mentioned; has improved the esprit de corps of the train service; and, in a short time, the reduction in operating expenses will liquidate the first cost of the new supply.

This supply is taken from the South Fork of Bonita Creek, which flows down the eastern slope of White Mountain (Sierra Blanca). The watershed is a granite and porphyry formation, heavily timbered, and the stream is fed by snow and rain. This combination yields an excellent water, carrying on an average 104 parts per million of incrusting and 16 parts of nonincrusting solids. The North Fork of the creek carries 284 and 41 parts, respectively. Below the junction of these forks the water contains 179 parts of incrusting and 27 parts of nonincrusting solids; and a branch pipe line takes water from the creek during intervals in dry years when the daily flow of the South Fork is less than the consumption.[2]

[1] Campbell, J. L., The water supply of the El Paso & Southwestern Railway from Carrizozo to Santa Rosa, N. Mex.: Am. Soc. Civil Eng. Trans., vol. 70, pp. 164–189, Dec., 1910.

[2] In the original paper the dissolved solids are expressed in grains per gallon.

* * * The water is taken to and along the railway in pipe lines. The system includes 116 miles of wood pipe, 19 miles of iron pipe, one 422,000,000-gallon storage reservoir, four 2,500,000-gallon service reservoirs, two pumping plants in duplicate, and accessories of valves, standpipes, etc.

From a small concrete dam across the creek, at an elevation of 7,728 feet, the pipe line drops down the narrow valley eastward 5½ miles to an elevation of 6,980 feet, where it turns abruptly north, rising in 1 mile to a table-land 7,215 feet above sea level, across which it continues northward 5 miles to the storage reservoir, which is on the north edge of this elevated country. Hereafter, this reservoir will be called the Nogal reservoir, from the old mining village of Nogal lying 1½ miles to the north and 600 feet below it. From this reservoir, the line drops abruptly to the Carrizozo plain and crosses the latter northward to Coyote, at mile 156 on the railway, at an elevation of 5,810 feet, passing on the way 6 miles east of Carrizozo, to which a branch pipe runs, Carrizozo being 5,430 feet above sea level. There is a 2,500,000-gallon reservoir at Coyote and a similar one at Carrizozo.

This describes the gravity section of the line which brings the water from the mountain stream to the railway. From Nogal reservoir to the latter the capacity of the pipe is equal to the future daily requirements; from the source of supply to the reservoir the pipe has twice as great a capacity, thereby storing surplus water. This section is 32 miles long, with a 6-mile branch line.

The second, or pumping section, extends eastward along the railway, rising from an elevation of 5,810 feet at Coyote to 6,750 feet on the Corona summit, which is the watershed line between the Rio Grande on the west and the Rio Pecos on the east. At Coyote a pumping station lifts the water to Luna Reservoir and the pumps at mile 171, and the latter lift it to the reservoir on Corona summit at mile 192½. This section is 36½ miles long.

The third, or gravity section, extends from the reservoir on the Corona summit to the Rio Pecos at mile 272, dropping from an elevation of 6,750 to 4,570 feet in 80 miles. The pipe line extends to Pastura, 58½ miles from Corona, as shown in figure 49.

Where the pipe line passes a water tank on the railway a 4-inch branch pipe is carried to the bottom of the tank and up to the top, where it is capped by an automatic valve. A gate valve is placed in the branch pipe at its junction with the pipe line.

There are regulating, relief, check, blow-off, and air valves, air chambers, and open standpipes on the line too numerous to mention in detail. They are designed to keep the wood pipe full, regulate flow, prevent accumulation of pressure and water hammer, and remove sediment.

* * * A study of the profile developed a system of hydraulic grades, pipe diameters, and open standpipes limiting the pressure to 130 pounds per square inch, except on 19 miles of the pump main between Coyote and Corona, where the estimated maximum pressure is 310 pounds.

Investigation justified the assumption that wood pipe under a pressure of 130 pounds would give satisfactory service for 25 years, on which basis it would be less expensive than cast iron, and therefore it was used. Cast iron was considered preferable to steel for pressures not exceeding 310 pounds on account of its greater durability.

* * * * * * *

Water is delivered to the Santa Fe's new transcontinental low-grade line which crosses the El Paso & Southwestern Railway at Vaughn and has a division point there. On its adjacent divisions the Santa Fe had the same trouble with local waters which compelled the El Paso & Southwestern to find a better supply. The Bonita water is conducted to and used at points 160 miles from its origin on Bonita Creek.

OSCURO SUPPLIES.

The railroad supply at Oscuro is obtained from two deep wells that tap Cretaceous sandstones. (See fig. 33 and the chapter on water in the Cretaceous formations.) This water is soft but has a high sodium content. (See analyses, p. 276.) The domestic supplies are obtained from a few private wells.

DOMESTIC SUPPLIES AT TULAROSA AND LA LUZ.

The domestic supplies at Tularosa and La Luz are taken chiefly from the irrigation ditches. The water of Tularosa River is clear in its upper courses where it emerges from springs, but becomes roily before it reaches the village. A public supply could be obtained either by sinking wells or by constructing a gravity pipe line from one or more of several mountain springs. The latter project would probably be preferable because it would provide better water than could be obtained from wells, and the cost of maintenance would be less.

SUPPLIES AT MESCALERO AGENCY AND CLOUDCROFT.

The waterworks at the Indian agency is supplied from the large limestone springs that discharge into Tularosa River in that vicinity. The water is of good quality. (See analysis, p. 302.) The supply from these springs is also used to operate a small power plant. The supply at Cloudcroft is pumped from springs and is also low in dissolved solids.

ALAMOGORDO SUPPLY.

The public and railroad supplies at Alamogordo are obtained from several groups of springs in Alamo Canyon. The water is collected by a system of ditches and is allowed to flow through the rock canyon. Thence it is conducted by gravity through an iron pipe, ranging in diameter from 18 to 10 inches, into two cement-lined reservoirs on the débris slope in the NW. ¼ sec. 33, T. 16 S., R. 10 E., about 2 miles southeast of the town. The capacity of the reservoirs is reported to be about 500,000 gallons each. The supply is carried in a 10-inch main from the reservoir to Alamogordo, where it is delivered under a gravity pressure of about 100 to 130 pounds per square inch. The system was installed by the railroad company about the time the railroad was built but is now owned by the Alamogordo

Improvement Co. The water is of good quality, as is shown by the analysis (p. 302).

SACRAMENTO RIVER PIPE LINE.

The general supplies for Orogrande and other mining settlements in the Jarilla Mountains, as well as the railroad supply at that point and the live-stock supply on one of the McNew ranches, are derived from a pipe line that taps the Sacramento River. The water is diverted about sec. 10, T. 19 S., R. 12 E. (Pl. III, in pocket), below the lowest series of large springs. Thence it is led through a ditch, 10¾ miles long, to the Upper Juniper reservoir, which is reported to have a capacity of about 5,000,000 gallons, and thence a short distance to the Lower Juniper reservoir, which is reported to have a capacity of about 7,500,000 gallons. From the lower reservoir the water is led by gravity through a 6-inch pipe, for a distance of nearly 25 miles, to the Nannie Baird reservoir in the Jarilla Mountains, which has a capacity of 11,600,000 gallons. Thence it is distributed by gravity through a system of mains and service pipes. The altitudes along the line are about as follows: Upper Juniper reservoir, 5,880 feet, Lower Juniper reservoir, 5,190 feet; lowest point on the plain, 4,000 feet; highest elevation in Jarilla Mountains, 4,455 feet; Nannie Baird reservoir, 4,400 feet. The gravity pressure in the distributing system amounts to about 75 pounds per square inch at the smelter and about 125 pounds at the railroad tank.

The conducting capacity of the pipe line is reported to be about 445,000 gallons in 24 hours, or approximately 300 gallons a minute. The supply at the source is reported to fluctuate greatly, and the loss by seepage and evaporation in the reservoirs and open ditch are heavy. Mr. J. J. Murray, one of the engineers in charge, who made many careful observations, reported the following data: The ditch in the last 3 miles of its course loses in summer about 1,000,000 gallons a day, or fully 1½ second-feet. The leakage of the Upper Juniper reservoir reaches in large part the Lower Juniper reservoir, but the loss from the latter amounts to 500,000 gallons a day when the reservoir is full. The Nannie Baird reservoir when nearly full loses 100,000 gallons a day, in large part by evaporation, the area of the reservoir being about 4 acres, and the maximum observed evaporation on hot, windy days about 0.7 inch.

The system was constructed in 1906 by the Southwest Smelting & Refining Co. at a cost, including water rights, of $180,000. It was purchased by the railroad company in 1910. Prior to 1906 there was no supply in the Jarilla Mountains except the water hauled in by the railroad company. The present consumption, including supplies for locomotives and placer mining, is about 100,000 gallons per day.

In addition to this the McNew ranch is entitled to 15,000 gallons per day.

The water contains only a small amount of dissolved mineral matter. According to the analyses given in this paper (p. 302), it is very similar to the Bonita water and slightly less mineralized than that of the Alamogordo and El Paso supplies, but there is no doubt some variation in the mineral content of all the pipe-line supplies.

EL PASO PUBLIC SUPPLY.

The public supply for the city of El Paso, which in 1910 had a population of 39,279 and in 1912 several thousand more, is obtained from wells sunk into the valley fill underlying the upland north of the city, as is explained in the section on water in the valley fill (p. 115). The water is brought to the surface from a depth of about 200 feet by means of air lifts, and is collected in two small reservoirs at the pumping plant. Thence it is pumped into the system of mains, with which is connected a reservoir of 4,500,000 gallons capacity, situated at an altitude of about 3,900 feet. In 1912 there were 78 miles of mains, 204 hydrants, and 6,200 service connections, of which 4,873 had meters. The capacity of the plant was about 6,000,000 gallons a day; the maximum consumption, 5,250,000 gallons; and the average consumption, 4,000,000 gallons. The value of the entire system was estimated at $1,232,000, and the total cost of operation, exclusive of interest on investment or new construction, was estimated at 11 cents per 1,000 gallons delivered. The prices charged ranged from 30 to 20 cents per 1,000 gallons where meters are installed. These data are of interest in view of the fact that the entire supply is obtained from deep wells with low-water level. As shown by the analysis (p. 305), the water contains only small amounts of dissolved mineral matter. The sanitary conditions are good. The waterworks are owned and operated by the municipality.

WATERING PLACES ON ROUTES OF TRAVEL.

INTRODUCTION.

Although a railroad now extends through the length of Tularosa Basin, there is still much travel by wagon between the settlements in this basin and those in the Pecos, Estancia, and Rio Grande valleys. Travel over the desert is no longer attended with as much danger as it was in the early days, but the distances between satisfactory watering places are still inconveniently long, and in the dry seasons it is frequently necessary to carry water for parts of a trip. To the old ranchers and prospectors of the region, who are familiar with the roads, the landmarks, and the watering places, a journey across the desert seems simple enough, but to strangers who have occasion to travel through the region and to the settlers who have but recently come to New Mexico and who are not familiar with the local geography, such a journey presents more difficulties. For their use the following detailed description of routes and watering places is given. In connection with these descriptions the maps in Plates I. II. III, and VI, and figures 50 and 51 should be consulted.

ROUTES OF TRAVEL.

RAILROAD STATIONS AND CONNECTING ROADS.

Railroad connections.—The El Paso & Southwestern Railroad, by connecting with the Rock Island system east of Tucumcari and with the Southern Pacific west of Tucson, constitutes a part of one of the transcontinental routes over which pass each day several well-appointed trains, running between Chicago and Los Angeles. At Vaughn this railroad crosses the Belen cut-off of the Atchison, Topeka & Santa Fe system; at Torrance it is met by the New Mexico Central; and at El Paso it connects with roads leading in various directions.

Stations.—The three largest towns on this railroad within the Tularosa Basin are Carrizozo, which has 700 inhabitants; Tularosa, which has 600 inhabitants, and Alamogordo, which has 2,000 inhabitants. Each of these towns has hotel and livery accommodations and stores at which provisions and camping equipment can be bought. Corona is a small town between Ancho and Torrance, and post offices are also maintained at Tecolote (Eichel post office) and Gallinas (Holloway post office). Ancho is a settlement having stores and a post office. Pumping stations connected with the railroad pipe line are situated at Luna and Coyote, but there are no accommodations and no water supply for the public at these points. Jake's is a section house at which water can be obtained. Oscuro is a small settlement with stores and hotel accommodations. Three Rivers has a depot, a store, and a post office. Dog Canyon is a small settlement with a post office which is called Shamrock; Escondida, Turquoise, and Desert are switches at which section houses are located, and Newman is a switch at which a railroad pumping plant is maintained. Robsart, Polly, North, Salinas, Kearney, Omlee, Elwood, Alvaredo, and Hueco are only switches where trains may pass, and have no inhabitants, no shelter, and no water supply.

Wagon roads.—A well-graded county highway connects Alamogordo with Tularosa by way of La Luz. A road also leads southward from Alamogordo to Dog Canyon and thence along the railroad to El Paso (p. 248).

The best road from Tularosa to Three Rivers crosses the upland some distance east of the railroad (Pl. II, in pocket). Turner's ranch, at which there is a drilled well, earth reservoir, and watering trough, is situated about 5 miles north of Tularosa and over one-half mile west of the main road. A road also leads from Tularosa to Three Rivers on the west side of the railroad. When the survey was made this lower road was rougher, less frequently traveled, and not more favored with respect to watering places than the upper, but since that time improvements have been made on it.

The best road from Three Rivers to Oscuro starts on the east side of the railroad, but about 3½ miles from the Three Rivers depot it crosses to the the west side and continues on the west side in the rest of its course to Oscuro. There are no watering places along this road.

Two wagon roads connect Three Rivers with Carrizozo. One of these runs by way of Oscuro, Jake's, and Polly, and remains near the railroad. It has watering places at Oscuro and Jake's (p. 257) and at several homesteads between Polly and Carrizozo. The other road leads up the valley of Three Rivers for a distance of about 9 miles and then turns northward on the east side of the Godfrey Hills, and passes the I bar X ranch. This road is somewhat rough, but has good watering places at the I Bar X ranch (p. 256) and at a number of springs and wells between that ranch and Three Rivers. (See Pls. I, in pocket, and VI, p. 26.)

The wagon road most commonly used in going from Carrizozo to Ancho passes the Bar W ranch (p. 250) and then trends northeastward to the railroad, which it follows closely the rest of the way. The pumping plant at Coyote forms a convenient landmark for this route by reason of its conspicuous position and two high smokestacks. It is 12½ miles from Carrizozo and 11 miles from Ancho. After leaving the Bar W ranch there is no reliable watering place until some distance beyond Coyote. Red Lake (p. 261) is about 3 miles north and 3 miles west of Coyote, but is not conveniently reached from this road. About 6 miles north of Coyote and less than a mile west of the wagon road and railroad is the J. B. French ranch (p. 253) where a supply of satisfactory water can be obtained. A short distance farther north, on the east side of the railroad, is the Horace French ranch, where there is also a well and a supply of satisfactory water. (See analyses, p. 268.)

Table of distances.—The following table gives the distances between the principal stations on the main line of the railroad between El Paso and Torrance. For descriptions of watering places see pages 249–265.

Distances in miles between railroad stations.

	El Paso.	Newman.	Orogrande.	Dog Canyon.	Alamogordo.	Tularosa.	Three Rivers.	Oscuro.	Carrizozo.	Ancho.	Corona.	Torrance.
El Paso	0	19	48	75	86	99	116	128	144	167	195	203
Newman	19	0	29	56	67	80	97	109	125	148	176	184
Orogrande	48	29	0	27	38	50	68	79	95	119	146	154
Dog Canyon	75	56	27	0	11	25	41	52	68	92	119	127
Alamogordo	86	67	38	11	0	14	30	42	58	81	109	117
Tularosa	99	80	50	25	14	0	17	29	45	68	96	104
Three Rivers	116	97	68	41	30	17	0	12	28	51	79	87
Oscuro	128	109	79	52	42	29	12	0	16	39	67	75
Carrizozo	144	125	95	68	58	45	28	16	0	24	51	59
Ancho	167	148	119	92	81	68	51	29	24	0	27	36
Corona	195	176	146	119	109	96	79	67	51	27	0	8
Torrance	203	184	154	127	117	104	87	75	59	36	8	0

ROUTES TO PECOS VALLEY.

General conditions.—The railroad trip from Tularosa Basin to Pecos Valley is made by going north to Vaughn, east over the Belen cut-off to Clovis, and thence southwest and south over another branch of the Atchison, Topeka & Santa Fe system, or it can be made over a southern route by way of El Paso and Pecos, Tex. Both of these routes are long, tedious, and expensive, and there is therefore considerable inducement to make the trip more directly by wagon. The trip can also be made by going to Vaughn and there taking an automobile stage which runs to Roswell daily, a distance of fully 100 miles.

The mountains east of the Tularosa Basin and the plateau that lies back of them contain a number of small settlements and enough springs and other watering places to make travel comparatively easy. Since in many places the mountains are steep and high, the main routes of travel were through the more open passes or up the larger canyons.

Alamogordo routes.—A branch railroad runs from Alamogordo up Fresnal Canyon in the abrupt escarpment of the Sacramento Mountains, through the stations of Mountain Park and Highrolls, to a point some distance beyond the summer resort known as Cloudcroft. This remarkable little railway, by means of a switchback and numerous sharp reverse curves and horseshoe bends, ascends more than four-fifths of a mile in its course from Alamogordo to Cloudcroft, a distance of 26 miles by rail and 13 miles by air line. A good wagon road with steep grades also leads to Cloudcroft by way of Fresnal Canyon. Cloudcroft is provided with waterworks, and satisfactory water can be obtained also at Mountain Park and other points along the road.

Plate III (in pocket) shows the roads and watering places east of Cloudcroft, and figure 50 shows the post offices and mail routes between Cloudcroft and Artesia and the distances between the post offices. According to Jesse Mills, one of the mail carriers, there is water at Mayhill, at Elk, at several points along the road between Mayhill and Elk, at Lower Penasco, at points 7 and 15 miles from Lower Penasco on the road between that post office and Hope post office, at Hope, and at Artesia.

Tularosa routes.—An excellent road, built chiefly by the Indians of the reservation, leads from the village of Tularosa, up the valley of Tularosa River, past the small mining camp of Bent, to the Mescalero Agency, a distance of 19 miles. Water in abundance is found along this road. There is daily mail and stage service between

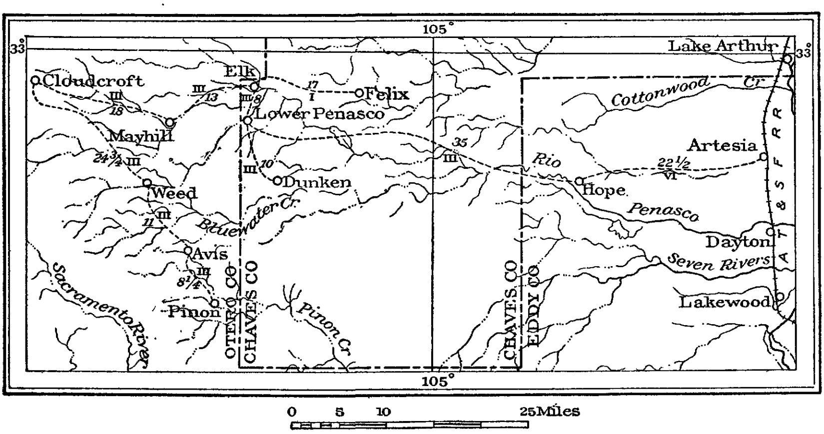

FIGURE 50.—Map showing settlements connected with Cloudcroft by mail routes and route from Cloudcroft to Artesia. After post-route map of New Mexico, Jan. 1, 1914. Arabic numbers show distances between points; roman numerals show number of days per week that mail is carried.

Tularosa and Mescalero. From the agency a road leads northeastward across the divide to the Ruidoso and thence to Roswell, and another road leads southeastward, connecting with Cloudcroft and other settlements in the Sacramento Mountains. (Pl. III, in pocket.)

East of Oscuro and Three Rivers station the Sierra Blanca is so lofty and precipitous that it can only with difficulty be crossed. Hence, these stations are not connected by any direct roads with the settlements east of the mountains.

Carrizozo routes.—Carrizozo is the supply station for a number of settlements that lie farther east (fig. 51). A stage route furnishing daily mail service leads northeastward to the old mining town of Whiteoaks, a distance of about 12 miles. A branch railroad leads eastward through the open pass between Carrizo Mountain and the Sierra Blanca, to Capitan, a distance of 22 miles. A system of mail routes also connects Carrizozo, more or less directly, with Nogal, Parsons, Capitan, Fort Stanton, Lincoln, and a number of other small settlements in the "Mesa" region, and with Roswell, in the Pecos Valley. The "Mesa" settlements of Lincoln County are not far apart and have no lack of good watering places, but the eastern part of the trip to Roswell is less favored.

Ancho routes.—A good wagon road with easy grades leads from Ancho to the small mining town of Jicarilla, picturesquely situated in the mountains of the same name. Over this road, which is about 8 miles long, a stage carrying the mail is operated daily except Sunday. Various roads connect Jicarilla with Whiteoaks and points farther east. A reliable water supply is found at Jicarilla (p. 257).

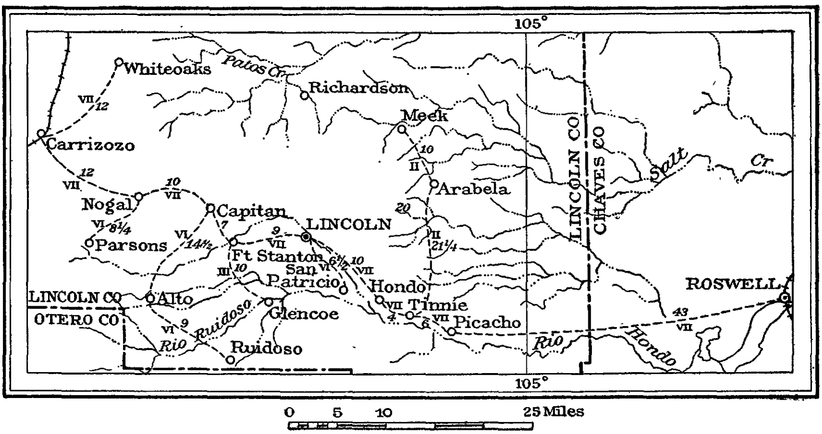

FIGURE 51.—Map showing settlements connected with Carrizozo by mail routes and route from Carrizozo to Roswell. After post-route map of New Mexico, Jan. 1, 1914. Arabic numbers show distances between points; roman numerals show number of days per week that mail is carried.

ROUTES TO ESTANCIA VALLEY AND ADJACENT REGIONS.

GENERAL CONDITIONS.

Except in the area covered by the Gallinas Mountains the region immediately north of Tularosa Basin is a rather open plateau that presents few obstacles to travel. On the west it is bordered by the escarpment of a still higher plain, known as the Chupadera Plateau; toward the north it extends as the Mesa Jumanes, to the Estancia Valley, where it ends in an abrupt cliff; toward the northeast it is separated by only low hills and bluffs from the extensive upland that slopes toward the Pecos.

The two principal routes leading north from Tularosa Basin are (1) the Corona route, which follows the railroad and passes east of the Gallinas Mountains; and (2) the Gran Quivira route, which passes west of these mountains and leads more directly to Estancia

Valley. The Corona route is the nearest way to Pinos Wells, Encino, and Vaughn; the Gran Quivira route is much more direct to Mountainair and the villages of the Manzano foothills, and is about 15 miles shorter than the Corona route to Willard, Estancia, or Santa Fe. The Corona route follows the railroad and remains close to water and food supplies; the Gran Quivira route passes through a vacant region with long distances between watering places. Both routes are, on the whole, good wagon roads.

CORONA ROUTE.

Carrizozo and points west of the malpais to Torrance and Cedarvale.—The road from Carrizozo to Corona follows the railroad in its general course. Water is to be had at either of the ranches between Coyote and Ancho shown in Plate I (in pocket), at the village of Ancho, and at a few points between Ancho and Corona. With a slight detour the trip to Ancho can be made by way of Red Lake (Pl. I).

Persons coming from the direction of Ozanne Spring pass Duck Lake, Red Lake, and the French ranch that is between Red Lake and Ancho, as shown in Plate I. Those coming from a point west of the malpais either take the same route or else cross the malpais at the upper or lower crossing, and thence go by way of Carrizozo.

At Torrance will be found hotel accommodations and a water supply obtained from the railroad pipe line. There are also a few ranches with wells in that vicinity.

Cedarvale is a village where food supplies and water can be obtained. The water, which is hard but otherwise not seriously mineralized, is derived from a drilled well 298 feet deep. Several other wells are in use on homesteads near Cedarvale.

Torrance to Vaughn and beyond.—A wagon trip to Duran or Vaughn presents no special difficulties, since water can be obtained at both stations. There are no successful wells in the immediate vicinity of Vaughn, but the town is supplied with water from the El Paso & Southwestern Railroad pipe line.

A well 218 feet deep, yielding very hard water, is reported about 7 miles southwest of Vaughn (sec. 1 or 2, T. 3 N., R. 16 E.). A small but reliable supply of water is to be had from a spring on Monroe Williams's ranch, about 8 miles north-northwest of Vaughn, and a few springs and wells are scattered at widely separated points farther north. The small settlement of Pintada, on Pintada Canyon, is intermediate between Vaughn and the settlements on the Pecos above Santa Rosa.

In the extensive area lying between the El Paso & Southwestern Railroad and Pecos River there are few reliable watering places, except in a belt near the river where homesteads with good wells are found. Before making a trip across this upland prairie information should be procured in regard to watering places.

Water can be obtained at several points along the railroad between Vaughn and Fort Sumner, chiefly from railroad cisterns which are provided with supplies shipped in by the railroad company. At Buchanan, which is 36 miles by rail from Vaughn, there is a railroad cistern and also a well. Between Vaughn and Buchanan cisterns have been constructed at the stations of Iden, Casaus, and Cardenas. From Buchanan a mail route extends southeastward a distance of 37 miles to Dunlap post office, situated about 12 miles due west of the river. From Yeso station, 12½ miles east of Buchanan, a mail route runs to Elvira, 12 miles almost due north, and to Guadalupe, on Pecos River, about 10 miles above Fort Sumner. East of Ricardo are several wells that yield satisfactory supplies. The well at Agudo is 208 feet deep and furnishes a small amount of satisfactory water.

In regard to the automobile road from Vaughn to Roswell, C. M. Farnsworth, proprietor of the automobile stage, made the following statement in March, 1912:

There is no permanent water on the entire trip of 100 miles. At our half-way station, which is about 50 miles from Roswell, we supply water by hauling from a ranch and windmill which is about 15 miles distant. During the rainy seasons there are numerous water holes that will hold water for two or three months, but these are not to be depended upon.

Torrance to Pinos Wells, Encino, and beyond.—A mail route extends from Cedarvale to the small settlement of Pinos Wells. Northeast of the post office there is a shallow-water area in which are two large alkali flats and a tract covered with gypsum sands. In this area there are several ranches with shallow wells, the water from which is highly mineralized but can, with reasonable precautions, be given to horses. Water of better quality, hauled from springs on the west side of the basin, can generally be obtained at the ranches for drinking and cooking.

The trip from Pinos Wells to Encino can be made by going on either the east or the west side of the alkali flats. Along the road between the Pinos Wells and Encino basins there is a ranch with a well that yields fairly good water. The wells in the shallow-water area south of Encino yield highly mineralized water, and there are few reliable watering places in that area before Encino is reached. Pinos Wells post office is some distance west of the direct route from Torrance to Encino.

On the road between Encino and Vaughn there are no watering places except near Encino.

In the region north of Encino there are a few wells, but in some parts of the region they are far apart. A good watering place is D. J. Bigbee's ranch (NW. ¼ sec. 23, T. 7 N., R. 13 E.), about 15 miles north-northwest of Encino, at which there is a drilled well 230 feet deep, with a good yield of satisfactory water. Several wells will also be found on the road between Encino and Bigbee's ranch. Palma is a small settlement almost due north of Encino and about 24 miles distant by wagon road. It is connected with Encino by a mail route, along which there are two watering places, one a well and the other a "tank" filled with surface water. From Palma the Pecos River settlements to the north and the vicinity of Las Vegas can be reached.

