Series 1933, No. 8 Issued August 1937

UNITED STATES DEPARTMENT OF AGRICULTURE

Soil Survey

of

The Barstow Area, California

By

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Bureau of Chemistry and Soils

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University of California Agricultural Experiment Station

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SOIL SURVEY OF THE BARSTOW AREA, CALIFORNIA[1]

By R. EARL STORIE, in Charge, and D. F. TRUSSELL, University of California

AREA SURVEYED

The Barstow area occupies a part of the Mojave River Valley in the southeastern part of California (fig. 1). It lies wholly in the Mojave Desert and is situated approximately in the center of San Bernardino County, about 100 miles northeast of Los Angeles and about 40 miles north of San Bernardino. The area follows Mojave River from a point where it joins with the Victorville area (*2*),[2] about 1 mile north of Oro Grande, to a point about 5 miles east of Harvard, on the Union Pacific Railroad, and Newberry, on the Atchison, Topeka & Santa Fe Railway—a distance of about 50 miles. The width of the area ranges from 1½ to 13 miles.

FIGURE 1.—Sketch map showing location of the Barstow area, California.

The area covered by this survey widens a few miles west of Barstow to include Hinkley Valley and a small part of Stoddard Valley directly south of Lenwood. Between Barstow and Daggett the area is about a mile and a half wide, and east of Daggett it broadens to a width ranging from 6 to 13 miles to include the lower Mojave Valley. This section is bounded (approximately) on the north by the Union Pacific Railroad and on the south by the Santa Fe. The eastern boundary of the area is about a mile west of Cady Mountains. The total area covered by the survey is 285 square miles, or 182,400 acres.

The area includes the recent flood plains of Mojave River and the alluvial terraces bordering it, particularly those of Hinkley Valley and lower Mojave Valley. Fairly recent and old alluvial fans extend downward from the desert mountains which flank the valley at a distance ranging from 2 to 8 miles. The recent alluvial fans have a slope ranging from 100 to 400 feet to the mile, and most of the older fans have a sloping terracelike relief and are severely

[1] The field work of this survey was carried on by the Division of Soil Technology of the University of California. A part of the expense was borne by the Division of Water Resources of the State Department of Public Works. Much of the information set forth was obtained from a number of local residents and others. Walker Jones, deputy horticultural commissioner of San Bernardino County, supplied figures on the acreage of alfalfa; Dix Van Dyke and the Barstow Printer supplied valuable historical data; and additional information was given by Miss Waterman of Barstow and F. E. Lucking, division superintendent of the Southern Sierra Power Co. The State of California Division of Water Resources supplied maps of the area and data they collected regarding water-table conditions in the Mohave Basin.

[2] Italic numbers in parentheses refer to Literature Cited, p. 46.

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eroded. The recent flood-plain deposits of Mojave River range from one-half to 1 mile in width. They comprise areas of riverwash and soils of the Cajon and Foster series. The younger alluvial fan and terrace areas are occupied by soils of the Hesperia and Daggett series, with the Rosamond soils occurring on the low flat areas such as those bordering Troy Dry Lake. The older and more elevated fans and terraces, some of which are eroded, are occupied by soils of the Stacy, Adelanto, Laveen, Mohave,[3] and Tijeras series.

Troy Dry Lake and Calico Dry Lake occupy the lowest parts of closed basins that receive drainage waters following storms, but most of the time they present a flat hard surface devoid of vegetation. They are shown on the soil map as playa deposits.

Sand dunes occur in a number of places paralleling the channel of Mojave River, a well-defined belt of them extending across lower Mojave Valley from a point about 4 miles southeast of Yermo nearly to Newberry. Some of the dunes rise to a height of 25 feet above the level of the plain. The eastern edge of this belt is rather sharply defined, but the western edge is more or less irregular. Another dune area lies northeast of Newberry, bordering Troy Dry Lake. In the dune areas in lower Mojave Valley there is a growth of mesquite, about which wind-blown sand has collected.

In only a few places does the area include any mountainous land. This is shown on the map as rough stony land and rough broken land.

West of Bryman the valley of Mojave River is bordered by a nearly perpendicular cliff 100 or more feet high and east of that town by steep fans and old eroded alluvial terraces that extend back to Granite Mountains which lie southeast of the area. The elevation at the point where Mojave River enters the area is about 2,600 feet above sea level and where it leaves, in the vicinity of Harvard, about 1,800 feet. The river has a fall of about 15 or 20 feet to a mile. Newberry Mountain, a part of which is included in this area, has an elevation of about 3,500 feet above sea level and is the highest point.

Mojave River rises in the San Bernardino Mountains about 30 miles south of the southernmost part of the area, at an elevation of 6,000 or 7,000 feet. It flows throughout the year at Oro Grande, near which it enters the Barstow area, but it disappears in the vicinity of Hodge into the sandy stream bed. It reappears and flows for a short distance in the vicinity of Barstow and again about 2 miles southwest of Harvard. No doubt these reappearances are due to the presence of underlying strata which force the flow to the surface (7). The Mojave has been termed an "upside-down river" because of this subterranean flow. Throughout its entire length, the river bed is occupied by coarse sandy deposits which are blown into sand dunes very readily. Only in times of flood does surface water pass Barstow, and only during exceptional floods does water discharge into Soda Lake, a dry saline drainage basin of the river situated about 60 miles northeast of Barstow. Surface run-off from the alluvial fans and valleys is infrequent, owing to the low rainfall of this section.

[3] The soil series name "Mohave" was established and named in the soil survey of the Middle Gila Valley area, Arizona, in 1917. It is not the same as the local name, "Mojave," as applied to the river and valley in this area.

Creosotebush (*Covillea tridentata*)[4] is the most common plant in this area, as it is throughout the Mojave Desert region. It grows on all the alluvial fans and terraces, where the soils are well drained, of light texture, and free of alkaline or saline salts. Associated with creosotebush is a small shrub known as bur-sage (*Franseria dumosa*). These two plants comprise the native vegetation on the Hesperia, Daggett, Stacy, Laveen, Mohave, and Tijeras soils. Creosotebush is of smaller size on the Mohave and Tijeras soils than on the others. The Mohave and Tijeras soils are the most maturely weathered soils of the area. The Tijeras soils have a hardpan at a slight depth. In washes on the deeper alluvial fan soils, where runoff is more frequent, creosotebush grows larger, in many places attaining a height ranging from 6 to 8 feet. Mormon tea (*Ephedra californica*), and buckwheat-brush, locally known as cigarette plant, (*Eriogonum inflatum*) are associated with creosotebush in many places, but are not of such wide occurrence. Mormon tea was observed growing on the sandy soils of the valley where there has been some movement by the wind.

Water-loving plants, including screwbean mesquite (*Prosopis odorata*), common mesquite (*P. juliflora*), rabbitbrush (*Chrysothamnus mohavensis*), saltgrass (*Distichlis spicata*), willows, and cottonwood, grow on soils where the water table is close to the surface, particularly on the Cajon and Foster soils. Common mesquite also grows on the dune phases of both the Cajon and Laveen soils, and saltgrass is prevalent on soils where there is moisture and some "alkali."[5] Several kinds of saltbush grow on the edges of playas where the soil is of heavier texture and on soils containing salts. These include shadscale, or spiny saltbush (*Atriplex confertifolia*) and cattle spinach (*A. polycarpa*). The saltbushes are most common on Adelanto sand, the Rosamond soils, and the dune phases and poorly drained phases of the Laveen soil. Alkali-resistant or alkali-tolerant plants grow on land that contains considerable alkali. Inkweed (*Dondia suffrutescens*) is the most common of these plants on soils of the Rosamond series, on edges of the dry playas, and on the poorly drained phase of Laveen sandy clay loam. In the vicinity of Newberry, where the water table is high and the soil contains considerable alkali, saltgrass covers a large area. Wire grass (a species of *Juncus*) and Indian sugarcane (*Phragmites communis*) also grow in this vicinity.

The Spanish explorer, Francisco Garces, was the first white man to traverse Mojave River, which he discovered on March 9, 1776. During the early part of the nineteenth century, this river was used as a part of the route for travel across the desert. The early trappers and traders welcomed the growth of mesquite and cottonwood and the opportunity to rest themselves and their pack animals and to obtain water. Large caravans crossed the desert, by way of the Old Spanish Trail, from Los Angeles, through Barstow, Las Vegas, and east to Santa Fe. The river was named "Mojave" in 1844 by John C. Fremont, who descended from the Tehachapi Pass and traversed the

[4] Identification of plants made at California Academy of Sciences, San Francisco.

[5] Strictly speaking, the term alkali refers to such salts as sodium carbonate, which give a highly alkaline reaction in water, and it is not applicable to neutral salts like sodium chloride, sodium sulphate, calcium chloride, and magnesium chloride. Local use of the term has, however, included all salts as alkali, whether strictly alkali or not.

valley. He camped in a moist area on the river near the present site of Barstow and again in another moist area, later termed Camp Cady.

In the early sixties, a number of livestock ranchers began ranging their herds of cattle on the moist lands along the river, but they were harassed by the Paiute Indians, and ranching became very dangerous. In order to stop depredations by the Indians, the United States Government established a military post at Camp Cady on the river about 15 miles northeast of Daggett.

In the early days, a stage route followed the course of Mojave River, but much difficulty was experienced in crossing the river because of the wide sand washes. The construction of the railroad from Mojave to Needles in the early eighties opened up the desert, and settlements were established at Waterman (now Barstow) and Daggett. In 1882 borax and large deposits of silver were discovered in the Calico district about 5 miles northeast of Daggett, and until 1892 a large quantity of silver was shipped from the Calico mines. The Waterman mine, north of Barstow, also produced heavily.

The Daggett ditch was partly constructed in 1894, but the company constructing it went into bankruptcy, and the ditch was not completed until 1902. The land under irrigation from this ditch was the first large area on the desert to be irrigated. Smaller areas farther west along the river were irrigated by surface flow. In about 1906, areas along the river and in Hinkley Valley were irrigated by pumping water from wells. The completion of the Salt Lake Railroad (in 1905), now a part of the Union Pacific system, was a further incentive to agricultural development.

With the exception of the people in the towns along the railroads, all the population is located on the irrigated farms and small homesteads in the valley. Nearly all the rural inhabitants are American born. A large number of railroad workers live in Barstow and Yermo, both of which are important railroad points. Most of the unskilled laborers on the railroads are Mexicans. Barstow is the most important town. Yermo, located on the Union Pacific Railroad about 14 miles east of Barstow, is inhabited largely by railroad workers. Other towns on the railroad are Bryman, Helendale, and Hodge, in middle Mojave Valley; Hinkley, in Hinkley Valley; and Daggett, in the lower Mojave Valley. Minneola and Newberry, on the Santa Fe Railway in lower Mojave Valley, and Harvard, on the Union Pacific Railroad, are used for water stations only.

The Barstow area is well provided with transportation facilities. The main line of the Atchison, Topeka, & Santa Fe Railway follows Mojave River through the area to Daggett where it crosses the south end of lower Mojave Valley and extends to Needles. The Union Pacific Railroad uses the same route to Daggett, where it branches north through Yermo and Harvard and extends eastward to Las Vegas and Salt Lake City. A line of the Santa Fe extends from Barstow west through Hinkley to Mojave and San Francisco. Several transcontinental paved highways cross the area. United States Highway No. 466 crosses the northeastern part and joins United States Highway No. 91 at Barstow. They pass through Yermo to Las Vegas and Salt Lake City; and United States Highway No. 66 enters the extreme southeastern part and approximately parallels the Santa Fe Railway to the western border. The main county roads

are good. There are bridges across Mojave River at Daggett and Barstow. During high water (which rarely occurs) difficulty may be experienced in crossing at other points. Although the river bed is usually dry, it is extremely sandy and is difficult to cross.

Electric power is available for pumping underground water for domestic purposes and for irrigation in the vicinity of Barstow and the valley to the west. Schools, churches, and other social institutions are available. The Barstow Union High School maintains a motorbus service providing transportation for all pupils in the area.

Alfalfa, dairy products, turkeys, and a few poultry products are the only agricultural commodities marketed to any extent outside of the area. Alfalfa hay is the chief commodity. It is hauled by truck to markets on the coast and other points in southern California.

CLIMATE

The climate is characteristic of that of the Mojave Desert region, in that the total annual precipitation is very low, the humidity is low, the summer temperature is high, and the daily range in temperature is great. Strong winds occur at some seasons.

The mean annual rainfall ranges from about 5 inches in the southwestern corner to approximately 3 inches in the extreme northeastern part which is farther out on the desert. At Barstow, which is situated about midway between the eastern and western boundaries, it is 3.62 inches. More than 60 percent of the mean annual precipitation falls during the months of December, January, February, and March, when plants are dormant. Wide fluctuations in the amount of precipitation occur from year to year, owing to heavy downpours which may occur in one place and not in another, in their passage from the mountains to the south and across the desert.

The average date of the last killing frost is March 9 and of the first is November 8, giving an average frost-free season of 244 days. The latest recorded date of killing frost is April 3, and the earliest is October 19.

In general the length of the growing season and the temperature increase with a decrease in altitude, that is, the growing season is shorter in the extreme southwestern part of the area, where the elevation is about 2,600 feet, than it is in the extreme northeastern part, where the elevation is about 1,800 feet. The nights are usually fairly cool, and during the summer the days are hot.

Winds follow down the Mojave Valley. The prevailing direction of the wind at Bryman is from the south, at Barstow and Daggett from the west. During the spring, winds reach a velocity ranging from 25 to 35 miles an hour at Daggett. A large quantity of sand is moved by the strong winds in the dry channel of Mojave River, and some sand dunes are associated with riverwash in the river channel. Blowing and moving sand constitutes a serious problem in establishing crops on some of the sandier soils, but windbreaks of tamarisk along the fences and ditches have aided to some extent in relieving this condition.

High temperatures and low humidity promote rapid evaporation. Evaporation from a free water surface probably amounts to more

than 7 feet annually. The scanty rainfall is soon disposed of, and large quantities of water are required for irrigation. No doubt, a large amount of evaporation takes place from areas where the water table is close to the surface.

The rainfall is so slight that, at some distance from Mojave River, very little grass springs up on the desert. Crops cannot be grown without irrigation. The rainfall is so uncertain and so scanty that not even the practice of summer fallow carries over enough moisture for crops from one year to the next.

Table 1, compiled from the records of the United States Weather Bureau station at Barstow, gives the more important climatic data representative of conditions in this area.

TABLE 1.—*Normal monthly, seasonal, and annual temperature and precipitation at Barstow, San Bernardino County, Calif.*

[Elevation, 2,105 feet]

Month	Temperature			Precipitation		
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year (1904)	Total amount for the wettest year (1918)
	°F.	°F.	°F.	*Inches*	*Inches*	*Inches*
December	46.8	87	12	0.60	(1)	0.50
January	47.8	82	12	.62	(1)	.13
February	51.7	86	16	.49	0.30	.75
Winter	48.8	87	12	1.71	.30	1.38
March	57.8	94	21	.56	.10	2.18
April	62 2	99	30	.07	.00	(1)
May	67.8	111	34	.04	.00	.62
Spring	62.6	111	21	.67	.10	2.80
June	77.4	113	40	.00	.00	2.97
July	83.4	114	50	.12	.40	1.28
August	82.8	112	48	.15	(1)	.06
Summer	81.2	114	40	.27	.40	4.31
September	74.3	111	39	.16	.60	1.48
October	64.0	97	27	.51	.00	.78
November	54.9	90	14	.30	.00	.24
Fall	64.4	111	14	.97	.00	2.50
Year	64.2	114	12	3.62	.80	10.99

[1] Trace.

AGRICULTURAL HISTORY AND STATISTICS

Very little attempt was made to utilize the lands of the Mojave Valley in the early days, owing to the aridity of the section, but during the dry period in the sixties a number of stockmen drove their livestock into the valley from the area south of San Bernardino and San Gabriel Mountains and pastured them on the subirrigated lands along the river. Roving Indians disputed the settlement of the white men, and ranching was extremely hazardous at that time, but the Indians were finally subdued by organized expeditions and by the military organizations established at Camp Cady. Follow-

ing this period, isolated ranches were established along Mojave River, and a few of the ranchmen used the surface flow for irrigation in producing native grasses for pasture. During the boom of 1885, a number of attempts were made to colonize the desert, but most of these resulted in failure. Subsequent to 1900, agricultural development on the desert was gradual, and ranches were established east of Barstow, in the Helendale district, and in Hinkley Valley. During this period a large number of homesteads were filed on throughout the Mojave Desert, but only a small proportion of these have been developed in an agricultural way, as many of the homesteaders located in places where no underground water for irrigation was available. Many others had no intention of bringing their holdings under cultivation except to put in the minimum amount of work necessary in order to hold title to the land and then try to sell out at a profit. Many abandoned homesteads are scattered over the desert, particularly in the lower Mojave Valley and in some of the side valleys. The more recent agricultural development is along the south side of lower Mojave Valley where a number of settlers, who have private supplies of water from wells, are devoting a very small acreage to crops (pl. 1, *A*). Development has been of a permanent character in the middle Mojave Valley west of Barstow, where good wells for irrigation purposes are located and where the water table lies at a depth ranging from 5 to 30 feet. Most of this type of irrigation has been developed within the last 20 years.

