

U. S. DEPARTMENT OF AGRICULTURE,  
BUREAU OF SOILS—MILTON WHITNEY, Chief.  
IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA AGRICUL-  
TURAL EXPERIMENT STATION, THOMAS F. HUNT, DIRECTOR;  
CHARLES F. SHAW, IN CHARGE SOIL SURVEY.

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RECONNOISSANCE SOIL SURVEY  
OF THE LOWER SAN JOAQUIN VALLEY,  
CALIFORNIA.

BY

J. W. NELSON, IN CHARGE, AND J. E. GUERNSEY, OF THE  
UNIVERSITY OF CALIFORNIA, AND L. C. HOLMES AND  
E. C. ECKMANN, OF THE U. S. DEPARTMENT  
OF AGRICULTURE.

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MACY H. LAPHAM, INSPECTOR, WESTERN DIVISION.

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[Advance Sheets—Field Operations of the Bureau of Soils, 1915.]



WASHINGTON:  
GOVERNMENT PRINTING OFFICE.

1918.

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## LETTER OF TRANSMITTAL.

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U. S. DEPARTMENT OF AGRICULTURE,  
BUREAU OF SOILS,  
*Washington, D. C., October 16, 1917.*

SIR: During the field season of 1915 a reconnoissance survey was made of the Lower San Joaquin Valley, Cal. This work was done in cooperation with the University of California Agricultural Experiment Station, and the selection of the area was made after conference with State officials.

I have the honor to transmit herewith the manuscript report and map covering this area, and to recommend their publication as advance sheets of Field Operations of the Bureau of Soils for 1915, as authorized by law.

Respectfully,

MILTON WHITNEY,  
*Chief of Bureau.*

Hon. D. F. HOUSTON,  
*Secretary of Agriculture.*

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MAP.

Soil map, reconnaissance survey, Lower San Joaquin Valley sheet, California.



# RECONNOISSANCE SOIL SURVEY OF THE LOWER SAN JOAQUIN VALLEY, CALIFORNIA.

By J. W. NELSON, In Charge, and J. E. GUERNSEY, of the University of California, and L. C. HOLMES and E. C. ECKMANN, of the U. S. Department of Agriculture.—Area Inspected by MACY H. LAPHAM.

## DESCRIPTION OF THE AREA.

### GEOGRAPHY.

The reconnoissance soil survey of the Lower San Joaquin Valley covers an important part of the physiographic division known as the Great Interior Valley of California, which occupies the central part of the State. This latter valley is almost 500 miles in length with an average width of between 40 and 50 miles, and extends in a general northwest-southeast direction from the city of Redding on the north, in latitude  $40^{\circ} 35'$ , southeastward to south of Bakersfield, or about latitude  $35^{\circ} 10'$ . It is flanked on its eastern side by the lower foothills of the Sierra Nevada Mountains and on its western side by the Coast Ranges. The valley is inclosed around its northern extension by the Klamath Mountains, connecting the east-side and west-side ranges, and around its southern end by the Tehachapi Mountains, which likewise may be considered as the merging, in this part of the State, of the Sierra Nevada Mountains and the Coast Ranges. The boundary of the valley on all sides is relatively distinct, but somewhat more so on the western than on the eastern side. The ends are rounded or blunt rather than sharply pointed. At a point a little nearer the northern than the southern boundary of the valley there is a break in the Coast Ranges through which the drainage waters find an outlet to the west. However, the bottom of the opening across the mountain ranges is lower than sea level, so that the sea advances as an arm through the ranges into the valley. The rivers of the valley, therefore, enter the sea within the valley, and do not flow as rivers across the inclosing ranges. Elsewhere the inclosing ranges are practically unbroken.



Fig. 1.—Sketch map showing location of the Lower San Joaquin Valley area, California.

That part of the Great Interior Valley lying north of the drainage outlet through the Coast Ranges is known as the Sacramento Valley, being drained by the Sacramento River, which enters the valley as a large stream through a gorge in the inclosing ranges at its northern end. The southern and larger part is known as the San Joaquin Valley, and is drained by the San Joaquin River, which is formed largely within the valley by the union of a number of streams from the surrounding mountains, mainly from the Sierra Nevada Mountains. The two main streams mentioned unite just inside the break in the Coast Ranges. There is no natural boundary between the two main valleys, as they merge at the confluence of the north and south drainage in a low region belonging as much to one valley as to the other. A previous survey, similar to the present one, covered practically all the Sacramento Valley. Its southern boundary was established along latitude  $38^{\circ}$  north, this east and west line being an approximate boundary between the two valleys. This survey covers the lower or northern part of the San Joaquin Valley and is a continuation of the earlier soil survey work in the Sacramento Valley.<sup>1</sup> The present survey adjoins, along a part of its western side, the area covered by the reconnaissance soil survey of the San Francisco Bay Region.

The area trends northwest and southeast, and its extreme length is about 100 miles. Its average east and west width is between 45 and 50 miles. Its southern boundary on the west side of the valley trough is along latitude  $36^{\circ} 50'$ , while the San Joaquin River forms the southern boundary on the east side. The eastern and western boundaries of the area are formed by the foothills of the Sierra Nevada and Coast Range Mountains, respectively. The greater part of the area is covered by topographic maps prepared by the United States Geological Survey, and these were used where available as base maps for the accompanying soil map. The base maps prepared by the Bureau of Soils in the detailed soil surveys of the Merced and Madera areas were used for a part of the southeastern section, and revised copies of county maps were used for a part of the southwestern section. The area covers 4,760 square miles, or 3,046,400 acres.

#### TOPOGRAPHY AND ELEVATION.

That part of the Great Interior Valley covered by this survey does not differ greatly in topography and physiography from other parts, or from many other structural valley basins and troughs of the State.

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<sup>1</sup> Reconnaissance Soil Survey of the Sacramento Valley, Cal., Field Operations of the Bureau of Soils, 1913, and Reconnaissance Soil Survey of the San Francisco Bay Region, Field Operations, 1914. See also Soil Survey of Stockton Area, Cal., Field Operations of the Bureau of Soils, 1905; Modesto-Turlock Area, 1908; Madera Area, 1910; and the Merced Area, 1914.

It consists of a broad, basinlike valley which has been filled to unknown depths by wash from the inclosing mountains. This vast amount of valley-filling material has been deposited by different agencies, operating through long periods of time. It is probable that some of the deposits were accumulated in salt or brackish water, while others were laid down in fresh water. It is likely, however, that most or nearly all of the present surface deposits were distributed across land surfaces as alluvial-fan and flood-plain material by the present streams or their counterparts. It is only along the margins of the valley that consolidated rocks which represent much earlier formations of both sedimentary and igneous character are encountered. The side slopes of the valley have a relatively low gradient and are longer on the east side than on the west, owing to the larger quantities and coarser texture of filling material carried in from the eastern mountains. Regular slopes seldom extend to the trough of the valley, usually being marked in their lower parts by flattened or basinlike surfaces.

The higher slopes and the rolling and more elevated areas along the sides of the valley are occupied by older alluvial deposits, which have been materially altered by weathering and erosion. More recent alluvial deposits occupy the narrow valleys which modern streams have formed in the older deposits, and also occur as alluvial fans superimposed on the old sediments of the plains.

The area ranges in elevation from several feet below sea level to about 1,000 feet above, these extremes being represented by the island region in the northwestern part of the survey where the land surface is protected from inundation by levees, and some of the higher points along the sides of the valley. The greater part of the area has an elevation of less than 250 feet, and much of it an elevation of less than 100 feet. The axis of the valley, beginning below sea level west and northwest of Stockton, rises gradually to the southward until at Firebaugh, on the San Joaquin River near the southern boundary of the area, an elevation of about 156 feet is reached. The region adjacent to the valley trough is often flat or basinlike for considerable distances. The valley slopes rise gradually from these flats, and rarely attain an elevation of more than 300 or 400 feet before the main foothills of the mountains are reached. Some of the older valley deposits along the margins of the valley reach an altitude of 425 feet, but elevations greater than this usually represent outstanding spurs or jutting ridges of the mountains which border the survey.

#### DRAINAGE.

The drainage of the area is effected by a large number of streams which flow down the valley slopes approximately at right angles

to the San Joaquin River, the principal stream of the area. This stream rises in the mountains to the east and flowing westward forms the southern boundary of the area to the trough of the valley, where it swings sharply to the northwest and preserves a rather regular course to near the northern boundary of the survey. The drainage which it receives in its course through the valley is greater than that received from other sources. All of the main streams come from the east side of the valley and pursue rather parallel courses to the valley trough, where they join the main valley drainage. The west side of the valley contributes relatively little drainage, owing to the less extensive watersheds and lower precipitation. The general character and normal discharge of the main streams of the area are discussed in a subsequent chapter on irrigation. The principal streams of the east side of the valley are mentioned, in order of their occurrence from north to south. The Calaveras River, rising to the east of the survey and draining some of the outer mountainous region, has an outlet into the island region northwest of Stockton. The next stream of importance is the Stanislaus River, which rises in still higher regions and reaches the axis of the valley northwest of Modesto. The Tuolumne and Merced Rivers do not differ essentially in their main features, and, like the Stanislaus, drain high, mountainous regions of rough, rugged character. From the Merced River southward there are a number of smaller streams which do not reach back into the higher mountains, and so have less permanent flows. Chief among these are the Chowchilla and Fresno Rivers and Bear and Mariposa Creeks. The upper San Joaquin River, above the point where it reaches the valley trough, is similar to the Merced and Tuolumne Rivers. Surplus waters from the southern part of the San Joaquin Valley occasionally reach the San Joaquin River near the point where this stream swings northwestward along the valley trough. The drainage of the western side of the valley is carried by minor intermittent streams. These usually are not of sufficient size to maintain well-marked channels for long distances after emerging upon the valley slopes. Several of them have gravelly beds for several miles into the valley, and are comparable with the smaller, intermittent streams of the east side.

The streams of the east side enter the valley through intrenched bottoms or minor alluvial valleys and proceed to the main valley trough without receiving any lateral drainage, while those on the west side are less well defined and have no alluvial bottoms. The drainage of the valley slopes is carried almost entirely by minor streams which originate on the slopes and empty their waters into basins rather than into the major streams. The uplands flanking the main streams along their upper courses in the valley gradually

disappear toward the valley trough, merging with the bottoms along the main streams through rather uniform valley slopes.

The area as a whole has better surface drainage and is subject to less destructive floods than the Sacramento Valley. The detailed drainage is more fully discussed in the descriptions of the soils in the following pages. The poorest drained parts are the San Joaquin delta region and the flat region adjoining the trough of the valley, which have slight fall and receive surplus water from both adjacent valley slopes and from the overflow of the San Joaquin River.

#### POPULATION.

The population of the area as near as can be determined from the returns of the census was about 93,000 in 1910. Since that time there has been a moderate increase. The area had about 59,000 inhabitants in 1900. Of the total population, about 37,000 resided in incorporated cities in 1910, as compared with about 21,500 in 1900. The population is very largely American born, with small numbers of Asiatics and Europeans.

The middle slopes of the east side of the valley contain most of the population. Stockton is the largest and most important city, with a population of 23,253 in 1910. There are other cities or towns having populations between 1,000 and 5,000 in 1910. These include Merced, Madera, Modesto, Turlock, and Oakdale. There are several villages and towns of a few hundred inhabitants each.

#### TRANSPORTATION.

The area is well supplied with transportation facilities. Main lines of the Southern Pacific Railroad, which connect on the north between Lathrop and Tracy, traverse the area on each side of the valley. The same system has several branch lines, chief of which is the Stockton-Oakdale branch traversing the eastern part of the survey. The main line of the Atchison, Topeka & Santa Fe Railroad also traverses the eastern side of the valley, while the Western Pacific Railroad crosses the northern part. The Yosemite Valley Railroad, connecting Merced with the Yosemite Valley, and the Sierra Railway, connecting Oakdale with mountainous regions to the east, are lines of less importance. There are two electric lines in the area, the Central California Traction, which operates between Stockton and Sacramento, and the Tidewater Southern Railway, between Stockton and Turlock.

Boats of shallow draft ply between San Francisco and Stockton and points along the Sacramento and San Joaquin Rivers, and carry considerable freight. Passenger service by boat is maintained between Stockton and San Francisco and other river and bay points.

The extension of water transportation for some distance up the San Joaquin River has been proposed, but at present the river during the summer months does not carry sufficient water for navigation.

The road system of the area is very good. The State highway is the main road on the east side of the valley, and extends the length of the area closely paralleling the line of the Southern Pacific Railroad. The Lincoln Transcontinental Highway crosses the northern part of the area.

Many products of the area, such as dried or fresh fruits, nuts, canned products, dairy products, and grain are shipped to distant markets, as are similar products from other parts of the State. The more perishable or bulky products have a more restricted distribution.

#### CLIMATE.

##### SEASONS.

The climate of this area is characterized by a rainy winter season and a dry summer season. The winter days usually are rainy, cloudy or foggy, and cool, but some bright, warm days are interspersed; the summer is marked by practically cloudless days, low humidity, and high temperature. The winter season commonly is considered as extending from November to April, although there are wide variations in the duration of the rainy period.

##### PRECIPITATION.

The rainfall in this part of the San Joaquin Valley decreases from north to south, and with minor exceptions is considerably less on the western side of the valley than on the eastern side. The heaviest precipitation occurs in the higher region along the margin of the valley. Sacramento, a short distance north of this area and near the middle of the Great Interior Valley, has an annual rainfall of 19.28 inches; Stockton, in the northern part of the area, 14.57 inches; Modesto, in the central part, 11.32 inches; Storèy, in the southern part, 9.56 inches; and Bakersfield, southeast of the area, 5.39 inches. Antioch, a short distance north of the area and on the western side of the valley, receives 12.94 inches annually; Tracy, 10.37 inches; Los Banos, in the southwestern part of the area, 8.52 inches; and Mendota, near the southern boundary, 6.29 inches. The difference in the amount of rainfall due to elevation and position with reference to the mountains is shown by comparing points located a little west of the trough of the valley with others near its eastern margin. Tracy, Westley, and Los Banos, on the west side of the valley, annually receive 10.37 inches, 10.66 inches, and 8.52 inches, respectively, while Milton, northeast of the area, La Grange and Le Grand, towns on the eastern side and occupying elevations 100 to 500 feet above the

first-named stations, receive 21.90, 16.91, and 12.57 inches, respectively. The rains usually are of 2 or 3 days duration, are seldom torrential in character, and are succeeded by several days of fair weather.