The road from Encino to Estancia Valley crosses a low divide with gentle grades. Although there are few wells on the dividing upland the distances between watering places are not very great. At Negra, a station 5 miles west of Encino, the railroad company has several wells, and there are other wells in that vicinity, all of which yield good water. Immediately west of the divide there are ranches at which water of fairly good quality can be obtained. Some of the shallow wells in the lowest part of Estancia Valley yield salty water, but the water from the deeper-drilled wells is generally less highly mineralized.

Cedarvale to Willard, Estancia, and beyond.—Water can be obtained at Progresso and at several ranches on or near the road that leads from Cedarvale to Willard. The supply at Progresso is derived from a dug well about 35 feet deep, and is of satisfactory quality. Between Willard and Stanley there are numerous wells, nearly all of which yield good water. Plenty of water will also be found in going from Estancia Valley to any of the villages in the Manzano foothills.

From Estancia the upland in the vicinity of Palma is reached by way of Pedernal Mountain or by a somewhat longer road leading up the Canada Colorada, or Red Canyon. Watering places are passed at a number of points between Estancia and the Pedernal Hills, and there are also several ranches with reliable supplies in Red Canyon. On the Pedernal route water will be found at a ranch 5 miles from Palma and sometimes at a ranch 9 miles from Palma.

The road from Stanley to Santa Fe leads to the north end of Estancia Valley and then descends rapidly to Galisteo Creek. About 3 miles beyond the point where the descent begins the road passes through a narrow opening in an igneous dike, known as the "Gateway." There is no well near the north end of Estancia Valley, but a shallow well will be found at the Gateway, and there are other watering places between the Gateway and the village of Kennedy. From Kennedy the city of Santa Fe and the numerous smaller settlements of the north-central part of the State are easily reached.

Table of distances.—The following table gives the distances between the principal points reached by the Corona route:

Distances in miles between points north of Tularosa Basin, via Corona route.

	Alamogordo.	Corona.	Torrance.	Vaughn.	Pinos Wells.	Encino.	Palma.	Cedarvale.	Willard.	Estancia.	Santa Fe.
Alamogordo	0	109	117	145	129	144	168	120	a 147	a 159	a 234
Tularosa	14	96	104	132	116	131	155	107	134	146	221
Carrizozo	58	51	59	87	71	86	110	62	a 89	a 101	a 176
Corona	109	0	8	36	b 20	35	59	11	38	50	125
Torrance	117	8	0	28	12	27	51	10	37	49	124
Duran	129	20	12	16	......	......	......	......	......	......	......
Vaughn	145	36	28	0	c 37	17	c 41	38	57	54	......
Santa Rosa	186	78	70	42	79	59	......	80	99	......	......
Pinos Wells	129	b 20	12	c 37	0	20	44	9	25	36	d 111
Encino	144	35	27	17	20	0	24	29	40	37	......
Palma	168	59	51	c 41	44	24	0	53	c 56	44	......
Cedarvale	120	11	10	38	9	29	53	0	27	39	114
Progresso	135	26	25	......	13	......	......	15	12	24	99
Willard	a 147	38	37	57	25	40	d 56	27	0	12	87
Estancia	a 159	50	49	54	36	37	44	39	12	0	75
Moriarty	176	67	66	71	53	54	......	56	29	17	58
Stanley	a 191	82	81	......	d 68	......	......	71	44	32	43
Gateway	a 202	93	92	......	d 79	......	......	82	55	43	32
Kennedy	a 211	102	101	......	d 88	......	......	91	64	52	23
Santa Fe	a 234	125	124	......	d 111	......	......	114	87	75	0

a Via Corona. b Via Torrance. c Via Encino. d Via Estancia.

GRAN QUIVIRA ROUTE.

Carrizozo and points west of the malpais to Gran Quivira.—The trip from Carrizozo to Gran Quivira (p. 255) can be made either by way of Red Lake or by way of Indian tank. (Pl. I, in pocket.) From Indian tank (p. 256) a road can be taken that leads nearly due north and joins the Red Lake road about 12 miles from the tank, or a more westerly route can be followed running near the escarpment of the Chupadera Plateau. All are naturally good roads, and there is not much choice between them. The Red Lake route has but slight advantage in distance over the right-hand Indian tank route, but it is about 5 miles shorter than the left-hand Indian tank route.

The Red Lake route was not traversed south of its junction with the Indian tank route, and consequently its junctions with the roads from French's north ranch and Warden's ranch, respectively, are not accurately shown in Plate I. The last watering place on this road before reaching Gran Quivira is Red Lake (p. 261). The following landmarks along the road are convenient: The junction with the Indian tank road is 12 miles from Red Lake and 21 miles from the Gran Quivira well; the conspicuous ridge known as the "Divide" is 17 miles from the Gran Quivira well; the large, crater-like sink hole on the west side of the road is 9 miles from this well; and the south ruins, which though almost completely demolished can be recognized on account of their conspicuous position on the west side of the road, are 3½ miles from the Gran Quivira well. After leaving the south ruins the road becomes very sandy. When Red Lake is dry it is generally expedient either to haul water from Carrizozo or to make a detour to French's ranch or some other ranch in the vicinity of Ancho.

The following are convenient landmarks on the left-hand Indian tank road: A large sink hole, about 10 miles from the tank and 28 miles from the Gran Quivira well; a pond that contains water after the summer rains but is dry most of the time, near the road and less than a mile from the sink hole; the "Divide," 15 miles from the Gran Quivira well; two monuments on the east side of road, 5 miles from the well; and the junction with the main road from Carrizozo, 2 miles from the well. In going southward from the Gran Quivira well, this road is the third branch road that leaves the main route and trends southwestward. When Indian tank (p. 256) is dry, water can be hauled from Carrizozo or a detour can be made to French's ranch at the northwestern extremity of the younger lava bed (p. 254).

Persons coming from the west can take a short course by turning northward after they have descended from the Chupadera Plateau, but there is no good road in this direction and it is generally more expedient to go east to Indian tank or Duck Lake (p. 253) for a water supply.

Gran Quivira to Willard, Estancia, and beyond.—The road from Gran Quivira to Willard leads northward and enters Estancia Valley through a rock canyon several miles before reaching Willard. The routes leading out of Estancia Valley have been described in connection with the Corona route. (See pp. 234–236.)

Gran Quivira to Mountainair, Manzano, and beyond.—From Gran Quivira the settlements of the Manzano foothills are easily reached by way of Mountainair. The townsite well at Mountainair, which is drilled to a depth of 303 feet, yields a small but sufficient supply of good water that is available to the public. On the road leading from this village to Manzano, about 4 miles north of Mountainair (SW. ¼ sec. 8, T. 4 N., R. 7 E.), is the 110-foot drilled well of S. R. Seymour, which yields good water. Shallow wells will be found in the Arroyo Mesteno, a short distance farther north, and there are wells and springs in the vicinity of Punta. Watering places will be found at convenient intervals along the principal roads in the foothills between Punta and Chilili. The Rio Grande valley can be reached either by way of Abo Canyon or by way of Tijeras Canyon.

Table of distances.—The following table gives the distances between the principal watering places and objective points on the

Gran Quivira route. Distances given in this table can be compared with distances between the same points as given in the table for the Corona route.

Distances in miles between watering places on Gran Quivira route.

	Alamogordo.	Carrizozo.	French's ranch (Duck Lake).	Indian tank.	Red Lake.	French's ranch (near Ancho).	Ancho.	Warden's ranch.	Gran Quivira.	Mountainair.	Willard.
Alamogordo	0	58	75	75	74	78	[a] 84	83	[a] 107	130	[b] 132
Carrizozo	58	0	17	17	16	20	[a] 26	25	[a] 49	72	[b] 74
McDonald's spring (Bar W ranch)	60	2	15	15	14	18	24	23	47	70	72
Pramberg's well	64	6	11	11	10	14	20	19	43	[a] 66	[a] 68
French's ranch (Duck Lake)	75	17	0	2	7	11	17	16	35	58	60
Indian tank	75	17	2	0	5	9	15	14	33	56	58
Red Lake	74	16	7	5	0	4	10	9	33	56	58
French's ranch (near Ancho)	78	20	11	9	4	0	6	5	32	55	57
Ancho	[a] 84	[a] 26	17	15	10	6	0	4	35	58	[b] 60
Warden's ranch	83	25	16	14	9	5	4	0	31	54	56
Gran Quivira	[a] 107	[a] 49	35	33	33	32	35	31	0	23	25
Mountainair	130	72	58	56	55	55	58	54	23	0	25
Punta del Agua	138	80	66	64	64	63	66	62	31	8	15
Manzano	143	85	71	69	69	68	71	67	36	13	20
Willard	[b] 132	[b] 74	60	58	58	57	[b] 60	56	25	25	0
Estancia	[b] 144	[b] 86	72	70	70	69	[b] 72	68	37	25	12
Santa Fe	[b] 219	[b] 161	147	145	145	144	[b] 147	143	112	100	87

[a] Via Red Lake. [b] Via Gran Quivira.

ROUTES TO RIO GRANDE VALLEY.

GENERAL CONDITIONS.

Two sets of physical barriers intervene between the settlements of eastern Tularosa Basin and those on the Rio Grande: (1) The lava beds, gypsum sands, and alkali flats along the axis of Tularosa Basin, and (2) the mountain ranges on the west side of the basin (Pl. I, in pocket). The tongue of younger lava forms a barrier 43 miles long that can not be crossed by wagon except at the two places where roads have been built over it, and the gypsum sands and alkali flats form a barrier which is not crossed by a wagon road in a north-south distance of about 30 miles. The mountains are interrupted by a number of gaps and low passes through which lead the principal roads to the Rio Grande.

HANSONBERG ROUTE.

General outline.—The shortest route from Carrizozo and points farther north in Tularosa Basin to San Antonio, on the Rio Grande, is by way of the Hansonberg ranch and Carthage post office. From points farther south in Tularosa Basin the trip to San Antonio can also be made by way of the Mockingbird Gap route. Persons taking the Hansonberg route go north of the younger lava; those taking the Mockingbird Gap route either cross the lava or go around its south end. (See fig. 1, p. 12, and Pl. I, in pocket.)

The Hansonberg ranch is reached either by way of the so-called iron mines or by way of Ozanne Spring, both routes crossing the southern part of the Chupadera Plateau or the northern part of the Oscuro Mountains. Hansonberg is situated near the west base of the mountains and is separated from Carthage by a desert plain.

To Hansonberg by way of iron mines.—The road to the iron mines leads north of the two old craters known as the Cerros Prietos. Roads from Indian tank, from the north end of the younger lava, and from Duck Lake by way of Serano tank (p. 262) all converge near the foot of the Chupadera Plateau about 2 miles east-northeast of the north crater, where a small canyon emerges from the plateau. Chupadera Spring (p. 251) is situated some distance up this canyon. The road ascends the flank of the plateau on the south side of the canyon, near the contact between the old lava and the limestone and gypsum formations, and continues near this contact until the northwestern corner of the lava bed is reached.

To Hansonberg by way of Ozanne.—Persons going to Ozanne Spring by a road leading north of the younger lava bed generally stop for water at French's ranch, near Duck Lake (p. 254), at the northwestern extremity of this bed. From Duck Lake the road trends southwestward near the margin of the old lava bed for a distance of nearly 4 miles and then branches, the north fork leading westward over the lava and the south fork continuing in a southwesterly direction along the edge of the lava.

The north fork crosses about 2 miles of lava and then continues about 2 miles farther in a westward direction to Phillips well (p. 260), whence Ozanne Spring is reached by way of Schole's well (p. 262).

The south fork avoids the lava by making a small detour. After leading southwestward for some distance it branches, the right-hand road leading to Ozanne Spring by way of Schole's well, and the left-hand road leading to Red Canyon. In Red Canyon one road leads northward to Ozanne Spring and Hansonberg, while others lead southward to the upper crossing, to the 7 X 7 ranch and the lower crossing, and to Estey and Mockingbird Gap. Persons coming from any of the points just mentioned or from still farther south approach Ozanne Spring by way of Red Canyon. Those coming by way of the upper crossing can obtain water at Lower Willow Spring (p. 265) or at Lee's ranch (p. 257); those by way of the lower crossing at the 7 X 7 ranch (p. 263); and those from farther west at Mill's ranch (p. 259) and Estey (p. 253). Between these points and Ozanne Spring water is obtained at Schole's ranch, known as the Red Canyon ranch, and said to be situated about 12 miles north of Estey.

Table of distances.—The following table gives the distances between certain of the watering places on the Hansonberg route:

Distances in miles between watering places on Hansonberg route.

	Carrizozo.	Ancho.	Gran Quivira.	Indian tank.	French's ranch (Duck Lake).	Ozanne Spring.[a]	Iron mines.[a]	Hansonberg.[a]	Carthage.[a]	San Antonio.[a]
Carrizozo	0	24	49	17	17	41	30	50	67	77
Ancho	24	0	35	15	17	41	27	47	64	74
Gran Quivira	49	35	0	33	35	59	45	65	82	92
Indian tank	17	15	33	0	2	26	12	32	49	59
French's ranch (Duck Lake)	17	17	35	2	0	24	13	33	50	60
Phillips well	25	25	43	10	8	16	......	26	43	53
Schole's well[a]	31	31	49	16	14	10	......	20	37	47
Ozanne Spring[a]	41	41	59	26	24	0	......	10	27	37
Hansonberg[a]	50	47	65	32	33	10	20	0	17	27
Serano tank	20	20	38	5	3	26	10	30	47	57
Chupadera Spring	23	[b] 20	[b] 38	5	6	......	7	27	44	54
Iron mines[a]	30	27	45	12	13	......	0	20	37	47
Hansonberg[a]	50	47	65	32	33	10	20	0	17	27
Carthage[a]	67	64	82	49	50	27	37	17	0	10
San Antonio[a]	77	74	92	59	60	37	47	27	10	0

[a] Distances from this point were not determined but are estimated.
[b] Via Indian tank.

MOCKINGBIRD GAP ROUTE.

General conditions.—Mockingbird Gap lies between the San Andreas and Little Burro ranges. It is in the western part of T. 9 S., R. 5 E., about 25 miles west-northwest of Oscuro and nearly an equal distance south of Hansonberg. It forms the easiest pass to the Jornada del Muerto and is much used in going to the settlements on the Rio Grande from San Antonio to Elephant Butte. A road also leads northward through the gap between the Little Burro and Oscuro ranges, but it is not extensively used. Most of the watering places on the various roads leading to Mockingbird Gap are shown on the map, Plate I (in pocket).

Oscuro and Three Rivers to Mockingbird Gap.—The main Mockingbird Gap route is the road from Oscuro, which leads over the lava at the lower crossing and thence follows the general course of the telephone line.

After leaving Phillips Spring, which is a well-known and reliable watering place (p. 260), no water is to be had along this road until Thomas McDonald's tank (p. 258) is reached, or, when the tank is dry, until McDonald's ranch (p. 258) is reached. This ranch is situated at the east end of the gap, within the drainage area of Tularosa Basin, and Murray is situated at the west end of the gap and on the opposite side of the divide. Both places have reliable water supplies. The trip from Three Rivers can be made by way of Oscuro or by way of Malpais Spring (p. 259).

Carrizozo to Mockingbird Gap.—The shortest route from Carrizozo to Mockingbird Gap is by way of the upper crossing (Pl. I). After going over the lava bed it is generally advisable to take the road that runs near the west margin of the lava to the lower crossing, and thence take the mail route, which follows the telephone line. On this route water can be obtained at Lower Willow Spring (p. 265) and at the 7 X 7 ranch (p. 263). From the 7 X 7 ranch the trip can also be made over a less frequented road by way of Mills ranch, where water can be obtained (p. 259).

Since in recent years the upper crossing has not been in good condition, loaded wagons from Carrizozo have generally been taken by the somewhat longer route through Oscuro and over the lower crossing.

Duck Lake and Red Canyon to Mockingbird Gap.—From French's ranch, near Duck Lake, at the north end of the younger lava bed, a road leads southward between the lava and the limestone hills and joins the road from Carrizozo at the upper crossing. The only watering place on this road is at Lee's ranch (p. 257), situated less than a mile north of the upper crossing. (Pl. I, in pocket.)

Persons coming from Red Canyon will find the best route by way of Estey and Mills ranch, at both of which water can be obtained.

Tularosa and Malpais Spring to Mockingbird Gap.—From Tularosa and points farther south the trip to Mockingbird Gap is made by a road that leads past Black Lake ranch and the south end of the lava to Malpais Spring (p. 259). From this spring roads lead northward to Mound Springs (p. 259), northwestward to James R. Gililland's ranch (p. 254), and westward to the alkali flats. The road to Gililland's ranch leads the most directly to Mockingbird Gap. On this road the watering places between Malpais Spring and Murray are Gililland's and McDonald's ranches. Mound Springs and McDonald's tank are situated east of this road. (See Pl. I, in pocket.)

Mockingbird Gap to the Rio Grande.—The roads leading from Mockingbird Gap to the towns on the Rio Grande cross an extensive plain, a part of which has shallow water. On the road to Carthage water is obtained at Smith's ranch, about 10 miles from Murray. The road to Engle and Elephant Butte passes several ranches at which water can be obtained.

Table of distances.—The following table gives the distances between watering places that are used in going to the Rio Grande by way of Mockingbird Gap:

Distances in miles between watering places on Mockingbird Gap route.

	French's ranch (Duck Lake).	Carrizozo.	7 X 7 ranch.	Estey.	Oscuro.	Thomas McDonald's ranch.	Murray.	Three Rivers (railway station).	Tularosa.	Malpais Spring.	Gililland's ranch.
French's ranch (Duck Lake)	0	17	24	34	b 33	a 45	a 48	b 45	62	48	44
Lee's ranch	18	13	6	a 16	......	27	30	......	......	30	26
Carrizozo	17	0	18	a 28	16	a 39	a 42	28	45	45	a 38
Lower Willow Spring	20	11	7	a 17	......	28	31	......	......	......	27
Willow Spring reservoir	19	13	5	15	......	26	29	......	......	......	25
7 X 7 ranch	24	18	0	10	10	21	24	c 22	c 40	24	20
Estey	a 34	a 28	10	0	15	d 16	d 19	c 27	c 45	d 23	......
Mills ranch	a 33	a 27	9	5	14	11	14	c 26	......	18	......
Oscuro	b 33	16	10	15	0	24	27	12	29	a 29	23
Phillips Spring	......	19	7	12	3	21	24	15	32	......	20
Thomas McDonald's tank	a 41	a 35	16	d 11	20	4	7	c 32	......	......	......
Thomas McDonald's ranch	a 45	a 39	21	d 16	24	0	3	c 36	45	20	12
Murray	a 48	a 42	24	3	27	3	0	c 39	48	24	16
Three Rivers (railway station)	b 45	28	c 22	c 27	12	c 36	39	0	17	17	25
Tularosa	62	45	c 40	c 45	29	45	48	17	0	25	33
Black Lake	......	......	......	......	......	29	32	......	16	9	17
Malpais Spring	48	45	24	23	a 29	20	24	17	25	0	8
Mound Springs e	38	a 32	14	d 13	17	14	18	27	35	10	6
Roberts ranch (Old Mayes ranch)	33	a 27	9	13	12	......	......	......	40	15	11
Gililland's ranch	44	a 38	20	......	23	12	16	25	33	8	0
Murray	a 48	a 42	24	3	27	3	0	c 39	48	24	16
Carthage f	......	72	54	49	57	33	30	69	78	54	46
San Marcial f	82	76	58	53	61	37	34	73	82	58	50
Engle f	93	87	59	64	72	48	45	84	93	......	......

a Via upper crossing.
b Via Carrizozo.
c Via lower crossing.
d Via Mills ranch.
e North spring; another spring 1½ miles farther south.
f Distances from this point are estimated via Mockingbird Gap.

LAVA GAP ROUTE.

Lava Gap was at one time important as the approach to the Tularosa Basin through which passed one of the military roads that connected Fort Stanton with the Rio Grande valley. It is still extensively used by persons living in the Tularosa Basin and farther east who go to Eagle, Elephant Butte, Palomas Springs, and other points in the Rio Grande valley. The gap is situated in the San Andreas Range between Capitol and Salinas peaks. (See Pl. I.) It is traversed by a good road, but the approach is somewhat steeper than that to Mockingbird Gap.

The trip through Lava Gap is best made by way of Gililland's ranch (Pl. I, in pocket), which is reached by several roads from different directions. The road from Tularosa leads past Black Lake ranch and Malpais Spring, as already indicated (p. 242 and Pl. II, in pocket). The road from Three Rivers also leads south of the lava and joins the road from Tularosa at the south point of the lava, about 2 miles from Malpais Spring. From Oscuro and points farther north the shortest routes cross the lava and lead from the lower crossing to Gililland's by way of Roberts ranch (the old Andy Mayes ranch) (p. 262) and Mound Springs (p. 259).

The distance from Gililland's ranch to the summit of Lava Gap is estimated to be about 10 or 11 miles. Walter George's ranch, a dependable watering place (p. 254), is situated along this stretch of the road, about 6 miles from Gililland's. Dripping Spring (p. 253) and E. E. Thurgood's ranch (p. 264) are situated between George's ranch and the summit of the gap, but they are nearly a mile south of the road and are not generally used as watering places.

The road from Lava Gap to Engle crosses the Jornada del Muerto and is approximately 40 miles long. Watering places along this route are the Hopel tank, the Tucson ranch, and the Deep Wells. At the Tucson ranch, which is one of the ranches of the Victoria Land & Cattle Co., there is a permanent spring that yields water which is said to be rather highly mineralized but to be used for drinking and culinary purposes.

The distances between the principal watering places east of Gililland's ranch are shown in the table on page 243.

SULPHUR CANYON ROUTE.

Alamogordo and Tularosa to Sulphur Canyon.—The Sulphur Canyon route is the shortest route from Alamogordo and Tularosa to Cutter, Engle, Elephant Butte, and Palomas Springs, and is for this reason frequently traveled. (See Pls. I and II, in pocket.)

The main road leads from Tularosa with a westerly course, over the northern part of the white sands, as shown on the map, Plate II. This road passes several wells in the vicinity of Tularosa, the last one that is generally used by travelers being on the ranch of H. W. Purday, NE. ¼ sec. 28, T. 14 S., R. 9 E. (p. 261). After leaving these wells there is no watering place until Ritch's tank (p. 262) on the west side of the sands is reached. About 2 miles beyond the tank is a well belonging to W. L. Ritch (p. 261), which, however, is not always kept in repair. There are also a few wells, some of them yielding bad water, on the west side of the valley within several miles of the road. (See list, pp. 268–299.) The most reliable watering place on the road is the spring at the ranch of George E. Stone, situated in the canyon. In dry seasons, when Ritch's tank is empty, this spring may be the first place along the road after leaving Purday's ranch at which water can be obtained.

West side of the malpais to Sulphur Canyon.—Persons coming to Sulphur Canyon from some northerly point will find a series of ranches, most of them uninhabited, at some of which water can be obtained either from wells or tanks. (See Pls. I and II, in pocket.) Most of the well water is unfit for human use and should be given to horses with caution. These ranches are described in the list of watering places (pp. 249–265), under the headings "Jackson ranches," "Henderson ranches," and "Hunter ranches." Cistern water for drinking can generally be obtained at the ranch of Mark Hunter, situated about 4 miles north of the main road.

East side of the malpais to Sulphur Canyon.—From Three Rivers and points farther north on the east side of the younger lava bed the trip to Sulphur Canyon can be made by way of Tularosa, or by the shorter route leading past Malpais Spring and the ranches on the west side of the alkali flats.

Dog Canyon to Sulphur Canyon.—From the Dog Canyon settlement the trip can be made either by way of Alamogordo, Tularosa, and Ritch's tank, or by a road leading over the south end of the white sands (Pls. I and II). The following watering places will be found on the southern route: The well at the Point of Sands (p. 260), Lucero's north ranch (p. 258), Baird's ranch (p. 250), Baird's north wells (p. 250), and Ritch's ranch (p. 261). The last-named ranch is situated 4 miles south of the main road from Tularosa. The best drinking water along this road is obtained from the well at Baird's ranch, but a supply of water from a mountain spring is usually kept at Ritch's ranch for drinking purposes.

Sulphur Canyon to Cutter and Engle.—After emerging from the San Andreas Mountains the road to Engle and Cutter crosses the open desert of the Jornada del Muerto. There are no dependable watering places along this part of the road, but one or more earth reservoirs furnish water in certain seasons.

Table of distances.—The following table gives the distances between the principal watering places used in going to the Rio Grande valley by way of Sulphur Canyon:

Distances in miles between watering places on Sulphur Canyon route.

	Alamogordo.	Tularosa.	Purday's ranch.	Ritch's tank.	Stone's ranch.[a]	Malpais Spring.	Dog Canyon (railway station).	Point of Sands.	Baird's ranch.	Ritch's ranch.
Alamogordo	0	14	19	[b] 46	56	39	11	20	[c] 45	[b] 52
Tularosa	14	0	5	32	42	25	25	[d] 34	[d] 52	38
Purday's ranch	19	5	0	27	37	......	......	......	[e] 47	33
Ritch's tank	[b] 46	32	27	0	10	26	([b])	......	20	6
Stone's ranch [a]	56	42	37	10	0	33	[c] 62	49	24	10
Malpais Spring	39	25	......	26	33	0	[c] 50	......	43	29
Jackson "home" ranch	[b] 46	32	......	16	23	10	......	......	33	19
Mark Hunter's ranch	......	......	......	5	12	21	......	47	22	8
Dog Canyon (railway station)	11	25	......	......	[c] 62	[b] 50	0	13	38	[c] 52
Point of Sands	20	[d] 34	......	......	49	......	13	0	25	39
North Lucero ranch	36	[d] 50	......	29	33	52	29	16	9	23
Baird's ranch	[c] 45	[e] 52	47	20	24	43	38	25	0	14
Baird's north well	[c] 50	[e] 47	42	15	19	38	43	30	5	9
Ritch's ranch	[b] 52	38	33	6	10	29	[c] 52	39	14	0
Stone's ranch [a]	56	42	37	10	0	33	[c] 62	49	24	10
Cutter [a]	[b] 80	66	61	34	24	[f] 57	[c] 86	73	48	34
Engle [a]	[b] 84	70	65	38	28	[f] 61	[c] 90	77	52	38

[a] Distances from this point are estimated.
[b] Via Tularosa.
[c] Via Point of Sands.
[d] Via Alamogordo.
[e] Via Ritch's ranch.
[f] Via Sulphur Canyon.

SAN AGUSTIN PASS ROUTE.

Alamogordo to San Agustin Pass.—The routes from Tularosa Basin to Las Cruces and Dona Ana converge between the San Andreas and Organ ranges and lead through the San Agustin Pass, which is also known as the Organ Pass. After leaving the farming settlement that surrounds Alamogordo the road to Las Cruces and Dona Ana takes a direct course to a point on the southeast margin of the white sands, commonly called the "Point of Sands." At this point there is a shallow well that is much used by travelers and is the first watering place found on the road after leaving the Alamogordo settlement. (See Pls. I and II, in pocket, and p. 260.) From this well a road leads westward across the sands to the Eddy prospect, North Lucero ranch, Baird's ranch, and Ritch's ranch, but the road to San Agustin Pass and thence to Las Cruces or Dona Ana leaves the sands and leads southwestward past two ranches belonging to W. H. McNew (one of which is the old Pelman ranch) and past Bennett's ranch, which is also known as the old Leatherman ranch (pp. 249–265). A little over 2 miles beyond the well at the Point of Sands a right-hand road leaves the main road and leads around the south end of the white sands to the Lucero ranches.

There are two routes from Bennett's ranch to San Agustin Pass. The northern route, which is the more frequently traveled, passes a short distance south of the Gold Camp, where there is a water supply (p. 255), and past the Thompson ranch, where there is a shallow well (p. 263). The southern route passes a short distance south of the so-called Steam-pump ranch, where there is also a water supply (p. 263). The northern and southern routes come together a little more than 2 miles east of the summit of San Agustin Pass.