Alfalfa is practically the only crop of importance, a total of 2,278 acres being devoted to this crop, divided as follows:[6] Barstow district (includes lower Mojave Valley), 492 acres; Helendale district, 434 acres; Hinkley district, 794 acres; Hodge district, 198 acres; and Bryman district, 360 acres. These figures, which were obtained in 1932, represent most of the irrigated acreage. Probably 250 acres devoted to other crops, such as onions and corn, are irrigated. The total irrigated acreage is probably about 3,000 at present (1933).

Chilean, Hairy Peruvian, and Smooth Peruvian varieties of alfalfa are grown. Most of farmers in the Hinkley district use mixed seed of Hairy Peruvian and Chilean. The Chilean variety seems to be longer lived on the drier bench lands. From five to seven cuttings of alfalfa a year are made at intervals of about 1 month, and total yields average about 6 tons an acre, although many farmers having good land and an ample water supply, with good management obtain from 7 to 9 tons. Nearly all the alfalfa is produced on soils of the Foster, Cajon, Hesperia, and Daggett series, all of which are of sandy texture and have very deep friable subsoils.

The quantity of water used in growing alfalfa is very large, owing to the sandiness of the soils, the high summer temperature, and the low humidity. Much of the alfalfa is baled directly from the windrows in the field and sold outside of the valley. Only a small proportion is used for feed on the farms. Considerable alfalfa hay is produced for use by commercial rabbit raisers, the alfalfa being cut so that a maximum quantity of leaves is saved. This hay is marketed in Pomona, La Verne, Chino, Fontana, Etiwanda, and other towns in the citrus district, and sold at a price above the average.

[6] Figures supplied by Walker Jones, deputy horticultural commissioner, San Bernardino County, Calif.

Very little attempt is made to rotate crops. Alfalfa occupies the land as long as a fairly good stand is maintained, after which the field is plowed and reseeded. A few farmers, particularly those having livestock, rotate alfalfa with corn and barley. On such farms the alfalfa is plowed under after the fifth to seventh year, the land planted to barley, then to corn. Pima and Mexican June varieties of corn seem to do well in the dry desert air. The growing of a clean-cultivated crop, such as corn, aids in the eradication of saltgrass which grows abundantly on the flood plains along Mojave River. Sudan grass and sweetclover are produced to some extent on land close to the river, where the water supply is ample. The production of sweetclover could be extended on some of the saline soils where alfalfa does not thrive so well.

Very little fruit is produced. A small acreage is devoted to Bartlett pears and apples in the middle Mojave Valley, but it is diminishing each year. A few plantings of peaches, figs, and apricots, mainly for home use, are scattered over the area. Vegetables have been produced commercially in the middle Mojave Valley west of Barstow and near Bryman, and onions particularly have been successful. The sandy soils should be especially adapted to some kinds of vegetables.

The dairy type of farming has not been developed to a great extent. A creamery located in Barstow supplies local needs for dairy products, and small shipments are made outside the area. Most of the dairy herds are of mixed Holstein-Friesian and Jersey breeds and, at the time this survey was made, there was one herd of purebred Holstein-Friesians. A few beef cattle are grazed on the subirrigated land along Mojave River, but cattle raising and feeding is of slight importance.

Turkeys and chickens are not so numerous as in the district to the south, although several large flocks of turkeys were kept a few years ago and were sold with considerable profit. The combination of climate and soil seems desirable for raising poultry, and more livestock and poultry could be kept with profit. Although the alfalfa-hay market has been fairly good, the feeding of alfalfa to dairy animals not only would provide a local market for the hay, but the manure made available would aid greatly in maintaining yields of alfalfa and other crops, since the soils are sandy and low in organic matter.

Most of the farms are operated by the owners. Some labor is employed on the larger ranches during the summer, and most of it is supplied locally. The improved ranches are small, ranging in size from 5 to 50 acres. Only four improved ranches include more than 100 acres each.

Table 2 gives data compiled from the 1930 Federal census on the number of farms, acreage, value of land, buildings, and implements by townships. Barstow and Yermo Townships are within the confines of this area, but Oro Grande Township includes a number of farms south of it. Census figures for San Bernardino County as a whole do not apply to this area as conditions in this part of the county differ greatly from those in the part south of San Bernardino Mountains.

TABLE 2.—*1930 census data pertaining to the Barstow area, California*

Township	Farms	All land in farms	Crops harvested	Idle land	Value of--			
					Farm land and buildings	All farm buildings	Dwellings	Implements and machinery
	Number	*Acres*	*Acres*	*Acres*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Barstow	91	12,599	1,393	1,369	950,600	131,190	83,850	64,695
Yermo	5	430	86	--------	80,000	25,100	6,250	4,350
Oro Grande	99	16,848	1,274	2,464	1,579,389	279,771	149,300	94,222

SOILS AND CROPS

As the soils of the Barstow area have developed under a very low rainfall, they have characteristics distinctly different from those of soils where the rainfall is much higher. The soils are very low in organic matter, predominantly of light-gray or light brownish-gray color, and high in lime. In general, they are light colored, owing to the lack of organic matter caused by the small amount of native vegetation, dry air, and high temperatures. Owing to the low rainfall, the soils have a high lime content, as the lime and other comparatively soluble constituents remain in the soil instead of being leached out; and, as a result, these desert soils may be considered to be well supplied with the mineral constituents but low in nitrogen which comes from the organic material. Nearly all the soils are of coarse sandy texture and have low water-holding capacity.

The soils may be combined in five fairly well-defined groups, based on their position, general age, mode of formation, and profile development as reflected by the compact structure of the heavy-textured subsoil layers and accumulations of lime. The soils in each group have many characteristics in common. The groups are: (1) Soils of the recent alluvial flood plains, (2) slightly to moderately developed soils of the alluvial fans and terraces, (3) immaturely developed soils of the older alluvial fans, (4) semimaturely developed soils of the old alluvial fans and terraces, and (5) maturely developed soils of the old alluvial fans and terraces, having caliche hardpanlike layers. The salient characteristics of the individual soils are indicated in table 3.

TABLE 3.—*Characteristics of the soils of the Barstow area, California*

Soil type	Alkali	Drainage	Native vegetation	Use
Cajon fine sand	Slight or free	Fair to good	Willows, cottonwood, mesquite, saltgrass.	Alfalfa pasture. Subject to overflow. Moving sand.
Cajon fine sand, dune phase.	do	Fair	Mesquite and Mormon tea.	None. Expensive to level. Moving sand.
Cajon loamy fine sand	Variable amount.	do	Willows, cottonwood, mesquite, and saltgrass.	Alfalfa.
Foster sand	Slight or free	do	Willows, cottonwood, and saltgrass.	Do.
Foster fine sandy loam	Slight	do	do	Alfalfa and field crops.

TABLE 3.—*Characteristics of the soils of the Barstow area, California*—Continued

Soil type	Alkali	Drainage	Native vegetation	Use
Rosamond fine sandy loam	Variable amount, slight, moderate, or strong.	Fair to poor	Saltbush, inkweed, or none.	Not used because of alkali content.
Rosamond sandy clay loam	Variable amount, moderate to strong.	do	None or alkali-tolerant plants.	Not used.
Hesperia sand	Free	Good	Creosotebush and bur-sage.	Alfalfa.
Daggett sand	do	do	Creosotebush, bur-sage, and Mormon tea.	Alfalfa. Requires a large quantity of water.
Daggett gravelly sand	do	Good to excessive.	Creosotebush and bur-sage.	Do.
Daggett gravelly sand, stony phase.	do	Excessive	do	Not used. Stony and subject to wash.
Stacy stony sandy loam	do	do	Creosotebush	Not used. Too high for economical use of water. Stony.
Adelanto sand	Some soluble salts in subsoil.	Subdrainage restricted.	Saltbush	Small area in alfalfa in connection with other soils.
Adelanto sand, deep phase	Free	Fair to good	Creosotebush and bur-sage.	Alfalfa.
Laveen sandy clay loam	Normally free	Fair	Creosotebush	Not used to an appreciable extent. Lacks water supply.
Laveen sandy clay loam, dune phase.	Two-thirds of soil alkali spotted.	Poor drainage in area between dunes.	Mesquite on dunes; playas bare or saltbush.	Not used to an appreciable extent. Most of the land poor.
Laveen sandy clay loam, poorly drained phase.	High alkali content.	Poor. High water table.	Saltgrass, inkweed, and bare areas.	No agricultural value.
Mohave sandy loam	Variable amount, about one-half alkali free	Fair to good	Small creosotebush and desert sage on alkali-free areas.	No cropping, owing to lack of water. Alkali-free areas might be farmed.
Tijeras gravelly sandy loam	Free	Good to excessive.	Small creosotebush and desert sage.	Too shallow and eroded for agricultural use.
Tijeras and Daggett gravelly sandy soils, undifferentiated.	do	Excessive	Creosotebush and desert sage.	Badly eroded. Nonagricultural.

In the examination and classification of soils many borings are made; road cuts, pits, and escarpments along streams are examined; and holes are dug for detailed study of typical soil profiles. These field examinations, together with studies made in the laboratory, are the means employed to determine the classification of soils into series and types. In soil classification, as developed in the United States, the soil series is the fundamental unit. It includes soils having essentially the same color, structure, sequence, and development of the several horizons, relief, and drainage, and approximately the same parent material. The series are given geographic names taken from the location in which the included soils were first recognized. The types within the series are named according to the texture of the surface soil, as sand, sandy loam, silt loam, or clay. The type name added to the series name gives the complete name of the type. A phase is a subdivision of a type, having characteristics worthy of recognition as of importance in land use, yet not sufficiently different from the typical soil to justify the establishment of a new type. For example, in this area, Laveen is the name of a series; Laveen sandy clay loam, the name of a type; and Laveen sandy clay loam, dune phase, the name of a phase, or slight variation from the type.

Ten different soil series represented by 20 soil types and phases, in addition to 5 miscellaneous land types, are recognized and mapped in the Barstow area.[7]

In the following pages, the soils of the Barstow area are described in detail, and their agricultural relationships are discussed; their location and distribution are shown on the accompanying soil map; and their acreage and proportionate extent are given in table 4.

TABLE 4.—*Acreage and proportionate extent of the soils mapped in the Barstow area, California*

Type of soil	Acres	Percent	Type of soil	Acres	Percent
Cajon fine sand	5,440	3.0	Laveen sandy clay loam, dune phase	12,992	7.1
Cajon fine sand, dune phase	2,944	1.6	Laveen sandy clay loam, poorly drained phase	3,520	1.9
Cajon loamy fine sand	5,248	2.9	Mohave sandy loam	5,312	2.9
Foster sand	1,216	.7	Tijeras gravelly sandy loam	6,976	3.7
Foster fine sandy loam	1,728	1.0	Tijeras and Daggett gravelly sandy soils, undifferentiated	6,144	3.4
Rosamond fine sandy loam	4,224	2.3	Riverwash	11,136	6.1
Rosamond sandy clay loam	3,072	1.7	Playa deposits	1,536	.8
Hesperia sand	3,200	1.8	Dune sand	2,304	1.3
Daggett sand	19,712	10.8	Rough stony land	8,320	4.6
Daggett gravelly sand	38,336	21.0	Rough broken land	3,840	2.1
Daggett gravelly sand, stony phase	7,360	4.0			
Stacy stony sandy loam	2,112	1.2			
Adelanto sand	8,448	4.6			
Adelanto sand, deep phase	3,200	1.8	Total	182,400	
Laveen sandy clay loam	14,080	7.7			

SOILS OF THE RECENT ALLUVIAL FLOOD PLAINS

The soils of the recent alluvial flood plains include those derived from recent alluvial accumulation occurring on the flood plain of Mojave River, and they are subject to overflow during floods. They have undeveloped profiles of stratified character but predominantly loose soil material extending to a depth of 6 feet or more. This group includes the Cajon soils, which are light gray or light grayish brown, and the Foster soils which are dull brownish gray. The soils of both series are calcareous, are unleached, and are highly micaceous. Probably 50 percent of the acreage devoted to alfalfa is of these soils, owing to their low-lying position on the flood plain where they can be easily and cheaply irrigated.

The Cajon soils are derived from granitic materials. The subsoils are composed of stratified material mainly of coarse sandy texture and more or less mottled with rusty-brown stains. Neither compaction nor definite structural aggregates have developed in the soil mass. The soils have free drainage, but, in most places, the ground water table lies within a depth of 12 feet. They are low in organic matter and subject to considerable movement by wind action when the vegetative cover is removed. In the virgin condition they support a cover of saltgrass, arrowweed, willows, cottonwood, and mesquite in the moister areas and in the drier places, Mormon tea, spiny saltbush, rabbitbrush, and other plants. The native vegetation varies according to the amount of salt, or alkali, present. Some areas are spotted with alkali. The Cajon soils differ from the Foster soils in their lighter color and less mottling in the subsoil.

[7] Where the Barstow area joins the earlier soil survey of the Victorville area on the south, a few minor inconsistencies in soil classification appear as a result of the more detailed mapping in the present survey. These are set forth in the discussions of the individual soil series and types.

In this area the Cajon soils occupy somewhat lower and less well-drained positions adjacent to the river channel than is typical of these soils, and an intermittently high or fluctuating water table is indicated by iron stains.

The subsoils of the Foster soils are normally lighter in color than the surface soils, but they differ from the surface soils in that they are highly mottled with red and yellow iron stains, and are in general of coarse texture. In this area, the Foster soils are somewhat lighter in color than those mapped elsewhere. The soil material is loose to a great depth and has developed no definite structure. Under virgin conditions these soils support a cover of willow, cottonwood, brush, and saltgrass. Drainage conditions are normally poor, as the water table is at a slight depth during periods when the river carries water. These soils occupy a position ranging from 4 to 8 feet above the present bed of Mojave River. Most of the land occupied by them is relatively free of alkali, although there are some alkali-spotted areas. The organic content in most places is fairly high.

Cajon fine sand.—Cajon fine sand is typical of the soils of the Cajon series. Light-gray highly micaceous sand or fine sand extends to a depth of more than 6 feet without any zone of compaction or development of a profile. This soil occurs in areas ranging from one-fourth to one-half mile in width along Mojave River and lies from 3 to 8 feet above the present level of the channel. These areas are not continuous but are broken by areas of Foster soils and riverwash.

The chief limitations of this soil are danger of overflows, movement by strong winds, and sandy texture. The danger of overflow is slight, as Mojave River is only occasionally in flood. This factor, however, must be reckoned with in developing tracts of land. In some of the lower areas the water table is within 2 or 3 feet of the surface. Much of this land supports a growth of saltgrass and other wild grasses, together with willow, cottonwood, and mesquite trees. It has some value for grazing, although the soil may contain a slight amount of alkali. With the lowering of the water table and irrigation, the soluble salts, chiefly sodium chloride, can be controlled. The soil has a low water-holding capacity (from 3 to 8 percent), but where an ample supply of water for irrigation is available, from 4 to 6 tons of alfalfa an acre are produced. Other field crops do not produce so heavily in proportion. Until the crop covers the ground the soil blows badly. A gravelly subsoil occurs in places as pockets or stringers, and where such a subsoil occurs the value of the soil for crops is materially lowered.

As this soil is of coarse texture and low in content of organic matter, the addition of barnyard manure is of value in increasing the water-holding capacity and productiveness.

Cajon fine sand, dune phase.—The dune phase of Cajon fine sand differs from typical Cajon fine sand principally in the occurrence of sand dunes ranging from 3 to 20 feet in height that have been piled up by the wind (pl. 1, *B*). In some areas the dunes, or hummocks, are fairly stable and are kept in place by a growth of mesquite, Mormon tea, and other shrubs, but in other places the sand moves continually when the wind blows. The soil material in the level areas between the hummocks or dunes consists of light-gray micaceous fine sand or loamy fine sand which is bare of vegetation

or supports some alkali-tolerant plants and in most places contains some alkali. Tests show black alkali in some places, which gives these spots a black slick appearance.