Snowfall is rare in the area except in the foothill margin, where light and quickly disappearing snows usually occur each season. Thunderstorms and hail are very rare.

Fog is of common occurrence throughout the rainy season in all but the foothill regions. The fog, forming in the night along the lower parts of the valley, often extends well up toward the higher lands and usually continues for sometime after daybreak. Occasionally it persists throughout the entire day, as in the delta region and along the San Joaquin River.

The following table, compiled from Weather Bureau statistics, indicates the rainfall condition of the area:

*Mean monthly and annual precipitation at various stations in or near the Lower San Joaquin Valley area.*

Month.	Sacramento, 1850 to 1912.	Stockton, 1867 to 1912.	Modesto, 1871 to 1911.	La Grange, 1868 to 1911.	Merced, 1872 to 1911.	Le Grand, 1900 to 1911.	Storey (Madera). 1900 to 1911.
	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>
January.....	3.94	3.02	2.94	3.48	2.35	2.62	1.95
February.....	2.85	2.27	1.44	2.61	1.48	1.85	1.51
March.....	2.99	2.30	1.71	2.68	1.89	2.72	1.85
April.....	1.58	1.08	.85	1.40	.95	.89	.83
May.....	.80	.66	.48	.72	.54	.52	.47
June.....	.13	.12	.12	.09	.12	Trace.	.01
July.....	.02	Trace.	.01	Trace.	.01	.01	Trace.
August.....	.01	.01	Trace.	.01	.02	Trace.	Trace.
September.....	.24	.22	.19	.28	.21	.20	.12
October.....	.83	.68	.52	.89	.49	.91	.44
November.....	2.00	1.50	1.31	2.03	1.17	1.34	1.05
December.....	3.89	2.71	1.75	2.72	1.59	1.51	1.33
Year.....	19.28	14.57	11.32	16.91	10.82	12.57	9.56

Month.	Fresno, 1881 to 1911.	Antioch, 1879 to 1911.	Tracy, 1879 to 1911.	Westley, 1889 to 1911.	Newman, 1889 to 1911.	Los Banos, 1873 to 1911.	Mendota, 1894 to 1908.
	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>
January.....	1.71	2.70	1.91	2.25	2.24	1.77	1.20
February.....	1.36	1.93	1.39	1.42	1.55	1.11	1.04
March.....	1.81	2.30	1.80	2.10	2.18	1.40	1.07
April.....	.97	.78	.83	.67	.68	.57	.34
May.....	.56	.50	.56	.55	.54	.85	.37
June.....	.11	.12	.17	.09	.06	.07	.03
July.....	Trace.	Trace.	Trace.	.02	Trace.	.01	.01
August.....	Trace.	.02	.01	Trace.	.02	.01	Trace.
September.....	.29	.25	.21	.20	.21	.13	.13
October.....	.63	.66	.51	.53	.80	.33	.45
November.....	1.13	1.30	1.08	1.07	1.09	.97	.70
December.....	1.47	2.38	1.90	1.76	1.81	1.30	.95
Year.....	10.04	12.94	10.37	10.66	11.18	8.52	6.29

## TEMPERATURE.

The mean temperature is generally higher in the southern than in the northern part of the valley. The temperature is quite uniform throughout the area, except in the summer season when there is considerable variation in the northern part of the area, due to the cooling influence of air movements from the coast. The following table gives the mean seasonal and annual temperatures at several points in this part of the State:

*Mean seasonal and annual temperature.*

Station.	Winter.	Spring.	Summer.	Autumn.	Year.
	° F.	° F.	° F.	° F.	° F.
Sacramento.....	47.4	58.0	71.1	61.5	59.6
Stockton.....	47.9	59.2	72.0	61.5	60.1
Fresno.....	47.1	61.5	79.7	64.5	63.2
Bakersfield.....	49.1	63.9	82.4	65.3	65.1

During the summer months the temperatures are high. Temperatures of 100° F. are common, and at practically all points in the valley extremes of 110° to 115° have been recorded. Farming operations are carried on continuously, however, and heat prostrations are practically unknown. The nights are seldom oppressive. Freezing temperatures occur at intervals through the winter months. Light frosts are of common occurrence, and thin films of ice are sometimes formed in the lower portions of the valley. A minimum winter temperature of 20° F. is rare, and a minimum of about 25° F. is unusual. The range of winter temperatures is affected by the elevation and by the movement of air currents. The most severe cold is often experienced along the trough of the valley and in the smaller river valleys, where the local topography restricts the movement of the air. Along the foothill slopes and on the more rolling parts of the floor of the valley, frosts are commonly very light, and in exceptional years only is the degree of cold sufficient to affect the growth of the more tender crops. Throughout the winter and spring months there is an abundant growth of vegetation. The following table is indicative of the temperature conditions in the area:

Monthly and annual absolute maximum, minimum, and mean temperatures at various stations in or near the Lower San Joaquin Valley area.

Month.	Sacramento.			Stockton.			Modesto.			Merced.		
	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
January.....	72	19	45.6	68	22	46.5	81	25	46.6	72	20	47.0
February.....	76	21	50.2	79	24	50.0	92	28	50.1	79	23	51.0
March.....	80	29	54.2	80	31	54.5	87	33	55.9	86	25	55.0
April.....	89	35	57.9	91	31	58.9	95	40	62.2	96	31	60.0
May.....	103	39	62.9	102	40	64.1	105	42	69.4	105	32	67.3
June.....	106	44	68.8	103	40	69.9	108	52	76.6	109	40	75.3
July.....	110	41	72.5	110	42	72.6	111	60	81.5	116	40	81.7
August.....	108	48	72.0	105	40	72.5	110	53	79.9	114	41	79.3
September.....	106	43	69.0	104	45	69.0	110	50	74.7	110	35	73.7
October.....	98	36	62.2	90	36	61.7	106	41	65.3	102	28	64.8
November.....	81	27	53.4	84	25	53.9	90	30	55.8	86	21	55.4
December.....	69	24	46.3	67	23	47.1	84	15	48.1	75	16	48.3
Year.....	110	19	59.6	110	22	60.1	111	15	63.8	116	16	63.2

Month.	Le Grand.			Storey (Madera).			Fresno.			Antioch.		
	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
January.....	78	23	46.0	71	19	45.2	72	20	45.4	88	27	46.5
February.....	82	21	48.5	76	20	48.6	83	24	49.2	82	28	50.8
March.....	83	28	51.3	80	29	52.3	87	28	54.9	91	35	54.4
April.....	98	29	57.4	99	29	58.0	101	34	61.2	83	38	59.7
May.....	112	31	63.7	110	35	64.4	110	38	68.4	104	40	66.1
June.....	110	32	72.9	109	37	72.3	112	42	75.8	106	45	72.0
July.....	117	36	80.3	114	45	78.7	115	50	82.0	110	55	75.8
August.....	112	40	77.2	114	45	77.0	113	51	81.2	109	53	74.5
September.....	108	36	72.6	109	39	71.1	111	42	74.3	109	51	71.1
October.....	97	26	63.9	98	27	61.8	100	36	64.7	92	44	63.4
November.....	83	20	51.7	84	22	52.2	84	27	54.6	90	32	53.8
December.....	78	21	45.2	76	20	44.2	74	23	46.8	74	21	48.3
Year.....	117	20	60.9	114	19	60.5	115	20	63.2	110	21	61.4

Month.	Tracy.			Westley.			Newman.			Los Banos.		
	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
January.....	72	26	46.9	75	24	47.8	70	24	47.7	81	20	48.8
February.....	82	26	50.5	79	26	51.9	74	24	51.6	77	25	50.9
March.....	82	30	54.8	85	32	56.2	91	30	55.7	80	30	55.4
April.....	94	36	60.9	94	40	64.0	96	33	62.1	98	40	62.6
May.....	103	45	69.1	105	38	70.1	106	38	69.1	100	45	68.3
June.....	106	50	75.9	109	52	77.6	108	39	76.5	106	52	75.4
July.....	114	56	79.9	115	52	82.7	115	48	82.0	110	57	80.0
August.....	115	51	77.5	113	50	79.2	114	48	80.2	110	56	78.8
September.....	107	48	72.0	105	52	74.0	112	43	73.6	106	50	72.8
October.....	93	41	63.5	94	40	66.8	99	36	64.8	92	40	64.6
November.....	80	25	54.2	82	26	56.7	80	22	56.1	84	28	55.2
December.....	76	18	49.6	71	25	48.5	73	24	48.0	80	24	48.6
Year.....	115	18	62.9	115	24	64.6	115	22	64.0	110	20	63.4

## FROSTS.

The occurrence of killing frosts is irregular, depending upon elevation and air drainage, but as a rule frosts are likely to affect the most tender vegetables and the more tender fruits up to the 1st of March. December 1 is a fair average date of the first killing frost in the fall. Killing frosts have occurred as late as the middle of April and as early as the last week in October. The following table of frost data is compiled from the records of various Weather Bureau stations in the region:

*Dates of killing frosts.*

Station.	Number of years covered by record.	Average date of last killing frost in spring.	Average date of first killing frost in fall.	Latest date of killing frost in spring.	Earliest date of killing frost in fall.
Antioch.....	15	February 22.....	December 8.....	April 13.....	November 23.
Lodi.....	15	March 12.....	November 16....	April 12.....	October 11.
Merced.....	15	April 7.....	December 3.....	April 13.....	November 11.
Storey (Madera).....	13	February 23.....	.....do.....	April 12.....	October 20.
Tracy.....	15	February 17.....	November 18....	.....do.....	November 24.
Sacramento.....	63	.....	.....	April 26.....	November 11.
Fresno.....	20	February 23.....	December 3.....	April 13.....	Do.

## WINDS.

The prevailing movement of the wind in the San Joaquin Valley is from northwest to southeast. During the spring, summer, and fall months it is rarely in any other direction, but during the winter period there is more or less wind movement from the southeast, south, and southwest, depending upon the frequency of the winter storms. Winds that are destructive to property are practically unknown, though during the spring months winds of two or three days' duration often attain considerable velocity and are of concern to the farmers, particularly in the nonirrigated districts, because of their extreme drying effect and their tendency to drift the sandy soils.

## AGRICULTURE.

## DEVELOPMENT.

There is little definite information available with respect to conditions in the San Joaquin Valley prior to 1840. The limited records indicate that there was an Indian population, plentiful game, and a large number of wild horses and cattle. The Indians made no attempt to till the soil, and the Mexicans who succeeded them did but little more, confining their efforts to cattle raising. The Americans who settled in the valley in the forties engaged in more

methodical stock raising, and during the fifties the production of crops to supply the demands of the miners who had settled in the region was slowly developed. The first efforts in this direction consisted of growing wheat, without irrigation, which largely gave way later to barley, owing to decreases in returns from the former crop. Grain farming in the sixties began to assume an importance equal to that of stock grazing. At this time irrigation began to develop, bringing about a decided change in the character of crops grown and in general conditions of agriculture. During the seventies several ditch systems were constructed and irrigation farming was extended, and it became apparent this form of agriculture was destined to become the predominant type. As the area irrigated has expanded a marked diversification of crops and cropping systems has taken place, and the present agriculture includes the production of both general farm crops and many special crops introduced from widely separated regions.

The recent development of the valley has been rapid, and it is difficult to obtain accurate data as to the acreage and total production of the various crops, but the figures given in this report are sufficiently accurate to indicate their relative importance. The figures are based on the census of 1910, on data compiled by county officials or county farm advisers, on information obtained from farmers of the area, and from observations made in the field.

#### GRAIN AND HAY CROPS.

The production of dry-farmed grain is an extensive industry in the valley, and promises to continue so until increased population and expansion of irrigation lead to the substitution of more intensively cultivated crops. Barley, wheat, oats, and rye, named in order of their importance, are grown throughout the area under widely different conditions and with greatly varying yields. Wheat formerly was the most extensive grain crop, but this has largely been superseded by barley. From 300,000 to 350,000 acres of barley are grown annually in the area, the yields ranging from about 6 to 30 sacks<sup>1</sup> per acre. Some soils are cropped continuously, but the greater part of the crop is grown on land which is allowed to lie fallow every alternate year. In the northern part of the west side of the valley high yields are obtained, but in the southern part the yields are low owing to the lighter rainfall. The crop is harvested with combined harvesters. About 60,000 to 80,000 acres of wheat are grown annually. Most of the wheat fields are fallowed every other year. From 50,000 to 75,000 acres of oats and less than 10,000 acres

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<sup>1</sup>A sack contains about 100 pounds.

of rye are grown. Grain is grown on the delta lands to rotate with potatoes, barley being most commonly used. Grain is cut green for hay on 75,000 to 100,000 acres. Medium to heavy textured soils are preferred for growing grain, the light soils giving mediocre yields. Most lands of the area when irrigated are too valuable for grain production, except as a rotation crop, so that most of the grain grown is produced under dry-farming methods.

Alfalfa is the leading irrigated crop of the area, between 175,000 and 200,000 acres being devoted to it. About one-half the acreage is in Stanislaus County, where irrigation is widely developed. Alfalfa is generally cut five to seven times each season, depending upon seasonal variations both in weather and in water supply. The average yield per season for the area is about 3 tons per acre, but this yield is doubled on well cared for fields, and yields of 8 to 10 tons are occasionally obtained. A large acreage is used as pasture for dairy cattle. Alfalfa does best on deep, well-drained soils of medium texture. It is also grown successfully on sand and clay soils, but with smaller yields and the necessity of more frequent reseeding. A dependable supply of water for irrigation is necessary for the best results, but some fields on favorable soils are very productive without irrigation. The price of alfalfa hay varies widely, the baled product averaging about \$8 to \$10 per ton.