Tularosa and La Luz to San Agustin Pass.—The old stage route to Las Cruces led by a nearly direct course from Tularosa to the Point of Sands, as is indicated in Plates I and II, and thence followed the general course already outlined to San Agustin Pass. It was joined by a road from La Luz. These old roads can still be traveled, but persons now going from Tularosa or La Luz to the Point of Sands will do better to take the somewhat longer road by way of Alamogordo. On the old stage route satisfactory water can be obtained at the two wells shown on Plate I and at several others nearer Tularosa or La Luz, but between these wells and the Point of Sands there is no satisfactory watering place. The springs in the arroyos yield very poor water. (See analysis, p. 300.)

Dog Canyon to San Agustin Pass.—The main road from the Dog Canyon settlement joins the road from Alamogordo at a point 3½ miles northeast of the Point of Sands. A shorter but poorer road leads more directly from Dog Canyon to the McNew ranches. From the McNew ranches to San Agustin Pass the routes are the same as from Alamogordo to the pass. (See Pl. I.)

West side of white sands to San Agustin Pass.—Persons going to Las Cruces or El Paso from some point on the west side of the Tularosa Basin will find a more or less distinct road leading southward and joining the road from Alamogordo a short distance north of Bennett's ranch (Pls. I and II). Water will be found at the McDonald, Hunter, Ritch, and Baird watering places. Probably the most dependable of these watering places south of Gililland's ranch are Mark Hunter's ranch, Ritch's ranch, Baird's ranch, and the South Lucero ranch (pp. 249–265). Most of the water along this road is poor and should be given to horses with caution. Good water will, however, be found at Baird's ranch and at the South Lucero ranch. San Nicholas Spring, which was a well-known watering place in the early days, is west of the main road and is now seldom used by travelers. The shortest route to San Agustin Pass leads about a mile west of Bennett's ranch. (See Pl. I.)

Orogrande to San Agustin Pass.—A road leads from Orogrande to San Agustin Pass by way of the Cox ranch, which is also called the San Agustin ranch (Pl. I). This road was not traversed and its course is therefore not accurately shown on the map. According to the information obtained there is no satisfactory watering place between Orogrande and the Cox ranch, but there is a water supply at this ranch.

San Agustin Pass to Las Cruces and Dona Ana.—The small mining camp of Organ is 2 miles west of the summit of San Agustin Pass. At this place will be found a store, post office, and well. The well, which is on the ranch of C. R. Walter at the west end of the settlement, is dug to the depth of 25 feet and drilled the rest of the distance to a total depth of 60 feet. It has a permanent though rather small supply of hard but otherwise satisfactory water, which is pumped by a windmill and stored in a masonry reservoir. The water is sold at small price to travelers. Several roads lead from Organ to Las Cruces and the other settlements on the Rio Grande. In the fall of 1912 a new automobile road was being projected. There are several watering places between Organ and the Rio Grande, but they are not on the main roads.

Table of distances.—The table on page 249 gives the distances between the principal watering places on the routes leading through San Agustin Pass.

ROUTES TO EL PASO.

Outline.—The trip from Alamogordo or points farther north to El Paso can be made either by following the railroad or by taking a more western route past the Point of Sands (Pl. I). Although the route along the railroad is considerably shorter than the western routes it should so far as possible be avoided because it is very sandy.

Western routes.—In going to El Paso over the western routes the same roads to Bennett's ranch are generally followed as in going to Las Cruces (p. 246), although the most direct route from Alamogordo leaves the road to Bennett's ranch at the east McNew ranch (Pelman ranch (Pl. I, in pocket). Between Bennett's ranch and the Hitt ranch there are various roads, and the exact course that is taken by a traveler at any given time is determined by the wells which are in repair at that time. In general the routes that remain farthest from the mountains are the shortest and smoothest and best adapted for automobile travel, but the most western routes pass the most dependable watering places. There is generally an adequate number of watering places on these roads, but in 1912, owing to the demoralization of the ranching business that followed a series of dry years, most of the wells were so much neglected that no water could be obtained from them. In that year water supplies were available at the Cox ranch, the Globe Spring ranch, and the Hitt ranch, but not always at Bennett's ranch, the Cox windmills, or the Coe ranches. (See Pl. I, in pocket, and pp. 249–265.) Water supplies were also available at several points between the Hitt ranch and Fort Bliss. At the Hitt ranch, now owned by E. O. Lockhausen, there are two wells over 300 feet deep that yield dependable supplies of good water. (See analysis, p. 305.)

Eastern route.—A road leads along the west side of the railroad from north of Dog Canyon to El Paso. On this road water supplies can be obtained at Orogrande and Newman, and generally at the section houses at Escondida, Turquoise, and Desert. The region on both sides of the railroad is very sparsely settled and has only a few widely scattered wells.

Distances between watering places.—The following table gives the distances between certain watering places on roads leading from Tularosa Basin to Las Cruces and El Paso:

Distances in miles between watering places on routes to Las Cruces and El Paso.

	Alamogordo.	Dog Canyon (railway station).	Point of Sands.	Bennett's ranch (Leatherman).	Malpais Spring.	Ritch's ranch.	Baird's ranch.	South Lucero ranch.	Organ.	Las Cruces.	El Paso.[a]
Tularosa	14	25	b 34	b 56	25	c 38	b 52	b 50	b 72	b 86	b 116
La Luz	6	17	b 26	b 48	33	c 46	......	b 42	b 64	b 78	b 108
Alamogordo	0	11	20	42	39	c 52	45	36	58	72	102
Dog Canyon (railway station)	11	0	13	35	50	52	38	29	51	65	95
Point of Sands	20	13	0	22	......	39	25	16	38	52	82
East McNew ranch (Pelman)	25	18	5	17	......	38	24	12	33	47	77
West McNew ranch	28	21	8	14	......	35	21	9	30	44	74
Bennett's ranch (Leatherman)	42	35	22	0	65	36	22	9	16	30	60
Malpais Spring	39	50	......	65	0	29	43	56	81	95	125
Ritch's ranch	c 52	52	39	36	29	0	14	27	52	66	96
Baird's north well	50	43	30	27	38	9	5	18	43	57	87
Baird's ranch	45	38	25	22	43	14	0	13	38	52	82
North Lucero ranch	36	29	16	13	52	23	9	4	29	43	73
South Lucero ranch	36	29	16	9	56	27	13	0	25	39	69
Bennett's ranch (Leatherman)	42	35	22	0	65	36	22	9	16	30	60
Gold Camp	50	43	30	8	73	44	30	17	9	24	59
Thompson ranch	52	45	32	10	75	46	32	19	6	21	......
Steam Pump ranch	51	44	31	9	74	45	31	18	8	23	57
Orogrande	38	27	......	......	......	......	......	......	d 35	d 50	......
Cox ranch	55	48	35	13	78	49	35	22	7	21	52
Organ	58	51	38	16	81	52	38	25	0	15	59
Las Cruces	72	65	52	30	95	66	52	39	15	0	......
Globe Spring	58	51	38	16	81	50	38	25	15	30	44
Coe's home ranch	71	64	51	29	94	65	51	38	28	......	31
Hitt ranch (Lockhausen) [a]	83	76	63	41	106	77	63	50	40	......	19
Fort Bliss [a]	96	89	76	54	119	90	76	63	53	......	6
El Paso [a]	102	95	82	60	125	96	82	69	59	......	0

a Via Globe Spring and Coe's home ranch.
b Via Alamogordo.
c Via Ritch's tank.
d Estimated.

WATERING PLACES.

The following alphabetically arranged list includes the principal watering places used by travelers in the Tularosa Basin. Watering places that are outside of this region but situated on routes leading from it are not included in this list, but are briefly described in connection with the route descriptions.

One of the principal difficulties in connection with the desert watering places of this region is the high mineralization of the water, making much of it unfit for human use and some of it undesirable for watering horses. This subject is more fully discussed on pages 134–136. Analyses of the water from most of the watering places in this list will be found in the tables on pages 268–305.

The information here given should be used with discretion. From time to time watering places are allowed to go to ruin and new wells are drilled or new reservoirs are constructed at other places. For this reason directions that are given in this paper and are accurate for 1911 or 1912, when the investigation was made, need to be amended by information obtained from local sources.

Ancho railroad well.—The old railroad pumping plant, now used to supply water for the cement works at Ancho, is situated in a draw about 2 miles east-southeast of that town, and some distance north of the road leading to Jicarilla. The water from the several wells at this point is pumped to Ancho, where it and the water from the Bonita pipe line constitute the only supplies. This water is of satisfactory quality. (See analyses, p. 268.)

Baird's ranch and wells.—At the ranch of J. A. Baird, situated about 3 miles west of the large alkali flat, not far from the west margin of sec. 24, T. 17 S., R. 4 E. (Pls. I and II, in pocket), there is a drilled well 210 feet deep, which has been pumped at the rate of about 12 gallons a minute, and which yields water of good quality. (See analysis, p. 290.) The equipment includes a windmill, tank, and watering trough.

Two drilled wells with windmills belonging to Mr. Baird are situated on the road between Ritch's and Baird's ranches, a distance of 5¼ miles from the latter and less than a mile from the alkali flat. (Pl. II, in pocket.) They are 120 feet deep, have a water level 60 or 70 feet below the surface, and yield freely, but their water is too salty for human use and should not be given to horses except in necessity, although it is used for watering range stock. (See analysis, p. 286.)

Bar W ranch.—See Carrizozo Spring (p. 251).

Bennett's ranch.—The ranch of G. A. Bennett, formerly known as the Leatherman ranch, is situated near the southwest corner of sec. 36, T. 20 S., R. 5 E., on the west side of a large inclosure (Pl. I). The water supply is obtained from a drilled well and is of good quality (analysis, p. 296). The equipment includes a windmill, tank, and watering trough. In 1912 the ranch was uninhabited and the pump was out of repair.

Black Lake ranch.—In the SE. ¼ sec. 8, T. 13 S., R. 8 E., along the road leading from Tularosa to the south point of the malpais (Pls.

I and II), in an arroyo that leads southwestward through the area of quartz-sand dunes, is the Black Lake ranch, where there are two dug wells with windmills, a surface reservoir, and watering troughs. The water, which stands about 17 feet below the surface, is rather highly mineralized (see analysis, p. 280), but can be used for watering horses and for cooking and drinking if necessary. There is also a cistern which generally contains rain water, which is more desirable for culinary use.

Carrizozo Spring.—This spring is situated in the SE. ¼ sec. 26, T. 7 S., R. 10 E., a little over 2 miles north of Carrizozo, in an arroyo in the midst of a conspicuous grove of trees, on the main road leading northward from Carrizozo (Pls. I and VI). This spring, which at the time it was visited yielded about 50 gallons a minute of satisfactory water (see analysis, p. 300), furnishes the live-stock supply and a small irrigation supply for what has until recently been the headquarters of the Bar W ranching establishment. Since the town of Carrizozo came into existence the spring is no longer important as a watering place for travelers, and its use as a camping place is discouraged.

Chaves Spring.—Chaves Spring is situated northeast of Chaves Mountain, in the SW. ¼ sec. 23, T. 9 S., R. 10 E. (Pl. VI, p. 26).

Chosa Spring.—The spring at the Chosa ranch is situated in sec. 5, T. 13 S., R. 9 E., about 7 miles south-southwest of Three Rivers depot (Pls. I and II, in pocket). The water, which issues near the base of a rather high west-facing bank at the rate of several gallons a minute, is very hard but can be used for drinking and culinary purposes (analysis, p. 300). Apparently it contains some hydrogen sulphide when it emerges from the ground. This spring was formerly a well-known watering place, but the road on which it is situated is not now an important route of travel.

Chupadera Spring.—The name Chupadera Spring is applied to several springs in or near the Chupadera Plateau. One of these springs is situated in a small canyon on the north side of the road that leads north of the Cerros Prietos (old craters) to the iron mines, about a mile from the east margin of the plateau (Pl. I, in pocket). This spring was formerly used by travelers as a watering place but is not very accessible and is not much used at present. The water is said to be of poor quality.

Coe's ranches.—The Coe home ranch is situated on the plain between the Organ and Franklin mountains, a short distance east of the Fillmore Pass. It is on the westernmost route to El Paso, but several miles west of the more direct eastern route. The various roads are, however, changed from time to time, and are not accurately shown on Plate I. The water supply at the home ranch is derived from a drilled well 349 feet deep, in which the water is reported to stand 327 feet below the surface. The water is soft. (See analyses, p. 298.)

The North Coe ranch is situated on the plain about 10 miles north-northeast of the home ranch and is on the main El Paso road (Pl. I, in pocket). The water supply is obtained from a drilled well reported to be 180 feet deep and to have a water level 142 feet below the surface. The water is of good quality.

The South Coe ranch is situated south of the drainage divide, about 4 miles north of the Texas line, and at the point where the two El Paso roads meet (Pl. I). The well at this place is reported to be about 350 feet deep, to have a water level 328 feet below the surface, and to yield soft water.

In 1912 none of the Coe ranches could be depended on for water, but supplies can usually be obtained at the home ranch and the north ranch.

Cooper's ranch.—On the ranch of James Cooper, which is situated 2½ miles west-southwest of Ancho, there are two wells with windmills, and two large earth reservoirs that are filled in part with flood waters. The analysis of the water from one of the wells is given on page 268.

Cox ranch and wells.—The headquarters of the W. W. Cox ranching establishment, often called the San Agustin ranch, is situated near the north end of the Organ Range, 4 or 5 miles southeast of San Agustin Peak. It is at a prominent cliff and terrace feature, a short distance above the desert flat, and in plain view from the east and north. It is on the direct road from Orogrande to Organ and can be reached from the El Paso routes by branch roads not shown on the map, Plate I. At this ranch there is a reliable water supply.

There are also several wells with windmills on the plain east of the headquarters ranch. Two drilled wells at the point indicated in Plate I as the Cox windmills have been much used by travelers, but in 1912 were out of repair and furnished no supply. (See also Globe Spring ranch, Steam-pump ranch, and Thompson ranch.)

Coyote Springs.—Upper Coyote Spring is a Bar W watering place, situated in the SW. ¼ sec. 11, T. 8 S., R. 10 E., only a mile or two south of Carrizozo (Pls. I and VI). It no longer has the importance that it once possessed but is still used to some extent by travelers approaching Carrizozo from a southerly direction. The water is of satisfactory quality. (See analysis, p. 300.)

Lower Coyote Spring is situated near the north margin of sec. 8, T. 8 S., R. 10 E., about 3 miles west-northwest of the upper spring, and another spring is situated near the northeast corner of sec. 5, T. 8 S., R. 10 E., nearly a mile north-northeast of Lower Coyote Spring proper. Both springs issue along a west-facing escarpment formed by ledges of limestone and sandstone (Pl. VI, p. 26). Their yield is small, and they are of no consequence except as range watering places.

Dow's well.—See Gran Quivira (p. 255).

Dripping Spring.—According to the best information obtainable, Dripping Spring is situated about three-fourths of a mile south of the Lava Gap road, and about 1½ miles east of the summit of this gap. It was formerly used by travelers, but at present yields little water and is seldom visited.

Duck Lake is situated near the northwestern extremity of the younger lava bed, only a short distance west of J. B. French's ranch (Pls. I, in pocket, and VI, p. 26). It is a shallow natural depression that contains surface water for some time after each rainy season, but has lost most of its importance as a watering place for travelers since French's well was sunk.

Estey, a mining camp, at present uninhabited except for a watchman, is situated on secs. 25 and 36, T. 8 S., R. 6 E., in the eastern foothills of the Oscuro Mountains (Pls. I and VI). It is in a conspicuous position and from the east can be seen and recognized for many miles. The water supply at this place is obtained through a gravity pipe line from a small spring about 2½ miles west of the buildings. The water is hard and ferruginous, but fairly satisfactory for drinking and for culinary use. (See analyses, p. 300.)

Fleck's ranches.—The home ranch of W. N. Fleck is 4 miles east of the depot at Orogrande and is not on any well-traveled route. (Pl. I.) The water supply is obtained from a well reported to be 540 feet deep with a water level probably not less than 400 feet below the surface. The equipment includes windmill, gasoline engine, two steel tanks, and watering troughs. The water is somewhat salty, but can be given to horses and used for drinking and cooking.

Most of the other wells east of the railroad and south of Turquoise that are shown on Plate I belong to W. N. Fleck. The Wilde well, 5 miles north of the home ranch (Pl. I), is reported to be 526 feet deep and to have a water level 244 feet below the surface. In 1912 it was out of repair and did not furnish a supply. The water is salty but is used for live stock. (See analysis, p. 298.)

Flowing wells.—See Shoemaker's flowing wells (p. 263).

French's ranch near Ancho (*J. B. French*).—The old J. B. French home ranch is situated between Ancho and Coyote, nearly a mile west of the railroad. It is 6 miles southwest of Ancho on the road leading from that town to Red Lake. (Pl. I.) The water supply is derived from a 6-inch cased well, 166 feet deep, ending in sandstone, and tested at 22 gallons a minute. It is hard but otherwise of satisfactory quality. (See analysis, p. 268.)

French's ranch (*near Duck Lake*).—A ranch belonging to J. B. French is situated in a rincon at the northwestern extremity of the younger lava bed, 2½ miles northwest of the crater and a short distance east of Duck Lake. It is immediately south of the road that leads around the north edge of the lava (Pls. I and VI). The water is obtained by means of a windmill from a combination dug and drilled well about 102 feet deep. The yield of the well is not great, but a considerable quantity of water is stored in the underground openings and in a large well-constructed surface reservoir. The water is of satisfactory quality. (See analysis, p. 268.)

French's ranch (*Horace French*).—The ranch owned by Horace French is situated on the east side of the railroad between Ancho and the J. B. French home ranch. It is nearly a half mile from the railroad culvert through which the wagon road passes, and this culvert is 2½ miles northeast of the J. B. French ranch, one-half mile northeast of Largo switch, and 4 miles southwest of Ancho (Pl. I). The water supply is obtained from a 6-inch cased well that is reported to be 150 feet deep and to have a maximum yield of 8 gallons a minute. The water is of satisfactory quality. (See analyses, p. 268.)

Gallacher's ranch.—See Indian tank (p. 256).

George's ranch.—The ranch of Walter George is situated on the Lava Gap road, about 6 miles from James Gililland's ranch and a somewhat less distance from the gap. At this ranch there is a dug well sunk into limestone and shale to a depth of about 40 feet, and also an earth reservoir that receives flood waters. The well water is reported to be of fairly good quality for drinking and culinary uses. The water level fluctuates and in dry seasons the yield is small. The ranch is extensively used by travelers as a watering place.

Gililland's ranch.—The ranch of James R. Gililland is situated about 2 miles west and one-fourth mile south of the northeast corner of T. 11 S., R. 6 E., near the base of the slope that projects from the San Andreas Mountains. (Pls. I and VI.) A dug well about 50 feet deep yields water which, undiluted, is too salty for human use and undesirable for watering stock (see analyses, p. 278), but which is, so far as possible, mixed with flood waters stored in an earth reservoir. In spite of the poor quality of the supply this ranch is extensively used by travelers on the Lava Gap route for watering horses.

A similar well and reservoir will be found at the ranch of W. F. Gililland, about 4 miles south-southwest of James Gililland's ranch. Still farther south is a watering place belonging to Thomas McDonald and supplied by a pipe line leading from a spring nearer the mountains.

Globe Spring ranch.—The Globe Spring ranch, which is one of W. W. Cox's range watering places, is situated on Soledad Arroyo near the foot of the Organ Mountains, above the desert flat, and not far from the middle of the west margin of T. 23 S., R. 5 E. (Pl. I). It is on the westernmost route to El Paso and can be reached by a detour of several miles from the more easterly valley road, the branch roads not being shown on the map. Water is led through a pipe line from a spring nearer the mountains to the ranch house, where it flows by gravity into a steel tank at the rate of about 2 gallons a minute. The water is soft and otherwise of good quality. (See analysis, p. 300.) Spring water also occurs farther up Soledad Arroyo. The original Globe Spring was a short distance north of the present supply.

Gold Camp.—About 5 miles northeast of San Agustin Peak is Gold Camp. It is less than a mile north of the north road from Bennett's ranch to Organ, from which it is easily reached. (See Pl. I.) It stands high above the desert plain and in full view from the east, and it is reported to have a reliable supply of good water.

Gran Quivira.—The Gran Quivira house and well are situated on or near sec. 31, T. 1 N., R. 8 E., about one mile west-northwest of the principal ruins and about the same distance east of the edge of the Chupadera Plateau (Pl. I). They are on a relatively low, sandy, cedar-covered tract and can not be seen from a great distance. The ruins on the rocky ridge just east are, however, conspicuous. The well in use is a dug hole approximately 80 feet deep, with a water level 73 feet below the surface. It yields a very small supply of water that is comparatively soft (see analysis, p. 268), but has at times become filthy through neglect. There are several abandoned wells at the same place. Since this paper was written a well has been drilled by C. Spence a short distance west of the Gran Quivira ranch.

Gray's ranch.—The Al. Gray ranch, which is in the NE. ¼ sec. 20, T. 13 S., R. 9 E. (Pls. I and II), has several shallow wells. The well now in use is a dug hole in which water stands 12½ feet below the surface. It is equipped with windmill, reservoir, and watering trough. The water is highly mineralized, but can be used for drinking and cooking. (See analysis, p. 280.)

Hembrillo Spring.—See Ritch's ranches (p. 261) and Plate I (in pocket).

Henderson ranches.—Two old watering places, formerly controlled by George Henderson but now abandoned, are situated a few miles west of Salt Creek, one on or near the S. ½ sec. 14, T. 13 S., R. 5 E., and the other a little over 1½ miles farther southwest (Pls. I and II). At the north ranch, where the water in a shallow well is reported to have been too salty for use, a large earth reservoir was constructed. At the south ranch there is a dug well with water 71 feet below the surface. In 1911 neither of these places could be relied on for a water supply.

Hunter ranches.—The two Hunter ranches are situated a few miles west of the alkali flats and a few miles north of the main road between Tularosa and Sulphur Canyon. The ranch of Mark Hunter is on or near sec. 17, T. 14 S., R. 5 E., and that of William Hunter is on the S. ½ sec. 19, in the same township, a distance of 1½ miles south-southwest of Mark Hunter's ranch. Several watering places south of the white sands formerly known as Hunter ranches are described under "McNew's ranches" and "Point of Sands." (See Pls. I and II.)

The well at Mark Hunter's ranch is dug to a depth of about 70 feet, has a water level 54 feet below the surface, and yields water which is too salty for human use and undesirable for stock use. (See analysis, p. 280.) This supply is supplemented by flood water that is stored in an earth reservoir, and by rain or other soft water for household use that is stored in a cistern.

At William Hunter's ranch there is a dug well with water standing 53 feet below the surface.

I Bar X ranch.—The I Bar X ranch is situated on the E. ½ sec. 25, T. 9 S., R. 9 E., near the northern extremity of the Godfrey Hills, and about 6 miles east-northeast of Oscuro (Pls. I and VI). It is on the road that leads from Three Rivers to Carrizozo by way of the east side of the Godfrey Hills. There are several shallow wells at this ranch, but travelers can most conveniently obtain water for themselves at the gravity ditch near the road, and for their horses at the corral supplied from this ditch. The yield of the ditch is about 50 gallons a minute; the water is of good quality. (See analysis, p. 300.)

Indian tank.—This watering place is situated at the ranch of Gallacher Bros., near the east end of the older lava bed, and less than 2 miles north of the younger lava bed (Pl. I). It consists of a small gully in the lava, across which a substantial dam has been constructed. It is filled with surface water in the rainy season, but its supply may fail in dry seasons. The water is, of course, much softer than the well water of the region.

Iron mines.—The so-called iron mines were not visited, but are reported to be situated on the road between Indian tank and Hansonberg, approximately 12 miles from Indian tank. At the iron mines water is stored in a tank, but the supply may fail in dry seasons.

Jackson ranches.—Three old range watering places, known as the Jakson ranches but now controlled by Thomas McDonald are found west of Salt Creek. (See Pls. I and II.)

The "home ranch" is situated on or near the SW. ¼ sec. 25, T. 12 S., R. 5 E., less than 2 miles from Salt Creek. Its water supply is derived from two dug wells that have a water level about 94 feet below the surface. The water is highly mineralized but can with caution be used for watering horses and in necessity for drinking. (See analysis, p. 280.) The equipment includes two windmills, a surface reservoir, and watering troughs.

Another "Jackson ranch" is situated about 4½ miles south-southwest of the "home ranch," on or near the NE. ¼ sec. 16, T. 13 S., R. 5 E. At this point there is a 6-inch drilled well said to be about 280 feet deep, but with a water level less than 50 feet below the surface. The water is highly mineralized but can be used.

The third "Jackson ranch," which is situated 3 miles south-southwest of the second ranch, near the north margin of sec. 32, T. 13 S., R. 5 E., had no available water supply in 1911, but it has a drilled well 204 feet deep which when in repair is said to yield the best water of any well in this locality.

Jake's Spring.—Near the west margin of sec. 10, T. 9 S., R. 9 E., a little over half a mile south-southeast of the section house (Pls. I and VI), is Jake's Spring, which yields water of fair quality (analysis, p. 300) at the rate of several gallons a minute.

At the section house there is a tunnel in the sandstone east of the railroad from which water flows at the rate of a few gallons a minute. This water is led across the right of way to a small reservoir, which is the only watering place along the road between Oscuro and Polly. The water is similar in mineral character to that from the spring and can be used for all purposes. (See analysis, p. 300.) Drinking supplies should be taken directly from the tunnel.

Jicarilla.—The small mining town of Jicarilla is supplied with water conducted through a pipe line from a drilled well situated nearly 2 miles farther up the gulch. This well, which is 402 feet deep, yields an ample supply of good water. (See analysis, p. 175.)

Leatherman ranch.—See Bennett's ranch (p. 250).

Lee's ranch (*James Lee*).—The ranch of James Lee is near the west margin of the younger lava bed, somewhat over half a mile north of the upper crossing, near the northeast corner of sec. 19, T. 8 S., R. 9 E. (Pls. I and VI). The well at this ranch was dug to a depth of 104 feet, below which a 6-inch hole was drilled to a total depth of 152 feet. The water level is normally about 90 feet below the surface and is said to be lowered about 10 feet when the well is pumped at a rate of about 5 gallons a minute. The equipment includes windmill, steel tank, and watering troughs. The water is hard but fairly satisfactory for drinking and cooking. (See analysis, p. 270.)

Lee's ranch (*Oliver Lee*).—The home ranch of Oliver Lee is near the south end of the Sacramento Mountains and Mr. Lee has several other watering places in the same region. The well at his valley ranch, 4½ miles north of the Wilde well (Pl. I), is 130 feet deep and yields water of good quality. (See analysis, p. 296.) The equipment includes windmill, gasoline engine, tank, and watering troughs.

Lomitas Springs.—The springs at the Lómitas ranch are situated near the south margin of secs. 3 and 4, T. 14 S., R. 9 E., along the road between Tularosa and the south point of the malpais. (Pls. I and II.) The water, which is used for range stock and also to irrigate a small field, is very hard but can be used for drinking and culinary purposes. (See analysis, p. 300.)

Lower Coyote Spring.—See Coyote Springs (p. 252).

Lower Willow Spring.—See Willow Springs (p. 265).

Lucero ranches.—The North Lucero ranch, situated about one-half mile west of the alkali flat, near the north margin of sec. 5, T. 19 S., R. 5 E. (Pls. I and II), has two dug wells about 65 feet deep, which yield water that is too salty for human use and that should be given to horses with caution. (See analysis, p. 296.)

The South Lucero ranch, situated 4 miles farther south-southeast, and about 2 miles southwest of the south end of the large alkali flat (Pls. I and II), has a drilled well, about 190 feet deep, that yields water of good quality. (See analysis, p. 296.)

Lumbley's ranches.—See Black Lake (p. 250) and Lomitas Springs, above.