Two fairly large bodies of the dune phase of Cajon fine sand are northwest of Lenwood and southwest of Todd School, respectively. A few attempts have been made to level the dunes so that the land could be irrigated, but with little success. The cost of leveling is expensive ($100 or more an acre), and soil movement continues even after the dunes are leveled. Windbreaks and the growing of some crop on the land to hold it would help considerably in remedying this drawback. Land of this phase is now of very low value.

Cajon loamy fine sand.—Cajon loamy fine sand is one of the most important agricultural soils in the Mojave Valley. Normally it lies high enough above the present channel of the river that the danger of overflow is less than on Cajon fine sand. This soil, however, occupies such a position that the underground water level remains at a depth ranging from 7 to 10 feet. Good wells are easily obtained, and the cost of pumping water for irrigation is comparatively low.

Fairly extensive areas are just east and west of Barstow, practically all of which are cropped to alfalfa (pl. 2, *A*). Other bodies are near Hodge and Helendale, and in the lower Mojave Valley southeast of Yermo and south of Harvard. The areas southwest of Helendale and those near Hodge have a medium content of alkali and are not of so high agricultural value as the areas near Barstow, which are only slightly affected. An area southeast of Harvard is of low value, owing to its high content of alkali salts. Nearly all areas contain a small quantity of black alkali.

The areas having the highest content of alkali support a growth of saltgrass, inkweed, rabbitbrush, and other alkali-tolerant plants. Farmed areas have been cleared of their native vegetation which consisted of willows, cottonwood, and mesquite. Much success has been attained in leaching the salts out of the surface layers of soil, through continued irrigation. Some landowners have had difficulty in obtaining good stands of alfalfa when the land was first planted, owing to concentration of soluble salts in the soil, but they state that this trouble has been largely removed after a number of heavy irrigations. Removal of the soluble salts is successful only in places where underdrainage is good.

Typically, the surface soil of Cajon loamy fine sand consists of a 1- to 2-foot layer of light brownish-gray or light-gray highly micaceous friable loamy fine sand, with inclusions of fine sandy loam, very fine sandy loam, and fine sand. It is one of the most varitextured soils of the area. The subsoil is of about the same color as the surface soil, but in most places it is sandier. Areas having a gravelly subsoil are numerous, and on such areas, yields are materially lowered. Both surface soil and subsoil are calcareous. A sample of surface soil collected near Barstow shows a calcium carbonate content of about 2 percent. The organic-matter content is low. Barnyard manure or other organic materials can be used to build up the fertility of the soil and its water-holding capacity.

Acre yields of alfalfa range from 5 to 6 tons on the better farms, and corn, Sudan grass, and truck crops have been grown successfully. Growers of alfalfa usually irrigate once every week or 10 days.

About 4 acre-feet of water are normally used for this crop during the growing season.

Foster sand.—In practically every respect Foster sand shows the typical profile of the Foster soils as described. The calcareous surface layer is dark brownish-gray sand or sandy loam that contains more organic matter than the lighter colored soils of the area. It ranges in thickness from about 4 to 14 inches and is underlain by lighter colored mottled sand or, in places, by gravel. It is variable in texture, and areas of loamy sand, fine sand, and sandy loam are included.

Areas of Foster sand occur adjacent to Mojave River in long narrow strips, extending from the southern edge of the area to the vicinity of Wild. This soil lies only a few feet above the present stream channel, and a number of gravelly sloughs extend through it.

The virgin areas were covered by a growth of cottonwood, willows, and saltgrass. About one-half of the land has been cleared and is now used for growing alfalfa. Water for irrigation is obtained from shallow wells ranging in depth from 4 to 7 feet. This soil has a relatively low moisture-holding capacity, ranging from 4 to 7 percent in the surface soil and considerably lower in the subsoil. The content of lime is somewhat lower than in most of the other soils of the area, yet it is present in sufficient quantity to cause effervescence with dilute hydrochloric acid. Yields of alfalfa are good over most of this soil, but the gravel pockets limit yields in some places. The area north of Wild contains a slight amount of alkali, but this is kept down through irrigation.

Foster fine sandy loam.—Foster fine sandy loam has a fine sandy loam or very fine sandy loam surface soil that is highly micaceous and in most places effervesces vigorously with dilute hydrochloric acid, indicating an abundance of lime. The surface soil is somewhat darker than that of Foster sand. The subsoil is stratified and of variable texture. Fine sandy loam and sandy loam predominate. In most places the material in the subsoil is mottled with red, yellow, and brown stains, indicating that, at one time, drainage conditions were poor or the water table was fluctuating. The subsoil shows no compaction. In a few places a little black alkali (sodium carbonate) is present, which tends to make the soil pack hard on drying. The organic-matter content is higher in Foster fine sandy loam than in any other soil in the area. This soil holds from 12 to 25 percent of water.

Narrow strips of this soil extend from the vicinity of Bryman to a point near Wild, and a few very small isolated areas are north of Lenwood. The surface conditions of all the areas are favorable for irrigation, and about 70 percent of the land is farmed. Nearly all of it is in alfalfa. A few patches of corn have been grown with considerable success. This soil should be good for a wide range of field-truck crops. Drainage conditions are fair at present. The water table lies at a depth ranging from 6 to 8 feet, but it was much higher in the past, as indicated by the mottled subsoil. Spots of this soil affected by alkali are indicated on the soil map. In some places, the presence of alkali materially lowers the value of the soil, and its heavier texture makes it more difficult to leach of injurious salts than Foster sand. Alkali-free areas should prove of consider-

able value for the production of corn and truck crops. Acre yields of alfalfa range from about 5 to 6 tons. Water for irrigation is applied at intervals of about 2 weeks during the growing season. The duty of water for alfalfa is probably about 3 or 3.5 acre-feet a year, but other crops require less copious irrigation.

SLIGHTLY TO MODERATELY DEVELOPED SOILS OF THE ALLUVIAL FANS AND TERRACES

This group includes soils that have developed to a slight or moderate degree from water-laid materials, as indicated by slight or moderate compaction, a moderate accumulation of colloidal clay, and a greater content of lime in the subsoils than in the surface soils. All these soils are permeable to water and roots to a depth of more than 6 feet. The Rosamond soils occur in playalike areas, and the Hesperia and Daggett soils occupy sloping alluvial fans or alluvial terraces.

Large areas of the Rosamond soils are of low agricultural value, owing to the accumulation of salts. The Hesperia and Daggett soils are free of injurious salts, but their stony, gravelly, or sandy texture limits their agricultural value in many places.

The soil materials of the Rosamond soils are of mixed mineralogical character, with granitic material predominating. The surface soils are light brownish gray or light grayish brown, and the subsoils are light brownish gray or light yellowish brown. The subsoils are generally stratified but of moderate compaction, with some colloidal staining and evidence of age. In most places the surface layers are of platy structure, and the subsoils break into medium-sized more or less platy clods. Both surface soils and subsoils are highly calcareous and in general have a moderate to high salt content. Surface drainage is so restricted that water stands on the surface of the ground following rains or when run-off from higher lands takes place. Flat playalike areas occur, which are devoid of vegetation, and small mounds have a native cover of inkweed, shadscale, or spiny saltbush, and other alkali-tolerant plants.

The members of the Hesperia series have light-brown or brown surface soils which are noncalcareous and friable. These are underlain by light brownish-gray or light grayish-brown calcareous subsoils which are only slightly more compact than the surface soils, and in which the lime is evenly disseminated rather than in accumulated form. In places in the lower part of the subsoil the lime is segregated in seams, and the soil material in place is rather firm, although it can be broken down rather easily. The Hesperia soils are derived largely from granitic sources, as indicated by the soil materials being rather micaceous. The texture throughout the soil mass is moderately uniform, with evidence of a slight accumulation of the finer colloidal and clay materials in the subsoils.

In this area these soils are lighter colored, slightly older, and more calcareous in the subsoils than the typical Hesperia soils heretofore mapped. They appear to represent a variation in development that may be caused largely by slightly more arid conditions.

The Hesperia soils occupy the higher sloping alluvial fans that are well drained and contain no alkali. The organic content is very low. In some places the surface soil material has been modified to some extent by the action of wind.

The virgin cover consists largely of large creosotebush and bur-sage.

The Daggett soils are characterized by light grayish-brown or light brownish-gray surface soils that are moderately calcareous and friable. At a depth of a few inches the material is slightly compact, although of only slightly heavier texture than that in the layer above. The material in this layer also contains considerably more lime which, in most places, is disseminated throughout the layer, although in some places it appears to be somewhat segregated. Below this, and continuing to a depth of about 36 inches, the material is light grayish-brown fairly loose stratified calcareous sand or sandy loam. This rests on brown or grayish-brown moderately compact calcareous variably textured soil material with a few lime segregations in the seams.

These soils are developed on young water-deposited material of mixed geological origin, although they are derived largely from granitic materials. They occur on steep to gently sloping alluvial fans and stream terraces. In a few places the relief has been slightly modified by the wind and is characterized by low small hummocks of sand formed around clumps of vegetation. These soils are well above the water table, have good to excessive drainage, and are free of alkali.

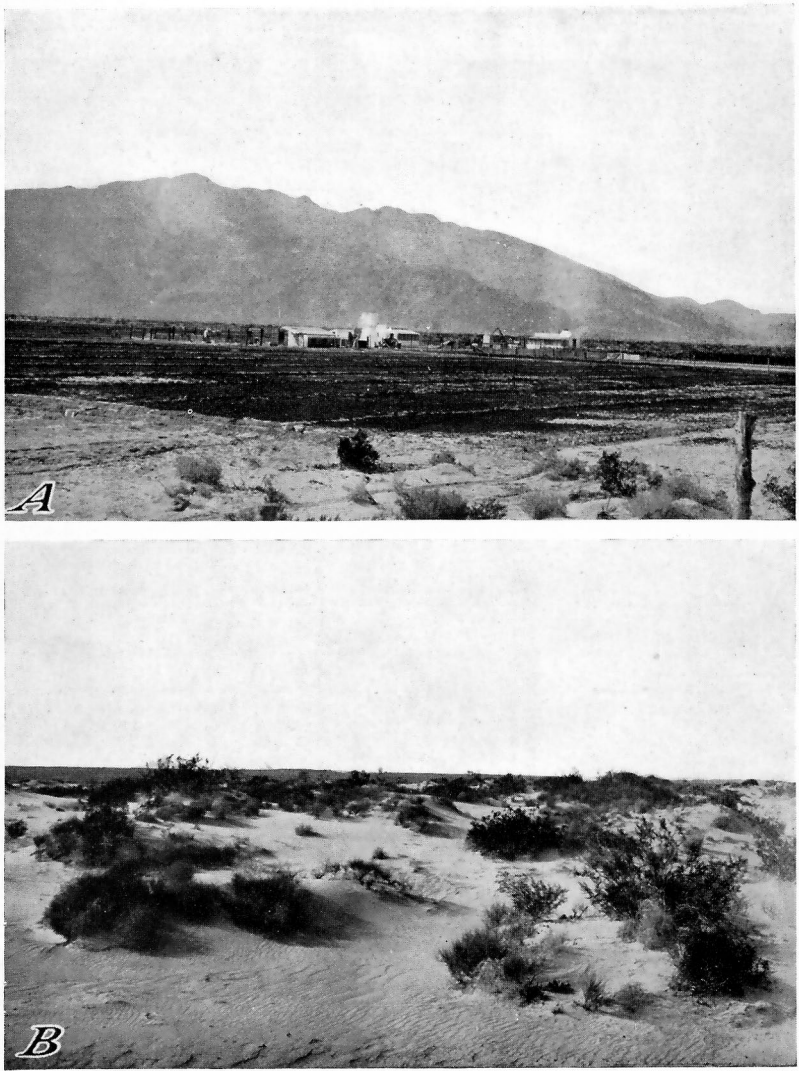
The higher fans are covered by a native vegetation of bur-sage and creosotebush, and the lower areas have a cover of desert sage, Mormon tea, and creosotebush. As with other dry desert soils, the organic-matter content is extremely low.

The Daggett is a new series of soils recognized for the first time in the Barstow area. In the earlier survey of the Victorville area, Daggett soils occur on some of the small steep alluvial fan slopes, but they are inextensive and are included with soils of the Cajon and Hanford series, which they join.

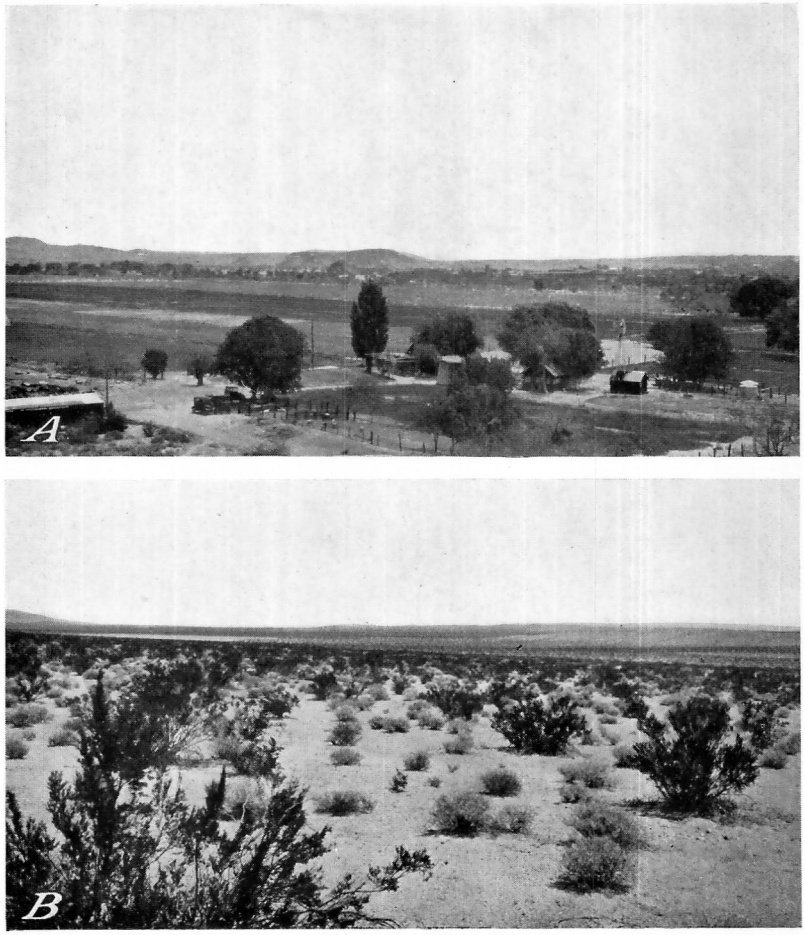
Rosamond fine sandy loam.—Rosamond fine sandy loam typically occurs as intervening areas between the soils occupying the alluvial fans, and those of the flood plains. The relief is flat, and run-off from the surrounding slopes remains on the soil for a long time following storms. Scattered isolated areas occur at Helendale and continue to the lower Mojave Valley. They normally lie from about 15 to 25 feet above the level of the river on flat terraces. Only about 15 percent of this soil has any value for crops, as the remainder has a high content of alkali.

The surface soil is typically light brownish-gray or light-brown fine sandy loam. At a depth ranging from 6 to 10 inches the soil material becomes heavier textured and more compact, and the lower part of the subsoil consists of light brownish-gray or light yellowish-brown varitextured material, mainly clay loam or loam, which is not so compact as the material above. The lower part of the subsoil in many places is mottled with yellow and brown stains. The lime content is high throughout the entire soil mass. Determinations on a sample of surface soil show a calcium carbonate content of 3 percent. The organic-matter content is low. Nearly all of the soil has a medium to high alkali content which renders it of low value.

Near Newberry, two bodies mapped as Rosamond fine sandy loam are not altogether typical. The soil here consists of fairly recent



A, Farmstead in lower Mojave Valley, showing areas of irrigated alfalfa land and adjoining desert land. Alkali-spotted areas are in this field. *B*, Sand dunes on Cajon fine sand, dune phase.



A, Alfalfa on Cajon soils along Mojave River near Barstow. *B*, Creosote bush and bur-sage on well-drained alluvial-fan slopes south of Lenwood, occupied by soils of the Daggett series. The eroded terrace in the distance is occupied by soils of the Tujeras series.

wash from the basic igneous rocks of Newberry Mountain, that is, it is gray when dry, but appears pinkish brown or reddish brown when wet. The soil has a light-gray alkali mulch over the immediate surface. The water table lies at a depth ranging from 2 to 3 feet below the surface, as seepage from the springs along the mountain keep it at a fairly constant depth. This area supports a native vegetation of saltgrass and Indian sugarcane. The salt content of the soil is high, averaging more than 3 percent in the surface soil, and black alkali was found in most of the samples collected. Owing to the high water table and the high alkali content, these two bodies have no value for cultivated crops.