Clover is a minor crop. It is grown on the delta lands as a part of the rotation system. Some timothy, redtop, and rye grass are grown on the Muck and Peat of the delta section, with good yields. They are grown as a part of the rotation system and not primarily as cash crops. The native-grass hay crop is unimportant. The yields are low and the hay is of poor quality. Outside the delta section hay, other than alfalfa and grain hay, is grown only on lands which are not at present suited to other crops.

#### MISCELLANEOUS FIELD AND TRUCK CROPS.

The nonsaccharine sorghums are rapidly increasing in importance, with probably about 15,000 acres now being grown in the area. The most common of these are the white durra (Egyptian corn), feterrita, milo, and kafir, named in order of their importance. The grain is fed to chickens, hogs, cattle, and horses. These crops make ensilage of good quality. The sorghums are grown on soils varying widely in texture. Those of medium texture generally produce the best yields, although most of the crop is grown on rather sandy soils. The best returns can not be obtained without irrigation, except on soils that are retentive of moisture or are subirrigated. Yields vary greatly, 1 to 2 tons per acre being considered a good yield. The grain usually sells for about \$25 to \$30 per ton. The cost of produc-

tion, excepting that for harvesting which is commonly done by hand, is not great. The introduction of binders promises to reduce greatly the cost of harvesting. Crop rotation is essential to maintain yields, and grain, beets, and beans make desirable alternates. As the time from seeding to harvesting is 90 to 120 days, it is possible to grow the sorghum crop after harvesting a crop of winter barley, or two crops of sorghum may be grown the same season, the second being used for ensilage if desired.

Sunflowers are grown in the area, chiefly near Manteca. The acreage varies widely from year to year. About 2,000 acres were grown in 1915, and good yields and prices were obtained. The seed is sold for chicken feed and for the manufacture of oil. Sunflower seed contains 15 to 18 per cent oil, and the crop would become better established if the market for the oil could be improved. The yield is about 1,400 pounds of seed per acre, and the price at the time of this survey was stated to range from  $2\frac{1}{2}$  to 4 cents per pound. Sunflowers are grown chiefly on sand and sandy loam soils free from alkali. Irrigation is not practiced, but it is believed by some that with irrigation the yields would be increased.

Rice has recently been introduced, and gives great promise of success. In 1915 there were about 1,000 acres of rice in Fresno County near Dos Palos, about 75 acres in Merced County near Merced, 200 acres in Stanislaus County near Paulsell, and 10 acres in San Joaquin County near Stockton. A larger acreage is grown farther south in the San Joaquin Valley, and over 15,000 acres were planted in the Sacramento Valley in 1914. The acreage given for the present survey represents the status of the industry after three years' growth. Apparently the crop is destined to become one of great importance in the area. The results seem very favorable where mistakes have not been made in the care of the crop. Extensive experiments are now being carried on in other parts of the State to improve methods of growing this crop. Large yields, 60 sacks per acre, have been obtained, but 30 to 40 sacks is more nearly the average yield. Rice sold at \$1.80 to \$1.90 per hundred pounds in the season of 1915. As the crop requires approximately 5 acre-feet of water, it may not be grown at a reasonable cost where water is expensive. The fields must be leveled carefully and checked. The rice is seeded in a dry soil, which is irrigated to obtain germination. When about 5 inches high, shallow flooding is commenced; a depth of 4 to 5 inches of water is maintained for most of the growing period, but the water is drawn off before ripening. Most of the crop is grown on heavy soils, but soils of lighter texture are suited to the crop where the water table is near the surface or where shallow hardpan is present to decrease the loss of the irrigation water by percolation. Indications are that it can often be

grown on soils which are too high in alkali to produce most other crops successfully, and that the flooding will at the same time reclaim these lands from alkali. In this way extensive areas of lands in the valley trough, which have heretofore been of little use except for pasture, may be utilized.

Most of the rice in the area is of the Wataribune variety. No insect pests have developed as yet, but certain weeds are troublesome. Rotating the crop will probably be practiced to control weeds when the fields have been cropped for several years.

Sugar beets are not extensively grown in the area at present although moderate acreages are devoted to the crop.<sup>1</sup> This crop could be grown successfully with favorable conditions of labor and markets.

The area generally is not considered well adapted to the production of corn, owing largely to adverse climatic conditions. Some fields of corn are successfully grown in the river valleys, especially in the Merced River bottoms. The crop has recently become popular on the Muck and Peat land, and promises to become more important. Several fields of flint corn have given an exceptional growth of stalk and heavy yields of large and well-filled ears on this organic soil. The upland soils do not seem so well suited to the varieties of corn that so far have been tried.

Approximately 15,000 acres of beans were grown in the area in 1915, about 12,000 acres of which were on Muck and Peat land and the low river bottoms. The delta region, including the part in the Sacramento Valley is the second largest bean center in the State. On the delta lands pinks, whites, and bayos are grown, and on the upland soils black-eyes, Mexican reds, and teparies. Except in the delta region, where beans are generally irrigated, the greater part of the crop is grown without irrigation. On the drier soils, however, yields are uncertain. Yields on the Muck and Peat land of the delta region range from about 18 to 23 sacks per acre; upland beans produce 10 to 15 sacks per acre.

Between 20,000 and 25,000 acres of potatoes are grown in the area, all but about 1,000 acres of which are grown in the island or delta section. The greater part of the potato crop of the entire delta region is marketed through Stockton. This consists of the product of 40,000 to 50,000 acres annually, or about three-fourths the potato acreage of the State. The yields on the delta vary widely, depending on whether the crop is grown on new land or land which has been continuously cropped. It is customary to crop new land continuously to potatoes until they are no longer profitable and then to alternate with barley as long as this is profitable, after which pota-

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<sup>1</sup> Since this report was written a sugar factory has been built and put in operation at Manteca.

toes may be included in longer rotations. Potato diseases in the delta areas are very difficult to eradicate, and long rotations, including crops of an entirely different character are necessary to maintain yields. The legumes and onions are not especially desirable as alternates.<sup>1</sup> Rotations have received little attention in the past, largely because of the prevailing one-year tenant system, and reduced yields are due in part to this fact. Most of the potatoes grown are of the Burbank variety. The American Wonder is also grown on the delta soils, and this variety and the Early Rose are popular on the upland soils. The selling price varies considerably, usually being about \$1 per sack on the river bank. Potatoes constitute one of the leading cash crops of most of the delta lands.

Practically all the onions grown in the area are produced on the delta lands, 2,000 to 3,000 acres being planted annually. They are not grown on the lowest, most typical Muck and Peat land, but mainly on fairly well drained soils made up more largely of alluvial sediments. The Yellow Danvers and Australian Brown are the principal varieties grown. On the uplands some other varieties are produced in the truck gardens. Onion growing is often very profitable, but the price received by the growers fluctuates widely.

About 2,000 acres of celery are grown annually in San Joaquin County, mainly on the low, heavy soils of the delta region where the ground-water level is high. Some is grown also on the Muck and Peat land. A large part of the above acreage, however, is produced outside the present survey on the San Joaquin delta lands to the north.

Asparagus is grown extensively on the delta lands of the area, but the acreage is decreasing. The product is canned locally and large quantities are shipped fresh to local and eastern markets. Yields usually are good, but prices fluctuate greatly.

The sweet-potato industry centers about Atwater and Livingston, in Merced County, which is the main sweet-potato section of the State. The crop is shipped fresh in bulk or is canned at Atwater. The Turlock vicinity also grows a large acreage. In 1913 Atwater shipped 510 cars and Livingston 200 cars. Turlock shipped 136 cars in 1914. Sweet potatoes yield about 10,000 to 15,000 pounds to the acre when grown with care on the better soils, but the average is about 7,500 pounds. The market price varies greatly, usually being lowest during the harvesting season. The earliest fall or late winter markets usually are much better than those of midseason, and the growers endeavor to sell early or store the potatoes until the prices have advanced. Successful storing of sweet potatoes requires great

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<sup>1</sup> Potato Growing in the San Joaquin and Sacramento Deltas of California, Circular No. 120, California Agricultural Experiment Station.

care, as they are very susceptible to attack by fungi. The crop is largely grown by Portuguese and Italians. The well-drained sand and sandy loam soils are best adapted to this crop and one to five irrigations is the rule. A relatively small acreage of yams also is grown.

Scattered small acreages of tomatoes are grown for local market. There is an important tomato district about Manteca. The crop is shipped to canneries outside the area, but canning facilities will probably be developed within the area. It is the usual custom to irrigate the young plants if the condition of the soil seems to demand it, and the irrigation may or may not be continued. Late irrigations seem to impair the quality of the product. The crop ordinarily is grown on sandy loam soil.

About 4,000 or 5,000 acres of melons are grown in the area, mostly near Turlock, which is one of the main melon-producing centers of the State. The remainder are produced near Livingston, Atwater, and Manteca. Melons are grown on sands and sandy loams; heavy soils give a large growth of vine but a poorer crop of melons. The sandy soils of the above districts are well adapted to the crop. Irrigation is practiced on the drier soils, but large areas are grown without it. The price received for the melons depends largely upon the time of ripening and the degree of competition encountered with other producing regions, such as the Imperial Valley. The earliest and latest markets pay the highest prices. Watermelons and cantaloupes are the most important melon crops at the present time. Casabas are produced on a smaller acreage. Turlock shipped 27 carloads in 1914, but the market seems limited. Persian melons are a recent introduction, having been grown only about three years in any considerable quantity. The acreage is increasing rapidly, owing to a growing demand for the fruit, which is of good color, texture, and flavor. Where plantings are made from home-grown seed the quality of the crop seems to deteriorate, and it is necessary to introduce new seed each year. The seed is brought largely from Colorado. Considerable acreages of cow melons, a coarse, poorly flavored product, are grown for cattle and hog feed. The price of melons fluctuates very widely; profits may be large or the entire crop may be unmarketable.

A few hops are grown in the river bottoms, but the industry is less important than in the Sacramento Valley. Experiments with hemp have been carried on in the delta region with satisfactory yields, but caring for and marketing the product has been difficult.

Cotton was grown in the bottoms of the Merced River as early as 1862. The yields and quality were good, the product selling above the usual market price, although the industry has disappeared.

Eucalyptus is commonly grown as windbreaks and borders. It grows rapidly and produces some wood for household use. It is also planted in small tracts, sometimes on poor or waste land, to supply fuel. After being well started the tree endures adverse conditions, such as a dry or alkali soil, and is therefore sometimes planted on lands which are of little value for other purposes.

As much as 1,200 acres of chicory was grown in San Joaquin County at one time, but none has recently been produced. The root is used as an adulterant for coffee, and the market has declined since the establishing of stringent food regulations.

There is a large pyrethrum plantation near Atwater, Merced County. This product is used in the manufacture of an insect powder.

Some Turkish tobacco has been grown in the area, but the quality has not proved very satisfactory.

Other minor crops, including eggplants, popcorn, and peanuts, are grown in small quantities.

#### FRUITS.

There are about 800,000 to 900,000<sup>1</sup> peach trees in the area, but only a few nectarine trees. Peaches are produced in orchards devoted exclusively to this fruit and in mixed orchards in which the peach trees are set as fillers with walnuts, figs, etc. The older trees are largely freestone varieties, such as the Muir, Lovell, Salway, Elberta, Early and Late Crawford, and others. The younger trees are largely clingstone varieties, such as the Tuscan (Tuskena), Phillips Cling, Orange Cling, Lemon Cling, and others. The freestone varieties are usually dried. Those grown chiefly for this purpose are the Muir, Lovell, and Elberta, while the other freestone varieties are sold as fresh fruit or dried. The clingstone varieties are sold to the canners and have brought a good average price in the past. Recently the peach market has been very poor, dried peaches selling at less than the cost of production. The peach growers are endeavoring to organize and improve the conditions. Peaches are largely planted on the lighter-textured soils of the area, the sands and sandy loams being most favored. Where used as fillers, the soil is selected for the main crop, and peaches are therefore sometimes grown on soils to which they are not best adapted. Irrigation usually is practiced, but important acreages are grown without it. The orchards are given clean cultivation and usually cultivated after each irrigation. Peaches are chiefly grown in the Modesto and Turlock irrigation districts, about Livingston and Atwater, and in the South San Joaquin irrigation district.

<sup>1</sup> Data in regard to number of trees obtained from reports of county and State horticultural commissioners.

There are about 50,000 fig trees in the area. These are grown on the east side of the valley, the largest plantings being near Merced, Merced Falls, Modesto, and Turlock, and on the west side near Patterson. The trees are commonly grown as borders around vineyards, fields, and orchards of other fruits, and the proportion of trees grown in orchards is not large. Recently, however, there has been extensive planting of fig orchards. About one-half the entire output of dried figs of the State is produced in Fresno county, which adjoins on the south the area surveyed. It seems that the extension of fig production should prove profitable. The Mission and Adriatic are the varieties commonly grown, the older trees being almost entirely of these varieties, while Smyrna figs comprise a large part of the recent plantings. Figs begin bearing in their fourth or fifth year where well cared for, but do not attain full bearing until several years later. They continue to bear for long periods of years if given proper attention. Figs do best on deep, well-drained soils of medium texture, although there are extensive plantings on heavier types. Many of the trees in the area are neglected and some are not irrigated, but some of the well-cared-for orchards have proved profitable. Fresh figs sometimes bring a high price, but because of the limited market and difficulties in transportation of the perishable product almost all the crop is dried. The Mission variety is the heaviest producer and the Smyrna the lightest.

There are about 50,000 apricot trees in the area. They are grown in small orchards throughout the east side of the valley, the chief district being in Stanislaus County. Apricots are commonly grown on light to medium textured soils of good depth and drainage, and where frost conditions are favorable, the trough of the valley generally being unsuited in the latter respect. The varieties commonly grown are the Tilton, Moorpark, and Royal. Some of the crop is sold to canners or as fresh fruit, but the greater part is dried. Apricots produce well under favorable conditions and are often very profitable. The fruit is more susceptible to frost than the peach, and as the soils are not always well selected, profits from different orchards vary widely. Under favorable conditions, yields of 10,000 pounds of fresh fruit may be expected, which equals about 1,700 pounds of the dried product. The trees usually are irrigated two or three times, and the crop fits in well with peach culture as the fruit matures before the peach crop is ready to be harvested, thus distributing the labor.