McDonald's ranch (Thomas McDonald).—The ranch of Thomas McDonald is in Mockingbird Gap, along the main road between Oscuro and Murray, about 3½ miles from Murray (Pl. I). The water supply is obtained from two dug wells that are about 50 feet deep and have a water level 21 feet below the surface. The supply is reported to be abundant and permanent. The equipment includes windmills, horsepower, reservoir, and watering trough. The water is of fairly satisfactory quality. (See also Jackson ranches and Gililland's ranch.)

McDonald's tank.—A large earth reservoir owned by Thomas McDonald is located on the south side of the main road from Oscuro to Murray, 4⅓ miles from McDonald's ranch and the same distance from the point where the Murray road is joined by the road from Estey (Pl. I). This reservoir is situated in a draw that leads farther northwest between the Oscuro and Little Burro mountains. Like all reservoirs supplied with flood waters, it is likely to be empty in dry seasons. The water is satisfactory for stock use but should, so far as possible, be avoided for culinary use and should always be boiled before it is used by man for drinking.

McNew's ranches.—Two ranches owned by W. H. McNew are situated on the road leading from Alamogordo to Las Cruces and El Paso. The first of these ranches reached in going southwest of the Point of Sands is in or near the SW. ¼ sec. 5, T. 19 S., R. 7 E., about 1½ miles from the edge of the white sands; the second is

2½ miles farther west-southwest and a little nearer the white sands. (See Pls. I and II.)

The first ranch has a dug well which is about 60 feet deep, has a water level 36 feet below the surface, and yields a supply that is highly mineralized but is used for watering live stock. (See analysis, p. 296.)

The second ranch has two wells and two windmills. The dug well is about 70 feet deep, has a water level 47 feet below the surface, and is said to yield mineralized water. The drilled well is reported to be about 250 feet deep and yields water that is highly mineralized but is used for drinking. (See analysis, p. 296.)

Malpais Spring.—At the edge of the younger lava bed, less than 2 miles northwest of its south point, near the west margin of sec. 9, T. 12 S., R. 7 E., on one of the main roads that connects the east and west sides of Tularosa Basin (Pls. I and II) is Malpais Spring. The water, which issues directly from a crevice in the lava at the rate of several second-feet, is salty and otherwise highly mineralized (see analysis, p. 300) and is unfit for human use, except in necessity, and should be given to horses with caution. The poor quality of both water and grass make this vicinity undesirable as a camping place.

Mayes's ranch.—The old Andy Mayes ranch, on the west side of the malpais, is now owned by Fred Roberts. (See Robert's ranch, p. 262.)

Milagro Spring.—In the NW. ¼ sec. 32, T. 9 S., R. 9 E., about 1½ miles east-northeast of Oscuro, in a ravine that cuts through the southern part of Milagro Hill (Pls. I and VI), is a Bar W watering place called Milagro Spring. The water is of satisfactory quality (see analysis, p. 300) and issues perennially in generous quantity. The vicinity of this spring has long been used as a camping place.

Mills ranch.—The ranch of A. C. Mills is in sec. 13, T. 9 S., R. 6 E., near an arroyo in the foothills east of Oscuro, approximately 4 miles south of Estey and 2 miles north (by air line) of the main road to Murray (Pls. I and VI). It is on a road that connects Estey with the Murray Road, and it can also be reached by a branch from the road that runs from the lower crossing to Estey. The water supply is obtained from a drilled well 30 feet deep that has a water level 17 feet below the surface and is reported to have a tested yield of about 13 gallons per minute. The water is hard but otherwise of satisfactory quality. (See analysis, p. 276.)

Moor Spring.—See Ritch's ranches (p. 261) and Plate I (in pocket).

Mound Springs.—A group of small springs issue from conspicuous mounds in sec. 23, T. 10 S., R. 6 E., and adjacent sections. (See Pls. I and VI, fig. 9, and p. 52.) Several of these springs have been developed as range watering places and furnish a highly mineralized water (see analysis, p. 300) that can with caution be given to horses and can in necessity be used for drinking. These springs form an old and well-known landmark and were once an important camping place.

Murray.—At the north end of the San Andreas Mountains, a short distance south of the northeast corner of the unsurveyed T. 9 S., R. 4 E., is Murray, a post office and small mining camp, which is important as a halfway point on the road between Oscuro and the Rio Grande. The water supply is obtained from the drilled well of J. P. Murray, said to be about 165 feet deep. The water is reported to be of fairly good quality and to be yielded freely.

Nogal Spring.—See Walnut (p. 264).

Orogrande.—The supply at Orogrande is obtained through a pipe line from the Sacramento River (pp. 227, 228). The water is of good quality. (See analysis, p. 302.)

Parker Lake.—A shallow natural depression in the gypseous plain 5 miles south of Bennett's ranch, near the foot of the débris slope adjacent to the San Andreas Range (Pl. I) is Parker Lake, which has had some importance as a watering place, but like other lakes of the region is frequently empty in dry seasons.

Pelman well.—See McNew's ranches (p. 258).

Phillips Spring is a reliable watering place on or near the SW. ¼ sec. 34, T. 9 S., R. 8 E., along the road leading from Oscuro to the lower crossing of the malpais. (Pls. I and VI.) It yields water of satisfactory quality (see analysis, p. 300), at the rate of about 3 gallons a minute.

Phillips well.—The well of E. E. Phillips is about 9 miles west of the younger crater, 2 miles west of the west margin of the older lava bed, and between 3 and 4 miles south-southwest of the Cerros Prietos, or old craters. (See Pl. I.) It is at the foot of a low westward-facing cliff in a draw that leads southwestward. This well is 732 feet deep and is said to have a water level about 680 feet below the surface. The water is hard but otherwise fairly satisfactory. (See analysis, p. 268.) At the time the locality was visited no pump had been installed, and the well could not be depended on for a water supply.

Point of Sands.—At the southeast margin of the white sands, near the southwest corner of sec. 14, T. 18 S., R. 7 E., on the main road from Alamogordo (Pls. I and II), is a shallow dug well, with a windmill, two steel tanks, and a watering trough owned by W. H. McNew, and extensively used by travelers. The water, which stands only 8 feet below the surface, is highly charged with sulphates (see analysis, p. 294), but is satisfactory for watering horses and can with caution be used for drinking and cooking.

Pramberg's well.—The well and windmill of John Pramberg are situated near the center of sec. 2, T. 7 S., R. 10 E., along the road between Carrizozo and the north end of the younger lava bed. (See

Pls. I and VI.) This well, which was only recently sunk and is not extensively used by travelers, is partly dug and partly drilled, its total depth being 128 feet. It yields a small supply of soft, sulphate water that is fairly satisfactory for drinking. (See analysis, p. 270.)

Purday's ranch.—The house and well of H. W. Purday are situated in an arroyo near the northwest corner of the NE. ¼ sec. 28, T. 14 S., R. 9 E., on the main road leading from Tularosa to Sulphur Canyon. (See Pls. I and II.) The well is dug about 35 feet deep, the water standing about 29 feet below the surface. It is pumped by windmill and small gasoline engine and furnshes a supply of hard but otherwise satisfactory water. (See analysis, p. 282.) This is an important watering place, as it is practically the last point along the road before reaching Stone's ranch that satisfactory drinking water can be obtained.

Red Canyon ranch.—See Schole's ranch and well (p. 262).

Red Lake.—One of the Bar W watering places, called Red Lake, is in or near the S. ½ sec. 22, in the unsurveyed T. 5 S., R. 10 E., about 3 miles north and 3 miles west of Coyote station. It is on the road leading from Carrizozo to Gran Quivira, and also on the road between Ancho and the north end of the younger lava bed. (Pl. I.) It occupies a natural depression in an open draw that heads farther northeast and supplies it with flood waters in the rainy season. The water is excellent for live stock but should be boiled before it is used for drinking by man. This depression is of such extent that it frequently holds water from one rainy season to another, but in dry years it is likely to be empty in the spring. It is an important watering place, especially for persons going to Estancia Valley by way of Gran Quivira.

Ritch's ranches.—The home ranch of W. L. Ritch is in the NW. ¼ sec. 19, T. 15 S., R. 5 E., a distance of 1½ miles west of the alkali flat and 4 miles south of the main road between Tularosa and Sulphur Canyon (Pls. I and II). At this ranch there is a dug well that is about 75 feet deep, has a water level 53 feet below the surface, and an abundant supply of water. The water is salty (see analysis, p. 282) but is used for watering live stock. It should not be used by man except in necessity.

Another dug well belonging to Mr. Ritch is situated 4 miles north of the home ranch, in the SE. ¼ sec. 31, T. 14 S., R. 5 E., along the main Sulphur Canyon road (Pls. I and II), but in 1911 this well was out of repair and afforded no supply. The water level is here 34 feet below the surface, and the water is reported to be unfit for human use, though it is used for watering horses.

Mention should also be made of Hembrillo Spring, which is situated in the N. ½ sec. 12, T. 16 S., R. 3 E., southwest of Ritch's ranch and near the edge of the mountains, and the spring at the Moor ranch, now owned by Mr. Ritch, which is situated at the edge of the mountains on sec. 2, T. 15 S., R. 4 E. (See Pl. I.)

Ritch's tank.—An earth reservoir called Ritch's tank lies on the road between Tularosa and Sulphur Canyon, west of the white sands and near the west margin of the alkali flats, in the SW. ¼ sec. 33, T. 14 S., R. 5 E. (Pls. I and II). As its supply is derived from flood waters it is likely to fail in dry seasons. The water is softer than the well water of the region but should be boiled before it is used for drinking.

Roberts ranch.—The ranch of Fred. Roberts is situated less than a mile from the west margin of the lava, midway between the lower crossing and Mound Springs (Pls. I and VI). The well at this ranch is 72 feet deep and yields water that can be given to horses but is undesirable for drinking or cooking. (See analysis, p. 278.) Softer water can generally be obtained from a rain-water cistern.

Salt Creek.—A small stream of clear, cool water that looks very attractive to a thirsty wayfarer flows through T. 11 S., R. 6 E., and T. 12 S., R. 6 E. (Pls. I and II). It is, however, so heavily impregnated with salt that it is unfit for use by man or beast (see analysis, p. 302), although it may have commercial value on account of its large content of sodium chloride.

San Agustin ranch.—See Cox ranch and wells (p. 252).

San Nicolás Spring.—In a canyon at the east edge of the San Andreas Mountains, in the SW. ¼ sec. 4, T. 20 S., R. 5 E. (Pl. I), is a watering place that was reached from the old salt road by the Mexicans long ago (Pl. V, p. 16), but is not now near any well-traveled route.

Schole's ranch and well.—The ranch of Fred. Schole, known as the Red Canyon ranch, is reported to be approximately 12 miles north of Estey, on the old mail route that at one time passed over the upper crossing and through the Red Canyon. It is still a convenient watering place for any one taking the Red Canyon route. The water is reported to stand 15 feet below the surface in red beds, and to be led to the surface at a lower level.

Another of Mr. Schole's wells that is a convenient watering place is situated on the road leading from the north end of the malpais to Ozanne Spring, about 10 miles from the spring.

Serano tank.—About midway between Duck Lake and the Cerros Prietos (old craters), on the road between Duck Lake and Chupadera Spring (Pl. I), is Serano tank. It is on the old lava bed and occupies a natural cleft in the rock similar to Indian tank, but it is smaller, less well constructed, and probably empty during longer periods.

7 X 7 ranch.—The old 7 X 7 ranch, now belonging to the Bar W ranching establishment, is situated a short distance from the west margin of the lava, nearly midway between the upper and lower crossings, in the SE. ¼ sec. 5, T. 9 S., R. 8 E. (Pls. I and VI). It is on the road from the upper crossing to Mockingbird Gap and also on the road from the lower crossing to Red Canyon and Ozanne. The water supply at this ranch is obtained from a 6-inch drilled well that is reported to be 252 feet deep, to have a head 180 feet below the surface, and to have been tested at 65 gallons a minute. The water is stored in a large surface reservoir, from which it is delivered to watering troughs. It is used for live stock but is too highly mineralized to be satisfactory for human use. (See analysis, p. 276.) A supply of better water is usually kept at the ranch for domestic use.

Shoemaker's flowing wells.—The two flowing wells of D. W. Shoemaker are situated near the southwest corner of the NW. ¼ sec. 1, T. 15 S., R. 8 E., in an arroyo leading into the white sands (Pls. I and II). They are, respectively, about one-half inch and 2 inches in diameter and are reported to be about 40 feet deep. The larger well yields slightly less than 3 gallons a minute by natural flow from a pipe discharging 9 feet above the surface. The water is rather highly mineralized, but satisfactory for drinking and for culinary use. (See analysis, p. 284.) Several other watering places will be found in this locality.

Soledad Spring.—See Globe Spring ranch (p. 254).

Steam-pump ranch.—The ranch of W. W. Cox, known as the Steam-pump ranch, is situated in a conspicuous position on the high bench between the San Andreas and Organ ranges. It is between the two roads that lead from Bennett's ranch to Organ and is easily reached from either of these roads (Pl. I). At this ranch there is a well which is reported to be dug to a depth of about 40 feet and drilled from the 40-foot level to a depth of about 200 feet. It is pumped by both windmill and gasoline engine and yields an adequate supply of water of satisfactory quality. There is also a water supply at a mine a short distance west of this ranch.

Stone's ranch.—An important watering place for travelers is Stone's ranch, situated on the Sulphur Canyon road on or near sec. 2 of the fractional T. 15 S., R. 3 E. The supply comes from a permanent mountain spring and is reported to be good water.

Thompson ranch.—The Thompson ranch, which now belongs to W. W. Cox, but is practically abandoned, is situated on the west side of a small mountain in the reentrant between the San Andreas and Organ ranges, and only 2½ miles from San Agustin Peak. It is on the north road from Bennett's ranch to Organ, less than 2 miles from the junction with the south road (Pl. I). At this place there is a dug well, 6 feet square and cased with lumber, in which the water stands about 17 feet below the surface. The pump and windmill are out of repair, but water for horses can be drawn with a bucket.

Three Rivers.—There are no wells at the railroad station of Three Rivers (Pls. I and II), but culinary supplies are obtained from the railroad cistern that is filled with Bonita pipe-line water shipped thither on tank cars, and live-stock supplies are obtained from Three Rivers water that is led to the station in a ditch. In the valley of Three Rivers, from a short distance above the station to the head waters of the main branch and Indian Creek there are numerous springs and shallow wells at which good water can be obtained. Water of satisfactory quality will also be found at several wells, springs, and gravity ditches along the road between Three Rivers and the I Bar X ranch.

Thurgood's ranch.—The ranch of E. E. Thurgood is situated about 1 mile south of the Lava Gap road, and only a short distance east of the summit of the gap. On account of its distance from the main road it is not generally used by travelers as a watering place. The water supply is obtained from two wells, one a dug well 50 feet deep reported to yield about 5 gallons a minute, and the other a drilled well 199 feet deep reported to yield 13 gallons a minute. The water is considered fairly good.

Upper Coyote Spring.—See Coyote Springs (p. 252).

Upper Willow Spring.—See Willow Springs (p. 265).

Walnut.—This is a station on the branch railroad leading east from Carrizozo. (See Pls. I and VI.) Water comes to the surface at several points in Nogal Arroyo near this station, and there are several ranches in the vicinity which have shallow wells that yield satisfactory water. (See analyses of water from wells on the Vega ranches, pp. 274, 276.)

Warden's ranch.—The water supply at Warden's ranch, which is in the SE. ¼ sec. 17, T. 4 S., R. 11 E., about 4 miles west-northwest of Ancho (Pl. I), is derived from two drilled wells, one 232 feet and the other 196 feet deep, both pumped by windmills. Their yield is ample for stock, and the water, except for its hardness, is fairly satisfactory for domestic use. An analysis of the water from the upper well is given on page 268. A pipe line nearly 5 miles long extends northwestward from the ranch. (See Pl. I.)

Whiteoaks.—The village of Whiteoaks is on the east side of Baxter Mountain, near the south end of the fractional T. 6 S., R. 12 E., and midway between Carrizozo and Jicarilla (Pls. I and VI). At this place there are several dug and bored wells which yield highly mineralized water. Domestic supplies are obtained chiefly from rain-water cisterns.

Whitewater Spring.—This spring, situated in the white sands near the Point of Sands well, is no longer used by travelers.

Wilde well.—See Fleck's ranches (p. 253).

Willow Springs.—Lower Willow Spring, which is a Bar W ranch watering place, is situated in the NW. ¼ sec. 29, T. 8 S., R. 9 E., leading to the upper crossing of the malpais, and about half a mile from it (Pls. I and VI). The water, which issues from the base of a low bank or cliff and flows through a pipe to a watering trough at a rate of perhaps 2 gallons a minute, is of fairly satisfactory quality for drinking and domestic use. (See analyses, p. 300.) A smaller spring of the same type occurs nearly one-quarter mile north-northeast of the main spring.

From Lower Willow Spring a pipe line leads across the lava to a cement reservoir that supplies a watering trough about a mile below the west end of the upper crossing. (See Pl. VI.) It is in use only in certain seasons.

Upper Willow Spring is situated near the south margin of sec. 35, T. 8 S., R. 10 E., on the east side of Willow Hill and about 10 miles from the lower spring.

ANALYSES.

METHODS OF ANALYSIS.

By R. F. Hare.

The water analyses were made in the following manner: The total solids were determined by evaporating measured amounts of water to dryness and drying the residue for one hour at 110° C. and the precipitate of calcium was titrated with a standard solution of potassium permanganate. Magnesium was precipitated with sodium phosphate and weighed as the pyrophosphate. The content of sodium and potassium was not determined directly, but was calculated from the amount of the acid radicles greater than that necessary to combine with calcium and magnesium. Carbonates were determined by titration with N/20 potassium bisulphate; this procedure gives both the carbonate and bicarbonate radicles, but they are both reported in the tables as carbonates (CO_3). The sulphates were precipitated with barium chloride and weighed as barium sulphate. Chlorine was determined volumetrically with N/30 silver nitrate. Nitrogen as nitrates, wherever estimated, was determined by the Kjeldahl method modified to include nitrates.

In examining the soil samples 50 grams of the air-dried soil was added to 500 cubic centimeters of distilled water, the mixture was thoroughly agitated, allowed to stand over night, and filtered. Portions of this filtrate were analyzed in the same manner as the water samples.

The calcium, magnesium, sodium, chlorides, sulphates, and carbonates that constitute the soluble solids of the waters and soils are in combination to form salts. The last three, being acid constituents, are combined with the first three, which are basic constituents. The chemist must, however, content himself with determining the amounts of these constituents, as no methods are known by which he can separate all the salts from one another as they occur in the solids. To judge the effect of these constituents on the soil used for agriculture, or on the waters for some uses, it is important to know as nearly as possible what salts are formed in their combinations. If the carbonates combine with calcium, for example, a salt is formed that is harmless for agriculture but constitutes temporary hardness in waters for domestic use. If, on the other hand, they are combined with sodium, they form a salt which constitutes "black alkali," but which in small amounts is desirable or unobjectionable in waters for domestic use.

With a knowledge of the properties of the salts that are possible from the constituents found and of the known laws of chemical affinity, it is possible to judge fairly well the proper grouping of these radicles in the formation of salts. The simplest possible combination is one in which only three salts are formed. Theoretically nine salts are possible in a mixture containing the three acids and three bases. These are calcium carbonate, calcium sulphate, calcium chloride, magnesium carbonate, magnesium sulphate, magnesium chloride, sodium carbonate, sodium sulphate, and sodium chloride. Moreover, the three carbonates may and often do change to bicarbonates in the presence of carbonic acid and are usually present as such in solutions. It is not possible, however, for all of these salts to remain in the same solution, as double decomposition or other condition would result in the formation of insoluble salts, and all but small amounts at least of some of these salts would thus be removed from the solution. Calcium chloride and sulphate and in part magnesium sulphate and chloride would be removed, for example, if the carbonate or bicarbonate of sodium were present. Calcium carbonate is likewise deposited as carbonic acid gas escapes from the water solution.

The following conventional method of expressing combinations of the radicles is adopted in this paper, and an examination of the character of the crystalline residue formed, as well as other properties of the salts resulting from the evaporation of the solution, seems to show that the combinations are a close approximation to the actual condition.

The amount of combined carbonic acid that gave an alkaline reaction with phenolphthalein when the water was titrated with N/20 potassium bisulphate was calculated to sodium carbonate (Na_2CO_3).

That amount of combined carbonic acid that gave an alkaline reaction with methyl orange was combined with the calcium as calcium carbonate ($CaCO_3$), any excess of carbonic acid going first to magnesium as magnesium carbonate ($MgCO_3$), then to sodium as sodium carbonate (Na_2CO_3). Any calcium or magnesium in excess of that combined as carbonates was calculated as calcium and magnesium sulphates ($CaSO_4$ and $MgSO_4$). All remaining sulphuric acid was calculated as sodium sulphate (Na_2SO_4). Any excess of calcium or magnesium over that combined with carbonic and sulphuric acids was combined as the chlorides ($CaCl_2$ and $MgCl_2$). The remainder of the chloride radicle was calculated as sodium chloride ($NaCl$). Sodium was calculated from its combination with the carbonate, sulphate, and chloride radicles. Occasional traces of nitrate, when determined, were calculated as sodium nitrate ($NaNO_3$). In a few analyses it was desirable to deviate slightly from this scheme of combination, the magnesium not being combined as magnesium sulphate until that part thought to be combined as magnesium chloride had been subtracted. When magnesium chloride is heated at a dull-red heat for ten minutes it loses its chlorine, but sodium and calcium chlorides do not. The amount of chlorine lost by heating the residue from the evaporation of certain samples in this manner was calculated as magnesium chloride. Potassium, when determined in these samples, was combined with the sulphate radicle.

The carbonates of calcium and magnesium represent the "temporary hardness" of the waters. The sulphates and chlorides of these two bases represent "permanent hardness." The total computed amounts of the chlorides and sulphates of magnesium and sodium and the chloride of calcium are included under "white alkali." In both the soils and the waters sodium chloride and magnesium sulphate are the most common and most abundant forms of white alkali. The carbonates and bicarbonates of sodium together constitute the "black alkali."

TABLES.

TABLE 1.—*Wells and analyses of well waters in Tularosa Basin, N. Mex.*

No.	Location.				Owner or name.	Type.	Depth.	Geologic source of water.	Water level.				Method of lift.	Tested capacity per minute.	Use of water.
	Township south.[a]	Range east.	Section.	Quarter.					Depth below surface.	Depth below bench mark.[b]	Altitude above sea level.	Date.			
							Feet.		*Feet.*	*Feet.*	*Feet.*			*Gallons.*	
1	1 N.	8	c 31	....	Gran Quivira......	Dug; cased with logs.	80	Waste overlying Carboniferous.	73	73.8	c 6,325	Oct., 1911	Bucket......	Small.	Domestic.
2	1 N.	8	c 31	....	.....do..........	.....do..........	24	.....do........	23	26.0	c 6,365	...do......	None........	Small.	Not used.
201	2 S.	12	11	SE....	Gallinas railroad well.	10-inch; uncased.	414	Carboniferous.	360	....	6,275	Aug., 1903	Steam; deep-well pump.	70	Do.
401	4	11	17	SE....	Warden Bros......	6-inch; uncased..	232	.....do........	c 215	....	c 5,800	....	Windmill...	d 40	Domestic and stock.
402	4	11	17	SE....	.....do..........	.....do..........	196	.....do........	c 135	....	c 5,855	....	.....do......	d 25	Do.
403	4	11	28	SE....	James Cooper e....	Drilled..........	....	.....do........	....	....	....	....	.....do......	....	Do.
404	4	11	28	SE....	.....do..........	.....do..........	....	.....do........	....	....	....	....	.....do......	....	Do.
405	4	12	c 29	....	Deep Ancho railroad well.	Drilled and cased	855	.....do........	210	....	c 5,990	Jan., 1907	Steam; deep-well pump.	....	Cement factory.
406	4	12	29	....	Ancho railroad well No. 4.	.....do..........	238	.....do........	114(?)	....	c 6,086	Nov., 1903	.....do......	40	Do.
407	4	12	29	....	Ancho railroad well No. 5.	.....do..........	215	.....do........	128(?)	....	c 6,072	Dec., 1903	.....do......	20	Do.
501	5	11	4	SE....	Horace French....	6-inch; cased....	150	Waste overlying Carboniferous (?).	....	....	....	....	Windmill...	d 8	Domestic and stock.
502	5	11	7	NW...	J. B. French......	.....do..........	166	Carboniferous (?).	c 154	....	c 5,600	....	.....do......	d 22	Do.
503	5	13	c 16	....	Jicarilla well	Drilled..........	402	Igneous rock..	....	....	c 7,400(?)	....	Steam; deep-well pump.	d 150	Domestic.
601	6	8	c 21	....	E. E. Phillips.....	6–4½-inch; cased.	732	Carboniferous.	680	....	c 5,100	....	None........	d 6	
602	6	9	c 2	SE....	J. B. French......	Dug, drilled, and tunneled.	102	Carboniferous or Cretaceous.	57	....	c 5,440	Oct., 1911	Windmill...	d 6	Domestic and stock.
603	6	9	c 25	NE...	Salt well..........	Drilled..........	235	Carboniferous.	50	....	c 5,350	....	None........	....	Not used.

a All wells are south of the base line except those at Gran Quivira (Nos. 1 and 2).
b The bench mark is generally at the well platform or curb. In most wells it is indicated by three notches cut into the wood.
c Approximate.
d Reported by owner.
e Well nearest the house.

No.	Substances dissolved in water (quantities expressed in parts per million).																Temperature of water.
	Total solids.	Radicles.						Undetermined, including water of crystallization.	Hypothetical combinations.								
		Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate (CO_3).[a]	Sulphate (SO_4).	Chloride (Cl).		Calcium carbonate ($CaCO_3$).[a]	Calcium sulphate ($CaSO_4$).	Magnesium carbonate ($MgCO_3$).[a]	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Sodium carbonate (Na_2CO_3).[a b c]	Sodium sulphate (Na_2SO_4).[b]	Sodium chloride (NaCl).[b]	Total white alkali.[c]
																	°F.
1	392	78	22	27	117	112	22	14	196	None.	None.	110	None.	None.	38	37	185	....
201	1,684	357	74	46	85	1,059	36	....	141	1,022	None.	366	None.	None.	68	60	494	....
401	3,647	514	159	240	119	1,992	133	490	199	1,477	None.	789	None.	None.	471	219	1,479	....
403	4,290	569	200	223	104	1,992	343	859	174	1,697	None.	994	None.	None.	None.	567	1,561	....
405	599	66	34	83	140	179	45	....	165	None.	58	84	None.	None.	165	75	324	....
406, 407	559	73	23	80	105	159	79	....	175	9	None.	115	None.	None.	90	130	335	....
501	2,051	251	116	225	164	1,038	172	85	273	483	None.	577	None.	None.	349	283	1,209	....
502	3,085	319	162	346	149	1,532	266	311	248	747	None.	809	None.	None.	531	439	1,779	62
503	541	99	23	14	98	171	22	114	163	112	None.	115	None.	None.	None.	37	152	....
601	1,911	361	76	83	149	1,028	55	159	248	889	None.	378	None.	None.	146	91	615	....
602	1,564	241	98	72	89	823	111	130	149	615	None.	486	None.	None.	None.	183	669	57

[a] Bicarbonates are reported as CO_3.
[b] Potassium is included with the sodium.
[c] White alkali includes the sulphates and chlorides of magnesium and sodium. Black alkali includes the carbonate and bicarbonate of sodium.

TABLE 1.—*Wells and analyses of well waters in Tularosa Basin, N. Mex.*—Continued.