Rosamond sandy clay loam.—The surface soil of Rosamond sandy clay loam consists of light brownish-gray calcareous sandy clay loam, or, in a few places, of very fine sandy loam. The subsoil is of about the same color and consists of stratified soil material showing some compaction but no particular structure. In places the surface is covered by a light-gray alkali crust and mulch that is hard in the topmost ¼-inch layer and soft and fluffy below, to a depth of about 2 inches. The subsoil in places is highly mottled with white lime concretions.

Areas of Rosamond sandy clay loam are southwest of Troy Dry Lake, near Todd School, 3 miles west of Barstow, and 2 miles west of Wild. This soil occupies flat, semilacustrine, playalike areas that are subject to run-off from higher land. The surfaces of many areas are slick, hard, and bare. Such areas are interspersed with small mounds that have a native cover of alkali-tolerant plants, such as inkweed. On more than 95 percent of this soil the alkali content is so high that the land has no value for agriculture. Several attempts to farm this soil have failed. Leaching out of the alkali would be impractical, owing to the heavy texture of the soil material, its low position, and lack of drainage outlets.

Hesperia sand.—Hesperia sand consists typically of light-brown loamy sand which contains a large proportion of coarse sharp sand particles. The areas mapped are of rather variable texture, and some of coarse sandy loam may be included. The surface soil extends to a depth ranging from 10 to 16 inches where the mildly calcareous subsoil is reached.

The entire soil mass is permeable and readily penetrated by roots and moisture, and the soil is well adapted to alfalfa in places where an abundant supply of water for irrigation is available. The soil has a low water-holding capacity (5 to 8 percent) and requires frequent irrigation to maintain a favorable moisture content. The organic-matter content is low. Barnyard manure is effective in improving the organic content as well as in increasing the water-holding capacity.

The soil occupies sloping alluvial fans, is well drained, and contains no injurious accumulations of alkali. In areas northeast and southeast of Hinkley the water table occurs at a depth ranging from 15 to 25 feet, and in those southwest of Helendale and north and west of Wild the underground water lies at a greater depth.

Virgin areas support a cover of creosotebush and bur-sage. Approximately 25 percent of the land is under cultivation to alfalfa. The land is easily cleared and leveled for irrigation. Acre yields

of alfalfa average about 6.5 tons. Water for irrigation is applied at intervals ranging from 6 to 10 days during the summer, that is, from three to five irrigations a cutting. This gives a total annual use of water ranging from about 5 to 8 acre-feet. Obviously an ample supply of cheap water must be assured in the utilization of this soil.

Daggett sand.—The surface soil of Daggett sand is somewhat loamy when moist. The subsoil, to a depth of 6 feet or more, consists of sand, coarse sand, and in places gravelly layers, with a slight degree of compaction in the upper part. The limiting factor in the utilization of this soil for crops is the open, porous, sandy character and low water-holding capacity of both surface soil and subsoil, so that a large quantity of water is necessary for crop growth. The organic content is also low, and the soil, when first brought under cultivation, contains little available nitrogen for plants.

Daggett sand occupies flat alluvial terraces, where the surface soil has been slightly modified by wind and a few sandy hummocks are scattered over the surface. The native vegetation consists of creosotebush, Mormon tea, bur-sage, and desert sage. The soil is free of alkali and has good drainage.

This is one of the most extensive soils in the Barstow area. Large bodies are in the lower Mojave Valley in the vicinity of Yermo, east of Daggett, and between Newberry and Harvard. Areas in the middle Mojave Valley are northeast of Hinkley and at Lenwood, and smaller scattered bodies occur near Hodge, Helendale, and Bryman. Only about 250 acres, of a total of 19,712 acres, are in crops. This lack of development is due to the fact that the soil is situated where the supply of water for irrigation from underground sources is uncertain and the cost of pumping is high. Yields of alfalfa are very good where the supply of water is sufficient to carry the crop through the season. No accurate figures are available regarding the duty of water for alfalfa, but the farmers on this soil state that this crop requires between 6 and 7 acre-feet a year.

Daggett gravelly sand.—The texture of Daggett gravelly sand is uniformly gravelly sand which in many places is somewhat loamy throughout the soil mass. At a depth of about 4 and extending to a depth of about 12 inches the material is slightly compact and has a higher lime content than the surface soil or the lower part of the subsoil. This slightly compact material does not retard the penetration of plant roots or the movement of moisture. In some places the lower part of the subsoil is very gravelly or stony. In color and other profile characteristics this soil is typical of the Daggett soils.

Daggett gravelly sand is developed on alluvial fans and gravelly stream terrace deposits. Some of the alluvial fans are fairly steep and subject to considerable erosion and deposition. The soil material is of mixed origin, although in some areas practically all is from granitic sources. Drainage is excessive in many places. The land supports a cover of large creosotebush, Mormon tea, desert sage, and bur-sage (pl. 2, *B*).

This soil is extensive. Large areas occur on both sides of Mojave Valley, and a number of areas occupy the benches above Mojave River in the lower Mojave Valley.

An area, about 1 square mile in extent, occurs 1 mile northwest of Hinkley, which represents a shallow development, consisting of a 2- or 2½-foot layer of gravelly sand resting on a planed-off slope composed of bedrock. No doubt this character of soil would have been more extensive had the survey been extended farther up some of the alluvial slopes where similar conditions were observed.

Only a small acreage of Daggett gravelly sand is farmed. The farmed areas are at the bases of the alluvial fans in the Bryman, Helendale, and Hodge districts, where the depth to underground water is not so great. Homesteads were located on most of the fans where this soil is extensive, but the prospects for agricultural development were poor, owing to the great depth to water, and most of the farms have been abandoned. Acre yields of alfalfa range from 5 to 7 tons. This crop requires a large quantity of water. A miner's inch will irrigate only about 1 acre. Where other conditions are favorable this soil can be improved and built up by adding organic matter, as it is very low in humus and available nitrogen.

Daggett gravelly sand, stony phase.—The stony phase of Daggett gravelly sand differs from typical Daggett gravelly sand chiefly in the presence of a fairly large content of stones, largely of granitic origin, that have been washed down and deposited on the fans. In a few places there is a cemented calcareous layer in the subsoil.

Areas of the stony phase occur on the higher alluvial fan slopes. None of this land is farmed, as cropping is prevented by the stone content, the danger of erosion, and the lack of water for irrigation. The largest areas are south of United States Highway No. 66 east of Barstow, well above a supply of water for irrigation.

IMMATURELY DEVELOPED SOILS OF THE OLDER ALLUVIAL FANS

This group includes soils that have developed moderately compact and heavier textured subsoils, as well as accumulations of lime in the lower part of the subsoils and substrata. These soils occur on old alluvial fans that at present are not being aggraded or added to but are being slightly eroded. The soils of the Stacy series, the only member of the group occurring in this area, are characterized by light brownish-gray surface soils underlain by reddish-brown moderately compact subsoils of heavier texture and, in turn, by a moderately compact light brownish-gray substratum composed mainly of lime-coated gravel and cobbles. In places seams of semicemented caliche are in the substratum. These soils are immature and are derived mainly from materials weathered from basaltic and rhyolitic transported materials, and they are calcareous throughout. They are somewhat grayer and represent a somewhat more advanced stage in development than the Stacy soils mapped in previous surveys.

The alluvial fan slopes on which the Stacy soils occur are stony, excessively drained, and eroded in places. The soils are free of alkali, except at the bases of the fans where they join soils of the Rosamond series. A well-developed desert pavement composed of rhyolitic and basaltic stones, ranging from 2 to 8 inches in diameter, covers the surface in most places. Although the stones are subangular, they fit into the pavement in a remarkably close pattern as though laid by hand. The light grayish-brown material immediately below the desert pave-

ment has a tendency to vesicular structure, and the reddish-brown heavier textured subsoil breaks to a coarse granular structure.

The native cover is mainly creosotebush and bur-sage, with some saltbush on the lower slopes.

Stacy stony sandy loam.—Stacy stony sandy loam consists of calcareous stony sandy loam to a depth ranging from 5 to 8 inches. This material rests on moderately compact calcareous stony loam or stony clay loam, which extends to a depth of about 18 inches, where a light brownish-gray mass of lime-coated cobbles and stones is reached. This material continues to a depth of more than 6 feet.

Only two areas, one northwest and the other southeast of Newberry Mountain, are mapped. This soil has little or no agricultural value, as the stones constitute more than 50 percent of the soil mass and, on account of its position on high fans, no water is available for irrigation.

SEMIMATURELY DEVELOPED SOILS OF THE OLD ALLUVIAL FANS AND TERRACES

This group includes soils that have developed extremely compact heavy-textured subsoils, as well as accumulations of lime that are the result of development of the soil under arid conditions for a long period. These soils occupy old alluvial fans and terraces. The compact heavy-textured subsoils materially interfere with the internal movement of moisture and the penetration of plant roots, and these soils do not have the range in agricultural value as do soils with less compact and more pervious subsoils.

The soils included in this group are members of the Adelanto, Laveen, and Mohave series. The Adelanto soils are derived from granitic materials and have noncalcareous or weakly calcareous brown surface soils and reddish-brown calcareous subsoils. The Laveen soils are of mixed origin and have light brownish-gray calcareous surface soils and brown calcareous subsoils. The Mohave soils, where typically developed elsewhere, have pronounced reddish-brown surface soils which are leached of lime, with reddish-brown or dull-red heavier textured subsoils of variable depth, which contain pronounced accumulations of lime in the deeper parts. In this area, however, the surface soils, in general, are covered with a thin veneer of calcareous sandy material, probably of wind-blown deposition. The Mohave soils are derived mainly from weathered granitic rocks but include some admixture of other materials. The members of all three series have light-gray lower subsoil layers or substrata of high lime content.

The surface layers of members of the Adelanto series are of brown or rich-brown color, of sandy texture, friable, and noncalcareous. The subsurface layer, which abruptly underlies the surface layer at a depth of a few inches, consists of brown or light reddish-brown compact noncalcareous or weakly calcareous sandy clay loam. This material, in turn, is underlain by very compact calcareous clay loam that contains segregated lime in large nodules. Roots do not seem to penetrate this layer, and the material, when disturbed, breaks into cubical aggregates. The material below this, which extends to a depth of 6 feet or more, is composed of light brownish-gray or drab brownish-gray very compact calcareous sediments of various textures.

The degree of compaction also varies considerably. Underdrainage is restricted by the heavy subsoil, and considerable alkali occurs in the lower part of the highly calcareous layer. These soils are developed on granitic alluvial deposits of the higher alluvial fans and terraces having a comparatively flat surface.

The virgin cover consists of cattle spinach, shadscale or spiny saltbush, and fourwing saltbush, with only a few scattered creosotebushes.

Where typically developed in the Victorville area (*2*), the soils of this series have a deeper surface soil than those in this area.

Soils of the Laveen series have a thin surface layer of calcareous light-gray material of vesicular structure, overlying a pale reddish-brown subsurface layer of compact sandy clay loam, in which the lime occurs in small nodules. This layer, distinctive of the Laveen soils, extends to a depth ranging from 8 to 15 inches, where it grades into drab brownish-gray compact clay loam which also contains lime segregated in nodules and seams. This material breaks into aggregates the size of small nuts, whereas the browner material above it breaks into larger aggregates of definite nut structure. Considerable colloidal glazing occurs on the surfaces of the aggregates. Drab-brown or gray-brown variable-textured uniformly calcareous sediments underlie the areas with the nodular accumulations of lime. This material is less compact than the material above and shows no definite structure when broken down. It contains considerable rusty-brown mottling. In places the material is of gravelly texture. In some places a well-developed desert pavement of small polished pebbles covers the surface, but in most places only a few gravel are scattered over the surface.

The Laveen soils are developed on old alluvial materials of mixed mineralogical origin, although a considerable part is supplied by granitic material. These soils occupy flat alluvial terraces well above the soils on the flood plain of Mojave River.

The Laveen soils in this area have a slightly browner and somewhat more pronounced profile development than those previously recognized and mapped in southern Arizona.

Soils of the Mohave series, as developed in this area, have a thin surface layer consisting of light brownish-gray light-textured sandy calcareous material which apparently represents a veneer of wind-blown material deposited over the typical surface soil of the Mohave soils. The typical surface soil is pale reddish-brown fairly compact noncalcareous or only weakly calcareous sandy loam or gritty loam, extending to a depth of 10 or 12 inches. The soil material below this is light brownish-gray or pale reddish-gray moderately compact sandy loam with a fairly high lime content. The material shows no visible structural aggregates when broken down. At a depth ranging from 16 to 24 inches is a semicemented highly calcareous layer which, in places, is very compact and hard but crumbles and breaks readily when dug out. This layer is from 10 to 15 inches thick, and below this, to a depth of 72 or more inches, the material is rusty-brown mottled calcareous sand which is fairly hard when dry.

The Mohave soils are among the older and more mature soils of the area, the parent materials of which probably were laid down partly by Mojave River and later modified and added to by wash

from the hills. These materials are derived mainly from granitic rocks but in places they include a small admixture of materials from basic igneous rocks and other sources.

These soils occupy old flat-topped terraces or benches and have been modified somewhat, particularly in the thin surface layer, by wind. The soils are normally well drained and free of alkali. The native vegetation is small creosotebush and desert sage.

Adelanto sand.—The 4- to 10-inch surface layer of Adelanto sand is typically sand, with minor inclusions of loamy sand or sandy loam. The surface soil has a low water-holding capacity and low organic-matter content, and it rests on compact gritty loam or sandy clay loam, underlain by very compact highly calcareous sandy clay loam that materially restricts the penetration of roots and moisture. During the course of the survey, alfalfa roots were observed spreading out over the top of this layer but not penetrating it. The lime content of this layer is more than 7 percent by weight, and in places the heavier textured layer has a soluble-salt content ranging from 0.2 to 0.5 percent. The substratum, beginning at a depth ranging from 24 to 36 inches, consists of very compact semiconsolidated sediments of sandy loam or sandy clay loam texture. An accumulation of more than 6 percent of lime occurs in seams in this material.

Following rains, water remains on the surface of the flatter areas, as subdrainage is restricted by the compact heavy-textured subsoil. This land supports a native vegetation consisting of a few creosotebushes and a number of species of saltbush.

Adelanto sand is most extensive on the gently sloping terrace south of Hinkley, and scattered areas are on the terraces near Wild and southwest and northwest of Helendale. Only about 100 acres are farmed in connection with other soils, particularly areas of the deep phase of Adelanto sand and Hesperia sand. The farmers recognize that Adelanto sand is inferior to the soils mentioned, in the production of crops. In irrigating, care must be used not to waterlog the surface soil, as the heavy subsoil greatly retards the movement of water. Irrigations should be frequent and light.

Adelanto sand, deep phase.—The deep phase of Adelanto sand shows a profile similar to that of typical Adelanto sand, in that it has a compact highly calcareous sandy clay loam upper subsoil layer, a calcareous compact lower subsoil layer, and a substratum of sandy loam or gritty loam. The surface soil ranges from 15 to 30 inches in thickness, is weakly calcareous, and has comparatively low water-holding capacity and organic-matter content. Soil of this phase is free of alkali.

Drainage is normally much better than that of the typical soil, but care must be used in irrigating in areas where the light-textured surface soil is comparatively shallow. In soil of the deep phase the heavier textured calcareous subsoil occurs at a much greater depth, giving better conditions for the development of plant roots and, therefore, a greater value for agricultural purposes. In some areas in the vicinity of Hinkley School, the sandy clay loam subsoil is lacking and the surface soil directly overlies the semicemented sandy loam or gritty loam substratum which seems to soften somewhat when moist.

About 5 square miles of this deeper soil occur in the Hinkley district, and a number of fields of fairly good alfalfa are on it. In its adaptability to alfalfa, this soil is rated equal to or slightly lower than Hesperia sand but higher than typical Adelanto sand. Acre yields of alfalfa average between 5.5 and 6 tons, with good stands yielding as high as 7 or 8 tons. From 5 to 6 acre-feet of water a season are commonly used in the irrigation of alfalfa.