There are about 50,000 olive trees in the area. Of the total area in olives about 800 acres are in the vicinity of Madera, the remainder of the acreage being scattered over the east side of the valley. Olives are susceptible to frost and usually are not planted where the danger

from this source is great. Some of the orchards now in bearing occasionally are injured by frost. A light-textured, deep, well-drained soil seems to give best results. Where fog is prevalent, as in the lower northern part of the area, the trees are infested with black scale, but where the summers are dry and hot there is less danger from this source. Olives must be hand picked to command a good price, and this makes their production expensive. The better olives are pickled, while oil is made from the rest. The demand for pickling olives exceeds that for oil olives, and the former are being most extensively planted. Pickled ripe olives are becoming established as an article of food, and the market apparently is rapidly growing.

Plum and prune production is not highly developed in the area, although there is a total of about 25,000 trees, the greatest number being in San Joaquin County. These crops have not become important in the area, but appear to do well in some localities.

Parts of the area are adapted to pear production, and some orchards are now in bearing, the river-bottom soils commonly being used for this purpose. Some of the foothill clay and clay loam soils also appear to be adapted to the fruit. Rather heavy, deep soils usually are preferred for pears, and they can be grown on somewhat less thoroughly drained soils than most other fruits. The quality of the product is high, but recent plantings have been restricted because of pear blight. This disease is disastrous when neglected, but can be controlled by concerted and continued effort. There are a few recent plantings and the industry may attain its former importance.

There are a few apple trees in the area, but no extensive commercial orchards. The trees usually are neglected and bear poorly. Conditions do not seem favorable to the development of this industry.

There are many cherry orchards in San Joaquin County to the north of the area, but only a small number of trees are in the present survey. The industry will probably not develop rapidly, as there are other better suited localities in the State. The northeastern part of the area, however, seems well adapted to the crop.

The climate makes the production of a wide range of semitropical fruits possible, such as the avocado, loquat, Japanese persimmon, and pomegranate. These fruits are grown as individual or ornamental trees or for home use, but there are no commercial plantings. Quinces are grown to a small extent. The loganberry, blackberry, dewberry, raspberry, currant, gooseberry, and strawberry are grown in limited quantities, but the acreage is scattered. These small fruits can be further developed to meet rising demands. They are grown successfully on soils of the San Joaquin and Madera series elsewhere in the San Joaquin and Sacramento Valleys, and more extensive plantings can safely be made on these and other soils.

There are about 15,000 orange, 3,000 lemon, and a small number of grapefruit (pomelo) trees in the area. The center of the citrus-fruit industry is northeast of Oakdale in Stanislaus County. A belt along a part of the upper valley slopes and lower foothills of the eastern side of the area seems to be climatically adapted to citrus fruits. This belt includes a wide range of soils, many of which are not suited to this industry. The fruit grown in this region ripens early and at present is practically free from scale, so that the development of the industry should be profitable wherever the soil and climatic conditions are favorable and irrigation is possible. Most of the area included within the survey is not adapted to the commercial growing of citrus fruits, however, although heavily bearing ornamental trees are widely distributed.

The largest raisin-grape district in the State, the Fresno district, adjoins the area on the south, and one of the largest table-grape districts, that around Lodi, adjoins it on the north. Grape growing within the area surveyed, however, has not been so extensively developed, although there are over 10,000,000 vines, including table, raisin, and wine grapes.

The table grapes are grown in the northern part of the area, the Flame Tokay and Emperor being the standard varieties. The Tokay does not color so highly in the southern part of the area, and neither it nor the Emperor is so extensively planted there, although the latter does well. Table grapes are grown on both heavy and light-textured soils, but the latter are preferable. The market for table grapes has been good during recent years and they have been profitable.

Raisin grapes are grown satisfactorily only where climatic conditions make sun drying without loss possible. The raisin-grape district is therefore largely in the southern half of the area, although Stanislaus County produces large quantities. Muscat, Alexandria, and Sultanina (Thompson Seedless) are the favorite varieties for raisins. The raisin market is sometimes unsatisfactory, but organization has greatly relieved some of the difficulties surrounding the growing and marketing of the crop and a further improvement of conditions is being made.

Wine grapes are largely grown in Madera County, but are also produced successfully throughout the east side of the area. The Zinfandel is the most common variety. Wine grapes are subject to wide fluctuation in market price. In 1915 there was little or no sale for them, except where previously contracted for by the wineries.

Grapes may or may not be irrigated. Some vineyards have done well without irrigation, and some have barely survived. The grapes usually are irrigated if possible in dry years, at least where the soils are not especially retentive of moisture. The grapes of the area

usually are free from serious pests, although phylloxera and other insect pests are troublesome in some sections. The vines usually are sulphured to prevent mildew, especially in the northern part of the area.

#### NUTS.

There are over 100,000 almond trees in the area, mainly centered about Oakdale and Oakley. The crop is early and susceptible to early spring frosts so that the land selected for these trees must have good air drainage. A deep, well-drained soil of medium to light texture seems best, although some plantings are made on more clayey types. The varieties commonly grown are IXL, Nonpareil, Ne Plus Ultra, Texas Prolific, and Drake. The varieties are not self-pollenating, and it is necessary that varieties be mixed in the plantings. Keeping bees in the orchards materially aids in the distribution of the pollen. Almonds yield a half ton to a ton per acre. The crop is marketed largely through the California Almond Growers' Exchange. Profits have been satisfactory during recent years. The trees usually are given at least one irrigation, but considerable areas are grown without irrigation.

There are a few old English walnut trees in the area, and more plantings have recently been made. The old trees have produced well, and the industry promises to develop, especially in San Joaquin County. Some extensive plantings have been made near Patterson on the west side of the valley in Stanislaus County. The walnut does well on deep, well-drained soils, which may vary in texture according to the root stock used. It is generally considered that extreme heat is detrimental. The vicinity of Stockton may prove well adapted to walnuts.

A few pecans, butternuts, and chestnuts are grown in the area. The possibilities of these crops are uncertain.

#### ANIMAL INDUSTRY.

The dairy industry of the area has grown rapidly in recent years. The outlook for dairying appears bright because of the favorable climate, transportation, and market facilities, and other features. There are about 65,000 dairy cows in the area, a small percentage of which are pure-bred, with Jerseys predominating. There are also some pure-bred Holstein, Hereford, Dutch Belted, and Guernsey cattle. About one-half the dairy cows in the area are near Modesto, Turlock, Patterson, and Newman, all in Stanislaus County. Most of the remainder are in western Merced County, with a few in the included part of Fresno County. In the delta section and in other parts of the area also there are small herds. The industry on the west side

of the valley is largely conducted by people of foreign birth, mainly Swiss and Portuguese; but on the east side it is engaged in chiefly by Americans.

The dairy industry is identified with the growing of alfalfa, which in some cases constitutes the only feed, the crop being both pastured and fed as hay. In some of the better dairies the cows are fed ensilage, grain, pumpkins, melons, and other feeds in addition to alfalfa, although the latter in all cases is the staple food. Under good management an average of one cow to about  $1\frac{1}{2}$  acres is the rule, although this varies considerably, depending on the quality of the land, supply of irrigation water, and other factors. As the winters are mild some of the herds are given little or no shelter, but this is not the practice of the best dairies. Some of the dairies are run as cheaply as possible, and with little attention to modern methods, while others are well equipped and conducted under modern methods. The product is handled by local creameries or by creameries in Sacramento and San Francisco. A large part of the dairy products of the northern part of the area is sent to San Francisco, while those of the lower side are disposed of to local wholesale dealers.

About 250,000 beef cattle are fed in the area, and a part or all of their feed is produced locally. Some are pastured in the adjoining mountains during the summer, and then brought into the area to be fattened on alfalfa and grain, and others are pastured on the low, alkali lands of the valley trough or on the hilly lands along the edges of the area surveyed. As the development of the valley proceeds and the large holdings are subdivided the number of cattle in the area increases. There are extensive areas in the lower valley trough that will probably be used only for pasture for a considerable time.

The conditions within the area are very favorable for the raising of hogs. A variety of feed, such as grain, alfalfa, and skim milk, is available in considerable quantity, and the climate is well suited to the industry. Hog raising is conducted largely in conjunction with dairying. In addition to the by-products of the dairy the feed consists of alfalfa and other products, such as grains, nonsaccharine sorghums, and stock melons.

Large numbers of sheep are raised in the area or in adjacent sections. These are kept in small flocks, chiefly by Portuguese and Basques, who rent pasture land, or by owners of large tracts, who keep larger flocks. The small owners herd their sheep from place to place, keeping them in the mountains adjoining the area in the summer and bringing them into the valley in the winter for pasturing in the stubble fields, vineyards, or potato and bean fields. The large owners pasture the sheep on their rougher lands and in stubble fields. There are few goats in the area.

Not enough horses and mules are produced in the area to supply the local demand, and both are imported for use on the farms.

Poultry raising is largely an incidental occupation; in but few cases has it become a specialized or principal industry. Cheap feed is available, and most of the area is well suited to poultry raising. While turkeys do well here, there are fewer raised than in the Sacramento Valley, where the industry is rather extensive.

Early farming in the area was not favorable to beekeeping, and the industry did not develop until within recent years, except along streamways where native flowering plants were abundant. As alfalfa, fruits, and other crops have been introduced, the production of honey has increased, but not in proportion to the increased acreage of suitable bee pasture. The industry seems to be centered in Stanislaus County. Bees serve a valuable purpose in pollenizing fruits. The open winters make beekeeping much easier than in regions where they must be given winter protection.

## SOILS.

### CLASSIFICATION.

The method of classification of the soils of this area is essentially a continuation of the system used in previous surveys of similar character.<sup>1</sup> The survey includes several areas covered by earlier detailed soil surveys, the results of which, with some modifications, are embodied in the map accompanying this report.

The soils of the area are extremely varied and intricately mixed in their occurrence; this is due to the broad region covered by the survey, to the great variety of soil-forming processes and sources of material, and to the complicated agencies which have altered the soils since their formation. The soils are classed with four main groups, or provinces of soil-forming material, on the basis of origin, mode of formation, and degree and character of subsequent alteration. The four groups are (*a*) residual soils, or those formed in place through the weathering and disintegration of consolidated rocks, (*b*) old valley-filling soils, or those formed in place from modified, or weathered, unconsolidated, water-laid deposits, (*c*) recent-alluvial stream-bottom and alluvial-fan soils, or those recently deposited by streams and not greatly modified since deposition, and (*d*) wind-deposited soils. In addition to these main groups some miscellaneous materials are mapped. The first group, residual soils, is inextensive in this survey, but is broadly developed in the adjoining mountains.

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<sup>1</sup> See Reconnaissance Soil Survey of the Sacramento Valley, Cal., Field Operations of the Bureau of Soils, 1913; of the San Francisco Bay region, 1914; and of the San Diego region, 1915.

The wind-deposited soils are likewise of minor extent. The second and third groups include by far the greater part of the soils of the area, and of these the old valley-filling soils are most extensive.

The four main groups are subdivided into soil series, each series including soils possessing similarities of color, character of subsoil and substratum, and origin and mode of formation.

The soil series is subdivided into soil types differentiated on the basis of texture; that is, the relative proportion of mineral particles of different sizes present.

The soil types are designated by textural names, such as clay loam, sandy loam, or sand, to which the series name is prefixed. The soil type is the unit of classification in ordinary soil mapping, but in some cases a phase of the type is differentiated. The character of the present reconnaissance survey precludes showing all the types separately on the map, and some combination and grouping of types was necessary. These groups or combinations of undifferentiated soils do not include a uniform range of texture, and in some instances include types of different series. This combination is made necessary by the complex occurrence of the soils and the small scale of the map used.

#### RESIDUAL SOILS.

The residual soils of the survey are derived through the weathering and disintegration in place of a great variety of consolidated rocks. These range in character from very soft or weakly cemented sandstones and shales, through harder sedimentary rocks or metamorphosed sedimentaries, such as slates, to massive igneous rocks, such as basalt, diabase, or granite. The soils of this province possess certain common characteristics. They typically occupy mountainous uplands or rolling surfaces, lying at elevations distinctly greater than those of the other groups, and are characterized by good drainage. They usually are rather poorly adapted to irrigation, owing to character of the surface and situation above accessible water supply. The soils vary widely in color, texture, and subsoil and substratum features. The residual soils are broadly divided into two subgroups, the first including soils derived from the igneous rocks and the second soils derived from sedimentary rocks.

The igneous rocks give rise to three series of soils in this survey, of which only one, the Aiken series, is derived from quartz-free or basic rock. This series comprises red soils and is inextensive. The quartz-bearing igneous rocks, largely granite, give rise to two series of soils, the Sierra and the Holland. The Sierra soils are red and the Holland brown.

The soils derived from sedimentary rocks are classed with four series, the Mariposa, Altamont, Kettleman, and Diablo. The Mari-

posa soils are derived mainly from slate and are yellow. The Altamont soils are brown and are derived mainly from sandstone and shale. The Kettleman soils are gray, but similar in origin to the Altamont. The Diablo series includes dark-gray to black soils, derived from shale and sandstone.