No.	Location: Township south.	Location: Range east.	Location: Section.	Location: Quarter.	Owner or name.	Type.	Depth.	Geologic source of water.	Water level: Depth below surface.	Water level: Depth below bench mark.	Water level: Altitude above sea level.	Water level: Date.	Method of lift.	Tested capacity per minute.	Use of water.
							Feet.		*Feet.*	*Feet.*	*Feet.*			*Gallons.*	
701	7	10	2		John Pramberg	Dug and drilled.	128	Cretaceous (?).					Windmill	Small.	Domestic and stock.
702	7	10	25	NW		Dug		Waste overlying Cretaceous.	35		a 5,390	Oct., 1911			Not used.
703	7	10	25	SE	Samuel Potts	do	70	do	62		a 5,380		Windmill	Adequate.	Domestic and stock.
704	7	10	28	NE	Mrs. L. A. McCall	do	29	do	28	28.1	a 5,210	Nov., 1911	do	Adequate.	Domestic.
705	7	10	29	SE	M. B. Foreman	do	35	do	34	36.0	a 5,165	do	do	Adequate.	Do.
706	7	10	32	S		do	(b)	do	15	15.5	a 5,180	do	do		Stock.
707	7	10	34	SW	Peter Johnson	Dug and drilled.	60	do	27	27.0	a 5,320	do	do	Adequate.	Do.
708	7	10	35	SW		Dug	(b)	do	18	20.9	a 5,370	Oct., 1911	Bucket		Do.
709	7	11	21	NE		do	(b)	Cretaceous or igneous.	82			do	None		Not used.
710	7	11	a 27	SW		do	(b)	Waste overlying Cretaceous.	70	73.0	a 5,575	do	do		Do.
711	7	11	a 28	NW		do	(b)	do.(?)	53	55.5	a 5,545	do	Windmill		Domestic and stock.
712	7	11	29	S		do	(b)	do	12	12.5	a 5,520	do	do		Domestic and irrigation.
713	7	11	29	SW		do		do	34	35.2	a 5,453	do	do		Domestic.
714	7	11	30	SE		do		do	88	89.5	a 5,400	do	do		Do.
715	7	11	32	NW		do		do	17	17.5	a 5,519	do	do		Do.
716	7	11	a 34	SE		do	(b)	Cretaceous	100		a 5,625	do	None		Not used.
801	8	9	19	NE	James Lee	Dug and drilled; 6-inch.	152	Carboniferous.	90		a 4,800	Nov., 1911	Windmill	5	Domestic and stock.
802	8	9	22	NW		Dug and drilled.		Cretaceous	22		a 4,980	do	None		Not used.
803	8	9	25	NE	M. W. Beagle	Drilled	115	Waste overlying Cretaceous.	105		a 5,075		Windmill	Small.	Domestic and stock.
804	8	9	29	SE		Dug	(b)	Cretaceous	29	32.8	a 4,990	Nov., 1911			
805	8	10	2	NE	A. C. Wingfield	Dug and drilled.	(b)	do	33	35.9	5,394	Oct., 1911	Bucket		

a Approximate.

b Sunk short distance below the water level.

No.	Substances dissolved in water (quantities expressed in parts per million).																	Temperature of water.
	Total solids.	Radicles.						Undetermined, including water of crystallization.	Hypothetical combinations.									
		Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate (CO_3).	Sulphate (SO_4).	Chloride (Cl).		Calcium carbonate ($CaCO_3$).	Calcium sulphate ($CaSO_4$).	Magnesium carbonate ($MgCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Sodium carbonate (Na_2CO_3).	Sodium sulphate (Na_2SO_4).	Sodium chloride (NaCl).	Total white alkali.[a]	
																		°F.
701	1,690	35	23	503	193	815	100	21	88	None.	82	None.	None.	123	1,205	165	1,370	....
703	1,526	262	53	101	78	715	155	162	130	714	None.	264	None.	None.	None.	256	520	....
704	2,101	295	69	196	75	894	277	295	125	834	None.	341	None.	None.	48	457	846	....
707	4,409	558	233	562	89	1,308	1,462	197	149	1,693	None.	140	802	None.	None.	1,426	2,368	....
711	1,118	104	24	174	74	225	266	251	124	184	None.	119	None.	None.	None.	439	558	....
801	2,640	377	96	193	61	1,261	244	408	103	1,142	None.	478	None.	None.	107	402	987	....
805	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	59.5

[a] White alkali includes the sulphates and chlorides of magnesium and sodium. Black alkali includes the carbonate and bicarbonate of sodium.

TABLE 1.—*Wells and analyses of well waters in Tularosa Basin, N. Mex.*—Continued.

No.	Location.				Owner or name.	Type.	Depth.	Geologic source of water.	Water level.				Method of lift.	Tested capacity per minute.	Use of water.
	Township south.	Range east.	Section.	Quarter.					Depth below surface.	Depth below bench mark.	Altitude above sea level.	Date.			
							Feet.		*Feet.*	*Feet.*	*Feet.*			*Gallons.*	
806	8	10	2	NW	Clarence Spence	Dug	30	Waste overlying Cretaceous.	30		a 5,380		Windmill	Small.	Stock.
807	8	10	2	NW	Humphrey Bros.	do	(b)	do	17		a 5,400		Bucket		Do.
808	8	10	2	NW	J. M. Cummins	do	(b)	do	17		a 5,400		do		
809	8	10	2	NW	John Beard	do	(b)	do	17		a 5,390		Pump		
810	8	10	2	NW	Dr. Pine	do	(b)	do			a 5,390		Bucket		
811	8	10	2	SW	Well at railroad crossing.	do	(b)	do	24	26.0	5,498	Oct., 1911	None		Not used.
812	8	10	2		Carrizozo railroad well No. 1.	Drilled and partly cased.	895	Cretaceous	90		3,350	Dec., 1901	Steam; deep-well pump.	50	Do.
813	8	10	2		Carrizozo railroad well No. 2.	do	161	do	35		5,405	Apr., 1903	do	35	Do.
814	8	10	2		Carrizozo railroad well No. 4.	do	1,125	Cretaceous and Carboniferous (?).	193		5,247	Oct., 1906	Steam; air lift.	50	Do.
815	8	10	3	NW	(c)	do	(d)	Waste overlying Cretaceous.	29	30.9	a 5,350	Nov., 1911	None		Do.
816	8	10	3	NW	(e)	do	(d)	do	38	41.4	a 5,350	do	do		Do.
817	8	10	6	SE.	W. H. Harris	do	(d)	Cretaceous	14		a 5,200	do	Bucket		Domestic.
818	8	10	9	NW	Harry Chant	do	36	Waste overlying Cretaceous.	a 32		a 5,330	do	Windmill	Adequate.	Irrigation.
819	8	10	10	NW	H. L. Humphrey	do	(d)	do	31	34.4	a 5,370	do	Bucket		Domestic.
820	8	10	10	SE.		do	(d)	do	24	25.3	a 5,445	Oct., 1911	do		
821	8	10	11	NW	(f)	do	(d)	do	40	43.0	5,425	Nov., 1911	do		
822	8	10	11	NW	Northwest corner	do	(d)	do	30	30.8	5,414	do			
823	8	10	11	NW	Paul Bentley	do	29	do	29		a 5,435	Oct., 1911	Bucket	2	Do.

a Approximate.
b Shallow.
c North half of quarter.
d Sunk short distance below the water level.
e South half of quarter.
f One-fourth mile east of northwest corner.

No.	Substances dissolved in water (quantities expressed in parts per million).																	Temperature of water.
	Total solids.	Radicles.						Undetermined, including water of crystallization.	Hypothetical combinations.									
		Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate (CO_3).	Sulphate (SO_4).	Chloride (Cl).		Calcium carbonate ($CaCO_3$).	Calcium sulphate ($CaSO_4$).	Magnesium carbonate ($MgCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Sodium carbonate (Na_2CO_3).	Sodium sulphate (Na_2SO_4).	Sodium chloride (NaCl).	Total white alkali.[a]	° *F.*
806	5,540	678	220	454	75	1,827	1,108	1,178	125	2,135	None.	395	554	None.	None.	1,151	2,100	....
807	4,441	661	218	406	54	1,499	1,263	340	90	2,125	None.	None.	854	None.	None.	1,032	1,886	....
808	6,112	689	295	776	81	2,300	1,483	488	135	2,156	None.	974	388	None.	None.	1,969	3,331	....
809	6,935	918	368	669	75	2,174	2,039	692	125	2,950	None.	116	1,353	None.	None.	1,700	3,169	....
810	3,171	448	166	318	54	1,302	741	142	90	1,400	None.	393	338	None.	None.	808	1,539	....
812	2,110	16	10	783	496	302	450	....	39	None.	35	None.	None.	793	447	743	1,190	....
813	1,341	237	54	93	51	735	182	....	85	691	None.	246	53	None.	None.	236	535	....
814	790	153	38	39	151	255	77	....	251	180	None.	159	23	None.	None.	99	281	....
816	1,448	252	52	108	71	684	166	115	118	695	None.	259	None.	None.	None.	274	533	59
817	3,320	273	183	488	117	1,333	649	277	195	664	None.	910	None.	None.	203	1,070	2,183	....
818	1,078	164	49	115	119	396	177	58	199	287	None.	242	None.	None.	None.	293	535	....
819	892	153	41	68	84	397	104	45	140	330	None.	206	None.	None.	None.	172	378	....
823	1,284	219	54	86	75	621	133	96	125	574	None.	270	None.	None.	None.	219	489	....

[a] White alkali includes the sulphates and chlorides of magnesium and sodium. Black alkali includes the carbonate and bicarbonate of sodium.

TABLE 1.—*Wells and analyses of well waters in Tularosa Basin, N. Mex.*—Continued.

No.	Location.				Owner or name.	Type.	Depth.	Geologic source of water.	Water level.				Method of lift.	Tested capacity per minute.	Use of water.
	Township south.	Range east.	Section.	Quarter.					Depth below surface.	Depth below bench mark.	Altitude above sea level.	Date.			
							Feet.		*Feet.*	*Feet.*	*Feet.*			*Gallons.*	
824	8	10	11	SW	C. W. Hyde	Drilled and partly cased.	30	Waste overlying Cretaceous.	25		a 5,455	Oct., 1911	Windmill	Adequate.	Domestic.
825	8	10	12	NW	J. M. Simms	do	70	do	67	70.2	a 5,430	do	do		Do.
826	8	10	13	NW		do	(b)	do	55	58.8	a 5,490	do	Bucket		
827	8	10	14		(c)	do	(b)	do	65	65.0	a 5,495	do	Windmill		
828	8	10	15	NE		do	(b)	do	42	43.6	a 5,470	do	Bucket		
829	8	10	15	NW	W. G. Thornborrow.	do	49	do	47	47.5	a 5,450	Nov., 1911	Windmill		Do.
830	8	10	17	NW	Reavley	do	60	Cretaceous	53						
831	8	10	19	NE	A. F. Roselle	6-inch, uncased	170	do	128		a 5,150	Nov., 1911	None		Not used.
832	8	10	19	SW	D. L. Byron	6-inch, cased	163	Waste overlying Cretaceous.	123		a 5,100	do	Windmill	Adequate.	Domestic.
833	8	10	23	NW	Mrs. M. L. Millican.	Drilled	127	Cretaceous	a 80		a 5,500	Oct., 1911	do	Small.	Do.
834	8	10	30	SW	J. C. Jensen	Dug and drilled.	38	do	32		a 5,160	Nov., 1911	do	Adequate.	Stock.
835	8	11	1	NE	F. J. Bright	Dug	(b)	Waste overlying Cretaceous.	102	103.5	a 5,825	Oct., 1911	do	Adequate.	Domestic and stock.
836	8	11	1	NW	Fred. La Lone	do	106	do	99	101.0	a 5,700	do	do	Adequate.	Do.
837	8	11	3	SW		do	(b)	do	41	41.3	a 5,620	do	do		
838	8	11	8	NW		do	119	Cretaceous	110		a 5,535	do			Domestic.
839	8	11	f 12	NW		do	(b)	Waste overlying Cretaceous.	47	51.9	a 5,740	do			
840	8	11	13	NE	Joseph George	do	52	do	48		a 5,900	do	Windmill	12	Domestic and irrigation.
841	8	11	25	NE		do	(b)	do	77	80.0	a 6,110	do	Bucket		Domestic and stock.
842	8	12	f 1	SE		do	76	do	a 72		a 5,940	do	Windmill	Small.	Do.
843	8	12	13	NE	Antonio Vega	do	45	do	41	42.7	a 5,990	do		Adequate.	Do.
844	8	12	14			do	(b)	do	41	44.6	a 5,960	do	Bucket		Do.
845	8	12	24			do	(b)	do	23		6,043	do	Windmill	Adequate.	Do.
846	8	12	23		(d)	do	(b)	do	47	47.0	a 6,050	do			

a Approximate. b Sunk short distance below the water level. c Center of section. d Near east margin.

No.	Substances dissolved in water (quantities expressed in parts per million).																	Temperature of water.
	Total solids.	Radicles.						Undetermined, including water of crystallization.	Hypothetical combinations.									
		Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate (CO_3).	Sulphate (SO_4).	Chloride (Cl).		Calcium carbonate ($CaCO_3$).	Calcium sulphate ($CaSO_4$).	Magnesium carbonate ($MgCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Sodium carbonate (Na_2CO_3).	Sodium sulphate (Na_2SO_4).	Sodium chloride (NaCl).	Total white alkali.[a]	°F.
829	1,212	191	56	120	72	550	185	38	138	463	None.	279	None.	None.	None.	306	585	.....
831	1,972	197	91	194	134	844	133	379	223	365	None.	454	None.	None.	331	219	1,004	62?
832	2,323	139	84	563	208	1,092	255	None.	347	.....	None.	329	None.	None.	1,226	420	1,976	.....
833	1,214	175	60	77	119	416	155	212	199	323	None.	236	49	None.	None.	195	480	.....
834	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	62?
836	1,329	241	48	131	119	625	166	None.	199	548	None.	238	None.	None.	71	274	583	.....
843	871	295	83	166	119	850	255	103	199	734	None.	415	None.	None.	None.	420	835	.....

a White alkali includes the sulphates and chlorides of magnesium and sodium. Black alkali includes the carbonate and bicarbonate of sodium.

TABLE 1.—*Wells and analyses of well waters in Tularosa Basin, N. Mex.*—Continued.

No.	Location.				Owner or name.	Type.	Depth.	Geologic source of water.	Water level.				Method of lift.	Tested capacity per minute.	Use of water.
	Township south.	Range east.	Section.	Quarter.					Depth below surface.	Depth below bench mark.	Altitude above sea level.	Date.			
							Feet.		*Feet.*	*Feet.*	*Feet.*			*Gallons.*	
847	8	13	*a* 30	SE	Joseph Vega	Dug	(*b*)	Waste overlying Cretaceous.	31			Oct., 1911	Windmill and horsepower.	Adequate.	Domestic and stock.
901	9	5	*a* 16		Thomas McDonald.	2 dug wells	50	Waste overlying Carboniferous.	21	23.0	*a* 5,000	Nov., 1911	Windmill	Adequate.	Do.
902	9	6	13		A. C. Mills	Drilled	30	Carboniferous.	17		*a* 4,850		do	13	Do.
903	9	8	5	SE	7X7 ranch	6-inch	252	Valley fill	*a* 180		*a* 4,500		do	65	Stock.
904	9	8	*a* 35	SE	R. Richardson	Dug	50		*a* 50				Dutch windmill.		Domestic and irrigation.
905	9	8	36	NE	E. G. Raffety	Drilled; cased 70 feet.	200	Cretaceous	99	99.0	4,905	Oct., 1911	None		Not used.
906	9	8													
907	9	9	21	NE	George Castle	7-inch	175	do	*a* 30		*a* 5,270		Gasoline; deep-well pump.	95	Irrigation.
908	9	9	25		I Bar X ranch	Dug	(*b*)	Waste overlying Cretaceous.	*a* 20		*a* 5,600			Adequate.	Domestic.
909	9	9	28	NW	A. Gschwind	7-inch	130	Cretaceous	70		*a* 5,230		Windmill	25	Domestic and irrigation.
910	9	9	31	NW	Oscuro railroad well No. 1.	Drilled	489	do	*c* 128		4,887	Aug., 1903	Steam; deep-well pump.		Locomotives.
911	9	9	31	NW	Oscuro railroad well No. 2.	do	965	do	*c* 100		4,915	Nov., 1906	do		Do.
912	9	9	31	NW	C. Ashford	do	149	do	*a* 105		*a* 4,910		Windmill	Adequate.	Domestic and irrigation.
913	9	9	31	SE	E. F. Jones	8-inch; cased 20 feet.	67	do	35		*a* 5,050		Gasoline; deep-well pump.	25	Irrigation.

a Approximate. *b* Sunk short distance below the water level. *c* Reported by owner.

No.	Substances dissolved in water (quantities expressed in parts per million).																	Temperature of water.
	Total solids.	Radicles.						Undetermined, including water of crystallization.	Hypothetical combinations.									
		Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate (CO_3).	Sulphate (SO_4).	Chloride (Cl).		Calcium carbonate ($CaCO_3$).	Calcium sulphate ($CaSO_4$).	Magnesium carbonate ($MgCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Sodium carbonate (Na_2CO_3).	Sodium sulphate (Na_2SO_4).	Sodium chloride (NaCl).	Total white alkali.[a]	° F.
847	2,067	295	93	178	149	972	177	203	248	666	None.	465	None.	None.	194	293	952	58
902	2,396	235	195	195	163	1,285	151	172	273	428	None.	977	None.	None.	298	249	1,524	66
903	3,341	547	139	245	104	1,771	324	211	174	1,621	None.	694	None.	None.	105	535	1,334	66
905	1,228	87	12	307	193	226	208	195	218	None.	42	None.	None.	None.	335	344	679	....
909	1,159	153	43	121	104	469	115	154	174	284	None.	216	None.	None.	142	190	548	....
910	1,098	2	6	412	321	215	115	....	5	None.	20	None.	None.	538	318	190	508	....
911	1,238	27	11	387	268	417	146	....	68	None.	39	None.	None.	109	619	241	860	....

[a] White alkali includes the sulphates and chlorides of magnesium and sodium. Black alkali includes the carbonate and bicarbonate of sodium.

TABLE 1.—*Wells and analyses of well waters in Tularosa Basin, N. Mex.*—Continued.

No.	Location.				Owner or name.	Type.	Depth.	Geologic source of water.	Water level.				Method of lift.	Tested capacity per minute.	Use of water.
	Township south.	Range east.	Section.	Quarter.					Depth below surface.	Depth below bench mark.	Altitude above sea level.	Date.			
							Feet.		*Feet.*	*Feet.*	*Feet.*			*Gallons.*	
914	9	9	31	SE	E. F. Jones	7-inch	108	Cretaceous	33		[a] 5,050		Windmill	Small.	Domestic and irrigation.
915	9	9	32	SW	Dr. G. Ranniger	Dug	([b])	Waste overlying igneous rock.	18		[a] 5,160		do	Adequate.	Do.
916	9	9	33	SW	Dr. A. McCallum	do	80	Cretaceous	57	58.8	[a] 5,150	Oct., 1911	Bucket	Adequate.	Domestic.
1001	10	7	[a] 10	SE	Fred. Roberts		72	Valley fill	70		[a] 4,370		Windmill	Adequate.	Stock.
1002	10	8	30	SE	A. S. Mayes	Dug and 4-inch cased.		do	69	76.2	[a] 4,400	Oct., 1911	None		Not used.
1003	10	9	4	W		Drilled	325		[a] 60				Windmill	Small.	Domestic.
1004	10	9	5	SE	Robert Young	Drilled and cased.	158	Cretaceous	80 (?)				Gasoline, deep-well pump.	20	Irrigation.
1004	10	9	8	NW	I. Braunstein	3-inch; cased	300	do					Windmill	Adequate.	Domestic and irrigation.
1005	10	9	9	NW	Anthony Borovansky.	Drilled	171	Cretaceous or igneous.	108	108.0	[a] 5,190		Bucket		Domestic.
1006	10	9	[a] 13	NE		Dug	([b])	Waste overlying igneous rock.	13		[a] 6,000	Nov., 1911	do		Do.
1007	10	9	[a] 25	SE		do	([b])	do	13		[a] 5,700	do	do		Do.
1101	11	5			E. E. Thurgood	do	50	Carboniferous(?).						5	Do.
1102	11	5			do	Drilled	199	do						13	Do.
1103	11	5			Walter George	Dug	40	Carboniferous.	[a] 20				Windmill	Small.	Do.
1104	11	6	[a] 10	NE	James Gililland	do	50	Valley fill	47	48.1	[a] 4,300	Nov., 1911	do	Adequate.	Stock.
1105	11	6	[a] 28		W. F. Gililland	do	50	do	[a] 50		[a] 4,150		do	Adequate.	Do.
1106	11	8	27	SE	Lee Short	8-inch; uncased	85	do	62	62.5	4,246	Oct., 1911	None		Not used.
	11	8	33		—— Regan	Dug	[a] 150	do							
1107	11	9	25	SE	A. B. Fall (4 wells)	Dug and drilled	100	Cretaceous and overlying waste.	14		[a] 4,800		None	15 each.	Do.

[a] Approximate.

[b] Sunk short distance below the water level.

No.	Substances dissolved in water (quantities expressed in parts per million).																	Temperature of water.
	Total solids.	Radicles.						Undetermined, including water of crystallization.	Hypothetical combinations.									
		Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate (CO_3).	Sulphate (SO_4).	Chloride (Cl).		Calcium carbonate ($CaCO_3$).	Calcium sulphate ($CaSO_4$).	Magnesium carbonate ($MgCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Sodium carbonate (Na_2CO_3).	Sodium sulphate (Na_2SO_4).	Sodium chloride (NaCl).	Total white alkali.[a]	
																		° F.
914	2,636	328	78	356	119	1,012	470	273	199	845	None.	389	None.	None.	154	775	1,318	....
916	1,314	198	49	144	104	567	169	83	174	432	None.	242	None.	None.	105	278	626	....
1001	4,216	547	164	564	89	1,991	741	120	149	1,655	None.	815	None.	None.	252	1,223	2,290	....
1002	11,092	634	213	2,874	30	2,270	4,457	614	49	2,089	None.	995	51	None.	None.	7,294	8,340	....
1004	3,288	355	136	353	89	1,500	359	496	149	1,006	None.	679	None.	None.	366	592	1,637	....
1004	1,822	58	31	510	104	901	186	32	145	None.	None.	None.	123	31	1,335	156	1,614	....
1005	2,742	295	119	367	74	1,263	417	207	124	835	None.	595	None.	None.	294	687	1,576	....
1007	3,893	509	119	410	73	1,863	421	498	123	1,565	None.	595	None.	None.	420	695	1,710	....
1104	8,768	389	128	2,273	129	1,347	3,412	1,090	215	1,031	None.	636	None.	None.	165	5,630	6,431	....
1105	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Salty.	....	....
1106	2,407	186	29	567	59	699	700	167	99	497	None.	145	None.	None.	344	1,155	1,644	65.5
1106	1,564	....	....	....	....	....	232	....	....	....	....	....	....	....	....	383	....	....

[a] White alkali includes the sulphates and chlorides of magnesium and sodium. Black alkali includes the carbonate and bicarbonate of sodium.

TABLE 1.—*Wells and analyses of well waters in Tularosa Basin, N. Mex.*—Continued.

No.	Location.				Owner or name.	Type.	Depth.	Geologic source of water.	Water level.				Method of lift.	Tested capacity per minute.	Use of water.
	Township south.	Range east.	Section.	Quarter.					Depth below surface.	Depth below bench mark.	Altitude above sea level.	Date.			
							Feet.		*Feet.*	*Feet.*	*Feet.*			*Gallons.*	
1108	11	9	25	SE	A. B. Fall (1 well).	Dug and drilled.	100	Cretaceous and overlying waste.	38				None	Small.	Not used.
1109	11	9½	13	NE	A. B. Fall	5 by 5 feet and tunnel.	50	Bowldery waste.	8	8.4	a 5,300	Oct., 1911	Gasoline; centrifugal pump.	500	Irrigation.
1110	11	9½	13	NE	do.	Large dug hole.	(b)	do.					do.	150	Do.
1201	12	5	25	SW	Jackson home ranch	2 dug wells.	(c)	Valley fill.	94	94.8	4,068	Nov., 1911	Windmill		Stock.
1202	12	9	a 1			Dug.	(c)	Waste overlying rock.	17	20.1		Dec., 1911	Bucket.		Domestic.
1301	13	5	16	NE	Jackson ranch	Drilled.	280	Valley fill.					Windmill		Stock.
1302	13	5	22	SW	George Henderson.	Dug.	(c)	do.	71	71.4	4,030	Nov., 1911	do.		Not used.
1303	13	5	29	SW	Jackson ranch	Drilled.	204	do.	a 100		a 4,025		None.		Do.
1304	13	8	8	SE	Black Lake ranch.	2 dug wells.	(c)	do.	17	17.9	4,167	Oct., 1911	Windmill	Adequate.	Stock.
1305	13	9	14	SE	Temporary railroad well.	Drilled.							do.		Do.
1306	13	9	20	NE.a	Al Gray ranch	Dug.	(c)	Valley fill.	12			Oct., 1911	do.		Do.
1307	13	9	20	SE.a	do.	do.	(c)	do.	4		4,279	do.	do.		Do.
1308	13	9	36	NE	R. Turner	Drilled.	a 170						Windmill and gasoline engine.	20(?)	Stock and domestic.
1401	14	4	25	SW		Dug.	(c)	Valley fill.	51			Nov., 1911	None.		Not used.
1402	14	5	8	SW	Mark Hunter	do.	70	do.	54	54.7	4,001	do.	Windmill		Stock.
1403	14	5	c 18	SE	William Hunter	do.	(c)	do.	53	53.7	3,990	do.	do.		Do.
1404	14	5	31	SE	W. L. Ritch	do.	(c)	do.	34	34.7	3,981	do.	do.		Not used.
1405	14	8	1			do.	(c)	do.	a 20		a 4,200				
1406	14	8	13	NW	Hill Bros.	Dug holes and tunnels.	40	do.	28	29.3	4,166	Dec., 1911	Gasoline, centrifugal pump.	75(?)	Irrigation.
1407	14	8	13	NW	A. J. Hill.	Dug.	40	do.	a 28				Windmill	Small.	
1408	14	8	25	NE	Well near northeast corner.	do.	(c)	do.	19	19.0	4,190	Sept., 1911	None.		Not used.
1409	14	8	25	SW		do.	(c)	do.	13	13.1	4,156	do.	Windmill.		Do.

a Approximate. b Shallow. c Sunk short distance below the water level.

No.	Substances dissolved in water (quantities expressed in parts per million).																	Temperature of water.
	Total solids.	Radicles.						Undetermined, including water of crystallization.	Hypothetical combinations.									
		Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate (CO_3).	Sulphate (SO_4).	Chloride (Cl).		Calcium carbonate ($CaCO_3$).	Calcium sulphate ($CaSO_4$).	Magnesium carbonate ($MgCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Sodium carbonate (Na_2CO_3).	Sodium sulphate (Na_2SO_4).	Sodium chloride (NaCl).	Total white alkali.[a]	° F.
1109	961	186	34	81	89	474	97	....	149	429	None.	169	None.	None.	53	161	383	....
1201	3,468	262	108	791	119	890	1,216	82	199	622	None.	564	None.	None.	None.	2,007	2,571	....
1302	8,308	611	154	1,506	115	1,476	2,626	1,820	193	1,816	None.	243	411	None.	None.	3,826	4,480	....
1304	4,856	656	237	[b] 442	134	2,370	616	401	224	1,925	None.	1,178	None.	None.	[c] 110	1,016	2,304	66
1306	3,976	476	183	377	89	2,097	306	448	149	1,415	None.	912	None.	None.	547	505	1,964	....
1308	2,637	437	144	128	22	1,585	197	124	37	1,435	None.	716	None.	None.	None.	325	1,041	....
1402	6,168	347	211	1,299	135	963	2,360	853	225	875	None.	432	485	None.	None.	3,297	4,214	....
1407	4,870	547	251	[c] 526	60	2,590	523	373	99	1,724	None.	1,254	None.	None.	557	863	2,674	....

[a] White alkali includes the sulphates and chlorides of magnesium and sodium. Black alkali includes the carbonate and bicarbonate of sodium.
[b] Potassium=18. Potassium sulphate=39.
[c] Potassium=17. Potassium sulphate=37.