Laveen sandy clay loam.—Laveen sandy clay loam has a profile typical of the Laveen soils. Scattered over the surface are a few gravel, or, in some places, a layer of sand a few inches thick that is being moved by the wind. To a depth of 2 or 3 inches the virgin soil consists of light-gray calcareous silty clay loam. This is underlain by compact highly calcareous sandy clay loam that becomes hard when dry. This material becomes lighter in color with depth but is still very compact. At a depth ranging from 18 to 24 inches, the material is less compact, of lighter texture, and contains less lime.

The largest areas of Laveen sandy clay loam occur on flat terraces in lower Mojave Valley in the vicinity of Fairview School. A number of homesteads have been established at various times in this vicinity, but the depth to underground water and the lack of good wells for irrigation have prevented extensive farming operations. Only about 80 acres of the entire area covered by this soil are devoted to alfalfa, yields of which are fair, although the soil takes water very slowly.

Other bodies of Laveen sandy clay loam are east of Daggett, east of Yermo, southwest of Lenwood, and northeast and north of Hinkley. Most of the soil is free of alkali. About 1 square mile contains a moderate amount, and about 2 square miles contain a slight amount. The alkali-free and slightly affected areas are rated as fair soil, but the areas containing a moderate content of alkali are rated as poor.

The native vegetation consists of creosotebush and desert sage, on areas free of alkali, and of saltbushes on areas having a moderate content of salts. Water tends to remain on the surface following run-off from storms. Some movement of surface sand by wind occurs but not to the extent that it does on Daggett sand. Windbreaks are useful in the lower Mojave Valley where the prevailing west wind moves the sand eastward over the valley.

Laveen sandy clay loam, dune phase.—The dune phase of Laveen sandy clay loam covers a continuous area in the lower Mojave Valley, extending, in a crescent shape, from a point on the south side of the river about 3 miles southeast of Yermo to a point about 5 miles southeast of Harvard. The part of this area east of Fairview School near Troy Dry Lake has a surface covering of wind-blown sand ranging from 6 inches to 2 feet in thickness. Small wind-blown hummocks and large dunes are irregularly spaced over the area, and they occupy about 50 percent of the land. The soil material between the dunes is typical Laveen sandy clay loam, except where the surface is covered by wind-blown sand. Mesquite trees grow on the dunes and alkali-tolerant vegetation on the level areas between. The depth to the water table ranges from 3 to 10 feet. The soil is moist in these areas, and alkali is prevalent. Northwest of Newberry, the water table is close to the surface and the soil in the

small playas between the sand dunes contains considerable alkali. A number of homesteaders have settled on this soil mainly because the water lift is low, but after obtaining water, they have irrigated only small patches of land, as the heavier textured level material between the dunes contains too much alkali for the successful production of crops. The sand on the dunes is free of alkali, but the expense of leveling the land is prohibitive. A small area near the margin of the dune phase is irrigated and farmed to alfalfa.

Laveen sandy clay loam, poorly drained phase.—The poorly drained phase of Laveen sandy clay loam occurs north of Newberry, just south of the area of the dune phase of this type. The profile of soil of the poorly drained phase is typical of Laveen sandy clay loam in most respects, except that a number of layers of drab brownish-gray calcareous or alkali-cemented hardpan occur at a depth ranging from 30 to 40 inches. These hardpan layers are at about the depth of the ground-water table and are 2 or 3 inches thick. The native vegetation consists of alkali-tolerant plants, such as saltgrass and inkweed. Field determinations for alkali show a content of more than 1 percent, and a few samples indicate considerable black alkali. Owing to the high water table and the high alkali content, soil of this phase is of very low agricultural value, and none of it is farmed.

Mohave sandy loam.—Mohave sandy loam is representative of the Mohave soils as developed in this area. Bodies occur along the Union Pacific Railroad between Yermo and Harvard, and three-quarters of a mile north of Todd School. Some spots contain considerable gravel to a depth of 6 feet or more.

Owing to compaction in the subsoil and an exceedingly high content of lime in the lower part of the subsoil, it is doubtful whether this soil should be rated very high for alfalfa. None of the land is farmed, owing to lack of water for irrigation.

MATURELY DEVELOPED SOILS OF THE OLD ALLUVIAL FANS AND TERRACES HAVING CALICHE HARDPANLIKE LAYERS

The soils composing this group have the most pronounced development of profile in the Barstow area. They occupy old eroded alluvial fans and terraces, with a desert pavement and a calichelike layer (soft calcareous hardpan) at a depth ranging from 10 to 20 inches. They have no agricultural value because of their shallowness, rough eroded surface, and stoniness.

The Tijeras soils have the most highly developed profile among the soils of the Barstow area. They occupy old eroded terraces and alluvial fans, covered by a desert pavement, and they have the highly calcareous cemented caliche layer so typical of many desert soils. They are developed on materials of mixed mineralogical character, and the soil mass is calcareous throughout. The native vegetation consists mainly of small creosotebush, bur-sage, and a small amount of desert sage.

Surface drainage is excessive in most places, owing to the rapid run-off, and, during the course of the survey, some difficulty was experienced in finding a representative uneroded soil profile, as much of the material has been badly eroded.

Where not eroded, a desert pavement of dark-colored gravel and stones overlies the soil mass, the stones having a polished and var-

nished appearance on exposed surfaces. To a depth of about 3 inches, the soil is light-gray material of definitely vesicular structure. This is underlain by a layer of pinkish-brown or pale reddish-brown moderately compact material, although in many of the more sloping areas this layer is lacking or is gray where it grades into the underlying more calcareous subsoil. The subsoil is a light-gray softly or moderately cemented calichelike layer which extends to a variable depth, but in most places it begins at a depth ranging from 10 to 20 inches. The material ranges from a soft calcareous hardpan to a mass of soft highly calcareous white powder, the upper part of which is harder than the material below. With depth this material becomes less firmly cemented and is pinkish-gray calcareous gravelly sand or gravelly sandy loam.

Small areas of eroded Tijeras soils are included in the miscellaneous land type, rough broken land.

Tijeras gravelly sandy loam.—Tijeras gravelly sandy loam has a thin surface layer of light-gray sandy loam of vesicular structure. A few stones and gravel are scattered over the surface, and the soil material, to a depth ranging from 10 to 20 inches, is highly calcareous slightly compacted gravelly sandy loam of low organic content and low water-holding capacity. This material is underlain by a lime carbonate hardpan or calichelike layer ranging from 2 to 3 feet in thickness and overlying sand, gravelly sand, or gravelly sandy loam that is fairly loose yet contains a large quantity of lime in soft seams or evenly distributed throughout the soil material. Roots do not penetrate the upper and harder part of the hardpan layer.

This soil occupies old sloping eroded terraces and alluvial fan remnants along the edge of the valley, ranging from 50 to 200 feet above the channel of the river, and from 1 to 3 miles distant from it. On the west side of Mojave River, about 2 miles southwest of Helendale and farther south on the top of the mesa, three areas of Tijeras gravelly sandy loam lack a desert pavement and the surface soil is sandy loam or sand. The calcareous hardpan, which occurs in these areas at a depth ranging from 15 to 20 inches, is, in general, harder and more dense than that developed in the areas south and east of the river.

The native vegetation on this soil consists of small creosotebush and bur-sage. The land has little value for grazing, as grass grows only following seasons of exceptional rains.

None of the land is farmed, as the surface is too much eroded and too uneven for irrigation, and the soil is shallow, gravelly, and situated in areas without a water supply.

Tijeras and Daggett gravelly sandy soils, undifferentiated.—These undifferentiated soil materials occur on eroded sloping terraces and fans occupied by Tijeras gravelly sandy loam mixed with strips, ranging from 50 to 200 feet in width, of Daggett gravelly sand. The surfaces of such areas are badly dissected. The ridges occupied by Tijeras gravelly sandy loam have a gravelly sandy loam thin surface layer overlying the calichelike hardpan layer; and the Daggett gravelly sand areas are narrow strips consisting of deposits of gravelly sand, that are subject to wash and additional deposits of sandy or gravelly material following run-off from storms. Owing to these

factors, these undifferentiated soils have little or no value for agriculture. A very small area of this rough land joins rough broken land of the Victorville area.

MISCELLANEOUS LAND TYPES

In addition to the soil types and phases previously described, five classes of miscellaneous land types—riverwash, playa deposits, dune sand, rough stony land, and rough broken land—are mapped, all of which are nonagricultural.

Riverwash.—Riverwash includes alluvial deposits of coarse sand, medium sand, and in places fine gravel, occurring in the present channel of the Mojave River and along old, abandoned stream channels. The material is light gray and is composed mainly of granitic particles. All the areas are subject to overflow, but, except in cases of unusual floods, the channel is dry below the crossing at Hodge. Most of the land is bare of vegetation, but some of the old, abandoned channels support a cover of willows, cottonwood, and brush, and in places some saltgrass and a few other wild grasses. Thus, where the subterranean flow of water is sufficient the land provides some feed for livestock.

Riverwash occurs only in the first bottoms along Mojave River as a narrow strip, ranging from one-fourth to one-half mile in width, throughout the entire length of the area. In places there are a few sand dunes along the edge of the channel. Some of this land is used for pasture, but the greater part has no agricultural value.

On the southern boundary of the area riverwash joins with Hanford coarse sand of the Victorville area, which it resembles and into which it grades.

Playa deposits.—Playa deposits consist of clay, clay loam, or sandy clay materials which occupy the lowest flat areas, known as playas, in closed desert basins. Although usually dry, following freshets and desert storms, these playa flats are occupied by shallow, turbid, transient lakes formed by drainage waters, from which fine soil materials in suspension and salts in solution are deposited as the water evaporates. In most places salts, or alkali, are present in the drainage water in sufficient quantity and character to promote a highly dispersed condition of the clay and colloidal particles in suspension and an adverse impervious structure in the deposited soil materials.

The soil materials are light brownish gray or grayish brown, predominantly of fine texture, and extremely compact and hard when dry, although in a few places sandy layers occur in the underlying materials.

The playas are devoid of vegetation. On drying the surface has a glazed appearance. The playa deposits occupy Calico Dry Lake and Troy Dry Lake in the lower Mojave Valley, and very small areas in depressions in a number of places. The land is of practically no agricultural value, owing to the high salt content, heavy texture, compact structure of the soil material, and the danger of overflow.

Dune sand.—The dune sand areas consist of uniform light-gray or light brownish-gray calcareous micaceous loose sand extending to a depth of 6 feet or more. The sand is practically devoid of organic matter and is of very low water-holding capacity.

This class of material borders Mojave River, 3 miles west of Lenwood and southeast of Yermo. Small isolated patches are northeast of Hinkley and in the lower Mojave Valley. The sand dunes in the latter areas range from 10 to 20 feet in height, and most of them support some mesquite trees. Along the river, where the dunes are continually shifting and moving, the land supports very little vegetation.

Dune sand is of little agricultural importance. It would be very expensive to level the irregular surface for irrigation, and the sand would be difficult to keep from moving again into dunes.

Rough stony land.—Rough stony land consists of rugged mountainous areas, in which the relief is too steep and the soil too stony to warrant cultivation. In desert mountains, soil material is normally moved down the slopes about as fast as it forms from the rocks, so that the rock surfaces are devoid of soil covering, except in a few pockets where the material is lodged and held. Rough stony land in this area is barren, except in such pockets, where small creosotebush, desert holly, and cactus grow.

Areas mapped as rough stony land occur on Newberry Mountain and other isolated stony buttes in lower Mojave Valley, on the mountains northeast and northwest of Barstow, and on the lower slopes of Iron Mountain west of Hodge. This land has no agricultural value or significance.

Rough broken land.—Rough broken land includes areas too steep, eroded, or uneven for cultivation. It differs from rough stony land in the absence of rock outcrop or a stony or rocky surface. To a considerable extent the material consists of badly eroded old alluvial-fan or stream-laid deposits of unconsolidated or moderately consolidated character. Most of the material contains considerable gravel. In a few places very small areas of uneroded soil occur at the crest of the sharp eroded ridges. These areas have characteristics of the Tijeras soils as mapped in the Barstow area, and also of the Sunrise soils as mapped in the Victorville area to the south.

Bodies of rough broken land occur on the slopes paralleling the valley between the southern boundary of the area and Helendale. One area is near Barstow, one about 3 miles east, and one about 4 miles southwest. This land supports no vegetation, except scattered creosotebush and other associated desert shrubs. It has no agricultural value.

This land joins on the south with rough stony land of the Victorville area. As neither class of land is of agricultural value, the apparent inconsistence in classification is not of agricultural significance.

WATER RESOURCES AND IRRIGATION

Owing to low rainfall, irrigation is necessary for the growth of crops in this area. Practically no rain falls during the growing season, and only from 2 to 5 inches during the winter and spring, which is of little benefit to vegetation, with the exception of a scanty growth of native grasses following the heavier showers of spring. All water for irrigation, either pumped or obtained by gravity, comes from the flow of Mojave River, whether it be subter-

ranean or surface flow. There is no evidence of any underground water coming in from the side valleys.

Considerable investigation has been conducted regarding the storage, utilization, and organization for using the water of Mojave River in the vicinity of Victorville outside the confines of this area (*3*). The Mojave River Commission considered that of the 90,000 acre-feet discharge of the river at its headwaters, approximately one-third should be allowed for riparian lands along the river. It was proposed that about 60,000 acre-feet be available for use on the mesas east and west of Victorville.

Irrigation in the middle and lower Mojave Valley is of fairly recent origin. A number of earlier attempts were made to divert water from the river or pump it on a large scale for extensive tracts of land, but these did not materialize to a great extent. About 1885, work was started on a canal to carry water from the underflow of Mojave River from a point near Daggett to the mines of the then thriving mining district. The project was not carried very far but was taken over in 1894 by the Southern California Improvement Co. which constructed a dam and tunnel beneath the river west of Daggett and a canal 11 miles long to a point near Minneola. A succession of comparatively wet years caused the ditch to flow water by gravity, and about a dozen settlers started farming operations. The maximum flow of the ditch never exceeded 10 second-feet, and the settlers did not stay long on the desert, as windstorms and the blazing desert sun, together with an extremely sandy soil which absorbed an enormous quantity of water, were too much to contend with. The irrigation company became bankrupt about 1898, and the project lay idle until 1902, when private citizens bought the water rights and used the water on land just east of Daggett. Since then, from 150 to 250 acres of alfalfa have been irrigated by this system. The ditch probably does not carry more than 1½ or 2 second-feet at present (1933).

Another project contemplated irrigating from 20,000 to 40,000 acres of land between Yermo and Harvard on the north side of the river. This was started in 1910, and several wells were drilled and many miles of concrete canals laid out east of Yermo. The company was reorganized in 1917 and planned to reduce the irrigated acreage to about 8,000 acres. Now, all the pumping plants are dismantled and the cement canals are falling apart, as no land has been under irrigation in this project for several years.

At present (1933) a few gravity ditches, in addition to the submerged dam and ditch at Daggett, take water from Mojave River. One ditch, having a water right of 500 miner's inches, takes water out on the south side of the river about 4 miles south of Helendale; another diverts water on the north side directly west of Helendale and irrigates only a small acreage; and about 100 or 150 acres are irrigated northwest of Wild by owners of riparian water rights, who have rights to the remaining surface flow of the river, where water is diverted by means of a brush dam a few feet high. The surface flow usually diminishes to such an extent about June 15 that people using gravity water have to resort to pumping during the rest of the season.

More than 90 percent of the water used for irrigation is obtained from wells. Along the flood plain of Mojave River, wells yielding large flows are obtained at a comparatively slight depth by digging a

pit down to the water and then sinking a large casing from 4 to 6 feet in diameter, which amounts essentially to pumping directly from the subterranean river. Centrifugal pumps are used. The depth to the underground water west of Barstow along the river ranges from 2 to 10 feet. When pumping is under way, the water surface sinks to a depth ranging from 15 to 25 feet from the surface of the ground. Such wells are comparatively inexpensive compared with the deep drilled wells.

All the wells on the alluvial slopes, bench lands, and in the lower Mojave Valley are of the drilled type with the stovepipe casing. The depth to water in these districts ranges from 15 to more than 50 feet, depending on the distance from the river.

According to the Federal census, 540 acres were irrigated in the Mojave River basin in 1902, 4,608 acres in 1919, and 6,118 acres in 1929. It is estimated that approximately 40 percent of this acreage lies within the confines of the Barstow area. The entire basin had 86 pumping plants in 1920, with a total capacity of 45,960 gallons a minute (102 second-feet), and the 1930 census reported 231 pumping plants having a capacity of 126,776 gallons a minute (281 second-feet).