#### OLD VALLEY-FILLING SOILS.

The old valley-filling soils are composed of weathered and otherwise modified, relatively old, waterlaid, unconsolidated deposits, derived originally from a wide range of rocks. These soils vary widely in color, origin, mineral, or chemical character, and subsoil and substratum features. There are, however, certain characteristics which are common to the various series, the most constant one being their position, intermediate between the more elevated, residual soils and the lower-lying recent-alluvial soils. Exceptions occur, however, where valley slopes are occupied by recent-alluvial soils while adjoining lower-lying areas consist of older deposits; or where valley-filling materials were deposited over sandstones and shales and eroded, leaving residual soils exposed as lower-lying bodies. Another rather constant feature of the old valley-filling soils is the distinction between soil and subsoil. This is sometimes manifested simply by change in color, accompanied by the more compact and less permeable structure of the subsoil. In places the subsoil is decidedly heavier and very compact and refractory, and in several of the series there are distinct zones of cementation known as hardpan. Some of the series possess gravelly substrata, while others are identified by the calcareous nature of both the subsoil and substratum. The old valley-filling soils are often marked by a hummocky or hog-wallow surface. They merge in all features with the soils of the other groups and it is often difficult in their graphic representation on the soil map to draw sharp boundaries. Some of the soil groups mapped contain old valley-filling soils interspersed with the residual, recent-alluvial, or wind-laid soils, and are mapped as undifferentiated materials. The soils of the old valley-filling material often occur as elevated, fragmentary remnants of old water-laid deposits skirting the main valley or as more extensive and more even bodies on the valley floor. The old valley-filling group in this survey includes 12 soil series.

The Redding soils are red, have a thin layer of subsoil of heavier texture than the surface material, and are underlain by a distinct hardpan; at greater depths a gravelly substratum is encountered. The San Joaquin soils are red. They have a distinct heavy subsoil of heavier texture than the surface material and a hardpan layer, but are typically without the gravel substratum of the Redding.

The Madera series is brown, has a heavier textured subsoil and a hardpan layer which usually is less firmly indurated than that of the Redding or San Joaquin series. The Pleasanton series differs from the Corning series in having a brown color. The Corning series is practically the counterpart of the Redding series, except that it does not possess the distinct hardpan layer of the latter. The Antioch series is brown, with a calcareous subsoil usually heavier textured than the surface soils. The Oakdale series of soils is brown, with a subsoil which is more compact and often heavier textured than the surface soils, but without distinct hardpan or a gravelly substratum. The Fresno soils are light gray or gray to brownish gray, with brown variations. Typically, a gray hardpan layer is encountered within a depth of 6 feet, although this layer varies greatly in character. The Stockton and Merced series are both dark gray to black, with a lighter colored, calcareous subsoil, which in the Stockton series is cemented into a hardpan. The Alamo series is dark gray to black, with a hardpan and substrata quite similar to those of the San Joaquin series. The Montezuma series is dark gray to black, with a lighter colored subsoil. This series has no hardpan or gravelly substratum.

#### RECENT-ALLUVIAL SOILS.

The recent-alluvial soils have the common characteristic of being composed of the comparatively recent deposits of streams. The original water-laid surface usually is preserved, and in only rare instances do hog wallows, hummocks, or other irregularities appear. Most of the recent-alluvial soils are either uniform in texture to a depth of 6 feet or more or exhibit no consistent tendencies toward heavier or modified subsoils, and normally the 6-foot section shows the various layers of material as deposited by the stream. The heaviest textured types of the group are not very permeable; the lightest textured types are leachy and porous. In general, however, the recent-alluvial soils are deep, permeable, and the most valuable of their locality because of the absence of unfavorable subsurface features, such as the occurrence of bedrock as in the residual soils and of hardpan as in many of the old valley-filling soils. The recent-alluvial soils produce a very large part of the intensive and diversified crops of the State, and are the most extensively irrigated soils because of their productiveness and the relative ease of irrigation. They are represented in this survey by six series.

The Yolo series of soils is brown, typically nonmicaceous, and usually derived from materials washed from areas of sedimentary rocks. The Panoche soils are gray and calcareous. Otherwise they

resemble the soils of the Yolo series. The Hanford series includes brown, micaceous soils derived mainly from granitic materials. The Honcut series consists of reddish-brown soils with a reddish-brown subsoil. The Capay soils are brown to dark grayish brown, with a subsoil of the same color. They are similar in kind of material to the Yolo series but have poorer drainage. The Dublin soils are dark gray to black. The Sacramento soils are dark gray to black. They differ from the Dublin in being basin soils, in being nearly always poorly drained, and in being formed from materials derived from many kinds of rocks.

#### WIND-DEPOSITED SOILS.

The soils of this province represent in part an extension of similar material from the adjoining surveys of the San Francisco Bay region and the Sacramento Valley. They owe their present position and main surface features to movement of the soil material by winds. They are generally of sandy character and without marked differences between soil and subsoil. They are classed in this survey with a single series, the Oakley. The Oakley soils are brown and usually sandy, and the subsoil is similar to the surface material.

#### MISCELLANEOUS MATERIALS.

There were differentiated in this survey in addition to the soils identified with the main soil provinces three groups of material of miscellaneous character. The most important of these is Muck and Peat, which closely resembles some of the recent-alluvial soils in its low position. It consists mainly of organic matter in various stages of decomposition mixed with varying proportions of sedimentary material, and occupies depressed areas near or below sea level.

Rough broken and stony lands is another group, including Rough broken land and Rough stony land. The areas of this material have rough, broken, stony surfaces. Their extent is small, and the Rough stony land in the rougher and more mountainous sections predominates.

Riverwash and Tailings, as mapped in this survey, is similar in position to the recent-alluvial soils. It is nonagricultural owing to its flood-swept position and coarse, porous character. The Tailings include gravelly *débris* resulting from dredge or hydraulic mining.

The following table shows the actual and relative extent of the various soils mapped in the Lower San Joaquin Valley area:

*Areas of different soils.*

Soil.	Acres.	Per cent.	Soil.	Acres.	Per cent.
Oakley and Fresno sands, undifferentiated.....	219,392	7.2	Panoche adobe soils.....	40,192	1.3
Yolo clay loams.....	188,416	6.2	Diablo adobe soils.....	39,424	1.3
Altamont loams and clay loams..	176,640	5.8	San Joaquin loams.....	35,328	1.2
San Joaquin sandy loams.....	169,472	5.6	Panoche clay loams.....	35,072	1.2
Madera loams.....	157,440	5.2	Pleasanton and Antioch loams and clay loams, undifferentiated.	31,488	1.0
Stockton and Fresno soils, undifferentiated.....	148,480	4.9	Honcut loams.....	18,432	.6
Fresno sandy loam.....	31,744	4.8	Aiken loams.....	16,896	.6
Brown phase.....	116,480		Madera clay loams and clays.....	16,896	.6
Fresno fine sandy loam.....	104,192	4.4	Holland sandy loams.....	15,616	.5
Brown phase.....	30,976		Heavy dark-colored phase.....	1,024	
Capay and Merced clays, undifferentiated.....	116,992	3.8	Rough broken and stony lands...	16,384	.5
Madera sandy loams.....	99,584	3.3	Merced clay loam.....	15,104	.5
Madera and San Joaquin sandy loams, undifferentiated.....	88,832	2.9	Dublin and Yolo loams and clay loams, undifferentiated.....	14,336	.5
Hanford sandy loams.....	86,016	2.8	Sierra sandy loams.....	13,824	.5
Redding gravelly loams.....	85,504	2.8	Kettleman loams and clay loams..	13,056	.4
Hanford fine sandy loam.....	83,712	2.7	San Joaquin and Altamont sandy loams, undifferentiated.....	12,800	.4
Muck and Peat.....	80,896	2.7	Hanford sands.....	12,288	.4
Stockton adobe soils.....	72,448	2.4	San Joaquin clay loams and clays.	8,960	.3
Yolo loams.....	64,768	2.3	Alamo clay adobe.....	8,960	.3
Dark-gray phase.....	6,400		Dublin adobe soils.....	8,960	.3
Hanford loams.....	66,560	2.2	Antioch clay loam and clay.....	7,936	.3
Sacramento clay loams.....	60,672	2.0	Montezuma clay adobe.....	6,556	.2
Altamont sandy loams.....	51,968	1.7	Mariposa sandy loam and silt loam.	6,400	.2
Oakley and Madera sands, undifferentiated.....	51,200	1.7	Oakley sands.....	5,888	.2
Fresno loams.....	50,944	1.7	Riverwash and Tailings.....	4,864	.2
Aiken stony loams.....	48,128	1.6	Corning and Pleasanton loams, undifferentiated.....	4,096	.1
Altamont adobe soils.....	45,056	1.5	Stockton and Madera soils, undifferentiated.....	4,096	.1
Fresno clay loams.....	39,168	1.4	Panoche loams.....	4,096	.1
Heavy phase.....	4,096				
Oakdale sandy loams.....	40,960	1.3	<b>Total.....</b>	<b>3,046,400</b>	<b>.....</b>
Yolo adobe soils.....	40,192	1.3			

SOILS DERIVED FROM RESIDUAL MATERIAL.

AIKEN SERIES.

The soils of the Aiken series are residual and are derived mainly from the weathering of basic igneous or metamorphosed igneous rocks, such as diabase, basalt, andesite, amphibolite, and others. They are typically red, of various shades, but often contain reddish-brown phases, the red color being most pronounced when the soil is moist. The subsoil, where it differs from the surface soils, is either a lighter

or darker red and of heavier texture, a distinct subsoil being less common than in the Sierra series. Bedrock occurs at various depths, ranging from a few inches to 6 feet or more, although usually within the 6-foot soil section. Concentrations of lime usually are not apparent in either soil or subsoil, and the content of organic matter seems low. The topography varies from mountainous to hilly or rolling and much of the land is nonagricultural because of its rough, rocky, or dissected character. Drainage is good and the run-off may be excessive on the steeper areas. These soils differ from the Sierras in origin and other features and from the related Olympic series, of similar origin, in color. The Aiken series is inextensive in this survey and is represented by two groups of soil types, one of agricultural character and the other stony and untillable. The soils in this area seem similar to those recognized elsewhere in the State.

#### AIKEN STONY LOAMS.

*Description.*—The group—Aiken stony loams—consists of a number of different soils, but chiefly the loam, gravelly loam, and clay loam of the series. The soils range in color from pronounced reddish brown or red to deep red, and in places have a yellowish cast where influenced by slates or similar rocks, although the red colors, considered typical, predominate.

The subsoil closely resembles the surface soil in color and texture, but may be slightly lighter or heavier where the material is deepest. There are included patches of brown and grayish-brown material.

The surface soils contain only a small percentage of organic matter. They are droughty and shallow, usually resting at a depth of less than 12 inches upon the basic igneous rock from which they are derived. Small to large angular rock fragments and bowlders are present in the soil and subsoil and scattered over the surface. Small knolls and ridges covered with massive rocks occur within the group. These, if more extensive, would have to be mapped as Rough broken and stony lands. These soils usually occupy somewhat steeper slopes than the Aiken loams and are more subject to erosion.

*Location.*—This group of soils is confined to the lower foothills of the Sierra Nevada Mountains, and in a number of places marks the eastern boundary of the survey. The included portion is an irregular body of northwest-southeast trend which skirts the eastern side of the San Joaquin Valley, and represents the western and lower extension of a very large area of similar soils lying to the east.

*Topography and drainage.*—The surface features of this group usually are favorable to agriculture, but the shallowness of the soils, the stone content, and the rock outcrop generally preclude their cultivation. The topography is less uniform than that of the Aiken

loams, however, and the soils usually have a moderately rolling, sloping, dissected, and eroded or plateaulike surface. The soils are well to excessively drained, and no alkali is present. Much of the rainfall is lost as run-off owing to the steep slopes and the compact, shallow nature of the soils.

*Utilization.*—A scrubby growth of oak and brush are present in many places, but large areas are barren except for a moderate to light growth of grass. The group is considered as nonagricultural, but small patches could be utilized for crops. It is used mainly for pasturage, but this is not nearly so good as on the Aiken loams. Nearly all the group is poorly supplied with roads, and is far removed from shipping points.

Prices of land of this kind vary somewhat, but are generally less than \$10 per acre. The price is based largely on the value of the land for pasture.

#### AIKEN LOAMS.

The Aiken loams group includes the loam, gravelly loam, and clay loam of the Aiken series.

*Description.*—The Aiken loam consists typically of a medium-textured loam of red to deep-red color, with minor undifferentiated areas of reddish-brown or grayish-brown material. The soil mantle usually is much deeper than that of the Aiken stony loams. The soil usually occurs on hilltops, steep slopes, and ridge crests. It varies widely in depth, resting on the parent rock at depths of a few inches to several feet. Small quantities of angular rock fragments are scattered through the soil mass, but they seldom interfere with tillage. The subsoil closely resembles the surface material in texture where the soil is shallow, but in deeper areas it frequently approaches a clay loam and usually is lighter red in color. Some rock outcrop is present, but this is of minor importance and occurs as low, intruded masses of basic igneous material. The soil is somewhat silty in places, but sandy material is seldom present. The transition from soil to rock is much more abrupt than in the Sierra series with which the Aiken is frequently associated. The loam is the most extensive type in the group.

The Aiken gravelly loam closely resembles the loam in all features except the quantity of gravel present. It occurs locally, and is distinguishable by the relatively large content of quartzose gravel. Tillage is much more difficult on the gravelly loam, and the soil has a tendency to pack quite firmly when dry. It is more droughty than the loam and usually contains less organic matter. The gravel comes from the breaking down of the quartz veins that are so prominent in this part of the survey.

The Aiken clay loam generally occupies the more subdued topographic positions, and in places results from the weathering of rocks of slightly different character from those giving rise to the other members of the group. The type is frequently somewhat deeper than the loam and varies little in texture from the surface to the underlying rock, although the subsoil may be slightly lighter or heavier than the surface material. The soil and subsoil are variable in color, but the color closely resembles that of the loam. The clay loam is somewhat more difficult to till and in the deeper areas is fairly retentive of moisture.

The group includes patches of brown, yellowish-brown, or grayish-brown soils, especially where associated with the Mariposa soils. Sudden changes in depth are common, due mainly to the density and nearly vertical position of intrusive parent material.