TABLE 1.—*Wells and analyses of well waters in Tularosa Basin, N. Mex.*—Continued.

No.	Location.				Owner or name.	Type.	Depth.	Geologic source of water.	Water level.				Method of lift.	Tested capacity per minute.	Use of water.
	Township south.	Range east.	Section.	Quarter.					Depth below surface.	Depth below bench mark.	Altitude above sea level.	Date.			
							Feet.		*Feet.*	*Feet.*	*Feet.*			*Gallons.*	
1410	14	9	7	SW	Danford Ayers	8-inch; cased 60 feet.	180	Valley fill	18		4,210	Oct., 1911	Windmill	Small.	Domestic.
1411	14	9	8	SE	A. Bailey	Drilled; perforated iron casing.	56	do	*a* 22				do	Small.	Do.
1412	14	9	9	NE		Dug	(*b*)	do	10		*a* 4,335	Oct., 1911	None		Not used.
1413	14	9	9	SE	George Schaller	do	40	do	31	32.1	4,327	do	Windmill	Adequate.	Domestic and irrigation.
1414	14	9	10	NW		do	(*b*)	do	27		4,340	do	Bucket		Domestic.
1415	14	9	14	NE	M. W. Votaw	Dug and 9-inch drilled.	116	do	92	94.8	4,341	Sept., 1911	Gasoline, deep-well pump.	70	Irrigation and domestic.
1416	14	9	15	NW	Well near northeast corner.	Dug	(*b*)	do	42		4,341	Oct., 1911	Windmill		Not used.
1417	14	9	17	NE	Well near north margin.	do	(*b*)	do	22	22.7	4,245	do	None		Do.
1418	14	9	19	SE	Well on upland	do	(*b*)	do	21	21.1	4,228	Sept., 1911	Windmill		Do.
1419	14	9	25	NE	J. J. Sanders	do	80	do	77		*a* 4,370	do	None		Do.
1420	14	9	25	NE	do	do	90	do	87		*a* 4,360	do	do		Do.
1421	14	9	25	NW	L. E. Lumbley	do	(*b*)	do	*a* 125		4,320		Windmill		Domestic.
1422	14	9	27	NW	Elizabeth Kennedy.	do	(*b*)	do	56	56.7	4,278	Sept., 1911	do	Adequate.	Domestic and irrigation.
1423	14	9	27	SE	Well near northwest corner.	do	(*b*)	do	58	60.1	4,275	do			
1424	14	9	28	NE	W. H. Purday	do	35	do	29	31.2	4,270	do	Gasoline engine and windmill.	*a* 10	Irrigation and domestic.
1425	14	9	30	NE	Well in depression.	do	(*b*)	do	5		4,228	do	None		Not used.
1501	15	5	19	SW	W. L. Ritch's home ranch.	do	*a* 75	do	53	53.8	*a* 3,960	Nov., 1911	Windmill	Adequate.	Stock.

a Approximate.

b Sunk short distance below the water level.

No.	Substances dissolved in water (quantities expressed in parts per million).																	Temperature of water.
	Total solids.	Radicles.						Undetermined, including water of crystallization.	Hypothetical combinations.									
		Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate (CO_3).	Sulphate (SO_4).	Chloride (Cl).		Calcium carbonate ($CaCO_3$).	Calcium sulphate ($CaSO_4$).	Magnesium carbonate ($MgCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Sodium carbonate (Na_2CO_3).	Sodium sulphate (Na_2SO_4).	Sodium chloride (NaCl).	Total white alkali.[a]	° F.
1410	5,500	612	278	[b] 722	104	2,792	807	185	174	1,845	None.	495?	700?	None.	[b] 1,582?	470?	3,296	....
1411	3,201	383	175	261	104	1,545	328	405	174	1,065	None.	869	None.	None.	146	541	1,556	....
1413	3,262	569	179	129	97	1,813	279	196	161	1,714	None.	754	108	None.	None.	327	1,189	....
1415	2,164	273	123	173	119	1,044	199	233	199	659	None.	612	None.	None.	133	329	1,074	....
1418	2,236	306	120	101	164	949	155	441	273	669	None.	597	None.	None.	None.	256	853	....
1424	2,250	309	129	157	134	1,039	239	243	223	747	None.	640	None.	None.	None.	395	1,035	....
1501	4,441	350	229	783	140	995	1,587	357	234	870	None.	478	514	None.	None.	1,986	2,978	....

[a] White alkali includes the sulphates and chlorides of magnesium and sodium. Black alkali includes the carbonate and bicarbonate of sodium.
[b] Potassium = 22. Potassium sulphate = 49.

TABLE 1.—*Wells and analyses of well waters in Tularosa Basin, N. Mex.*—Continued.

No.	Location: Township south.	Location: Range east.	Location: Section.	Location: Quarter.	Owner or name.	Type.	Depth.	Geologic source of water.	Water level: Depth below surface.	Water level: Depth below bench mark.	Water level: Altitude above sea level.	Water level: Date.	Method of lift.	Tested capacity per minute.	Use of water.
							Feet.		*Feet.*	*Feet.*	*Feet.*			*Gallons.*	
1502	15	8	1	NW	D. W. Shoemaker	2-inch iron casing	*a* 40	Valley fill	Flow.		*a* 4,150	Sept., 1911	Artesian pressure.	3	Stock.
1503	15	8	1	NW	do	½-inch iron casing	*a* 40	do	Flow.		*a* 4,150	do	do	Very small.	Do.
1504	15	9	1	NE		Dug	(*b*)	do	55	58.2	4,333	do			Not used.
1505	15	9	1	SE	Well at northeast corner.	6-inch iron casing		do	46	47.5	4,341	do	Windmill		Stock.
1506	15	9	2		Well near middle north margin.	Dug	(*b*)	do	64		4,280	do			Not used.
1507	15	9	3		Well, middle south margin.	do	(*b*)	do	20	20.4	4,270	do	Windmill		Stock.
1508	15	9	6	NE	Mrs. R. B. Falconer		32	do			4,180		Hand pump.	Adequate.	Domestic.
1509	15	9	12	SE	Mrs. S. Fulton	Drilled; sheet casing.	34	do	30	30.9	4,331	Sept., 1911	Bucket		Do.
1510	15	9	12	SE	do	3-inch iron casing	60	do	31	32.8	4,331	do	None		Not used.
1511	15	9	24	SE	B. E. Stallberg	Dug and drilled.	140	do	85	86.4	4,257	do	Windmill	3	Domestic.
1512	15	9	24	SW	J. E. Snell	Dug	64	do	59	64.9	4,255	do	Bucket		Do.
1513	15	9	25	SE	J. R. Jones	do	(*b*)	do	*a* 60		*a* 4,260				
1514	15	10	6	NE	A. L. Goakes	do	(*b*)		75	75.4	4,355	Sept., 1911	Windmill		Domestic and stock.
1515	15	10	7	NE	William Fulton	do	81	Valley fill	76	78.8	4,346	do	Bucket		Not used.
1516	15	10	7	NW		Drilled; sheet casing.		do	35	36.0	4,342	do			
1517	15	10	9	SW	William Brubaker.	Dug and drilled.	125	do	*a* 120		*a* 4,330		Windmill		Stock.
1518	15	10	17	S		6-inch iron casing.		do	134	135.0	4,301	Sept., 1911	None		Not used.
1519	15	10	18	NW	Well at northwest corner.	Dug	(*b*)	do	48	50.6	4,305	do			
1520	15	10	28	SW		6-inch iron casing.			170	170.7	4,290	do	Pump		Do.
1521	15	10	30	SE		Dug	(*b*)	Valley fill	*a* 110		*a* 4,270				
1522	15	10	31	NW	A. J. Taylor	5-inch perforated casing.	138	do	*a* 86				Windmill	Adequate.	Domestic and stock.

a Approximate.

b Sunk short distance below the water level.

No.	Total solids.	Radicles. Calcium (Ca).	Radicles. Magnesium (Mg).	Radicles. Sodium and potassium (Na+K).	Radicles. Carbonate (CO_3).	Radicles. Sulphate (SO_4).	Radicles. Chloride (Cl).	Undetermined, including water of crystallization.	Hypothetical combinations. Calcium carbonate ($CaCO_3$).	Hypothetical combinations. Calcium sulphate ($CaSO_4$).	Hypothetical combinations. Magnesium carbonate ($MgCO_3$).	Hypothetical combinations. Magnesium sulphate ($MgSO_4$).	Hypothetical combinations. Magnesium chloride ($MgCl_2$).	Hypothetical combinations. Sodium carbonate (Na_2CO_3).	Hypothetical combinations. Sodium sulphate (Na_2SO_4).	Hypothetical combinations. Sodium chloride (NaCl).	Hypothetical combinations. Total white alkali.[a]	Temperature of water
																		°F.
1502, 1503	2,283	295	106	141	104	984	217	436	174	766	None.	554	None.	None.	None.	358	912	65.5
1505	2,520	241	97	143	104	795	220	920	174	581	None.	481	None.	None.	None.	364	845	....
1507	2,544	415	106	149	59	1,347	229	225	99	1,276	None.	558	None.	None.	None.	378	936	....
1508	2,204	327	103	121	89	1,055	186	323	149	912	None.	514	None.	None.	None.	307	821	65.5
1509	3,827	350	127	645	104	1,632	656	313	174	952	None.	631	None.	None.	674	1,082	2,387	....
1511	2,632	295	67	423	111	1,028	479	229	185	750	None.	333	None.	None.	344	790	1,467	....
1512	3,924	393	222	384	164	1,608	558	595	273	966	None.	1,103	None.	None.	66	921	2,090	....
1515	3,624	426	173	452	134	1,604	616	219	223	1,146	None.	863	None.	None.	157	1,016	2,036	....
1517	4,267	437	96	650	111	1,682	683	608	186	1,232	None.	480	None.	None.	635	1,126	2,241	....
1522	1,883	219	183	41	105	603	417	315	174	506	None.	308	474	None.	None.	104	886	....

Substances dissolved in water (quantities expressed in parts per million).

[a] White alkali includes the sulphates and chlorides of magnesium and sodium. Black alkali includes the carbonate and bicarbonate of sodium.

TABLE 1.—*Wells and analyses of well waters in Tularosa Basin, N. Mex.*—Continued.

No.	Location.				Owner or name.	Type.	Depth.	Geologic source of water.	Water level.				Method of lift.	Tested capacity per minute.	Use of water.
	Township south.	Range east.	Section.	Quarter.					Depth below surface.	Depth below bench mark.	Altitude above sea level.	Date.			
							Feet.		*Feet.*	*Feet.*	*Feet.*			*Gallons.*	
1523	15	10	31	NW	A. J. Taylor	Dug	(a)	Valley fill	81	83.5	4,260	Sept., 1911	Adequate.	Adequate.	Stock.
1601	16	4	36	NW	J. A. Baird	Drilled	120	do	b 65		b 3,922		Adequate.	Adequate.	Do.
1602	16	8	11	SE	Well in arroyo	Dug	(a)	do	6		b 4,150	Nov., 1911	None		Not used.
1603	16	9	2	NW		Drilled	b 175	do					Windmill		Domestic and stock.
1604	16	9	3		Well, middle north margin.	Dug	(a)	do	110		4,274	Sept., 1911	None		Not used.
1605	16	9	4	NW	F. C. Larson	7-inch iron casing.	100	do	63	67.6	4,256	do	Windmill	20	Irrigation.
1606	16	9	4	NW	do	6-inch iron casing.	100	do	63		b 4,256		Gasoline, deep-well pump.	75	Do.
1607	16	9	5	NE	B. Hassett	Drilled	32	do	b 28		4,224		Hand pump.	3	Domestic.
1608	16	9	5	SE	J. F. Haines	Dug	(a)	do	42		4,216	Sept., 1911			
1609	16	9	6	NW	Well in arroyo	do	(a)	do	15		4,233	do	Nc ne		Not used.
1610	16	9	6	SE	W. F. Thompson	do	17	do	12	12.9	4,230	do	Horsepower and windmill.	Adequate.	Domestic and stock.
1611	16	9	9	SW	Well at southeast corner.	do	(a)	do	49	50.8	4,218	do			Do.
1612	16	9	10	SE		do	(a)	do	82	85.5	4,233	do	Bucket		
1613	16	9	12	NE	—— Fribley	do	(a)	do	156	157.0	4,285	do	Windmill	Adequate.	Do.
1614	16	9	13	SE	Well near railroad.	do	(a)	do	71	73.7	4,307	do	Bucket		
1615	16	9	13	NW	M. Phillips	do	(a)	do	98	100.5	4,293	do			
1616	16	9	14	NW	J. A. Gore	do	95	do	89		4,256	do			Do.
1617	16	9	16	SE	Well at southeast corner.	do	(a)	do	41	41.7	4,217	do	Windmill		
1618	16	9	17	SE	Well in arroyo	do	(a)	do	10	12.5	4,200	do	do		Do.
1619	16	9	22	SE		do	(a)	do	47	48.6	4,227	do	do		Do.
1620	16	9	23	NW	C. W. Morgan	Dug and drilled.	65	do	54	55.4	4,232	do	do	Adequate.	

a Sunk short distance below the water level.

b Approximate.

No.	Substances dissolved in water (quantities expressed in parts per million).																	Temperature of water.
	Total solids.	Radicles.						Undetermined, including water of crystallization.	Hypothetical combinations.									
		Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate (CO_3).	Sulphate (SO_4).	Chloride (Cl).		Calcium carbonate ($CaCO_3$).	Calcium sulphate ($CaSO_4$).	Magnesium carbonate ($MgCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Sodium carbonate (Na_2CO_3).	Sodium sulphate (Na_2SO_4).	Sodium chloride (NaCl).	Total white alkali.[a]	°F.
1601	6,100	347	285	1,040	131	1,208	2,001	1,088	218	884	None.	732	540	None.	None.	2,639	3,911	....
1607	1,324	142	66	174	149	516	168	109	248	145	None.	330	None.	None.	220	278	828	67
1610	1,670	240	80	158	119	702	244	127	199	544	None.	398	None.	None.	None.	402	800	....
1611	1,847	131	81	381	164	873	217	....	273	744	None.	404	None.	None.	737	358	1,499	....
1613	1,316	197	66	107	134	490	186	136	223	365	None.	291	28	None.	None.	273	592	....
1616	1,177	184	64	121	134	488	186	None.	224	325	None.	320	None.	None.	None.	307	627	....
1617	1,990	208	94	248	134	813	266	227	223	402	None.	467	None.	None.	232	439	1,138	....
1618	2,493	317	119	277	111	1,071	412	186	186	824	None.	590	None.	None.	26	680	1,296	....
1620	2,168	131	119	382	134	870	368	164	224	141	None.	595	None.	None.	438	607	1,640	....

[a] White alkali includes the sulphates and chlorides of magnesium and sodium. Black alkali includes the carbonate and bicarbonate of sodium.

TABLE 1.—*Wells and analyses of well waters in Tularosa Basin, N. Mex.*—Continued.

No.	Location.				Owner or name.	Type.	Depth.	Geologic source of water.	Water level.				Method of lift.	Tested capacity per minute.	Use of water.
	Township south.	Range east.	Section.	Quarter.					Depth below surface.	Depth below bench mark.	Altitude above sea level.	Date.			
							Feet.		*Feet.*	*Feet.*	*Feet.*			*Gallons.*	
1621	16	9	23	NW	C. W. Morgan	9 to 5 inch perforated casing.	160	Valley fill	54				Electric motor, deep-well pump.	40	Irrigation.
1622	16	9	23	SE		Dug	(a)	do	52	53.1	4,255	Sept., 1911			
1623	16	9	25	NE	George Earl	Two 10-inch cased wells.	186	do	20	20.8	b 4,300	do	Steam, centrifugal pump.	375	Ice plant and irrigation.
1624	16	9	25	NE	do	One 10-inch cased well.	80	do	20		b 4,300	do			
1625	16	9	25	NE	do	do	186	do	20		b 4,300	do	Gasoline, centrifugal pump.		Irrigation.
1626	16	9	25	NW	Fred Le Min		60	do	39		4,275	do	Windmill		Stock.
1627	16	9	25	NW	J. F. Wayland	6-inch perforated casing.	50	do	20				None		Not used.
1628	16	9	25	NW	William Hurtig	3 inch; cased 80 feet.	148	do	20		4,285		Gasoline, deep-well pump.	b 7	Stock.
1629	16	9	25	SW	J. W. Pennington	Dug and drilled.	95	do	33	33.4	4,256				Do.
1630	16	9	26	NE	Deep test well	12 to 8 inch diameter.	1,004	do	35	42.7	4,255	Sept., 1911	None		Not used.
1631	16	9	26	NW	Well near northeast corner.	Dug	(a)	do	38	39.2	4,240	do	do		Do.
1632	16	9	26	SW	W. T. Campbell	do	40	do	30	30.0	4,237	do	Windmill		Stock.
1633	16	9	26	SW	D. M. Sutherland	8-inch casing	80	do	24		4,236				Domestic and stock.
1634	16	9	28	SW		Drilled	(a)	do	24	25.0	4,187	Nov., 1911	None		Not used.
1635	16	9	32	NW		Dug	(a)	do	9	10.5	4,131	do	do		Do.
1636	16	9	33	SW	R. W. Nibbs	2-inch casing	122	do					Gasoline, deep-well pump.	Small.	Domestic and stock.
1637	16	9	34	SW	—— Loomas	Drilled	67	do					Gasoline engine.	b 30	Domestic and irrigation.

a Sunk short distance below the water level.

b Approximate.

No.	Total solids.	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate (CO_3).	Sulphate (SO_4).	Chloride (Cl).	Undetermined, including water of crystallization.	Calcium carbonate ($CaCO_3$).	Calcium sulphate ($CaSO_4$).	Magnesium carbonate ($MgCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Sodium carbonate (Na_2CO_3).	Sodium sulphate (Na_2SO_4).	Sodium chloride (NaCl).	Total white alkali.[a]	Temperature of water.
	Substances dissolved in water (quantities expressed in parts per million).	Radicles.							Hypothetical combinations.									°F.
1621	3,060	290	167	438	156	1,109	669	231	261	629	None.	190?	506?	None.	761?	483?	1,940	....
1623, 1624	1,680	197	90	176	119	639	270	190	199	398	None.	448	None.	None.	None.	446	894	....
1626	4,241	437	219	495	156	1,250	1,072	612	261	1,132	None.	563	416	None.	None.	1,257	2,236	....
1629	5,540	642	139	552	150	2,520	357	1,180	250	1,841	None.	693	None.	None.	986	589	2,268	....
1630	3,049	598	86	201	54	1,801	210	....	90	1,908	None.	428	None.	None.	167	374	969	....
1632	6,660	407	347	1,118	209	2,745	1,179	655	348	901	None.	1,727	None.	None.	1,079	1,945	4,751	....
1633	....	340	240	[b] 410	....	1,240	700	....	292	397	None.	1,177	94	None.	None.	1,040	2,311	....
1635	6,464	476	290	1,212	256	2,405	1,483	342	428	1,034	None.	1,442	None.	None.	774	2,445	4,661	....
1636	3,360	215	117	248	98	916	315	1,451	163	507	None.	584	None.	None.	135	519	1,238	....

[a] White alkali includes the sulphates and chlorides of magnesium and sodium. Black alkali includes the carbonate and bicarbonate of sodium.
[b] Trace of potassium.

TABLE 1.—*Wells and analyses of well waters in Tularosa Basin, N. Mex.*—Continued.

No.	Location.				Owner or name.	Type.	Depth.	Geologic source of water.	Water level.				Method of lift.	Tested capacity per minute.	Use of water.
	Township south.	Range east.	Section.	Quarter.					Depth below surface.	Depth below bench mark.	Altitude above sea level.	Date.			
							Feet.		*Feet.*	*Feet.*	*Feet.*			*Gallons.*	
1638	16	9	35	NE	Mrs. Wertane	Drilled and cased.	*a* 200	Valley fill					Electric motor, deep-well pump.	Large.	Domestic and irrigation.
1639	16	9	35	NW	F. M. De Groodt	Dug and drilled	74	do	18		4,231	Sept., 1911	Windmill		Stock.
1640	16	9	35	NW	do	Dug	32	do	18			do			
1641	16	9	35	SE	Well at northeast corner.	do		do	33	34.5	4,236	do	None		Not used.
1642	16	10	7	NE		do		do	131	134.2	4,313	do	Windmill		Domestic and stock.
1643	16	10	7	SE	A. K. Gore	do	81	do	78	79.9	4,310	do	Bucket		Domestic.
1644	16	10	*f* 7	SE	B. M. Hudman	do	74	do	70	72.6	4,309	do	do		Stock.
1645	16	10	18	NW		do	(*b*)	do	57	60.1	4,298	Oct., 1911	None		Not used.
1646	16	10	19	NE	F. M. Evans	do	(*b*)	do	52	52.7	4,291	Sept., 1911	Windmill	Adequate.	Stock.
1647	16	10	20	NE	Baptist College	6-inch casing	*a* 160				*a* 4,340		None	Adequate.	Not used.
1648	16	10	29	NE	W. G. Ransom	Dug and drilled	*a* 280		100+		*a* 4,340	Sept., 1911	Electric motor, deep-well pump.	Adequate.	Do.
1649	16	10	31	NW	H. E. Strauss	Drilled			122	122.5	4,208	do	Bucket	Adequate.	Domestic and stock.
1701	17	5	26	NE	Baird's home ranch.	do	210	Valley fill	*a* 200		*a* 3,940		Windmill	12	Do.
1702	17	7	23		Well near center	Dug	10	do	5		4,005	Nov., 1911			
1703	17	9	1	SW	Well at northwest corner.	do	(*b*)	do	50	53.6	4,191	Sept., 1911	Windmill		Not used.
1704	17	9	1	SE	G. W. Ransom	do	104	do	98	101.8	4,210	do	Bucket		Domestic.
1705	17	9	2	NE	Well at northeast corner.	Drilled and cased.		do	39	39.6	4,213	do	None		Not used.
1706	17	9	2	SW	H. W. Schofield	Drilled	80	do					Windmill		Domestic.
1707	17	9	3	NE	Well at northeast corner.	Drilled and cased.	125	do	14	15.4	4,202	Sept., 1911	do	Adequate.	Domestic and stock.
1709	17	9	3	SE	A. B. Dillie	Drilled	135	do							

a Approximate. *b* Sunk short distance below the water level.

No.	Substances dissolved in water (quantities expressed in parts per million).																	Temperature of water.
	Total solids.	Radicles.						Undetermined, including water of crystallization.	Hypothetical combinations.									
		Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate (CO_3).	Sulphate (SO_4).	Chloride (Cl).		Calcium carbonate ($CaCO_3$).	Calcium sulphate ($CaSO_4$).	Magnesium carbonate ($MgCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Sodium carbonate (Na_2CO_3).	Sodium sulphate (Na_2SO_4).	Sodium chloride (NaCl).	Total white alkali.[a]	
																		°F.
1638	2,240	257	107	257	119	712	496	292	199	603	None.	359	136	None.	None.	651	1,146	67.5
1640	9,727	656	201	2,198	312	2,578	2,858	924	521	1,519	None.	999	None.	None.	1,046	4,716	6,761	....
1643	2,034	111	63	426	104	876	266	188	174	141	None.	312	None.	None.	780	439	1,531	....
1644	2,620	252	165	264	231	1,117	240	355	385	331	None.	821	None.	None.	334	395	1,550	....
1646	4,220	383	225	476	149	1,575	731	691	248	963	None.	1,120	None.	None.	None.	1,207	2,327	....
1649	880	83	59	103	45	363	160	67	74	180	None.	294	None.	None.	None.	263	557	....
1701	1,067	126	69	105	123	378	162	104	205	148	None.	343	None.	None.	None.	268	611	....
1702	4,196	558	214	322	47	2,329	336	390	79	1,788	None.	1,064	None.	None.	319	554	1,937	....
1703	5,660	426	307	802	179	2,680	878	388	299	1,043	None.	1,729	None.	None.	713	1,448	3,890	....
1704	2,516	262	137	233	104	1,194	221	365	174	655	None.	683	None.	None.	275	366	1,324	....
1706	3,288	316	149	470	134	1,472	465	282	224	754	None.	742	None.	None.	514	768	2,024	....
1709	2,584	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

[a] White alkali includes the sulphates and chlorides of magnesium and sodium. Black alkali includes the carbonate and bicarbonate of sodium.

TABLE 1.—*Wells and analyses of well waters in Tularosa Basin, N. Mex.*—Continued.

No.	Location.				Owner or name.	Type.	Depth.	Geologic source of water.	Water level.				Method of lift.	Tested capacity per minute.	Use of water.
	Township south.	Range east.	Section.	Quarter.					Depth below surface.	Depth below bench mark.	Altitude above sea level.	Date.			
							Feet.		*Feet.*	*Feet.*	*Feet.*			*Gallons.*	
1710	17	9	3	NW	Simeon Bowden	Dug and 7-inch cased.	65	Valley fill	24	23.7	4,165	Sept., 1911	Gasoline, centrifugal pump.		Irrigation.
1711	17	9	4	SW	Charles Pearson	2 to 1½ inch casing.	130	do	*a* 28				Handpump.	Small.	Domestic and stock.
1712	17	9	5	NE	C. C. Missik	Dug	60	do	32	31.8	4,139	Sept., 1911	None		
1713	17	9	8	SE	N. Leemaster	Drilled	100	do	24		*a* 4,120	Nov., 1911	Windmill		Do.
1714	17	9	9	NW	W. D. Jones	Dug and 2-inch cased.		do	28	28.8	4,127	Sept., 1911	Hand pump.	Small.	Stock.
1715	17	9	10		Judge Carter	Dug	32	do	31	30.6	*a* 4,150	Nov., 1911	Windmill		
1716	17	9	10		do	Dug and drilled.	103	do	31		*a* 4,150	do			
1717	17	9	11	NE	Well near northeast corner.	Drilled; sheet casing.		do	48	50.5	4,177	Sept., 1911			
1718	17	9	11	NW	Well at northwest corner.	Dug	(*b*)	do	22	22.5	4,178	do			
1719	17	9	11	SE	Well at northeast corner.	6-inch sheet casing.		do	48	49.0	4,160	do			
1720	17	9	13	SE	F. B. Chamberlin.	Dug	85	do	*a* 80		*a* 4,150		Windmill	Small.	Domestic and stock.
1721	17	9	15	NE	H. F. Patty	Dug and 7-inch cased.	62	do	31	31.2	4,131	Sept., 1911	Gasoline, centrifugal pump.	*a* 125	Irrigation.
1722	17	9	23	SW	J. L. Paxson	Cased	85	do	30		4,096		Bucket	Adequate.	Domestic.
1723	17	9	23	SW	do		*a* 50	do	30						
1724	17	9	24	NE	W. M. Rode	Dug	68	do	65		4,135	Nov., 1911	Bucket		Do.
1725	17	9	25	NE	Well at northeast corner.	6-inch casing							Windmill		Stock.
1726	17	9	25	SW	T. Edge	Dug	45	do	*a* 37				do	*a* 10	Domestic and irrigation.
1727	17	9	26	NE	J. S. Morgan	Dug and drilled.	90	do	42	42.7	4,081	Sept., 1911	Horsepower and gasoline engine.		Stock and irrigation.

a Approximate.

b Sunk short distance below the water level.