Preparing land for irrigation on the Mojave Desert involves removing brush, leveling, checking, and usually putting in concrete or metal pipe, as open ditches lose an enormous amount of water. Different farmers have estimated the cost to range from $50 to more than $100 an acre. In developing a desert homestead or farm, the cost of the well, pump, and power equipment must be added, which ranges from $500 to $4,000 a unit, depending on the type of well, its depth, and the type of pump and motor or engine. Prospective settlers should consider this initial cost in developing a desert farm before crops are planted, as many settlers in the lower Mojave Valley have met with failure.

Alfalfa is irrigated by means of border checks laid out from 200 to 700 feet in length and from 30 to 60 feet in width. In order to avoid deep percolation losses of water, the checks should not be longer than 300 feet on the porous sandy soils. Some farmers level their land and place the checks so that they have a fall ranging from 2½ to 4½ inches in 100 feet.

The irrigation season usually starts about the latter part of March and continues to October. From two to four irrigations at intervals ranging from 7 to 14 days are given a cutting of alfalfa. From 3 to 4 acre-inches of water a cutting are applied. On the sandier soils from 10 to 12 acre-inches a month are used, amounting to a duty of 5 to 6 acre-feet a year. Figures applicable to the fine sand and fine sandy loam soils bordering the river give a duty of 2.5 to 3 acre-feet. On those soils the crop is irrigated twice for each cutting. A farmer on Daggett sand in the lower Mojave Valley estimates that he used about 7 acre-feet on alfalfa, or a flow of 1 miner's inch to 1 acre on a continuous flow basis. On this basis, a pump delivering 500 gallons a minute would irrigate only about 55 acres. On the fine sand or fine sandy loam of the Foster or Cajon series the same quantity of water would irrigate approximately 100 acres.

The water table in Hinkley Valley throughout most of the pumped area is at a depth ranging from 10 to 20 feet from the surface.

Southwest of Hinkley the water table is much lower, and the wells do not seem so promising. The height of the water table drops very rapidly on the alluvial slopes bordering the middle Mojave Valley, where there is only a very narrow strip in which pumping is feasible. Only a few large wells are used for irrigation in the lower Mojave Valley, and the acreage of good soils on the alluvial flood plain of Mojave River is very small. On the terrace lands the number of good wells is small. In the Daggett district the water table is at a depth ranging from 50 to 80 feet, but the depth decreases eastward toward the line of sand dunes. The eastern edge of the dune area is called the "dike", and here the water table is close to the surface. This dike extends from a point about one-half mile north of Newberry in a northwesterly direction toward Yermo, where it terminates at the channel of Mojave River. East of the dike, the water table drops to a depth ranging from 25 to 50 feet. Several wells are located in the area having a high water table south and west of the dike, but the soil has such a high content of soluble salts that its value is very low for any agricultural use. North of Mojave River the water table is at a depth ranging from 40 to 80 feet, and with the large quantity of water required to irrigate the sandy soils, this depth makes pumping for irrigation very expensive.

Reservoirs such as those used in the Hinkley district should be used on the sandier soils, in order to increase the irrigating head. These reservoirs range from 100 to 150 feet square, with the sides and bottom waterproofed with clay obtained from nearby playas.

Material extension of irrigation in this area will have to be on sandy soils where the duty of water is low, and an ample supply should be assured before attempting extensive development by bringing in new land. With approximately 2,500 acres under irrigation within the middle and lower Mojave Valley, and assuming a duty of water of 4 acre-feet, approximately 10,000 acre-feet of water is used at present. The amount of water available for irrigation on the lower parts of the river is not known, and no estimates in regard to the supply are available.

ALKALI

In desert regions the rainfall normally is insufficient to wash out the soluble salts that are in the soil as a result of the breaking down of the parent soil materials. On the other hand, in regions of high rainfall these soluble compounds do not accumulate but are washed out entirely or leached down to the water table. Because of local usage, in this report the term "alkali" refers to any soluble salts which accumulate in the soil, because of arrested drainage and excessive surface evaporation, in such quantity as to be injurious to plant growth. The common salts classed under the term "alkali" are sodium chloride (table salt), sodium sulphate (Glauber's salt), sodium bicarbonate (baking soda), calcium chloride, and magnesium sulphate. These are all classed as white alkali, and sodium carbonate, or sal soda, also of frequent occurrence, is known as black alkali.

The white alkalies are considered less harmful than black alkali which not only is extremely toxic to plant growth, but deflocculates or puddles the soil and gives rise to an adverse impervious structure.

Soils containing black alkali are very difficult to reclaim because of these factors, particularly if they are of heavy texture, whereas soils containing white alkali are much more readily leached of the salts which are washed out and removed from the soil mass. The feasibility of such a procedure depends on texture of the soil, underdrainage, and amount of lime present. Soils of low calcium content in comparison with the sodium content are very difficult to leach, because the soil puddles and water does not drain through it. Where in sufficient proportion, calcium replaces the sodium in the absorptive complex and the sodium is washed out as chloride and sulphate, and the soil is left in good physical condition.

Gypsum or sulphur is often applied in the process of reclamation in areas where sodium carbonate, or black alkali, is present, in order to change it to the sulphate which can be washed out more readily.

Another factor which influences the toxic effects of alkali is its localization in the soil profile. A concentration near the surface prohibits the growth of most cultivated crops, whereas if it is at a depth ranging from 4 to 5 feet it may not have much effect on shallow-rooted crops. This feature is made use of by many farmers who plan to keep the alkali at sufficient depth not to be injurious. Such a procedure requires maintaining a downward movement of moisture under gravity, so that the alkali will not rise toward the surface.

On the soil map of the Barstow area, the lands are divided into four grades according to alkali accumulation. The grades are based on the total alkali content, the kind of alkali, and the visible conditions, such as the appearance of the crop or the kinds of alkali-tolerant plants growing on the land. The areas marked A indicate those strongly affected with alkali; M, moderately affected; S, slightly affected or alkali spotted; and F, alkali-free. The location of field samples, where tests for alkali were made, are shown by a dot. The percentage of total salts present, as determined by the Wheatstone electrolytic bridge, is indicated in the form of a fraction, thus: $\frac{0.30}{0.19}$B. The number above the line indicates the percentage of alkali in the soil to a depth of 1 foot, and the number below the line shows the average percentage of alkali to a depth of 6 feet. The letter B indicates the presence of black alkali.

In the strongly affected areas crop growth is prohibited to so great a degree that these areas have practically no value for agriculture. They are for the most part barren of vegetation or support alkali-tolerant plants, such as inkweed and saltgrass. In many places a thick crust of white salt accumulation occurs on the surface. The percentage of salts in the surface soil generally averages more than 1 percent and is associated with a high salt content in the subsoil. A high accumulation of alkali occurs in Rosamond fine sandy loam and Laveen sandy clay loam, poorly drained phase, near Newberry. In both soils the water table is at a depth ranging from 1 to 4 feet, and concentration of salts in the surface soil is extremely high. Black alkali also occurs. There are also high concentrations in Rosamond sandy clay loam and in the playa deposits bordering Troy Dry Lake, in Calico Dry Lake, and in other locations where these soils are mapped.

The areas moderately affected with alkali include soils which generally have a salt content between 0.4 and 1 percent of total salts, which is so distributed in the soil as to depress crop yields but not to prohibit plant growth. Many areas of the Rosamond soils contain a moderate quantity of salts and have very low agricultural value. A few areas of Cajon loamy fine sand also are moderately affected. This soil is sandy and has open subsoil layers so that leaching has been successful in materially reducing the salt content in some places. These areas have a saltgrass, saltbush, or rabbitbrush cover.

Slightly affected, or alkali-spotted, areas occur only in Foster sand, Foster fine sandy loam, Cajon loamy fine sand, and Laveen sandy clay loam, dune phase. The salt content in these soils ranges from 0.1 to 0.4 percent and is caused by a comparatively high water table, but the salt is so distributed throughout the soil mass that it has only a slight effect on crop growth. With the exception of Laveen sandy clay loam, dune phase, the other soils respond well to the control of alkali through careful irrigation.

The alkali-free areas have a salt content generally less than 0.1 percent and so evenly distributed throughout the soil mass as not to be injurious to crops. These soils are predominantly well drained and support a native cover of creosotebush.

RATING OF THE SOILS IN THE BARSTOW AREA ON THE BASIS OF THEIR AGRICULTURAL VALUE

In an area of this character, in which the soils, to a great extent, are still in an unutilized and desert condition, it is obvious that only slight evidence of soil capabilities can be drawn from present crop use, and a final inventory or rating of the soils in terms of their potential utilization when irrigated must be based largely on the inherent character of the soils in their natural state as expressed by the texture, structure, and other properties of the surface and lower layers of soil; relief; drainage; and relative freedom from salts.

The soils of the Barstow area are rated on the basis of such characteristics, according to the degree to which they present conditions favorable to the growth of crops. These ratings are expressed as indexes with soils having the highest rating given the highest index (*6*). In table 5 and the discussion following, only the final rating is given, reference to the steps and mechanics by means of which the final evaluation has been obtained being omitted. The final rating is comparable with that for other areas in California which have been covered by soil surveys and is based or graded on similar soil characteristics of similar weight. On this basis it is observed that no soils in grade 1 are present in this area, but that the best soils are in grade 2.

Enumeration of the soils according to these grades and ratings, in order of their evaluation, are set forth in table 5. Their extent and location are shown on the soil map accompanying this report and also on the small sketch map (fig. 2).

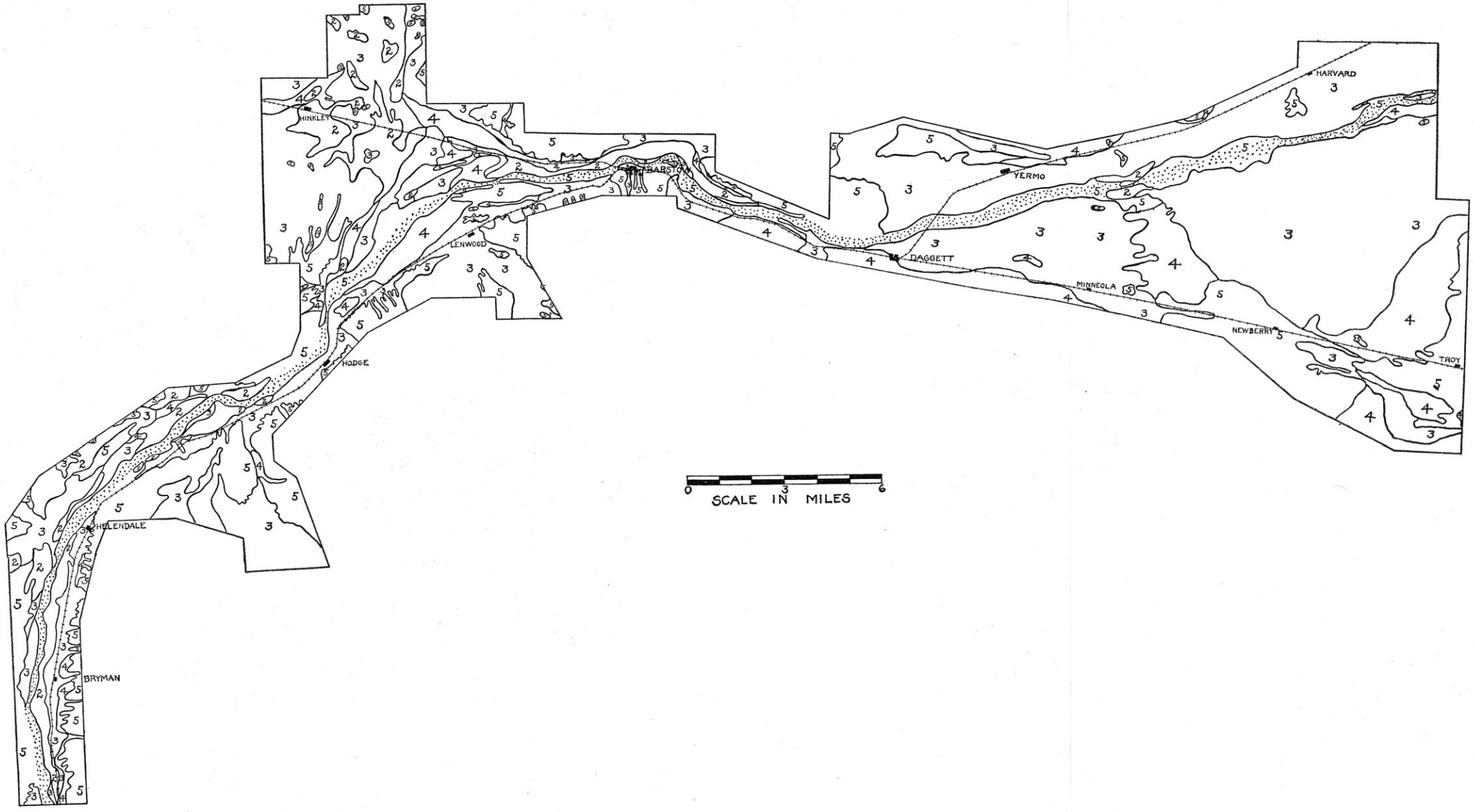


FIGURE 2.—Grouping of soils in the Barstow area, San Bernardino County, Calif. Grade 2, good soils; 3, fair soils; 4, poor soils; and 5, very poor soils.

TABLE 5.—*Rating of soils in the Barstow area, California, according to their agricultural value*

Grade	Soil type	Rating
	Foster fine sandy loam (slight alkali)	80
	Cajon loamy fine sand (slight alkali)	80
	Rosamond fine sandy loam (slight alkali)	80
2	Foster sand (alkali-free)	72
	Hesperia sand (alkali-free)	65
	Foster sand (slight alkali)	64
	Adelanto sand, deep phase (alkali-free)	62
	Rosamond sandy clay loam (slight alkali)	61
	Daggett sand (alkali-free)	59
	Cajon fine sand (alkali-free)	58
	Cajon loamy fine sand (moderate alkali)	54
	Mohave sandy loam (alkali-free)	54
	Laveen sandy clay loam (alkali-free)	54
	Cajon fine sand (slight alkali)	52
3	Daggett gravelly sand (alkali-free)	52
	Mohave sandy loam (slight alkali)	48
	Laveen sandy clay loam, dune phase (alkali-free)	48
	Adelanto sand (alkali-free)	45
	Laveen sandy clay loam (slight alkali)	43
	Mohave sandy loam (gravelly areas) (alkali-free)	42
	Adelanto sand (slight alkali)	40
	Rosamond sandy clay loam (moderate alkali)	40
	Laveen sandy clay loam, dune phase (alkali spotted)	36
	Rosamond fine sandy loam (moderate alkali)	36
	Mohave sandy loam (moderate alkali)	32
4	Laveen sandy clay loam (moderate alkali)	32
	Daggett gravelly sand, stony phase (alkali-free)	29
	Cajon fine sand, dune phase (alkali-free)	26
	Cajon fine sand, dune phase (slight alkali)	22
	Cajon loamy fine sand (high alkali)	20
	Stacy stony sandy loam (alkali-free)	19
	Rosamond fine sandy loam (high alkali)	18
	Rosamond sandy clay loam (high alkali)	16
	Tijeras gravelly sandy loam (alkali-free)	15
	Laveen sandy clay loam (high alkali)	14
	Mohave sandy loam (high alkali)	13
5	Laveen sandy clay loam, poorly drained phase (high alkali)	11
	Tijeras and Daggett gravelly sandy soils, undifferentiated (alkali-free)	5
	Riverwash	5
	Playa deposits	5
	Dune sand	5
	Rough stony land	5
	Rough broken land	5

The soils of grade 2 are of good quality and capable of being farmed to the various crops of the area, mainly alfalfa, in places where water is available for irrigation. Approximately 19 square miles, or 12,000 acres, are included in soils of this grade. They occur as narrow strips along Mojave River and in the Hinkley district, and, probably, about 800 acres are east of Barstow.

The soils in grade 3 are of fair quality, but their value is lowered by alkali, by heavy clay layers in the profile, by their light sandy or gravelly texture, or by other adverse features. The first three soils in this grade are of somewhat higher value than the rest but are not considered of sufficiently high quality to be placed in grade 2. The soils of this grade are scattered over the area, and approximately 111 square miles, or 71,000 acres, are included. The largest areas are on the fan slopes (most of which lie above an available water supply) bordering the valley and on the broad alluvial terraces in the lower Mojave Valley east of Daggett.

The soils of grade 4 are of poor quality, as their agricultural value is limited by accumulations of salts, stoniness, sand dunes, and other adverse factors. As a whole, the soils are not suited to an extensive development of irrigation.