*Location.*—The soils of the Aiken loams group occupy the highest general areas of agricultural lands in the eastern part of the survey. They occur in several rather inextensive areas along the eastern edge of the survey, from a point east of Stockton southeastward nearly to the Fresno River, in Madera County, and principally in the lower foothills of the Sierra Nevada Mountains. Eastward they gradually merge into the Aiken stony loams. In Madera County the group occurs as a series of outlying hilly areas, in places surrounded or nearly surrounded by soils of the Sierra series or by those derived from old sedimentary rock or from old valley-filling deposits.

*Topography and drainage.*—The surface of the Aiken loams is widely diversified in this area. The group occupies hilly, rolling, or broken areas generally of greater elevation than the soils to the west. Drainage is well established, and in many places much of the rainfall is lost as surface run-off, owing to the compact soils and pronounced slope. In places rock outcrop is abundant, and the land suited only to grazing.

*Origin.*—The soils of this group are residual in origin and rest upon the parent rock usually at shallow depth. Schists and other basic igneous rocks yield the soil material.

*Utilization.*—This group is nearly treeless and free from brush. A moderate growth of grass constitutes the main native vegetation. Except for minor plantings of deciduous fruits the soils are utilized mainly for grazing. A small acreage is devoted to grain, with moderate to light yield. The soils lie above present canal systems, and owing to their rather droughty nature can be used only for a narrow range of dry-farmed crops. Through the development of irrigation by pipe lines a wide range of crops could be produced, notwithstanding the generally shallow character of the soil. On favorable slopes, where the soil has sufficient depth citrus fruits would probably do

well, as the group occupies the same climatic belt as the citrus groves farther south. Intensive crops, such as fruits and nuts, would be necessary if water were developed, as irrigation would be costly, and the land could not profitably be used for general farm crops. In agricultural value the loam, clay loam, and gravelly loam rank in the order named, and the deep areas are the best. Blasting, where the rocks are schistose in character and upturned, would improve the land for fruit culture. At present these soils are of minor importance agriculturally, owing to their isolated location, shallow, droughty nature, and the high cost of irrigation. Much of the group is rather inaccessible, owing to the scarcity and poor condition of roads, and the distance from shipping points.

#### SIERRA SERIES.

The soils of the Sierra series are residual in origin, and are in general derived from the weathering of granitic rocks. They are typically red, but include extensive phases of light red or reddish brown, the latter being a variation between this and the Holland series. The red tint is most pronounced under moist field conditions. These soils usually are underlain by redder, very compact, and heavier textured subsoils, which in turn rest upon the granitic bedrock. In places the subsoil varies little in texture and structure from the surface soil. The total depth of soil and subsoil usually is less than 6 feet, but the soil material may be underlain by a thick stratum of partially disintegrated granite. The soils of this series appear low in organic matter, and the soil column is without apparent lime concentration. They occupy mountainous positions but are locally rolling or hilly or even gently sloping in small areas. Angular rock fragments and outcrops of the parent rock are locally abundant. Drainage is well established but not excessive, except that there is considerable run-off in the steeper areas. The soils of this series are differentiated from those of the Holland on the basis of color. They often support a native growth of brush or a local sparse timber growth. The soils are represented in this survey by one inextensive group of soils, the Sierra sandy loams.

#### SIERRA SANDY LOAMS.

The Sierra sandy loams group embraces the sandy loam, fine sandy loam, and coarse sandy loam of the Sierra series. A few small areas of Holland and Aiken soils, too small to differentiate on the map, are included.

*Description.*—The Sierra sandy loam is the most extensive type and consists of a friable to compact, rather coarse-textured sandy loam 18 inches to 6 feet or more in depth. It has a red, light-red,

or brownish-red color, which usually is intensified when the soil is wet. In the field the soil has a pronounced red appearance, but in small samples the color frequently fades to a reddish brown. The subsoil usually is more intense red than the surface material and is noticeably heavier, often being a clay loam or sandy clay. This dense layer does not continue to great depths; it usually averages 1 foot or 2 feet in thickness, grading into lighter textured and lighter colored material quite closely resembling the surface soil. Where the type is shallow, a distinct subsoil usually is absent, and the material continues quite uniform to the disintegrated granite below. At widely varying depths, but usually at less than 6 feet, the subsoil passes into partially disintegrated granite, which frequently continues for several feet before the unaltered rock is encountered. Coarse quartz sand and feldspar fragments usually are conspicuous in the partially altered material, giving it a very coarse appearance. The color of the partially weathered material frequently is brown, reddish brown or grayish brown, and it is generally permeable to both roots and water. The type is low in humus as a rule and packs somewhat when dry. Noticeable quantities of mica usually are present, and tillage is not difficult except for the uneven surface. Lime is rarely conspicuous in either soil or subsoil. Locally the dense subsoil layer is quite compact and closely approaches a hardpan.

The fine sandy loam member ranks second in extent in this survey and is nearly equal in area to the sandy loam. It frequently is somewhat more compact than the sandy loam, but in other respects it closely resembles that type. It has apparently been derived from fine-grained rocks, which frequently outcrop. The partially weathered layer overlying the unaltered rock usually is not so deep in this type, and the soil is generally more compact and somewhat less permeable.

The coarse sandy loam is very inextensive. It occurs only as small, irregular patches within other members of the group. The soil consists of open, friable, gritty material in which the red color is not quite so pronounced as in the other types. The subsoil features closely resemble those of the sandy loam. Mica usually is conspicuous. The type is more easily tilled than the other members of the group. The surface soil is also somewhat more permeable, and readily absorbs moisture. Rock outcrop is not unusual, but gravel or boulders are very uncommon in the soil column. Portions of the type are somewhat darker in color and closely approach the brown and dark-gray colors of the Holland series.

Very small undifferentiated areas of the Sierra loam occur within this group in this area. The soil differs from the sandy loam only in texture. As mapped in this survey the group includes some of the

soils recognized in the earlier detailed soil survey of the Madera area as the Media series and as Rough stony land.

*Location.*—The Sierra sandy loams group in this area occurs only in the eastern and northeastern parts of Madera County as a number of irregular areas forming the lower extension of the Sierra Nevada Mountains. The group is associated on the east with the soils of the Aiken and Holland series, and on the west with the old valley-filling deposits that give rise to the San Joaquin and Madera series.

*Topography and drainage.*—The soils of this group have a hilly, rolling, and sloping to dissected topography, and in places the surface is marked with rock outcrop. Both the surface drainage and subdrainage are good, but much of the rainfall is lost in the run-off, especially from the finer textured types. The granites giving rise to these soils usually are disintegrated to considerable depth, and hold much of the moisture which would otherwise be lost. The texture of the soil usually depends upon the composition and coarseness of the underlying rock.

*Utilization.*—The irregular surface and the difficulty of obtaining water for irrigation, together with their remote location, make the soils of this group of minor importance. They are devoted mainly to grain growing and pasture. Similar soils located elsewhere under like topographic and climatic conditions have been found suited to the growing of deciduous and citrus fruits, but water for irrigation is needed before intensive crops can be grown in this area. Owing to the irregular and hilly surface the water would have to be distributed by a system of pipe lines, as is done in the Fair Oaks region east of Sacramento, in order to force it to the hilltops. The soils are less productive of dry-farmed crops than the same soils in the Sacramento Valley owing to the lighter rainfall in this area. Grain yields usually are low, and profits are reduced by long hauls to market. Irrigation and the incorporation of organic matter are the greatest needs of this group of soils.

#### HOLLAND SERIES.

The soils of the Holland series are residual, and are derived mainly from the weathering of granitic rocks. They are typically brown, but include phases of various shades of this color, such as reddish brown. They are micaceous and usually friable with lighter brown or yellowish-brown subsoils. The subsoil in many places is similar to the surface soil in texture and structure, but in others it is heavier, more compact, and less permeable. No concentrations of lime are apparent in the soil or subsoil, and the organic-matter content usually is low. The surface is mountainous, hilly, or rolling, and the run-off excessive in the steeper, more broken areas. The series is similar to

the Sierra series in several respects, but differs from it in color and certain other features.

These soils are represented in this survey by one minor group, which includes several soil types, with an additional heavy, dark-colored phase which if more extensive would, because of its pronounced dark color, be recognized as representing material of a distinct but related series of soils.

#### HOLLAND SANDY LOAMS.

The Holland sandy loams group comprises the coarse sandy loam, sandy loam, and fine sandy loam of the Holland series, with very small inclusions of the Holland loam, and a dark-colored, heavy-textured phase of these soils.

*Description.*—The Holland coarse sandy loam consists of a brown, light-brown, or grayish-brown, coarse-textured, gritty sandy loam. It is friable, open in structure, and usually contains an appreciable amount of mica. In places the type is lighter in texture and approaches a sand. Its coarse, gritty nature is due to the coarse-grained character of the granite and quartz diorite from which it is derived. At 10 to 24 inches below the surface the soil gradually passes into a light-brown, brown, yellowish-brown, or reddish-brown, medium-textured sandy loam, closely resembling the surface material. The subsoil usually is lighter in color or redder than the surface soil, and may be similar to, lighter, or heavier in texture. There is in this area less difference between the soil and subsoil of this type than between those of the Sierra soils. The parent rock usually weathers deeply and the soil and subsoil frequently extend to depths greater than 6 feet. A considerable depth of partially weathered granite usually overlies the unaltered parent rock. Both soil and subsoil are quite permeable. This type is low in organic matter and is easily tilled, except for its usually uneven surface. Rock outcrop is not unusual, but gravel and loose stone are rarely present.

The Holland sandy loam is a friable, open-textured, micaceous soil of brown, light-brown, or grayish-brown color. It is a somewhat more desirable type than the coarse sandy loam, being somewhat more retentive of moisture. It is slightly higher in content of organic matter, and the material is less rapidly removed by erosion. The type is also more productive than the coarse sandy loam, but in other respects closely resembles that type.

The fine sandy loam member of the group is a brown to grayish-brown, smooth-textured, friable, micaceous soil. It is retentive of moisture and is derived from finer grained granite than the other types of the series. In places the fine sandy loam closely approaches the red or reddish-brown color of the Sierra series, and locally it

grades into a light, friable loam. In other features it closely resembles the Holland coarse sandy loam, and may alternate with the material of coarser textures in relatively short distances.

As mapped in this survey, the group includes the type formerly recognized in the detailed soil survey of the Madera area as the Media coarse sandy loam, patches of the Media sandy loam and fine sandy loam, and appreciable areas of Rough stony land.

*Location.*—The soils of this group are of small extent, being confined to the rolling, hilly, uneven, and sloping areas in eastern Madera County, forming a part of the lower slopes of the Sierra Nevada Mountains. They are associated with the Sierra series, and in places the area mapped is the western extension of larger and more uneven bodies located on the higher mountain slopes. Westward the group either merges into areas of sedimentary rock or gives way to extensive plains occupied by the soils of the San Joaquin and Madera series.

*Topography and drainage.*—The surface is uneven, rolling or hilly, with slopes of moderate to pronounced steepness. It is frequently marked by minor erosional stream ways which carry water during periods of unusually heavy rains. There is some rock outcrop, but the surface is generally smooth and the hills have a rounded outline. Much of the rainfall enters the soil and, where the material is coarse, soon passes into the deeper layers and down the slope. Drainage is good to excessive, and tillage can be carried on at nearly any time of the year.

*Origin.*—In this survey granites are the main source of the material. The texture of the soil is determined largely by that of the parent rock. At similar stages of weathering, the granite yielding the Holland series of soils apparently does not break down into such red soils as that giving rise to the Sierra series.

*Utilization.*—The native vegetation consists mainly of grass and a scattered growth of oak. These soils are of little importance for crops, because they are droughty, shallow, irregular in topography, and remote from shipping points, and because water for irrigation is not available. Grain and grain hay are the principal crops, and the yields usually are light. Considerable areas of the shallower and rougher land are used for pasture. Water for irrigation is difficult to obtain, but where it can be provided fruits, grapes, and other intensive crops can be grown. The soils warm up quickly in the spring and mature crops early. Roads and shipping points are not very satisfactory, but meet the needs of the products grown. These soils usually are owned in connection with areas more suitable for agriculture or in large holdings for pasture. Irrigation, good tillage, and the incorporation of organic matter are important requisites for good results in farming these soils.

*Holland sandy loams, heavy, dark-colored phase.*—The heavy, dark-colored phase of the Holland sandy loams includes material of sandy loam, loam, and, in small patches, clay loam texture.

*Description.*—The areas of sandy loam consist of 6 inches to several feet of a dark-gray or dark brownish gray, friable sandy loam which is sometimes micaceous. Brown, slightly reddish brown, or dark-brown patches sometimes occur which, if sufficiently extensive would be differentiated as the typical Holland or as Sierra material. The surface soil sometimes rests directly upon partially weathered granite rocks, which appear to be high in lime, as indicated by occasional calcareous crusts overlying the decomposed rock. Where a distinct subsoil occurs it usually is lighter colored than the surface material, and may be gray or brownish gray, grayish brown or dark gray in color. The dark-colored parent rock weathers into a lighter colored material having the appearance of marl and containing a high percentage of lime. Varying quantities of rock outcrop occur, and small amounts of rock fragments are sometimes present in the soil near such places. The soil is moderately high in organic matter, permeable to roots and water, and retentive of moisture. It is easily tilled, and forms a friable, mealy seed bed. This soil is not extensive and usually occurs on slightly elevated knobs, low, flattened, hilly areas, and on slopes usually surrounded by the loam and clay loam soils of this phase of the Holland series. The flatter areas are subject to some reworking and modification during rainy periods.

The loam member is the most extensive of this phase of the Holland soils in this survey. It usually is darker in color than the sandy loam and often presents a rather compact or puddled appearance when dry or freshly tilled. It generally occupies slightly lower areas than the sandy loam, and the drainage conditions are less satisfactory in wet weather. In other respects it corresponds to the sandy loam, with which it is closely associated and into which it frequently merges abruptly.

The included clay loam occurs as low, rather poorly drained areas of small extent in bodies of the loam and sandy loam. It frequently is puddled, and clods when plowed. It usually is higher in organic-matter content and darker than the sandy loam and loam, generally ranging from dark gray or dark brownish gray to black in color. The type is very sticky when wet and water sometimes stands for long periods in low places. It is difficult to till and care must be taken to handle it under proper moisture conditions.