No.	Total solids.	Radicles: Calcium (Ca).	Radicles: Magnesium (Mg).	Radicles: Sodium and potassium (Na+K).	Radicles: Carbonate (CO_3).	Radicles: Sulphate (SO_4).	Radicles: Chloride (Cl).	Undetermined, including water of crystallization.	Hypothetical combinations: Calcium carbonate ($CaCO_3$).	Hypothetical combinations: Calcium sulphate ($CaSO_4$).	Hypothetical combinations: Magnesium carbonate ($MgCO_3$).	Hypothetical combinations: Magnesium sulphate ($MgSO_4$).	Hypothetical combinations: Magnesium chloride ($MgCl_2$).	Hypothetical combinations: Sodium carbonate (Na_2CO_3).	Hypothetical combinations: Sodium sulphate (Na_2SO_4).	Hypothetical combinations: Sodium chloride (NaCl).	Hypothetical combinations: Total white alkali.[a]	Temperature of water.
																		° F.
1710	2,533	252	80	339	104	1,111	288	361	174	618	None.	398	None.	None.	528	475	1,401	....
1711	2,476	252	126	331	119	915	510	223	199	584	None.	629	None.	None.	None.	841	1,470	....
1712	7,280	470	371	1,211	37	2,580	1,897	714	62	1,514	None.	1,844	None.	None.	None.	3,130	4,974	....
1713	4,740	521	165	517	53	2,057	620	807	88	1,651	None.	819	None.	None.	351	1,024	2,194	....
1715	3,800	413	223	365	102	1,577	665	455	171	1,173	None.	936	138	None.	None.	928	2,002	....
1720	821	114	61	36	109	340	55	106	183	138	None.	303	None.	None.	None.	91	394	....
1721	11,640	755	750	1,482	149	3,786	2,841	1,877	248	2,225	None.	2,532	946	None.	283?	3,525	7,286	....
1722	2,140	241	120	201	105	976	244	255	174	580	None.	597	None.	None.	131	402	1,130	....
1723	3,760	525	184	392	164	1,949	439	107	273	1,412	None.	915	None.	None.	326	725	1,966	....
1725	1,363	186	86	111	128	481	244	127	214	340	None.	302	98	None.	None.	282	682	....
1726	1,463	197	94	106	148	689	104	125	248	332	None.	469	None.	None.	118	172	759	....

Substances dissolved in water (quantities expressed in parts per million).

[a] White alkali includes the sulphates and chlorides of magnesium and sodium. Black alkali includes the carbonate and bicarbonate of sodium.

TABLE 1.—*Wells and analyses of well waters in Tularosa Basin, N. Mex.*—Continued.

No.	Location.				Owner or name.	Type.	Depth.	Geologic source of water.	Water level.				Method of lift.	Tested capacity per minute.	Use of water.
	Township south.	Range east.	Section.	Quarter.					Depth below surface.	Depth below bench mark.	Altitude above sea level.	Date.			
							Feet.		*Feet.*	*Feet.*	*Feet.*			*Gallons.*	
1728	17	9	26	NE	J. S. Morgan	Dug	46	Valley fill	42			Sept., 1911	Windmill		Domestic and stock.
1729	17	9	26	SW	Ed. Blair	do	(a)	do	29	29.7		do	Bucket		Not used.
1730	17	10	19	NE	Well at southeast corner.	do	75	do	b 45				do		Domestic.
1731	17	10	19	NW	School house	do	(a)	do	55	58.8	4,090	Sept., 1911	do		School.
1732	17	10	31	NE		do	(a)	do	96	96.7		do	do		Domestic.
1733	17	10	31	SW	W. M. Wells	do	(a)	do	82	85.7		do	Windmill		Do.
1801	18	5	34	SW	C. B. Eddy	do	8	do	6		3,902	do	None		Not used.
1802	18	7	14	SW	Point of Sands	do	(a)	do	8	8.9	3,972	do	Windmill		Stock and domestic.
1803	18	9	1	NE	J. A. Thomas	do	70	do	63	63.5	b 4,060	do	do		Domestic and irrigation.
1804	18	9	1	SE	W. L. Garrison	Dug and drilled.	82	do	57		b 4,040	do	do	14	Do.
1805	18	9	10	SE	J. S. Morgan	Dug	(a)	do	34	35.4	b 4,005	do	do		Stock.
1806	18	9	11	SE	A. J. Taylor	Drilled	50	do	b 36		b 4,005		do		Domestic.
1807	18	9	12	SE	Dr. Taylor	Dug and drilled.	87	do	b 58		b 4,025		None	Less than 28.	Not used.
1808	18	9	13	NW	—— Garrison	Drilled		do	20(?)		b 4,010		Windmill		
1809	18	9	13	SE	Eva A. Robinson	Dug and drilled.	103	do	41	41.9	b 4,000	Sept., 1911	do	b 15	Domestic and irrigation.
1810	18	9	14	NE	S. D. Camp	do	160	do	38	38.4	3,996	do	Windmill and gasoline engine.	c 140	Irrigation.
1811	18	9	14	SW	T. J. Cox	Dug	(a)	do	32	32.9	b 3,990	do	Bucket		Domestic and stock.
1812	18	9	25	NE	J. W. Merrill	Dug and drilled.		do	24	24.9		do	Windmill		Domestic.
1813	18	9	26	NW	W. H. McNew	Dug	50	do	30	30.7	b 3,972	do	do		Domestic and stock.

a Sunk short distance below the water level. b Approximate. c Reported by owner.

No.	Substances dissolved in water (quantities expressed in parts per million).																	Temperature of water.
	Total solids.	Radicles.						Undetermined, including water of crystallization.	Hypothetical combinations.									
		Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate (CO_3).	Sulphate (SO_4).	Chloride (Cl).		Calcium carbonate ($CaCO_3$).	Calcium sulphate ($CaSO_4$).	Magnesium carbonate ($MgCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Sodium carbonate (Na_2CO_3).	Sodium sulphate (Na_2SO_4).	Sodium chloride (NaCl).	Total white alkali.[a]	
																		° F.
1728	1,680	186	119	127	134	728	177	209	224	326	None.	590	None.	None.	37	293	920	....
1801	15,600	395	751	3,383	112	9,379	1,030	550	188	1,089	None.	3,738	None.	None.	8,339	1,700	13,777	....
1802	4,804	539	335	261	91	2,769	188	621	152	1,626	None.	1,667	None.	None.	427	311	2,405	....
1803	788	108	54	83	114	330	100	None.	190	108	None.	270	None.	None.	56	165	491	....
1804	1,468	180	107	69	108	421	299	284	180	365	None.	205	259	None.	None.	176	640	....
1805	3,751	312	290	392	97	1,811	556	293	162	839	None.	1,444	None.	None.	95	918	2,457	....
1806	2,724	204	179	286	111	1,183	321	440	185	440	None.	889	None.	None.	239	530	1,658	....
1809	1,804	216	116	150	120	827	199	176	201	460	None.	575	None.	None.	62	329	966	....
1811	1,452	156	97	126	125	558	194	196	208	246	None.	480	None.	None.	None.	320	800	....
1812	2,277	126	156	308	106	1,195	144	242	178	186	None.	774	None.	None.	660	238	1,672	....
1813	6,912	611	304	829	60	3,016	953	1,139	100	1,941	None.	1,515	None.	None.	643	1,572	3,730	....

[a] White alkali includes the sulphates and chlorides of magnesium and sodium. Black alkali includes the carbonate and bicarbonate of sodium.

TABLE 1.—*Wells and analyses of well waters in Tularosa Basin, N. Mex.*—Continued.

No.	Location.				Owner or name.	Type.	Depth.	Geologic source of water.	Water level.				Method of lift.	Tested capacity per minute.	Use of water.
	Township south.	Range east.	Section.	Quarter.					Depth below surface.	Depth below bench mark.	Altitude above sea level.	Date.			
							Feet.		*Feet.*	*Feet.*	*Feet.*			*Gallons.*	
1814	18	9	26	NW	W. H. McNew	Drilled	138	Valley fill					Gasoline engine.		Domestic and stock.
1815	18	10	6	SW	J. F. Pridmore	Dug	(a)	do	55	55.5		Nov., 1911	Bucket		Domestic.
1816	18	10	7	NW	— — Rupert	do		do	54	54.4		do	Windmill		Stock.
1817	18	10	7	NE	J. W. Hatfield	do	66	do	60	62.8		do	Bucket		Domestic.
1818	18	10	8	NW	James Madison	do	102	do	[b]97				Windmill	Small.	Do.
1819	18	10	18		Well near center	do	(a)	do	41	41.9		Nov., 1911	do		Not used.
1820	18	10	28	NW	J. E. Moore	do	85	do	[b]58				None		Do.
1821	18	10	28	SE	J. P. Moore	18-inch diameter.	91	do	86	86.5		Nov., 1911	Windmill	Small.	Domestic and stock.
1822	18	10	29	SW	— — Stannard	5-inch casing		do	70	71.0		do	None		Not used.
1823	18	10	33	NE	R. R. Shirk	18-inch diameter.		do	84	85.0		do	Bucket		Do.
1824	18	10	34	NW	J. F. George	do	115	do	100+				do		Domestic.
1901	19	5	5	NW	North Lucero ranch.	2 dug wells	[b]65	do	[b]40		[b]3,910		Windmill		Stock.
1902	19	5	27	NW	South Lucero ranch.	Drilled	190	do	[b]183		[b]3,870		do		Domestic and stock.
1903	19	6	12	NW	W. H. McNew	Dug	70	do	47	48.2	3,918	Nov., 1911	do	Adequate.	Stock.
1904	19	6	12	NW	do	Drilled	250	do					do	Adequate.	Stock and domestic.
1905	19	7	5	SW	do	Dug	60	do	36	38.7	3,922	Nov., 1911	do	Small.	Stock.
2001	20	5	[b]36	SW	G. A. Bennett. (Leatherman ranch).	Drilled	144	do	[b]130				do	Adequate.	Stock and domestic.
2101	21	4	[b]14		Gold camp	do	[b]180	Granite						Adequate.	Domestic.
2102	21	4	[b]27		Thompson ranch	Dug	[b]40		17	20.5		Dec., 1912	None		Not used.
2103	21	4	[b]25		Steam-pump ranch	Dug and drilled.	[b]200						Windmill and gasoline engine.		Stock and domestic.
2104	21	9	[b]2		Oliver Lee	do	130	Valley fill	103	102.6		Dec., 1912	do	10	Stock.

a Sunk short distance below the water level.

b Approximate.

No.	Substances dissolved in water (quantities expressed in parts per million).																	Temperature of water.
	Total solids.	Radicles.						Undetermined, including water of crystallization.	Hypothetical combinations.									
		Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate (CO_3).	Sulphate (SO_4).	Chloride (Cl).		Calcium carbonate ($CaCO_3$).	Calcium sulphate ($CaSO_4$).	Magnesium carbonate ($MgCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Sodium carbonate (Na_2CO_3).	Sodium sulphate (Na_2SO_4).	Sodium chloride (NaCl).	Total white alkali.[a]	°F.
1817	1,648	168	93	209	177	782	104	115	295	168	None.	463	None.	None.	435	172	1,070	....
1821	752	114	57	43	111	323	67	37	186	134	None.	286	None.	None.	None.	110	396	....
1901	3,019	120	106	858	104	241	1,541	49	174	171	None.	151	296	None.	None.	2,178	2,625	69
1902	502	66	44	49	122	161	58	2	164	None.	33	171	None.	None.	36	96	303	72
1904	3,404	416	94	435	53	2,009	139	258	88	1,292	None.	473	None.	None.	1,064	229	1,766	....
1905	8,967	443	437	1,400	139	4,834	487	1,227	233	1,188	None.	2,175	None.	None.	3,340	803	6,318	....
2001	630	77	57	49	100	250	75	22	168	32	None.	285	None.	None.	None.	124	409	....
2104	531	44	16	113	75	198	58	21	110	None.	20	53	None.	None.	232	95	380	64.5

[a] White alkali includes the sulphates and chlorides of magnesium and sodium. Black alkali includes the carbonate and bicarbonate of sodium.

TABLE 1.—*Wells and analyses of well waters in Tularosa Basin, N. Mex.*—Continued.

No.	Location.				Owner or name.	Type.	Depth.	Geologic source of water.	Water level.				Method of lift.	Tested capacity per minute.	Use of water.
	Township south.	Range east.	Section.	Quarter.					Depth below surface.	Depth below bench mark.	Altitude above sea level.	Date.			
							Feet.		*Feet.*	*Feet.*	*Feet.*			*Gallons.*	
2105	21	9	*a* 35	NE	Wilde ranch	Dug and drilled.	526	Valley fill (?)	*a* 244				Windmill and gasoline engine.	Adequate.	Stock.
2201	22	5	*a* 10		North Cox wells	6-inch casing, with Cook strainer.	138	do	*a* 123				Windmills		Not used.
2202	22	7			R. L. Raley	Dug	250	do	245				do	Adequate.	Stock.
2203	22	8	24	SW	Orogrande Railroad well.	Drilled and cased.	960	Carboniferous and igneous.	480 (?)		3,695 (?)		None		Not used.
2204	22	8	3	S	Shaft of Lucky Flat mine, Jarilla Mountains.	Dug	250	Carboniferous (?).	150		*a* 4,405		do	110	Do.
2205	22	9	15		Benton well	Drilled and cased.		Valley fill (?).	407		*a* 3,630	Dec., 1912	do		Do.
2206	22	9	22	SW	W. N. Fleck's home ranch.	do	540	do. (?)					Windmill and gasoline engine.	Adequate.	Stock.
2301	23	5 or 6			South Cox wells	6-inch casing, with Cook strainer.	*a* 137	do	*a* 123				Windmills		Not used.
2401	24	5			North Coe wells	do	180	do	*a* 142				do		Do.
2402	24	8	*a* 1		Mott well	Drilled	410?		365?						
2501	25	4	*a* 11		Mrs. M. L. Coe's home ranch.	6-inch casing, with Cook strainer.	349	Valley fill	*a* 327				Windmill and gasoline engine.	Adequate.	Stock and domestic.

a Approximate.

NOTE.—The El Paso & Southwestern Railroad Co. furnished the analysis of water from the railroad wells at Gallinas, Ancho (both analyses), Carrizozo (wells 1, 2, and 4) Oscuro (well No. 1), and Orogrande, and from the deep-test well on NE. ¼ sec. 26, T. 16 S., R. 9 E.

The analysis of the water from the well of A. B. Dillie, SE. ¼ sec. 3, T. 9. S., R. 17 E., was made for the Alamogordo Improvement Co. by T. L. Smith, jr., Eagle Lake, Tex.

The analysis of the water from the Lucky Shaft mine, Jarilla Mountains, was made for the mining company by H. D. G. Reynolds.

No.	Substances dissolved in water (quantities expressed in parts per million).																	Temperature of water.
	Total solids.	Radicles.						Undetermined, including water of crystallization.	Hypothetical combinations.									
		Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate (CO_3).	Sulphate (SO_4).	Chloride (Cl).		Calcium carbonate ($CaCO_3$).	Calcium sulphate ($CaSO_4$).	Magnesium carbonate ($MgCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Sodium carbonate (Na_2CO_3).	Sodium sulphate (Na_2SO_4).	Sodium chloride (NaCl).	Total white alkali.[a]	
																		°F.
2105	5,805	372	269	1,080	48	2,097	1,506	433	80	1,154	None.	1,340	None.	None.	313	2,485	4,138	......
2203	4,776	167	128	1,358	294	1,420	1,333	......	417	None.	60	551	None.	None.	1,448	2,223	4,222	......
2204	2,015	......	......	......	......	......	......	......	......	1,177	......	377	......	......	536	......	......	......
2206	2,528	124	72	617	120	890	579	125	201	14	None.	359	None.	None.	739	956	2,054	73
2501	321	35	13	61	84	74	39	14	88	None.	44	None.	None.	None.	110	65	175	......

[a] White alkali includes the sulphates and chlorides of magnesium and sodium. Black alkali includes the carbonate and bicarbonate of sodium.

TABLE 2.—*Analyses of spring waters in Tularosa Basin, N. Mex.*

No.	Location.				Designation.	Geologic source.	Altitude above sea level.	Yield per minute.	Use of water.
	Township south.	Range east.	Section.	Quarter.					
							Feet.	*Gallons.*	
S1	7	10	26	SE	Carrizozo (McDonald's) Spring	Waste overlying Cretaceous	5,370	a 50	Irrigation, stock, domestic.
S2	8	6	a 27		Spring supplying Estey	Carboniferous			Domestic and stock.
S3	8	9	29	NW	Lower Willow Spring	Cretaceous	a 4,875	a 2	Stock and travelers.
S4	8	10	22	SW	Upper Coyote Spring	Waste overlying Cretaceous	a 5,475	a 6	Stock.
S5	9	8	a 34	SW	Phillips Spring	Cretaceous	a 4,750	3	Travelers and stock.
S6	9	9	a 10	NW	Jake's Tunnel	do	a 5,200	a 3	Domestic.
S7	9	9	a 10	SW	Jake's Spring	do.(?)	a 5,250	a 4	Stock.
S8	9	9	32	NW	Milagro Spring	Cretaceous and igneous	a 5,200	Copious.	Stock and travelers.
S9	9	10	30	SW	I Bar X gravity ditch	Waste overlying Cretaceous	a 5,700	50	Stock, travelers, irrigation.
S10	10	6	23		Mound Spring No. 7	Valley fill	a 4,350	a 5	Stock.
S11	10	6	26		Mound Spring No. 25	do	a 4,350	a 2	Do.
S12	10	9	13	NE	Gravity ditch	Igneous	a 6,000	a 1	Do.
S13	11	9	35	NW	Spring on Fall's ranch	Cretaceous	a 4,700	Copious.	Irrigation.
S14	11	9½	13	NW.a	do	Igneous	a 5,350	Several.	Do.
S15	12	6	12	SW	Water immediately below surface of alkali flat.	Valley fill	4,125		
S16	12	6	14	NE	do	do	4,125		
S17	12	7	9	SW	Malpais Spring	Quaternary basalt	4,160	a 2,000(?)	Stock.
S18	13	9	5		Chosa Spring	Valley fill	4,305	Several.	Do.
S19	13	12	27	SE	Sulphur Spring	Peat accumulation	a 6,700		
S20	14	8	35	NE	Water hole	Valley fill	4,125		Irrigation and domestic.
S21	14	9	4	SE	Lomitas Springs	do	4,335	a 85	Irrigation and stock.
S22	15	8	10	SE	Water hole	do	4,080	None.	
S23	15	9	9		Seepage in arroyo	do	4,250	Small.	Domestic and stock.
S24	15	9	9		Shallow pool	do	4,250	None.	Not used.
S25	16	4	14	NW	Spring on alkali flat	do	3,940	a 3	Stock.
S26	16	9	7	NW	Seepage in arroyo	do	4,185	Small.	Do.
S27	16	11	a 2		Wooten Spring	Carboniferous	a 7,000	Abundant	Old railroad supply.
S28					Springs in James Canyon (Pecos River basin).	do	a 8,000	Abundant	Public and raiload supply at Cloudcroft.
S29	17	8	6	NE	Salt Spring	Valley fill	4,045	Small.	Stock.
S30	17	8	28	SW	Black Spring	Carboniferous (?)	4,040	a 1	Do.
S31	18	8	b 17		Salt Spring	(?)	4,050		
S32	19	5	4	NW	Water hole on alkali flat	Valley fill	3,900	None.	
S33	19	5			10-foot hole near south end of alkali flat.	do	3,890	None.	
S34	23	4	a 24		Globe Spring (Soledad Canyon)	Granitic rock (?)		2	Stock and domestic.

Substances dissolved in water (quantities expressed in parts per million).

No.	Total solids.	Radicles. Calcium (Ca).	Radicles. Magnesium (Mg).	Radicles. Sodium and potassium (Na+K).	Radicles. Carbonate (CO_3).[c]	Radicles. Sulphate (SO_4).	Radicles. Chloride (Cl).	Undetermined, including water of crystallization.	Hypothetical combinations. Calcium carbonate ($CaCO_3$).[c]	Hypothetical combinations. Calcium sulphate ($CaSO_4$).	Hypothetical combinations. Magnesium carbonate ($MgCO_3$).[c]	Hypothetical combinations. Magnesium sulphate ($MgSO_4$).	Hypothetical combinations. Magnesium chloride ($MgCl_2$).	Hypothetical combinations. Sodium sulphate (Na_2SO_4).[d]	Hypothetical combinations. Sodium chloride (NaCl).[d]	Hypothetical combinations. Total white alkali.[e]	Temperature of water.
																	°F.
S1	1,603	230	59	201	75	878	155	5	125	613	None.	294	None.	310	256	860	59
S2	2,244	240	187	164	90	1,337	133	93	150	610	None.	930	None.	239	219	1,388	....
S3	2,280	222	105	251	72	1,083	332	215	120	590	None.	521	None.	370	549	1,440	60
S4	1,258	208	47	94	104	520	144	141	174	470	None.	236	None.	None.	238	474	58.5
S5	1,938	230	85	245	119	954	204	101	199	510	None.	422	None.	365	336	1,123	64
S6	1,722	262	96	93	59	838	199	175	99	757	None.	379	76	None.	236	691	....
S7	1,625	241	86	90	89	700	195	224	149	615	None.	333	76	None.	228	637	62
S8	1,254	131	56	149	104	500	133	181	174	210	None.	277	None.	194	219	690	....
S9	948	90	59	41	114	426	100	18	190	46	None.	294	None.	235	165	694	59
S10	4,682	629	168	576	78	2,055	886	290	130	1,962	None.	837	None.	None.	1,462	2,299	....
S11	4,133	623	157	407	78	1,900	695	273	130	1,942	None.	661	94	None.	1,032	1,787	....
S12	2,000	288	74	194	102	893	244	205	170	745	None.	368	None.	109	402	879	62 ?
S13	1,897	312	59	219	149	49	186	23	248	722	None.	296	None.	301	307	904	....
S14	1,134	197	52	86	52	572	151	24	87	551	None.	230	23	None.	220	473	....
S15	....	Trace.	12,200	[f] 98,800	....	28,700	168,200	....	....	....	....	....	....	....	....	....	....
S16	....	Trace.	24,600	[g] 76,200	....	42,500	157,800	....	....	....	....	....	....	....	....	....	....
S17	5,500	739	168	[h] 748	60	2,367	1,130	288	99	2,378	None.	835	None.	36	1,864	2,735	66
S18	3,272	437	135	293	74	1,821	191	321	124	1,318	None.	674	None.	521	315	1,510	....
S19	....	230	53	[i] 48	194	482	50	....	322	344	None.	261	None.	48	82	391	....
S20	1,838	268	106	90	119	887	129	239	199	640	None.	527	None.	20	212	759	....
S21	2,602	448	120	107	89	1,409	165	264	149	1,321	None.	595	None.	None.	272	867	....
S22	8,056	601	163	1,737	74	2,719	2,118	644	124	1,874	None.	811	None.	1,111	3,495	5,417	....
S23	2,846	372	157	308	224	1,303	368	114	372	757	None.	783	None.	212	607	1,602	....
S24	259,500	None.	33,773	[j] 18,705	1,710	122,573	34,755	47,984	None.	None.	2,408	131,039	26,450	26,694	24,837	209,020	....
S25	9,413	722	184	2,266	136	2,432	3,348	325	227	2,145	None.	917	None.	274	5,524	6,715	66
S26	4,576	503	226	453	104	2,100	576	614	174	1,472	None.	1,126	None.	241	951	2,318	....
S27	1,324	272	54	48	217	486	63	....	....	....	....	....	....	....	....	....	....
S28	395	107	17	9	172	47	14	....	268	None.	16	59	None.	None.	23	82	....
S29	7,504	585	144	1,734	72	2,570	2,143	257	102	1,823	None.	716	None.	1,052	3,536	5,304	....
S30	8,970	623	187	2,060	85	2,971	2,526	518	143	1,923	None.	932	None.	1,287	4,167	6,386	....
S31	....	700	None.	[f] 3,620	180	2,970	3,600	....	....	....	....	....	....	....	....	....	....
S32	94,984	719	5,239	22,866	123	25,434	32,905	7,698	205	2,163	None.	26,071	None.	4,522	54,293	84,886	....
S33	....	610	770	[f] 18,800	210	17,570	9,400	....	....	....	....	....	....	....	....	....	....
S34	302	44	15	39	64	123	16	None.	108	4	None.	75	None.	88	27	190	....

[a] Approximate. [b] Location uncertain. [c] Bicarbonates are reported as CO_3. [d] Potassium is included with the sodium. [e] White alkali includes the sulphates and chlorides of magnesium and sodium. [f] Potassium=trace. [g] Potassium=1,200. [h] Potassium=16. [i] Potassium=4.3. [j] Potassium=851.

NOTE.—The analyses of samples on the alkali flat, SW. ¼ sec. 12 and NE. ¼ sec. 14 in T. 12 S., R. 6 E., of the Salt Spring on sec. 17, T. 18 S., R. 8 E., and 10-foot hole in T. 19 S., R. 5 E., are taken from U. S. Dept. Agr. Bur. Soils Circ. 61, 1912; the Sulphur Spring analysis was furnished by the Office of Indian Affairs; and the Wooten Spring and James Canyon analyses were furnished by the El Paso & Southwestern Railroad Co.

TABLE 3.—*Analyses of st ream waters in Tularosa Basin, N. Mex.*

Substances dissolved in water (quantities expressed in parts per million).

No.	Designation.	Total solids.	Radicles.						Undetermined, including water of crystallization.
			Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate (CO_3).	Sulphate (SO_4).	Chloride (Cl).	
1	Bonita Creek	244	46	8	19	41	97	14	
2	Three Rivers	1,619	334	45	106	125	772	a 170	
3	Tularosa River		120	34	b 48	149	229	39	
4	....do	1,392	208	65	109	104	716	75	115
5	Fresnal Creek	1,090	167	60	c 101	128	436	131	
6	La Luz and Fresnal creeks	1,700	230	104	147	104	799	226	90
7	Alamo Canyon	404	84	26	9	102	133	17	33
8	Salt Creek		650	420	d 7,000		3,620	10,800	
9	....do	34,348	814	694	8,262	75	3,788	13,295	7,420
10	....do	66,652	827	2,467	15,851	112	5,421	28,916	13,058
11	Sacramento River	240	53	20	34	84	58	9.3	None.

a Potassium=7.9. b Potassium=4.3. c Potassium=5.5. d Potassium=trace.

No.	Designation.	Hypothetical combinations.							
		Calcium carbonate ($CaCO_3$).[a]	Calcium sulphate ($CaSO_4$).	Magnesium carbonate ($MgCO_3$).[a]	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Sodium sulphate (Na_2SO_4).[b]	Sodium chloride (NaCl).[b]	Total white alkali.[c]
1	Bonita Creek	68	65	None.	40	None.	28	24	92
2	Three Rivers	208	853	None.	213	8	None.	270	491
3	Tularosa River	240	75	None.	168	None.	63	66	297
4	....do	174	470	None.	324	None.	186	124	634
5	Fresnal Creek	214	278	None.	296	None.	4	231	531
6	La Luz and Fresnal creeks	174	544	None.	520	None.	None.	373	893
7	Alamo Canyon	170	54	None.	119	6.5	None.	22	147
8	Salt Creek								
9	....do	125	2,597	None.	2,451	786	None.	20,969	24,206
10	....do	188	2,553	None.	4,535	6,093	None.	40,225	50,853
11	Sacramento River	132	None.	6.9	None.	None.	86	15	101

a Bicarbonates are reported as CO_3.

b Potassium is included with the sodium.

c White alkali includes the sulphates and chlorides of magnesium and sodium.

1. Sample taken from railroad pipe line at Carrizozo in spring of 1910. Analyses furnished by El Paso & Southwestern Railroad. Bonita Creek is outside the Tularosa Basin but the water is used extensively within the basin.
2. Sample taken from old pipe line at Three Rivers station. Three Rivers is supplied from springs. Analyses furnished by El Paso & Southwestern Railroad.
3. Sample taken from hydrant at Mescalero Agency. Analysis furnished by Office of Indian Affairs.
4. Sample taken at Tularosa Sept. 23, 1911.
5. Sample taken from pipe line at El Valle. Analyses furnished by El Paso & Southwestern Railroad.
6. Sample taken at La Luz railroad station Sept. 16, 1911.
7. Analyses furnished by El Paso & Southwestern Railroad.
8. Sample taken at road crossing in NE. ¼ sec. 15, T. 12 S., R. 6 E., in spring of 1911. Analyses made by F. H. Carpenter, Bureau of Soils, Department of Agriculture, and reported in Bur. Soils Circ. 61, p. 6, 1912.
9. Sample taken at road crossing in NE. ¼ sec. 15, T. 12 S., R. 6 E., Nov. 14, 1911.
10. Sample taken at road crossing in NE. ¼ sec. 19, T. 13 S., R. 6 E., Nov. 15, 1911.
11. Sample taken at tap of A. E. Kean, Orogrande waterworks, Dec. 3, 1912.