The soils and miscellaneous land types classed as grade 5 are of very poor quality for agricultural purposes, owing to their high salt content, stoniness, rough surface configuration, or other undesirable features. They should not be utilized for cropping.

MORPHOLOGY AND GENESIS OF THE SOILS

The Barstow area lies in the Great Basin desert region of the United States. The Sierra Nevada, about 80 miles to the west, and the San Gabriel and San Bernardino Mountains, to the south, cut off the Mojave Desert from the Pacific coast region to the west and south. Therefore, the rainfall is light and the air very dry. The seasonal distribution of rainfall is similar to that of the coast section but differs from that of the more southern arid section of southeastern California and southern Arizona, which has a summer type of rainfall.

Surrounded by barren desert mountain slopes, with a climate characterized by high temperatures, dry air, high percentage of sunshine, and an average annual rainfall of less than 5 inches, the soils have developed under typical desert conditions, which are reflected in their physical and chemical characteristics.

In many ways the Mojave Desert has more of the characteristics of the southwestern arid section of the United States than of the northern deserts of the Great Basin region. The northern deserts have a sagebrush cover, whereas the predominant cover of the Mojave Desert is creosotebush, locally termed "greasewood." A number of the soils of the Mojave Desert have a pink cast, which is characteristic of the soils of the southwest arid section, whereas most of the soils of the Great Basin are light gray. Much of this difference in color may be due to the prevalence of the light-colored lacustrine parent materials from which the soils of the Great Basin region are derived.

In more humid sections an excess of soluble minerals in the soil is rare, as the rainfall is sufficient to wash them out as fast as they go into solution; but here, with the light rainfall, the soils are unleached, as is evidenced by the high lime content of nearly all of them. They are classed as Desert soils in the general group of Pedocals of Marbut's classification (*4*). Color measurements on the soils of the Barstow area bring out the pink cast, together with the gray. In general, the soils are light brownish gray, and the more mature soils are pale reddish brown or dull reddish brown. This color suggests that these soils belong with the Red Desert group, rather than the Desert soils which are predominantly gray.

Under arid conditions, such as exist in this area, the composition of the rocks or parent materials from which the soils are derived is of great importance. The recently accumulated materials on the flood plain of Mojave River are of granitic origin and are highly micaceous, but the soils on the bordering alluvial fans are derived from a wider range or admixture of rock materials. The desert mountains are composed of sandstone, shale, and limestone, together with such volcanic rocks as lava, tuff, and basalt. Granites are widespread in the mountains southeast of the area and in the San Bernardino Mountains in which Mojave River rises.

With the exception of the heavier textured soils that occupy the local closed drainage basins and flat areas in the Mojave Valley, all the soils are of sandy texture. Of the soils separated and mapped in the Barstow area, seven belong in the sand group, six in the sandy loam group, and two in the sandy clay loam group. The sand content of all the surface soils submitted to mechanical analysis is more than 50 percent, and, with the exception of Laveen sandy clay loam, is more than 70 percent.

The organic-matter content of all the soils, except the Foster which have a high water table and support considerable vegetation, is very low. In general, the organic content averages about 1 percent or less, and in most of the soils the difference between the total amount in the surface soil and the subsoil is small. In soils formed under more humid conditions the organic content in the subsoils is ordinarily less than in the surface soils, because the plant roots, litter, and the plants themselves decompose and are worked into the surface soil.

In the process of soil development, soluble constituents, lime, colloidal clay, or both, are normally leached from the surface soil into the lower layers. The subsoils of the older soils of this area show some evidence of accumulations of lime and of colloidal material and considerable compaction in some. On the basis of the degree of development of the soil profile, as evidenced by this accumulation of clay or lime in the subsoil and the degree of compaction or cementation, the soils of the Barstow area may be placed in five groups as follows: (1) Soils of the recent alluvial flood plains, (2) slightly to moderately developed soils, (3) immaturely developed soils, (4) semimaturely developed soils, and (5) maturely developed soils.

Group 1, the soils of the recent alluvial flood plains, consists essentially of the recent flood-plain deposits of Mojave River, with little development of true soil characteristics. These soils are made up of loose stratified materials to a depth of 6 feet or more, which, owing to differences in the velocity of the water transporting the particles, were accumulated as stratified deposits. The texture of the materials in the different horizons of the soil profile is largely inherited from the parent material. The soils of two series, Cajon and Foster, are included in this group. The Cajon soils are light gray, and the Foster soils are not so well drained, are darker dull brownish gray, and have a much higher organic content than the other soils of the area. The soils of both series are developed from granitic materials.

The soils of group 2, the slightly to moderately developed soils, have profiles showing slight to moderate compaction and a higher lime content in the subsoils than in the immediate surface layers. The soils of three series are represented in this group, the Rosamond, Hesperia, and Daggett. The Rosamond soils are derived from mixed parent materials, deposited under semilacustrine conditions, and have light brownish-gray surface soils and light grayish-brown or light brownish-gray subsoils. The Hesperia soils are developed from granitic parent material and have brown weakly calcareous surface soils and light brownish-gray calcareous subsoils. The parent material of the Daggett soils is of mixed origin, though mainly

granitic. These soils have a native cover of creosotebush and bur-sage. The profile of Daggett sand is representative of the soils in this group and may be described as follows:

0 to 3 inches, light brownish-gray friable calcareous sand, with a few gravel on the surface but no desert pavement.
3 to 16 inches, light brownish-gray or light grayish-brown slightly compact calcareous sand which is sufficiently compact and colloidal-clay binding to stand up fairly firm in the bank when exposed. The material breaks into large irregular-shaped blocks which break down readily under slight pressure.
16 to 36 inches, brown, grayish-brown, or light brownish-gray friable sand. In many places the material in this horizon is stratified.
36 to 72 inches, brown or grayish-brown moderately compact sand. Accumulated lime appears in seams in this horizon.

Group 3 includes soils that have immaturely developed profiles, with moderately compact and heavier textured subsoils. They have a high accumulation of lime in the lower part of the subsoil and substratum. As developed in this area, they occur on sloping alluvial fans composed of basaltic and rhyolitic materials and are represented by only one soil type of the Stacy series. Following is a description of a profile of Stacy stony sandy loam, as observed 2¾ miles southeast of Newberry. The surface is covered by a well-developed desert pavement of polished or seemingly varnished rhyolitic or basaltic stones. In all the horizons, the stones make up more than 50 percent of the soil mass. The native cover is creosotebush, bur-sage, and desert sage.

0 to 6 inches, light brownish-gray calcareous stony sandy loam of vesicular structure.
6 to 16 inches, reddish-brown moderately compact calcareous stony loam which breaks to a coarse granular structure.
16 to 72 inches, a light brownish-gray mass of lime-coated gravel and stones of rhyolitic and basaltic origin. Here and there this substratum has seams of caliche between the stones.

Group 4 consists of soils with moderately to extremely compact subsoils that are of much heavier texture than the surface soils. Heavy accumulations of lime also are present in the subsoils. These soils represent a more advanced stage in development, as evidenced by their subsoil characteristics. They occupy old alluvial fans and terraces. The soils of three series are in this group—the Adelanto, Laveen, and Mohave. The parent material of the Adelanto soils is derived largely from granitic rocks. These soils are weakly calcareous and brown in the surface layers, and the subsoils are reddish brown and calcareous. The parent material of the Laveen soils is of mixed mineralogical origin. These soils have light brownish-gray calcareous surface soils and dull-brown calcareous subsoils. The Mohave soils where typically developed are derived mainly from granitic materials. They have noncalcareous reddish-brown surface soils underlain by reddish-brown or dull-red upper subsoil layers of heavier texture, which become highly calcareous in the lower part. As occurring in this survey their parent materials were derived from a somewhat wider range of rocks and have been modified in most places by a thin superficial veneer of wind-blown lighter brownish-gray sandy material of weakly to distinctly calcareous reaction. The soils of all three series have light-gray or light brownish-gray lower subsoil layers of high lime content.

Following is a description of a profile of Adelanto sand as observed about 2¼ miles south of Hinkley School. The soil here occupies a flat area and has a native cover of shadscale, or spiny saltbush, and fourwing saltbush. This soil has a shallower surface soil and a higher pH value than the same soil developed in the Victorville area to the south, where the rainfall is higher.

0 to 8 inches, brown friable weakly calcareous sand that breaks down to a single-grained structure or a fine-granular mass.

8 to 13 inches, brown or light reddish-brown compact slightly calcareous gritty sandy loam that breaks into hard clods when dry. The transition between this horizon and the sandy surface soil is abrupt.

13 to 28 inches, reddish-brown compact highly calcareous loam containing large nodules of lime ranging from one-eighth to one-half inch in diameter. When dry the soil material breaks to a definite cubical structure. Roots do not penetrate this horizon to a great extent.

28 to 72 inches, light brownish-gray or drab brownish-gray very compact calcareous semiconsolidated variable-textured sediments.

The profiles of the Laveen soils have a number of characteristics markedly different from those of the Adelanto and Mohave soils. The Laveen soils occur in flat terracelike areas which are most extensive in the lower Mojave Valley over that part formerly occupied by old Lake Manix. Following is a description of a profile of Laveen sandy clay loam, as observed about three-fourths mile southwest of Fairview School. The land here has a cover of small creosotebush and desert sage.

0 to 2½ inches, light-gray highly calcareous sandy clay loam of distinctive vesicular structure in place but breaking out in thin fragile plates.

2½ to 10 inches, reddish-brown or dull-brown compact calcareous sandy clay loam that breaks down with a platy structure in the topmost 2-inch layer and below into aggregates of definite nut structure. Lime is segregated in large nodules in this horizon.

10 to 20 inches, drab brownish-gray compact calcareous sandy clay loam. Lime is segregated in nodules and seams, and the material breaks into rounded aggregates the size of small nuts.

20 to 72 inches, drab variable-textured sediments that are calcareous and moderately compact, generally mottled with rusty brown. This material is less compact and contains less lime and more sand than the material in the horizon above.

The Mohave soils are widely developed in areas surveyed in the arid Southwest. The following description of a profile of Mohave sandy loam is typical as it occurs in the Barstow area.

0 to 3 inches, light pinkish-gray or brownish-gray calcareous sand or light-textured sandy loam that is fairly loose and lacks definite structure. It is a superficial layer of an accumulation of wind-laid material. The surface is coated with a few gravel, but the covering is not a typical desert pavement.

3 to 10 inches, reddish-brown or pinkish-brown fairly compact noncalcareous or weakly calcareous sandy loam. As observed in the field in other areas surveyed, this horizon in many places does not effervesce with dilute hydrochloric acid.

10 to 20 inches, light-brown or light grayish-brown calcareous moderately compact sandy loam. The amount of lime and the content of clay in this horizon increase with depth.

20 to 30 inches, light-gray very compact sandy clay loam semicemented with lime. This is the horizon having the greatest content of the finer soil particles and lime, and in place it appears to be a lime hardpan, but the material can be broken down rather easily after it is picked out of an excavation.

30 to 72 inches, rusty-brown sand that is rather compact in place but breaks down readily with handling. The material in this layer contains very much less lime than that in the overlying layer. The material in all the subsoil horizons breaks into irregular-shaped clods.

Group 5 includes soils that have the most pronounced profile development of any in the area. The Tijeras soil is representative of the soils of this group. It occupies old eroded alluvial terraces, with a desert pavement, and has a calichelike layer (a soft calcareous hardpan) at a depth ranging from 10 to 20 inches.

Following is a description of a profile of Tijeras gravelly sandy loam, as observed about 1 mile southeast of Lenwood. A well-developed desert pavement of dark-colored polished or seemingly varnished gravel and stones, ranging from one-fourth inch to 4 inches in diameter, lies on the surface. These stones are so well fitted together that they can be walked on with ease. They are of mixed mineralogical character.

0 to 3 inches, light-gray friable calcareous sandy loam of vesicular structure.
3 to 14 inches, pinkish-brown moderately compact calcareous sandy loam or gravelly sandy loam that has no definite structure.
14 to 36 inches, light-gray or white softly consolidated calichelike material. This is the horizon of maximum accumulation of lime which in some places resembles a soft calcareous hardpan.
36 to 72 inches, pinkish-gray moderately firm highly calcareous gravelly sand that, when broken, falls into lumps.

LABORATORY STUDIES

The mechanical analyses of nearly all the samples examined were made by a proximate method, whereby the air-dry soils were screened through a 2-millimeter sieve. The screened soil is shaken in distilled water with sodium oxalate as a dispersant, then washed through a 300-mesh sieve to remove the sands. The sands are then dried, screened, and separated into five grades—fine gravel, coarse sand, medium sand, fine sand, and very fine sand. The total silt and clay content is reported by difference.

Textural class names were checked by this proximate method, and the moisture-equivalent determination by plotting both these determinations on Davis and Bennett's soil-class diagram as suggested by Bodman (*1*). Thus the name of the texture is fixed by means of the total sand and the moisture-equivalent determinations. Both operations can be performed rather rapidly.

The samples from four soil profiles were also analyzed by the international more complete dispersion method, whereby the soil is pretreated with hydrogen peroxide and hydrochloric acid to remove organic matter and carbonates. The soil is then washed through a 300-mesh sieve to remove the sands. The silt and clay suspension which passes through the sieve is made up to volume, allowed to stand, and sampled by the pipette at the proper time intervals to give effective maximum diameters of silt at 50 microns, clay at 2 microns, and colloid at 1 micron.

The differences between the two methods are not very great, the amount of total sands ranging from about 1 to 6 percent less in the complete dispersion method. This is to be expected, as the soils of the Barstow area are calcareous. In heavier textured soils the dif-

ferences would be greater, as mechanical analyses of soils in other soil surveys have shown that by the proximate method the clays of the heavier types are not completely dispersed.

The moisture equivalents were determined by the standard method, whereby 30 grams of saturated soil are subjected to a force of 1,000 times gravity in a centrifuge. The moisture equivalents are reported in percentage of moisture calculated on the basis of oven-dry soil. They represent approximately the normal field-moisture capacity, or the amount of water that is held in a soil after a heavy rain or an irrigation where downward drainage is free and uninterrupted.

The reaction of a number of samples of soil were determined by the colorimetric method, and shown in the column headed "pH" in table 6. In most of the soils the reaction is strongly basic, in fact, most of the soils of this area are decidedly basic in reaction.

The results of mechanical analyses, moisture-equivalent determinations, and pH values are given in table 6.