This phase of the Holland sandy loams as mapped in this area includes some material classified in the earlier survey of the Madera area with the Dalton series of soils. This is confined to one area, not of sufficient extent to be indicated satisfactorily on the soil map.

*Topography and drainage.*—The surface features consist of rather subdued, gently undulating to hilly areas, marked in places with minor hummocks and slight depressions somewhat resembling “hog wallows.” Small patches of rock outcrop give local areas the appearance of Rough stony land. As a whole, the material is only moderately drained, the sandy loam occupying the most favorable position in this respect. The shallow variations are droughty in the summer. No alkali is present.

*Utilization.*—The heavy, dark-colored phase of the Holland sandy loams is of little value for agriculture at the present time. It is used principally for the production of grain and hay and for pasture. It lies above existing canals. Before a more intensive agriculture shall be possible, water must be provided. It is well supplied with roads but is distant from shipping points. The development of irrigation water and good tillage are the important needs of this land.

#### MARIPOSA SERIES.

The soils of the Mariposa series are residual in origin and derived from the weathering of sedimentary or metamorphosed sedimentary rocks, among which slates are often prominent. They are typically yellow, but have pronounced phases of light brownish yellow or grayish-yellow color. The soils are often shallow, with little variation between the soil and subsoil, and a bedrock substratum usually is encountered at a depth of less than 6 feet. The deeper areas sometimes have heavier textured and more compact subsoils. The material is typically free from concentrations of lime, and the soil seems low in organic matter. The series occupies hilly or mountainous areas with many included patches too steep or rocky for tillage. Drainage is well developed, with excessive run-off in some places. These soils are differentiated from the Altamont mainly on the basis of color, although they have other differences. They support a patchy growth of trees or brush.

One inextensive group of soils of the Mariposa series is mapped in this survey.

#### MARIPOSA SANDY LOAM AND SILT LOAM.

*Description.*—The Mariposa sandy loam consists of a light-yellow, brownish-yellow, or yellow, medium-textured sandy loam, from a few inches to several feet deep. The subsoil resembles the surface soil in color and texture, except locally or where the type approaches the soils of the Aiken series; in such places it is reddish brown, brown, or yellowish brown. Where the soil is 6 feet or more deep a slightly heavier textured subsoil is not uncommon. The type is subject to considerable variation, and includes material ranging from a

loamy, yellowish sand to a light loam, the texture depending largely upon the texture of the parent rock. Small to moderate quantities of gravel and cobblestones frequently are present in the soil and subsoil, and in some areas derived from sandstone there are noticeable quantities of mica. The soil is somewhat compact when dry, but it is tilled without difficulty except where the land is steep, or where bedrock is near the surface. The soil is low in organic matter, and no conspicuous concentration of lime is present in the soil or subsoil. Much of the rainfall in the shallow areas is lost as run-off, but the deeper material absorbs and holds moisture well and is readily permeable to roots. The type as encountered in this area differs somewhat in origin from much of the Mariposa series as previously mapped in that it is derived mainly from sandstones and conglomerates rather than from slates. Local reddish-brown spots are sometimes present, which, if sufficiently extensive, would be classed with the Sites series.

The Mariposa silt loam consists of a light-yellow, grayish-yellow, brownish-yellow, or yellow, rather heavy silt loam. It varies in depth from about 6 to 18 inches on ridge crests and hilltops to about 2 to 6 feet or more on the gentle slopes or along some of the minor drainage ways. The deeper phases are partly due to the influence of water in accumulating soil material in such places. Varying quantities of slate fragments or small amounts of quartz gravel from veins through the parent slates are common in the soil and subsoil. The soil has a very smooth, micaceous feel, due to the presence of minute flattened particles of slate. The subsoil resembles the surface soil in color and texture, but may be somewhat heavier in the deeper areas. Some undifferentiated bodies of the Aiken loams and of gray to dark-gray soils derived from slates are included. This type, like the sandy loam, is variable in texture. It is somewhat more retentive of moisture than the sandy loam, and is easily tilled. It is generally low in organic matter.

The group as mapped in this survey includes the Mariposa sandy loam and silt loam of the earlier survey of the Merced area.

*Location.*—The sandy loam of this group of soils occurs in a few small bodies along the eastern boundary of Merced County. The silt loam is confined to a few areas along the east and northeast boundary of Merced County; it represents the western extension of a broadly developed area extending up the Sierra slopes to the east. This type rests upon beds of upturned slate, from which it is derived.

*Topography and drainage.*—The sandy loam occupies gentle or moderate slopes to slightly hilly areas, and its drainage usually is more excessive than that of the silt loam. The shallow areas are

droughty, and subject to active erosion. The silt loam occurs in gently sloping or rolling to steep areas. The steeper slopes of this type also are subject to erosion. The nearly vertical position of the underlying slates sometimes retards surface run-off.

*Origin.*—The sandy loam member in this survey is principally derived from nearly horizontal beds of sandstone and conglomerates. These rocks have largely been removed by erosion, and the remnants occur as isolated, flat-topped buttes surrounded by lower slopes occupied by soil of this type.

*Utilization.*—A few scrubby oaks grow on these soils, but a moderate to scant growth of grass is the prevailing vegetation. The main use of these soils is for pasture, but the deeper phases produce moderate yields of grain hay. Blasting of the slates is successful elsewhere under similar conditions for growing fruits, as it loosens the underlying material and permits deep root development without creating unfavorable drainage pockets. These soils warm quickly in the spring and produce an early growth of grass. No irrigation water is available at present, and the land is not well located with reference to roads and shipping points. These soils usually are held in connection with areas of better land. Irrigation is the controlling factor in their intensive development.

#### ALTAMONT SERIES.

The soils of the Altamont series are residual in origin, derived largely from interbedded sandstones, shales, and similar sedimentary rocks. They are brown, but range in color from light to dark brown, and sometimes are reddish brown or very dark brown when wet. The subsoils usually are lighter in color, being light brown, yellowish brown or reddish brown, and generally rest on bedrock within 6 feet of the surface, although there are some deeper areas. The subsoils are often heavier than the surface material, but this distinction is not so common in the heavier textured types. These soils are lower in lime and organic matter than those of the related darker-colored soils of the Diablo series, but the subsoils are rather calcareous in places. They occupy rolling, hilly, or mountainous areas and are sometimes shallow and eroded on the steeper slopes, with abundant rock outcrop. The soils are well drained and are usually retentive of moisture. This series differs from the Diablo series in the color of the soil and the amount of lime present in the subsoil. The soils in their virgin state were in this survey treeless except for local areas, and supported a patchy growth of brush.

The series is represented in this survey by three groups of soils. Only a margin of the surrounding mountains in which these soils occur is included in this survey.

## ALTAMONT SANDY LOAMS.

The Altamont sandy loams group includes the sandy loam, fine sandy loam, and gravelly sandy loam types of the Altamont series.

*Description.*—The Altamont sandy loam consists of a brown, grayish-brown, or light-brown, medium-textured, rather friable sandy loam, 10 to 18 inches deep. Locally, the type carries a small percentage of mica, which is derived from the underlying sandstone. The subsoil is somewhat heavier in texture, and rests upon a rather soft sandstone at depths usually greater than 4 feet. The color of the subsoil usually is somewhat lighter than that of the surface soil. It ranges from light-brown, brown, or grayish-brown to slightly reddish-brown. The type contains a moderate to small percentage of organic matter, is open and friable, retentive of moisture, and is easily tilled except for the hilly topography. Local spots contain coarse, gritty sand, and a small quantity of waterworn gravel is sometimes present in the soil and subsoil. The material of the surface few inches frequently approaches a sand or fine sand in texture, but passes into heavier material below. The subsoil is generally a heavy loam or less frequently a clay loam, or even a clay, the heavier subsoil in many places having a pronounced reddish-brown or light-red color. Both soil and subsoil hold moisture unusually well for soils with such sloping surface, and crops seldom suffer from drought, as even in the dry summer the subsoil retains considerable moisture. The soil is quite variable in texture and in this respect the tops, sides, and lower slopes of hills are seldom the same, being influenced by wind action and perhaps somewhat by the different strata from which the soil material is derived.

The fine sandy loam member is brown in color, but usually of darker shade than the sandy loam. It is a very friable, smooth, and often micaceous soil, which is retentive of moisture. There appears to be less difference in color between the soil and subsoil of this type than in the case of the sandy loam, and the texture may be uniform to a depth of 6 feet or more, but a somewhat heavier subsoil is not uncommon. In extent and other respects, the type closely corresponds with the sandy loam.

The Altamont gravelly sandy loam is of very small extent. It usually is lower in organic matter and more difficult to till than the gravel-free soils, but in other respects it resembles the other two members of the group.

As mapped, this group includes the Arnold sandy loam and fine sandy loam as mapped in the Modesto-Turlock area.

*Location.*—The Altamont sandy loams occur principally southeast of Warnersville and northeast of Waterford. Soils of this group are confined to the east side of the valley, except southwest of Byron,

where they occur to a small extent. A few remnants of soil material belonging to the Redding series occur as patches along the margins of the group, and especially where it merges into that series. Scattered areas of similar material occur elsewhere on hilltops. These usually may be distinguished from the Altamont by reddish colors and by the presence of rounded quartzose gravel and cobbles. In other places the veneer of old valley-filling deposits has been removed, and the remaining gravel and cobble are scattered over the surface.

*Topography and drainage.*—The Altamont sandy loams have a varied topography, but are chiefly rolling to hilly. The range in elevation is from 50 to 125 feet. The surface has been somewhat diversified by erosion, but has a remarkably rounded and smooth appearance. Just north of the Stanislaus River a number of narrow, flat valleys wind through the hilly areas of this group, paralleling the general course of the river. These seem to be old abandoned drainage ways and are occupied by soils belonging mainly to the Oakdale series.

The slope and porosity of the Altamont sandy loams give them good drainage. Most of the rainfall is absorbed, except during periods of unusually heavy precipitation, when small erosional channels are sometimes formed. The soil material is derived from a feebly cemented sandstone.

*Utilization.*—The Altamont sandy loams are not utilized for intensive crops at present, but are important in grain growing. The yields usually are good, though not quite so heavy as on the Altamont loams and clay loams. In favorable years 10 to 15 sacks of barley per acre are obtained. Constant cropping, however, has proved harmful, and that practice has given way to fallowing in alternate years. The soils are above present canal systems, and no attempt has been made to obtain irrigation water. On somewhat similar types in the Sacramento Valley east of Sacramento, where irrigation water is available, good results are obtained with citrus fruits, olives, figs, almonds, and other intensive crops. The rolling topography of these soils in this area makes irrigation very costly.

The soils warm quickly in the spring, and crops mature early. The areas are well supplied with roads, but these are rather sandy and hauling is difficult. The soils are distant from markets.

Irrigation is necessary for the best returns from the soils of this group.

#### ALTAMONT LOAMS AND CLAY LOAMS.

The loams and clay loams of the Altamont series as mapped in this survey include four types, the loam, clay loam, gravelly loam, and stony loam.

*Description.*—The Altamont loam to about 12 inches in depth consists of a brown, grayish-brown, light-brown, or slightly reddish brown, friable, medium-textured loam. The subsoil usually is somewhat heavier, especially where the type is deeply weathered, although in shallower areas it is frequently similar to the surface soil. The subsoil usually is lighter in color than the surface soil, being brownish or reddish brown. The parent rock is deeply weathered in many places, especially along the eastern side of the valley, where it frequently is not encountered within the depth of 6 feet. Hilltops, steep slopes, and ridge crests, however, are subject to considerable erosion, and the soil in such places often rests upon the parent rock at depths of much less than 6 feet. The organic-matter content is generally low in the shallow areas, but moderate quantities usually are present in the deeper parts of the type, where the topography is more subdued. In well-developed areas the soil is quite uniform, but where the type is closely associated with soils of the Diablo and Redding series the surface frequently has a spotted appearance and rather sudden transitions from a sticky sandy loam to a clay loam or clay loam adobe are common. Little or no lime is apparent in the surface soil, but calcareous seams or concentrations are not uncommon in the subsoil and substratum. Tillage is not difficult, but where the soil is heavy it sometimes forms a cloddy surface when plowed. Occasional undifferentiated patches of Diablo clay adobe and Redding gravelly loam are included in this type. The loam type is much more extensive than the other members of the group in this area, and owing to its good moisture-retaining properties it ranks among the best dry-farmed grain soils in the area.

The clay loam is relatively inextensive. It consists of about 12 to 48 inches of light-brown to dark-brown clay loam overlying a light-brown, yellowish-brown, or reddish-brown subsoil of similar or heavier texture. The parent rock usually is deeper in this type than in the loam, and the soil generally contains more organic matter. Small quantities of gravel and cobbles sometimes occur over the surface of the type, being the last remnants of old eroded alluvial deposits. When dry, the type has a structure closely resembling that of adobe soils, but in other respects this type resembles the loam member.

The gravelly loam is a minor type, but is quite clearly defined as a grayish-brown to brown gravelly loam which includes some hummocks of undifferentiated Redding gravelly loam and minor areas of the Diablo clay adobe, with a few patches of the Arnold loam. The type is rather difficult to till, is usually low in organic matter, and grades into a conglomerate rock at shallow depth. It is rather compact and droughty, and usually has sufficient slope for quite active erosion. Exposed gray, cemented beds are not unusual on the

steeper slopes and ridges, giving the type quite a barren appearance in such places. The soil often has an uneven, hummocky surface. The type is shown on the map by gravel symbols.

The stony loam closely resembles the gravelly loam, except that it carries cobbles in addition to the gravel. This type is droughty, and is suited only for use as pasture land. It closely resembles the gravelly loam, and is shown on the map by stone symbols.

The group as recognized in this survey includes the Arnold loam of the earlier survey of the Modesto-Turlock area and the Altamont loam and clay loam of the Merced survey, with their gravelly and stony phases. The Arnold soils of the Modesto-Turlock area are now recognized as consisting mainly of Altamont material.