TABLE 4.—*Analyses of certain well waters in areas north of Tularoso Basin, N. Mex.*

[All analyses furnished by the El Paso & Southwestern Railroad Co.]

No.	Location.	Depth of well.	Depth from which sample was obtained.	Substances dissolved in water (quantities expressed in parts per million).																
					Radicles.						Hypothetical combinations.									
				Total solids.	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate (CO_3).[a]	Sulphate (SO_4).	Chloride (Cl).	Calcium carbonate ($CaCO_3$).[a]	Calcium sulphate ($CaSO_4$).	Magnesium carbonate ($MgCO_3$).[a]	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Sodium carbonate (Na_2CO_3).[a]	Sodium sulphate (Na_2SO_4).[b]	Sodium chloride (NaCl).[b]	Total white alkali.[c]	Total calcium and magnesium salts (incrusting).	Total sodium and potassium salts. (nonincrusting).
		Feet.	*Feet.*																	
1	Pastura	857	638	2,522	582	91	43	79	1,594	90	132	1,796	None.	410	33	None.	None.	108	551		
2	do	341	200+	2,972	624	125	88	186	1,772	72											
3	Tony	870	800+	2,775	575	124	19	86	1,741	30	143	1,719	None.	616	None.	None.	None.	49	665		
4	Epris	1,355	829	2,807																2,678	129
5	do	1,355	1,330	239,000																11,000	228,000
6	Gillespie			1,972																1,671	301
7	Ricardo	863+	300	3,775																2,671	
8	do	863+	510	5,191																3,833	
9	do	863+	595	324																180	
10	Duran	1,139		3,139	583	139	75	29	2,034	17											
11	Varney	850		2,323	598	103	85	107	1,775	48	179	1,786	None.	509	None.	None.	162	80	751		

a Bicarbonates are reported as CO_3.
b Potassium is included with the sodium.
c White alkali includes the sulphates and chlorides of magnesium and sodium.

1, 2, 4, 5, 10. Wells of El Paso & Southwestern Railroad.
3. Well of El Paso & Southwestern Railroad at Vaughn passing track.
6–9. Wells of Atchison, Topeka & Santa Fe Railroad.
11. Well of El Paso & Southwestern Railroad at milepost 199.

TABLE 5.—*Analyses of certain well waters in areas south of Tularosa Basin, N. Mex.*

No.	Location.	Depth of well.	Depth of water table below surface.	Substances dissolved in water (quantities expressed in parts per million).														
				Total solids.	Radicles.						Hypothetical combinations.							
					Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate (CO_3).[a]	Sulphate (SO_4).	Chloride (Cl).	Calcium carbonate ($CaCO_3$).[a]	Calcium sulphate ($CaSO_4$).	Magnesium carbonate ($MgCO_3$).[a]	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Sodium carbonate (Na_2CO_3).[a b]	Sodium sulphate (Na_2SO_4).[b]	Sodium chloride (NaCl).[b]	Total white alkali.[c]
		Feet.	Feet																
1	Hitt ranch	339	319	502	53	18	102	92	147	97	133	None.	6	82	None.	None.	121	160	363
2	Newman	332	272	530	40	21	106	54	53	193	90	14	None.	55	40	None.	None.	269	364
3	El Paso	600	193	312	40	13	d 62	......	53	32	......	......	......	......	......	......	......	......	......
4	Fort Bliss	249 and 410	169 and 190	329	38	18	52	119	52	22	......	......	......	......	......	......	......	......	......
5	....do	249 and 410	169 and 190	292	34	15	49	115	30	17	84	None.	53	None.	None.	47	45	28	73
6	....do	313 and 319	......	316	33	14	e 57	120	53	13	......	......	......	......	......	......	......	......	......
7	El Paso	398	19	356	32	10	e 103	......	71	56	......	......	......	......	......	......	......	......	......

a Bicarbonates are reported as CO_3.
b Potassium is included with the sodium.
c White alkali includes the sulphates and chlorides of magnesium and sodium.
d Potassium=7.
e Potassium=9.

1. Owned by E. O. Lochausen. East well. Temperature of water, 76¼° F.
2, 4, 5. Railroad wells. Analyses furnished by El Paso & Southwestern Railroad.
3. El Paso waterworks well No. 18. Analysis furnished by El Paso water department.
6. Two Army post wells. Analysis by Arthur Goss, New Mexico Agricultural Experiment Station. Reported in U. S. Geol. Survey Geol. Atlas U. S., El Paso folio (No. 166), p. 11, 1909.
7. Well of El Paso Milling Co. in Rio Grande Valley. Shallow water cased out. Analysis furnished by El Paso water department.

TABLE 6.—*Analyses of soils in Tularosa Basin, N. Mex.*

No.	Location.					Designation.	Physiographic situation.	Altitude above sea level.	Depth to underground water.	Vegetation.	Depth of soil analyzed.	Physical character of soil.
	Township, S.	Range, E.	Section.	Quarter.	Position on quarter.			*Feet.*	*Feet.*		*Feet.*	
A1	11	7	21	NW	Near northwest corner (?).	....	Gently southward sloping lowland.	4,200	*a* 25	Chamiso and alkali bushes.	0–1 1–2	Dark brown loam changing to pale yellow. Pale yellow loam becoming very hard.
A2	11	7	31	SW	....	....	do	4,155	*a* 10	Chiefly chamiso	0–1 1–5	Reddish loam. Do.
A3	11	8	27	SW	Near northeast corner.	Lee Short's ranch	Gently southward sloping lowland. Near lava bed.	4,308	62	Mesquite, chamiso, and grass	0–1 1–4	Brownish loam. Whitish, gypseous loam.
A4	12	6	15	NE	do	....	Plain above level of Salt Creek Valley and alkali flat depressions.	4,120	*a* 15	Creosote bush; also mesquite and chamiso.	0–1 1–3	Light-brown loam; slightly gravelly. Do.
A5	12	6	15	NW	Near northwest corner.	Salt Creek	Valley of Salt Creek; 3 feet above water in creek.	4,095	2.8	None	0–1 1–3	Gravelly loam. Do.
A6	12	7	8	SE	Near north margin	Malpais Spring	Low plain, about ¼ mile from spring.	4,160	1.3	Alkali bushes	0–1 1–2	Gray, granular soil. Do.
A7	12	7	8	SW	do	....	Low plain	4,155	3.0	do	0–1 1–3	Brownish granular soil. Brownish clayey soil to 3 feet; white material to 4 feet; white hardpan at bottom.
A8	12	7	9	SW	Near northwest corner.	Malpais Spring	Near spring	4,160	*a* 2	do	Surface crust.	Reddish soil and alkali crust.
A9	12	8	10	E	....	....	....	....	....	....	....	
A10	13	6	19	NW	do	....	Low plain but above level of Salt Creek.	4,058	*a* 23	Chamiso	0–1 1–2	Light-gray powdery soil. Light-gray powdery soil; hardpan at 2 feet.
A11	13	6	21	NW	Near road	....	do	4,065	*a* 25	Chamiso and grass.	0–1 1–5	Light-gray powdery soil. Do.
A12	13	6	21	SW	....	....	Alkali flat	4,030	*a* 2	None	0–1 1–5	

a Estimated.

No.	Water-soluble portion of soil; constituents in percentages of total soil.																			
	Total soluble solids.	Radicles.							Undetermined, including water of crystallization.	Hypothetical combinations.										
		Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate (CO_3).	Sulphate (SO_4).	Chloride (Cl).	Nitrate (NO_3).		Calcium carbonate ($CaCO_3$).	Calcium sulphate ($CaSO_4$).	Calcium chloride ($CaCl_2$).	Magnesium carbonate ($MgCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Sodium carbonate (Na_2CO_3).[a]	Sodium sulphate (Na_2SO_4).[a]	Sodium chloride (NaCl).[a]	Sodium nitrate ($NaNO_3$).[a]	Total white alkali.[b]
A1	1.91	0.31	0.04	0.14	0.01	0.89	0.22	None.	0.30	0.02	1.02	None.	None.	0.21	None.	None.	None.	0.36	None.	0.57
	2.20	.36	.05	.24	.01	.90	.46	None.	.18	.02	1.19	None.	None.	.08	0.012	None.	None.	.61	None.	.81
A2	4.00	.31	.19	.52	.01	1.30	.94	Trace.	.73	.02	1.04	None.	None.	.71	.19	0.03	None.	1.32	Trace.	2.22
	2.52	.29	.09	.31	.01	1.04	.48	Trace.	.30	.02	.97	None.	None.	.45	None.	None.	None.	.79	Trace.	1.24
A3	.36	.06	.02	.01	.01	.20	.02	None.	.04	.02	.19	None.	None.	.09	None.	None.	None.	.03	None.	.12
	1.51	.34	.03	.05	.01	.88	.08	None.	.12	.02	1.14	None.	None.	.09	None.	None.	None.	.13	None.	.22
A4	.61	.12	.01	.02	.01	.30	.03	None.	.12	.02	.39	None.	None.	.03	None.	None.	None.	.05	None.	.08
	1.41	.31	.02	.01	.01	.77	.02	None.	.27	.02	1.02	None.	None.	.06	None.	None.	None.	.03	None.	.09
A5	2.76	.31	.07	.54	.01	1.00	.83	None.	None.	.02	1.04	None.	None.	.33	None.	None.	None.	1.37	None.	1.70
	2.36	.16	.07	.53	.01	.64	.81	None.	.14	.02	.53	None.	None.	.33	None.	None.	None.	1.34	None.	1.67
A6	1.97	.28	.07	.21	.01	.91	.32	None.	.17	.02	.92	None.	None.	.33	None.	None.	None.	.53	None.	.86
	1.57	.22	.03	.16	.01	.74	.15	None.	.26	.02	.73	None.	None.	.15	None.	None.	0.16	.25	None.	.56
A7	5.36	.40	.24	.79	.01	1.33	1.61	None.	.98	.02	1.34	None.	None.	.50	.52	None.	None.	2.01	None.	3.03
	3.50	.36	.14	.51	.01	1.15	1.00	None.	.33	.02	1.21	None.	None.	.36	.28	None.	None.	1.30	None.	1.94
A8	16.52	1.20	.57	3.02	.02	3.64	5.71	None.	2.36	.05	4.01	None.	None.	1.01	1.42	None.	None.	7.67	None.	10.10
A9	.36	.10	.09	.01	.08	.14	.02	....	None.	.14	.15	None.	None.	.04	None.	None.	None.	.03	....	.07
A10	1.78	.31	.03	.18	.01	.94	.16	None.	.13	.02	1.04	None.	None.	.15	None.	None.	.18	.26	None.	.59
	1.72	.32	.02	.14	.01	.88	.17	None.	.18	.02	1.07	None.	None.	.08	None.	None.	.09	.28	None.	.45
A11	1.26	.29	.02	.03	.01	.78	.02	None.	.11	.02	.97	None.	None.	.09	None.	None.	.05	.03	None.	.17
	1.23	.30	.03	.01	.01	.82	.02	None.	.04	.02	1.00	None.	None.	.14	None.	None.	None.	.03	None.	.17
A12	4.78	.34	.05	1.23	.01	1.27	1.72	None.	.16	.02	1.14	None.	None.	.27	None.	None.	.37	2.84	None.	3.48
	3.16	.12	.03	1.00	.01	.65	1.35	None.	None.	.02	.39	None.	None.	.15	None.	None.	.37	2.23	None.	2.75

[a] Potassium is included with the sodium.
[b] White alkali is calculated as the sum of all the soluble salts except calcium sulphate and the carbonates and bicarbonates of calcium, magnesium, and sodium.

TABLE 6.—*Analyses of soils in Tularosa Basin, N. Mex.*—Continued.

No.	Location.					Designation.	Physiographic situation.	Altitude above sea level.	Depth to underground water.	Vegetation.	Depth of soil analyzed.	Physical character of soil.
	Township, S.	Range, E.	Section.	Quarter.	Position on quarter.			*Feet.*	*Feet.*		*Feet.*	
A13	13	8	2	NW								
A14	13	8	8	SE	Near road; ¼ mile southeast of ranch.	Black Lake ranch	Near arroyo	4,185	17	Mesquite; also other bushes and grass.	0–1 1–4	Brown sandy loam. Light gray gypseous soil.
A15	13	8	34	NW	Northeast corner		Plain	4,165	*a* 15	Chamiso and grass.	0–1 1–5	Light brown loam. Light gray loam.
A16	13	9	11		East of railroad							
A17	13	9	20	NE	North of house	Al. Gray ranch	Plain	4,280	*a* 8	Chamiso and alkali bushes.	0–1 1–5	Dark brown loam. Same to 1.5 feet, below which is light-gray gypseous soil.
A18	13	9	20	NE	Center of peach orchard	do	do	4,280				
A19	13	9	21									
A20	13	9	32									
A21	14	8	13	NW	Northwest of house	Hill Bros. ranch	do	4,195	28	Chamiso	0–1 1–5	Gray gypseous soil. Do.
A22	14	8	13	NW		do	do	4,195	28		Surface layer.	Black soil of an alkali spot.
A23	14	8	25	SW	Near well		do	4,170	13	Chamiso; also other bushes.	0–1 1–4	Brownish-gray gypseous soil. Do.
A24	14	9	14	NE	Peach orchard	M. W. Votaw's ranch	do	4,340	90			
A25	14	9	17	NE	Middle north margin	A. Bailey's ranch	do	4,270	22	Mesquite and grass	0–1 1–5	Brown "adobe." Same to 1½ feet, below which is gray gypseous soil.
A26	14	9	28	NW	Northeast corner	H. W. Purday's ranch	Upland; near arroyo	4,310	45	Mesquite, chamiso, and grass.	0–1 1–3	Light gray gypseous soil. Do.
A27	15	8	1	NW	80 feet southeast of wells.	D. W. Shoemaker's ranch.	Arroyo	4,128	6	Alkali bushes	0–1 1–6	Dark brown loam to ½ foot, below which is sand. Yellow sand.
A28	15	8	10	SE			Gypsum sands, near edge.	4,110	*a* 25	Various plants	Near surface.	Impure gypsum sand.
A29	15	9	7	W	½ mile east of Cerrito Tularosa.		Plain	4,175	*a* 25	Chamiso	0–1 1–4 4–5	Gypseous soil. Do. Do.

a Estimated.

No.	Water-soluble portion of soil; constituents in percentages of total soil.																			
	Total soluble solids.	Radicles.							Undetermined, including water of crystallization.	Hypothetical combinations.										Total white alkali.
		Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate (CO_3).	Sulphate (SO_4).	Chloride (Cl).	Nitrate (NO_3).		Calcium carbonate ($CaCO_3$).	Calcium sulphate ($CaSO_4$).	Calcium chloride ($CaCl_2$).	Magnesium carbonate ($MgCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Sodium carbonate (Na_2CO_3).	Sodium sulphate (Na_2SO_4).	Sodium chloride (NaCl).	Sodium nitrate ($NaNO_3$).	
A13	0.41	0.11	0.01	0.02	0.11	0.14	0.01	....	0.01	0.18	0.12	None.	None.	0.05	None.	None.	0.03	0.02	....	0.10
A14	.65	.11	.02	.05	.01	.30	.08	None.	.08	.02	.36	None.	None.	.06	None.	None.	None.	.13	None.	.19
	1.60	.33	.02	.16	.01	.84	.24	Trace.	None.	.02	1.09	None.	None.	.09	None.	None.	None.	.40	Trace.	.49
A15	1.24	.26	.02	.05	.01	.68	.07	None.	.15	.02	.87	None.	None.	.09	None	None.	None.	.12	None.	.21
	1.52	.34	.02	.06	.01	.85	.10	None.	.14	.02	1.11	None.	None.	.09	None.	None.	None.	.16	None.	.25
A16	2.29	.60	.01	.02	.09	1.33	.04	....	.19	.16	1.82	None.	None.	.06	None.	None.	None.	.06	....	.12
A17	2.66	.27	.04	.49	.01	.78	.76	Trace.	.30	.02	.90	None.	None.	.18	None.	None.	None.	1.25	Trace.	1.43
	1.72	.29	.03	.11	.01	.79	.17	None.	.28	.02	.97	None.	None.	.15	None.	None.	None.	.28	None.	.43
A18	2.27	.51	.04	.06	.08	1.31	.05	....	.22	.14	1.56	None.	None.	.18	None.	None.	.09	.08	....	.35
A19	1.58	.40	.01	.02	.09	.89	.01	....	.15	.16	1.14	None.	None.	.08	None.	None.	.04	.02	....	.14
A20	1.99	.49	.01	.05	.09	1.64	.02	....	.16	.16	1.46	None.	None.	.06	None.	None.	.12	.03	....	.21
A21	1.73	.27	.02	.11	.01	.76	.17	Trace.	.39	.02	.92	None.	None.	.12	None.	None.	None.	.28	Trace.	.40
	1.85	.27	.06	.11	.01	.89	.17	Trace.	.34	.02	.92	None.	None.	.30	None.	None.	None.	.28	Trace.	.58
A22	a 15.03	1.00	.67	a 2.44	.01	1.07	6.95	Heavy.	2.62	.02	1.51	1.56	None.	None.	2.62	None.	None.	6.20	Heavy.	10.88
A23	1.46	.28	.03	.06	.01	.77	.11	None.	.20	.02	.92	None.	None.	.15	None.	None.	None.	.17	None.	.32
	1.51	.27	.03	.10	.01	.89	.14	None.	.07	.02	.92	None.	None.	.15	None.	None.	.16	.19	None.	.50
A24	2.20	.57	.01	.02	.08	1.30	.01	....	.21	.14	1.72	None.	None.	.07	None.	None.	.04	.02	....	.13
A25	1.80	.29	.02	.18	.01	.86	.18	Trace.	.26	.02	.94	None.	None.	.09	None.	None.	.19	.30	None.	.58
	1.70	.27	.03	.10	.01	.76	.15	Trace.	.38	.02	.90	None.	None.	.15	None.	None.	None.	.25	None.	.40
A26	1.17	.28	.01	.06	.01	.77	.02	None.	.02	.02	.92	None.	None.	.06	None.	None.	.11	.05	None.	.22
	1.48	.27	.04	.10	.01	.84	.08	None.	.14	.02	.87	None.	None.	.18	None.	None.	.14	.14	None.	.46
A27	5.19	.26	.37	.57	.01	2.45	.63	None.	.90	.02	.87	None.	None.	1.86	None.	None.	.50	1.04	None.	3.40
	1.36	.27	.07	.03	.01	.93	.05	None.	None.	.02	.90	None.	None.	.36	None.	None.	None.	.08	None.	.44
A28	1.00	.27	.01	Trace.	.01	.68	Trace.	None.	.03	.02	.92	None.	None.	.03	None.	None.	None.	Trace.	None.	.03
A29	1.43	.28	.02	.08	.01	.82	.08	None.	.14	.02	.92	None.	None.	.12	None.	None.	.11	.13	None.	.36
	1.76	.26	.04	.20	.01	.96	.19	None.	.10	.02	.87	None.	None.	.21	None.	None.	.27	.30	None.	.78
	2.03	.29	.05	.25	.01	1.00	.28	None.	.15	.02	.97	None.	None.	.24	None.	None.	.18	.47	None.	.89

a The solids were deliquescent and increased from 15.03 to 16.12 on standing in air 24 hours. By analysis, Na=1.48, K=0.27, and KCl=0.50.

TABLE 6.—*Analyses of soils in Tularosa Basin, N. Mex.*—Continued.

No.	Location.					Designation.	Physiographic situation.	Altitude above sea level.	Depth to underground water.	Vegetation.	Depth of soil analyzed.	Physical character of soil.
	Township, S.	Range, E.	Section.	Quarter.	Position on quarter.							
								Feet.	*Feet.*		*Feet.*	
A30	16	9	5	NE	West margin of southwest quarter.	B. Hassett's ranch	Middle of arroyo	4,250	*a* 25	Grass	0 -1 1 -4	Red gypseous loam. Do.
A31	16	9	6	SE	Near well	W. F. Thompson's ranch.	do	4,241	11	Mesquite and alkali bushes.	0 -1 1 -3 3 -4	Dark reddish clay loam. Do. White material.
A32	16	9	6	SE	About $\frac{1}{10}$ mile northwest of well.	do	Upland; 250 feet from edge of arroyo.	4,255	*a* 25	Mesquite, chamiso, and grass.	0 -1 1 -4	Light-gray gypseous soil. Same to 3 feet, below which soil is redder and more clayey.
A33	16	9	7	NW	Near spring		Arroyo	4,185	3.8	Alkali bushes and salt grass.	0 -1 1 -4 4 -6	Brownish loam. Do. Do.
A34	16	9	25	NW	Near northeast corner.	Fred. Le Min's ranch	Plain	4,292	39	Mesquite and chamiso.	0 -1 1 -4	Do. Do.
A35	17	9	2	SW	Near northwest corner.	H. W. Schofield's ranch.	do	4,210	*a* 23	Alkali bushes (chiefly).	0 -1 1 -2.5	Do. Gypseous loam.
A36	17	9	2	SW		do	do	4,210	*a* 25	do	Surface layer.	Black soil of an alkali spot.
A37	17	9	2	SW	At new well	do	do	4,210	*a* 25	Mesquite and chamiso.	0 -1.5 1.5-5	Brownish loam. Gypseous soil.
A38	17	9	3	NW	West of house	Simeon Bowden's ranch.	Upland; near depression.	4,190	30	Chamiso and mesquite.	0 -1 1 -4	Do. Do.
A39	17	9	3	NW	do	do	In depression; near margin.	4,180	20	Alkali bushes and chamiso.	0 -1 1 -4 4 -5	Do. Do. White material.
A40	17	9	3	NW	do	do	Middle of depression	4,180	20	Mesquite	0 -1 1 -2 2 -5	Reddish adobe. Do. Do.
A41	17	9	15	NE	Near middle of east margin.	H. T. Patty's ranch	Plain	4,160	31	Mesquite and chamiso.	0 -1 1 -4	Do. Do.
A42	18	5	34	SW	Near camp house	Eddy's prospect	Alkali flat	3,900	2.1	None	Surface layer. 2.5	White crystalline material. Do.
A43	19	6	23	NW			Plain	3,970	*a* 60	Chamiso (chiefly).	0 -1 1 -5	Sandy loam. Do.

a Estimated.

Water-soluble portion of soil; constituents in percentages of total soil.

No.	Total soluble solids.	Radicles. Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate (CO_3).	Sulphate (SO_4).	Chloride (Cl).	Nitrate (NO_3).	Undetermined, including water of crystallization.	Hypothetical combinations. Calcium carbonate ($CaCO_3$).	Calcium sulphate ($CaSO_4$).	Calcium chloride ($CaCl_2$).	Magnesium carbonate ($MgCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Sodium carbonate (Na_2CO_3).	Sodium sulphate (Na_2SO_4).	Sodium chloride (NaCl).	Sodium nitrate ($NaNO_3$).	Total white alkali.
A30	0.75	0.17	0.02	0.01	0.01	0.49	0.01	None.	0.04	0.02	0.56	None.	None.	0.12	None.	None.	None.	0.02	None.	0.14
	1.40	.24	.07	.04	.01	.88	.01	None.	.15	.02	.75	None.	None.	.33	None.	None.	0.12	.02	None.	.47
A31	2.65	.29	.11	.29	.01	1.12	.48	None.	.35	.02	.94	None.	None.	.57	None.	None.	None.	.77	None.	1.34
	2.39	.26	.09	.31	.01	1.22	.35	None.	.13	.02	.87	None.	None.	.45	None.	None.	.37	.54	None.	1.36
	1.81	.27	.05	.11	.01	.89	.11	None.	.37	.02	.87	None.	None.	.24	None.	None.	.14	.18	None.	.56
A32	1.19	.26	.02	.04	.01	.77	.01	None.	.08	.02	.87	None.	None.	.09	None.	None.	.12	.02	None.	.23
	1.87	.26	.03	.11	.01	.86	.07	None.	.53	.02	.87	None.	None.	.15	None.	None.	.20	.11	None.	.46
A33	3.30	.28	.19	.37	.01	1.39	.65	None.	.41	.02	.92	None.	None.	.93	None.	None.	None.	1.02	None.	1.95
	1.35	.24	.02	.13	.01	.82	.07	None.	.06	.02	.78	None.	None.	.12	None.	None.	.25	.11	None.	.48
	.95	.24	.02	.01	.01	.61	.01	None.	.05	.02	.75	None.	None.	.12	None.	None.	None.	.02	None.	.14
A34	.36	.04	.02	.04	.01	.16	.07	None.	.02	.02	.12	None.	None.	.09	None.	None.	None.	.11	None.	.20
	1.66	.26	.05	.14	.01	.89	.16	None.	.15	.02	.87	None.	None.	.24	None.	None.	.12	.26	None.	.62
A35	2.49	.16	.05	.58	.02	.36	1.02	None.	.30	.04	.51	None.	None.	None.	0.19	0.04	None.	1.45	None.	1.64
	3.02	.31	.06	.45	.01	.96	.69	Trace.	.54	.02	1.04	None.	None.	.29	None.	.03	None.	1.14	Trace.	1.43
A36	8.66	.80	.39	1.10	.01	1.24	3.18	0.29	1.65	.02	1.76	0.79	None.	None.	1.51	None.	None.	2.50	0.43	5.23
A37	1.22	.28	.02	None.	.01	.74	None.	None.	.15	.02	.92	None.	None.	.12	None.	None.	None.	None.	None.	.12
	2.15	.36	.05	.16	.01	1.04	.24	None.	.29	[a] .02	[a] 1.21	None.	None.	.24	None.	.01	None.	.40	None.	.64
A38	1.89	.28	.07	.13	.01	1.01	.13	None.	.26	.02	.92	None.	None.	.33	None.	None.	.14	.21	None.	.68
	2.01	.27	.08	.20	.01	1.06	.21	None.	.20	.02	.90	None.	None.	.39	None.	None.	.16	.35	None.	.90
A39	2.28	.28	.08	.25	.01	1.12	.27	None.	.27	.02	.92	None.	None.	.39	None.	None.	.23	.45	None.	1.07
	2.32	.29	.08	.28	.01	1.14	.30	None.	.22	.02	.94	None.	None.	.39	None.	None.	.25	.50	None.	1.14
	3.08	.29	.05	.53	.01	1.69	.23	None.	.28	.02	.94	None.	None.	.27	None.	None.	1.20	.38	None.	1.85
A40	.74	.11	.03	.01	.01	.37	.01	None.	.20	.02	.36	None.	None.	.15	None.	.01	None.	.02	None.	.17
	1.29	.23	.04	Trace.	.01	.70	Trace.	None.	.30	.02	.75	None.	None.	.21	None.	None.	None.	.01	None.	.22
	1.43	.28	.05	None.	.01	.86	None.	None.	.23	.02	.92	None.	None.	.27	None.	None.	None.	None.	None.	.27
A41	2.35	.34	.08	.27	.01	.76	.65	None.	.24	.02	1.07	None.	None.	None.	.31	None.	None.	.69	None.	1.00
	1.99	.15	.08	.23	.01	.34	.60	Trace.	.58	.02	.48	None.	None.	None.	.33	None.	None.	.58	Trace.	.91
A42	62.95	.49	.40	18.43	.02	40.27	.60	None.	2.74	.05	1.60	None.	None.	1.98	None.	.01	55.61	.99	None.	58.58
	(b)	Trace.	Trace.	(b)	Trace.	(b)	Trace.	None.	....	....	....	....	....	....	....	....	(b)	....	....	....
A43	1.31	.30	Trace.	.02	.01	.76	.01	None.	.21	.02	1.00	None.	None.	.01	None.	None.	.05	.02	None.	.08
	1.23	.31	.01	.02	.01	.79	.01	None.	.08	.02	1.04	None.	None.	.03	None.	None.	.05	.02	None.	.10

[a] Total calcium carbonate=12.55 per cent; total calcium sulphate=60 per cent.

[b] Sample is practically pure sodium sulphate.

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