TABLE 6.—*Mechanical analyses, moisture equivalents, and pH values of samples of several soils from the Barstow area, California* [1]

Soil type and sample number	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay [2]	Colloid [3]	Total clay	Moisture equivalent (average)	pH	Solution loss
Daggett sand:	*Inches*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*		*Percent*
578305	0 – 3	6.89	14.55	11.24	30.01	21.01	8.16	4.28	2.82	7.10	6.45	8.2	0.72
578306	3 –16	16.25	18.68	17.95	22.65	12.20	6.29	2.76	3.47	6.23	6.25	8.6+	1.39
578307	16 –36	21.09	36.53	15.87	15.20	5.30	3.20	.92	1.37	2.29	3.57	8.6+	.87
578308	36 –72	16.95	42.13	16.12	17.31	2.79	1.52	.63	2.45	3.08	4.23	8.6+	.52
Mohave sandy loam:													
578309	0 – 3	8.55	18.74	12.64	25.75	15.15	8.58	6.73	3.76	10.59	7.71	8.6+	1.39
578310	3 –10	10.21	14.69	17.73	26.13	12.55	7.59	5.40	5.45	10.85	7.35	8.6+	1.08
578311	10 –20	4.24	16.12	7.94	29.11	17.94	11.80	4.81	7.04	11.85	11.56	8.6+	4.64
578312	20 –30	7.98	14.26	6.18	15.32	15.24	21.61	11.04	7.80	18.84	17.95	8.6+	8.17
578313	30 –72	12.85	26.69	19.02	27.38	6.56	3.57	2.87	2.54	5.41	4.65	8.6+	1.17
Adelanto sand:													
578331	0 – 8	9.82	14.54	21.71	29.89	13.45	6.54	1.24	2.49	3.73	4.35	7.8	.70
578332	8 –13	16.35	17.77	10.35	21.30	10.34	6.15	3.88	13.07	16.95	15.97	8.4	.81
578333	13 –28	8.26	15.81	7.70	21.79	13.22	8.49	4.95	18.43	23.38	18.92	8.6+	8.06
578334	28 –72	5.46	10.06	9.20	29.05	16.85	15.54	3.72	9.62	13.34	20.28	8.6+	6.09
Hesperia sand:													
578343	0 –12	30.99	31.31	21.89	6.20	.99	.86	1.30	5.39	6.69	6.54	8.6	.92
578344	12 –36	6.19	26.44	18.25	24.83	13.21	3.22	2.72	4.68	7.40	5.63	8.6+	1.20
578345	36 –72	12.63	23.61	25.72	19.46	9.46	1.64	2.67	3.72	6.39	5.15	8.6+	.41
Daggett gravelly sand:													
578301	0 – 4										6.13		
578302	4 –12										5.53		
578303	12 –36										5.08		
578304	36 –72										6.44		
Laveen sandy clay loam:													
578314	0 – 2½										16.30		
578315	2½–10										15.68		
578316	10 –20										18.09		
578317	20 –72										17.76		
Rosamond sandy clay loam:													
578323	0 –14										18.30		
578324	14 –72										31.91		
Stacy stony sandy loam:													
578325	0 – 6										11.37		
578326	6 –16										15.83		
578327	16 –72										9.03		
Rosamond fine sandy loam:													
578335	0 – 6										13.28		
578336	6 –18										18.74		
578337	18 –72										28.61		

Cajon fine sand:													
578338	0 -12	----------	----------	----------	----------	----------	----------	----------	----------	----------	6.15	----------	----------
578339	12 -72	----------	----------	----------	----------	----------	----------	----------	----------	----------	2.16	----------	----------
Tijeras gravelly sandy loam:													
578346	0 - 3	----------	----------	----------	----------	----------	----------	----------	----------	----------	12.21	----------	----------
578347	3 -14	----------	----------	----------	----------	----------	----------	----------	----------	----------	14.53	----------	----------
578348	14 -36	----------	----------	----------	----------	----------	----------	----------	----------	----------	15.86	----------	----------
578349	36 -72	----------	----------	----------	----------	----------	----------	----------	----------	----------	9.30	----------	----------
Foster sand: 578350	0 -10	----------	----------	----------	----------	----------	----------	----------	----------	----------	6.03	----------	----------
Foster fine sandy loam: 578353	0 -12	----------	----------	----------	----------	----------	----------	----------	----------	----------	15.28	----------	----------
Cajon loamy fine sand: 578355	0 -12	----------	----------	----------	----------	----------	----------	----------	----------	----------	5.23	----------	----------

[1] Analyses by pipette method.
[2] Clay includes particles from 0.005 to 0.002 millimeter in diameter.
[3] Colloid includes particles less than 0.002 millimeter in diameter.

Determinations of the carbonates in a number of selected samples are reported in table 7. These were determined by an adaptation of McMiller's method, whereby a 10-gram sample of oven-dry soil, previously passed through a 2-millimeter sieve, is placed in a flask and standardized hydrochloric acid added until effervescence ceases, the flask being heated very gently. The soil solution is filtered, washed until filtrate is free of acid, and then titrated with standardized sodium hydroxide, using phenolphthalein as an indicator. The percentage of carbonates is then calculated, assuming all carbonates present are calcium carbonate. The calcium carbonate content of all the subsoils is high.

TABLE 7.—*Determination of carbonates in several soils from the Barstow area, California*

Soil type and sample no.	Depth	Calcium carbonate	Effervescence
	Inches	*Percent*	
Daggett sand:			
578305	0 - 3	0.70	Slight.
578306	3 -16	1.65	Moderate.
578307	16 -36	.76	Do.
578308	36 -72	.43	Do.
Mohave sandy loam:			
578309	0 - 3	.78	Slight.
578310	3 -10	.51	Very slight.
578311	10 -20	4.17	Strong.
578312	20 -30	6.87	Very strong.
578313	30 -72	.68	Moderate.
Laveen sandy clay loam:			
578314	0 - 2½	7.33	Very strong.
578315	2½-10	10.74	Do.
578316	10 -20	7.25	Do.
578317	20 -72	1.83	Moderately high.
Adelanto sand:			
578331	0 - 8	.39	Slight.
578332	8 -13	.68	Do.
578333	13 -28	7.65	Very strong.
578334	28 -72	6.30	Strong.
Rosamond fine sandy loam: 578335	0 - 6	3.00	Moderate.
Cajon fine sand: 578338	0 -12	.77	Do.
Hesperia sand:			
578343	0 -12	.34	Slight.
578344	12 -36	.68	Do.
578345	36 -72	1.04	Moderate.
Tijeras gravelly sandy loam:			
578346	0 - 3	3.77	Strong.
578347	3 -14	5.25	Very strong.
Foster sand: 578350	0 -10	.40	Moderate.
Foster fine sandy loam: 578353	0 -12	3.25	Strong.
Cajon loamy fine sand: 578355	0 -12	2.26	Moderate.

The approximate organic-matter content is reported for a number of soils in table 8. This was obtained by determining the total loss on ignition, and then deducting the CO_2 (taken from the determinations of $CaCO_3$ by the McMiller method). Although this is not an exact method, it gives an approximation of the relative amount of organic matter in the soils of the area.

TABLE 8.—*Approximate amount of organic matter in several soils from the Barstow area, California, determined by loss on ignition*

Soil type	Depth	Volatile matter after deducting CO_2	Soil type	Depth	Volatile matter after deducting CO_2
	Inches	*Percent*		*Inches*	*Percent*
Daggett sand	0–3	0.93	Adelanto sand	0–8	0.70
Do	3–16	.87	Do	8–13	1.13
Mohave sandy loam	0–3	1.07	Cajon fine sand	0–12	1.12
Do	3–10	1.00	Foster sand	0–10	1.50
Do	10–20	1.33	Foster fine sandy loam	0–12	2.59

The figures for organic-matter content, obtained on the soils of the Barstow area, are very low, as, exclusive of the Foster soils, they average only 0.95 percent for the surface soils.

Color analyses were made of a number of samples of surface soils by comparing them with a rotating disk composed of segments of white, black, red, and yellow (*5*). A suspension of the soil in water (being careful to thoroughly break down the lumps) is applied to a piece of blotting paper. A disk of this blotting paper is cut out and mounted on the face of the color disk, which is rotated until the colors on the two match. The percentages of white, black, red, and yellow are then recorded. Some difficulty was experienced in making the sandy soils of the Barstow area adhere to the blotting paper. These results are reported in table 9, together with color analyses of two soils from other areas in California for comparison. It will be noted that the percentages of red and yellow are relatively high.

TABLE 9.—*Color analyses of 3 soils from the Barstow area, California, and of 2 from other areas in California*

Soil type	Depth	White	Black	Red	Yellow	Resultant color
	Inches	*Percent*	*Percent*	*Percent*	*Percent*	
Mohave sandy loam	0–3	21	39	15	25	Light brownish gray.
Daggett sand	0–3	28	34	13	25	Do.
Tijeras gravelly sandy loam	0–3	26	26	17	31	Do.
Do	3–14	27	18	23	32	Do.
Yolo loam (from northern California, under a rainfall of 17 inches).	0–12	10	64	9	17	Brown.
Hames clay loam (from the Paso Robles area).	0–12	6	68	13	14	Dark brown.

The soluble-salt content of a number of soils was determined by using Hibbard's approximate method, and the results are reported in table 10 in parts per million of CO_3, HCO_3, Cl, and SO_4. Carbonates (CO_3), bicarbonates (HCO_3), and chlorides (Cl) were determined by titration, and sulphates (SO_4) were determined by precipitation with $BaCl_2$ and comparison with standard tubes of SO_4.

TABLE 10.—*Soluble-salt content of several selected soils from the Barstow area, California*

Soil type	Depth	CO_3	HCO_3	Cl	SO_4
	Inches	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*
Rosamond sandy clay loam	0–12	0	366	50	500
	12–24	0	250	150	1,500+
Rosamond fine sandy loam	0–12	3,072	378	540	5,000
	0–12	60	366	190	1,500
	0–12	60	427	0	2,000+
Cajon loamy fine sand	0–12	480	732	460	300
	12–36	216	585	50	0
Foster sand	0–12	336		50	0
Laveen sandy clay loam, poorly drained phase	0–12	180	427	120	4,000
	12–24	240	158	230	1,750
	24–48	156	84	100	400
Adelanto sand	8–13	0	683	0	200
	13–28	180	610	60	400
	28–72	156	536	80	350

SUMMARY

The Barstow area is situated in the Mojave Desert in San Bernardino County, Calif., about 100 miles northeast of Los Angeles. It has an area of 285 square miles, or 182,400 acres. The greater part of the area lies in the flat flood plain of Mojave River, with bordering alluvial terraces and steep alluvial fans that extend down from the mountains of the desert. The elevation at the point where Mojave River enters the area is about 2,600 feet, and where it leaves, about 1,800 feet.

Mojave River extends through the area and normally carries surface water for only a short distance, but the flow of underground water in the gravel below the bed of the river is considerable. This subterranean flow is forced to the surface in a number of places by natural dikes under the channel. The river rises in San Bernardino Mountains about 30 miles south of the area, and only in years of exceptional flood does it drain into Soda Lake, a dry saline closed drainage basin about 60 miles northeast of Barstow. Practically no surface water drains from the alluvial fans.

The agricultural section is thinly populated, except in Hinkley Valley and in the Helendale-Bryman district. The greater part of the population is located in the towns of Barstow and Yermo. The Union Pacific Railroad and the Atchison, Topeka & Santa Fe Railway offer good transportation facilities. Two transcontinental highways cross the area.

The summers are characterized by hot days with relatively cool nights, and the winters generally are mild. Freezing weather is common during the winter, but it does not last long. The average length of the frost-free season is 244 days. The mean annual temperature is 64.2° F. Strong winds are of common occurrence. The mean annual rainfall at Barstow is 3.62 inches, and irrigation is necessary for the production of crops.

Alfalfa, the principal crop, is grown mainly in Hinkley Valley and on the flood plain of Mojave River near Barstow, Wild, Helendale, and Bryman. A few isolated plantings are east of Daggett. Only small acreages are devoted to barley, corn, Sudan grass, and vegetables. A few herds of dairy cattle are kept.

Nearly all of the soils are of sandy texture, of light brownish-gray or light-brown color, are low in organic matter, and are high in lime. They all are developed on alluvial materials but differ in profile characteristics, ranging from those that show no development of a profile to those with well-developed profiles having compact subsoils and calichelike layers of lime accumulation.

Soils of the Cajon and Foster series are of recent alluvial accumulation, having been deposited by Mojave River. They are of good depth and, where not too sandy and free from alkali, are the best soils in the area for alfalfa.

Soils of the Rosamond, Hesperia, and Daggett series are young alluvial soils. They are deep but have slight to moderate compaction in their subsoils. The Rosamond soils are developed under conditions of poor drainage and are limited in their use, owing to a moderate to high content of alkali. The Hesperia and Daggett soils are of good depth and permeable, but in places their use is limited, owing to their sandy texture.

The Stacy soils occur on high alluvial fans, are very stony, and have heavier textured and highly calcareous subsoils. They are of low agricultural value.

The Adelanto, Laveen, and Mohave soils are developed on old alluvial terraces and have heavy-textured compact subsoils. Large accumulations of lime are in the subsoils. These soils are not used for agriculture at present, owing to lack of available irrigation water, and potentially they are of only fair quality.

Soils developed on old eroded alluvial terraces that have calichelike layers of lime in the subsoil are classed in the Tijeras series. They are of practically no agricultural value, owing to their stone content, slight depth, and eroded condition.

Alkali is present in places where the water table is high or in flat playalike areas. Four grades of alkali accumulation are shown on the soil map, including high, medium, and low or spotted degrees of concentration, and alkali-free areas. High and medium alkali accumulations occur in the Rosamond soils, Laveen sandy clay loam, poorly drained phase, and playa deposits. Spotted alkali conditions are present in a number of places in the Cajon and Foster soils. The feasibility of reclamation of the alkali-affected areas depends to a large degree on the texture of the soil, drainage conditions, and the kind of alkali salts present. On the sandy Cajon and Foster soils, leaching with heavy irrigations has made possible the production of alfalfa on soils that previously contained injurious concentrations of alkali.

Water for irrigation is obtained partly by gravity from Mojave River above Wild, but mostly from wells. Most of the good wells for use in irrigation are in the flood plains of Mojave River and in the Hinkley district. The duty of water for alfalfa ranges from 3 acre-feet a year on the heavier soils to 7 acre-feet on the sandier, more porous soils.

The soils of California are grouped, according to their agricultural value, into five grades—(1) excellent soils, (2) good soils, (3) fair soils, (4) poor soils, and (5) very poor soils. On the basis of this

system of rating, no grade 1 soils are in the Barstow area; approximately 12,000 acres are included in grade 2; 71,000 acres in grade 3; and the rest in grades 4 and 5.

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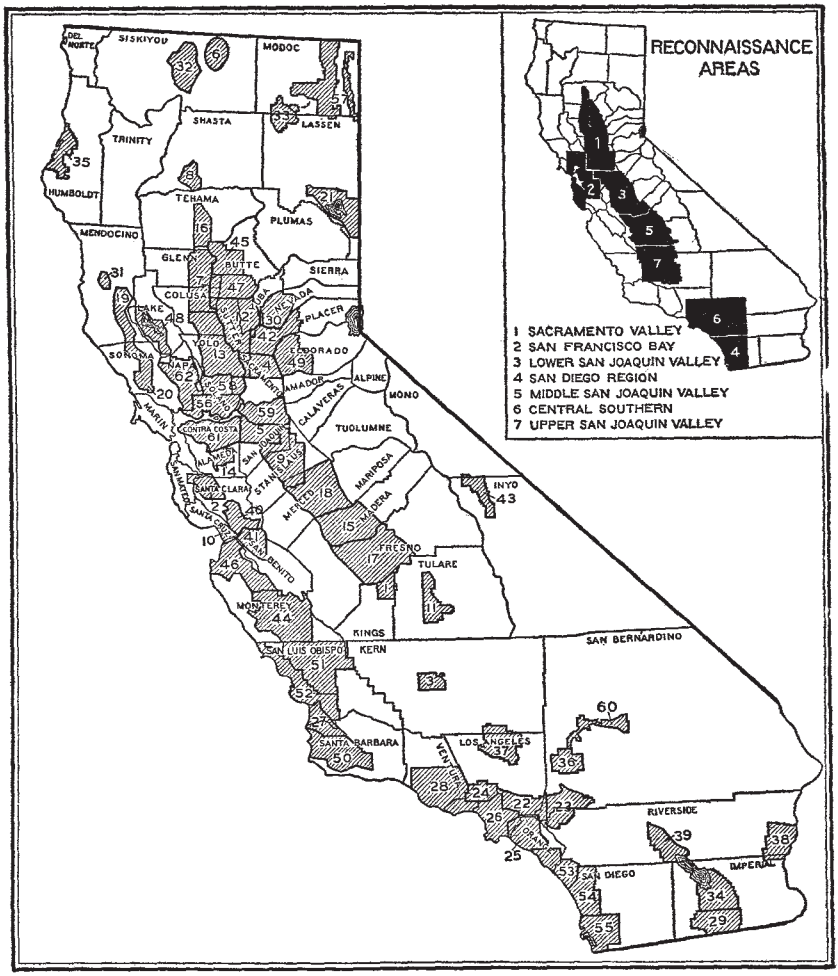

Areas surveyed in California, shown by shading.

1. Hanford.
2. San Jose.
3. Bakersfield.
4. Sacramento.
5. Stockton.
6. Butte Valley.
7. Colusa.
8. Redding.
9. Modesto-Turlock.
10. Pajaro Valley.
11. Portersville.
12. Marysville.
13. Woodland.
14. Livermore.
15. Madera.
16. Red Bluff.
17. Fresno.
18. Merced.
19. Ukiah.
20. Healdsburg.
21. Honey Lake.
22. Pasadena.
23. Riverside.
24. San Fernando.
25. Anaheim.
26. Los Angeles.
27. Santa Maria.
28. Ventura.
29. El Centro.
30. Grass Valley.
31. Willits.
32. Shasta Valley.
33. Big Valley.
34. Brawley.
35. Eureka.
36. Victorville.
37. Lancaster.
38. Palo Verde.
39. Coachella Valley.
40. Gilroy.
41. Hollister.
42. Auburn.
43. Bishop.
44. King City.
45. Chico.
46. Salinas.
47. Oroville.
48. Clear Lake.
49. Placerville.
50. Santa Ynez.
51. Paso Robles.
52. San Luis Obispo.
53. Capistrano.
54. Oceanside.
55. El Cajon.
56. Suisun.
57. Alturas.
58. Dixon.
59. Lodi.
60. Barstow.
61. Contra Costa.
62. Napa.

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