*Location.*—The Altamont loams and clay loams group is extensive, occurring as bodies in the foothills of eastern San Joaquin, Stanislaus, and Madera Counties and along the foothills forming the western boundary of the area. The gravelly and stony parts are confined mainly to eastern Merced County, since in other parts the patches of gravel and cobble are minor fragmental remnants of old alluvial deposits, the erosion of which has left the stony material.

*Topography and drainage.*—The group occupies sloping, rolling, hilly, or mountainous land, with occasional precipitous slopes where the sandstone, conglomerate or shale outcrops. A few areas of Rough broken land, too small to be mapped separately, are included. Some impure limestone is sometimes present in the parent rocks, but this and the conglomerate are not extensive. The loam and clay loam generally occupy the gentler slopes and low hilly areas, although they are quite rough and steep in places and occasionally occupy the buttelike areas. Drainage and erosion are excessive over the steeper parts of the group, especially in the compact and shallow areas of the gravelly and stony types. The gently sloping areas of smooth surface absorb most of the moisture received as rainfall.

*Utilization.*—The stony and gravelly types and steep parts of the loam and clay loam are used almost entirely as pasture; they produce a rather scant growth of grass. The deep and heavier areas are mainly under cultivation, and rank among the best dry-farmed grain soils of the area. A rather heavy growth of wild oats and grasses occurs on the areas not used for grain. No attempt to grow intensive crops has been made, but grapes and certain other fruits might do moderately well in areas that are deep, friable, and retentive of moisture. Irrigation has not been developed. The chief source of water would appear to be the major streams entering the valley or storage reservoirs. Pumping from wells has not proved feasible. Land values vary greatly, depending mainly on location, depth of soil, and topography. The least desirable areas usually are owned in connection with better agricultural lands or in large tracts

used as grazing land. The group is well supplied with roads, but the greater part is distant from shipping points.

These soils require irrigation for their intensive development.

#### ALTAMONT ADOBE SOILS.

The Altamont adobe soils group comprises the clay adobe and clay loam adobe of the Altamont series, the former seemingly predominating.

*Description.*—The Altamont clay adobe typically consists of a brown, light-brown, or dark-brown clay which cracks badly upon drying. The tendency toward an adobe structure is a little less pronounced than in the related Diablo clay adobe, but is sufficient materially to affect field conditions. Large and numerous cracks appear in the field when the soil is exposed to dry weather without cultivation, and further surface cracking of the major blocks may produce a condition approaching a natural mulch. Where the land is cultivated the larger cracks are prevented from developing and the soil is more easily kept moist. Rock outcrop is rare, although protruding sandstone ledges or some gravelly patches are found, as in Merced County. The soil appears lower in organic matter than the Diablo clay adobe. The subsoil, encountered at varying depths below a few inches from the surface, is generally light brown or yellowish brown in color, with occasional phases of reddish brown, and frequently is somewhat lighter textured and higher in calcareous material than the surface soil. The subsoil stratum in places is only a few inches thick, and rests directly on the parent rock; in other places it continues to depth of several feet.

The Altamont clay loam adobe is the counterpart of the clay adobe in all essential features except its lighter clay loam texture. The adobe properties are a little less marked than in the clay, but the areas occur in small bodies intricately associated with the clay adobe. Slightly different textures in the parent rock are often represented.

This group as mapped includes several variations which do not properly belong to the Altamont series. The areas in Merced County average darker in color than in the northwestern part of the survey, and have some dark gray to nearly black inclusions, identical with the Diablo series of soils. These variations, here and elsewhere, are so intimately mixed with the typical material that separation on the map is not practicable. A reddish-brown variation of small extent also is included.

*Location.*—The largest and most typical body of these soils is in the northwestern part of the survey, in the region west of Bethany, where a number of small bodies having a total area of several square

miles occur as extensions from the area covered by the survey of the San Francisco Bay region. The soils are mapped in eastern Merced County essentially as they are mapped in the detailed soil survey of the Merced area. Altamont loams and clay loams in the southwestern part of the area, as well as various other groups of upland soils in other localities, include undifferentiated areas of adobe soils.

*Topography and drainage.*—This group of soils is most typically developed, as regards surface and drainage features, in the region west of Bethany. In this section the surface is rolling to hilly, with some minor slopes and ravines too steep for cultivation, although most of it is tilled. Parts of the area covered by the group reach a considerable elevation. The drainage is good, and is excessive on the steeper and shallower parts. In Merced County these soils occur as narrow strips on hillsides, and are associated with other members of the Altamont series or with soils of the Redding series. The principal areas in the eastern part of the survey lie northwest, and south of Snelling and east of Planada. As in the main part of the group, the surface, although not so mountainous in appearance as west of Bethany, is rolling to sloping, and the land is well drained.

*Utilization.*—A large part of the soils of this group in Merced County and the steeper areas in the northwestern part of the area are used for pastures. The tillable areas are used for grain and grain-hay production, except where they occur as small bodies within nonagricultural soils, in which case they, too, are used for pasture. These soils often produce a more abundant growth of grass than the adjoining lighter textured types.

The soils do not appear capable of a very diversified use until irrigated, and as the development of irrigation will be difficult, the present systems of cropping will no doubt prevail for some time.

#### KETTLEMAN SERIES.

The Kettleman series of soils are residual in origin and derived from interbedded shale, sandstone, and similar sedimentary rocks. The soils are gray with brownish variations and the subsoils gray or grayish brown and rest on bedrock at depths usually less than 6 feet below the surface. Both soil and subsoil are calcareous. The subsoil is usually similar in texture to the soil in shallow areas, but where bedrock is several feet deep the subsoil material may be heavier in texture and more compact. Lime is more abundant and more uniformly distributed through the soil profile in this series than in the Altamont or Diablo series. The Kettleman soils occur under arid conditions and are low in organic matter. They occupy rolling, hilly, or mountainous areas, are frequently shallow, and cut in varying degree by rock outcrop. The soils are well drained and in their native state nearly free from tree or brush growth.

## KETTLEMAN LOAM AND CLAY LOAM.

The group Kettleman loam and clay loam includes the loam and clay loam types of the series.

*Description.*—The Kettleman loam consists typically of a gray to light-gray or brownish-gray usually friable loam. Brownish variations occur which resemble the brown soils of the Altamont series into which they sometimes grade. The subsoil may be similar to the surface soil or it may be slightly lighter gray or browner, heavier in texture, and more compact. It is underlain by bedrock of sandstone and shale. These rocks are frequently quite deeply weathered, but along ridge crests and hill slopes or where subject to erosion they may lie near the surface. The soil contains little organic matter. Both soil and subsoil are calcareous, the soil sometimes, and the subsoil usually, effervescing with hydrochloric acid.

Where not too steep the type can be maintained in a good condition of tilth under favorable cultural practice, but some of the heavier variations tend to puddle and form clods if cultivated when wet.

The Kettleman clay loam, which is not an extensive type, is subject to considerable variation in depth. It consists usually of a gray or light-gray to brownish-gray clay loam soil though there occur brownish variations, which in color and character approach the related and frequently associated Altamont soils. The subsoil may be similar to the surface soil, or may vary slightly in color and texture, being in this case heavier and more compact.

The organic-matter content is generally rather low and the type is less open and friable in structure than the Kettleman loam, and is somewhat more inclined to puddle and form clods under cultivation. It can, however, be maintained in a friable physical condition under favorable conditions of moisture and culture. Both soil and subsoil material are usually distinctly calcareous and are quite retentive of moisture. The material is generally weathered quite deeply but shallow areas of soil occur, in which the bedrock lies near the surface or occasionally outcrops.

*Location.*—The group Kettleman loam and clay loam is inextensive. It is confined to the extreme southwestern part of the survey, where it occupies a marginal area along the hills west and southwest of Dos Palos. The topography is rolling to hilly. Most of the surfaces are sufficiently smooth and moderate in slope to allow cultivation, but steep slopes and rough surfaces broken by erosion or rock outcrop occur. Drainage is excessive and the soils are subject to erosion. They are developed under conditions of low rainfall.

*Utilization.*—The soils of the group generally support a scanty vegetation consisting of grasses. No water supply is available for irrigation and the lands are of low value and used only for pasture.

## DIABLO SERIES.

The soils of the Diablo series are residual from sedimentary rocks, such as shales, sandstones, and impure limestones, usually being identified with more calcareous rocks than the related and associated Altamont soils. They are typically dark gray to black in color, becoming darker when wet. The subsoil usually is lighter colored than the surface material, showing various shades of gray or brown, although the black soil in places rests directly upon the parent rock. The subsoil is generally heavier and more compact than the surface soil, the difference being most marked in the light-textured types. As a rule bedrock occurs within 6 feet of the surface. The soils appear high in organic matter and are calcareous, especially in the subsoil. These soils occupy rolling to hilly areas, and are well drained and retentive of moisture. They are largely treeless, though forested patches occur along ravines or in some other locations.

One group of these soils is mapped in this survey. The soils mapped do not differ essentially from broader, typical areas elsewhere.

## DIABLO ADOBE SOILS.

The group Diablo adobe soils include areas of clay adobe and clay loam adobe, of which the first type seems to predominate. Some lighter textured material is included.

*Description.*—The Diablo clay adobe typically consists of a dark-gray to black clay, free from gravel or rock fragments. It is very sticky and is untillable when wet; where not cultivated it assumes upon drying a cracked, checked, and often a granulated structure, large cracks sometimes extending downward to the subsoil. The dark-colored surface soil sometimes extends to the underlying bedrock, but is normally underlain at depths of 12 to 20 inches or more by a lighter colored subsoil without the adobe structure. Local variations in color occur in the subsoil, which may be grayish brown, light brown, yellowish brown, or light gray. In these variations the subsoil usually rests upon calcareous shales and sandstones at less than 6 feet, and the rock may be found at any depth from a few inches downward.

The Diablo clay loam adobe is more or less similar to the clay adobe in color, depth, and character of the soil and subsoil, but usually has a less pronounced adobe structure and a less intense dark color. It is associated with and merges into the clay adobe.

The group includes minor areas of lighter textured soils belonging mainly to the loam and clay loam types of the same series. The typical color is often relieved by brownish shades, while some areas include considerable brown soil which, if sufficiently extensive to be

differentiated, would be classed with the Altamont series. The group also includes remnants of old unconsolidated water-laid deposits, which, where of sufficient extent, are mapped with the Redding or a related series. The subsoils are calcareous, with limy material apparent as streaks or other concentrations. The group includes some rather shallow phases in the northeastern part of the survey. In such places the soils are less retentive of moisture and of lower value than elsewhere. The thorough disintegration of the parent material leaves few rocks or gravel particles in the soil, but small areas carry more resistant fragments of the parent rock or the gravelly remains of interbedded conglomerates. Much of the gravel is the residue from superficial unconsolidated gravelly deposits which have been eroded away.

*Location.*—These soils are confined to two sections. The first is in the rolling hills and mountains bordering the valley in the northwestern corner of the area. They are not extensive in this region, and are associated with other upland soils, from which it is sometimes difficult to separate them. The other and most extensive occurrence is in the northeastern part of the survey, where irregular areas occupy the low, hilly parts of that section. The Altamont loams and clay loams and Redding gravelly loams also are prominent in this locality, and are separated with difficulty from the Diablo soils. Each of these groups contains undifferentiated material of the others, and abrupt changes on single hill slopes are common. Some of the Diablo adobe soils as mapped include flattened ridge crests bearing soil material belonging to the Redding series.

*Topography and drainage.*—The Diablo adobe soils as encountered elsewhere in the State have a rolling, hilly, or mountainous surface, and some of the areas in this survey have a similar topography, but a large part of the group rises almost imperceptibly from the higher valley slopes occupied by soils derived from old valley-filling materials eastward to pronounced rolling or choppy uplands, but rarely attains the mountainous aspect of some of the series mapped in the survey of the San Francisco Bay region. These moderately rolling areas are common in the northeastern part of the survey, where the soils are derived from soft and sometimes only partially consolidated shales and sandstones. The drainage of the Diablo adobe soils is good except in occasional minor flats or swales, which may be wet for short periods. Some of the shallow soil on hill crests or around the margins of tablelike upland areas is droughty and unsuited to crop production.

*Utilization.*—Much of the group is broken by patches of shallow soil and choppy surfaces to such an extent that tillage is not undertaken or is confined to minor irregular areas. The nonagricultural

parts are used for pasture. The tilled portions, of considerable extent throughout the moderately rolling areas, are devoted to the production of grain and grain hay. These soils are rather retentive of moisture when properly tilled, but do not seem adapted to intensive farming without irrigation. Like many of the other upland soils bordering the valley slopes, they could be made much more productive with irrigation, but conditions are unfavorable and irrigation probably will not be extensively developed in the near future.

#### SOILS DERIVED FROM OLD VALLEY-FILLING MATERIAL.

##### REDDING SERIES.

The soils of the Redding series are derived from old, unconsolidated water-laid deposits which apparently were originally washed from a wide range of rocks. They are typically red, but as mapped include materials of several shades of red and reddish brown. The soils prevailingly contain subangular or rounded quartzose gravel ranging up to 3 or 4 inches in diameter. The soil profile to a depth of 6 feet or more is variable, but the surface soil typically gives way at less than 24 inches to a deep-red, compact clay loam or clay which is relatively free from gravel and only a few inches in thickness. This heavy subsoil rests upon a red, inundurated hardpan, 1 inch to several inches thick, which in turn is underlain by substrata of gravel or very gravelly beds with interstitial fine soil material. In some places, the gravelly substrata are very compact or partly cemented. The entire soil column apparently is low in lime and organic matter.

The Redding series occupies remnants of old elevated, extensive plains which have been modified to varying degrees by erosion and other processes. The soils sometimes occur as even-surfaced plains or they may have a rolling, undulating, or hilly topography. They typically occupy elevations higher than the recent-alluvial, but lower than the residual soils. The general surface drainage is good, but the soils are periodically boggy because of the poor underdrainage. A general tendency toward a "hog-wallow" surface accentuates this condition by arresting the run-off from the inclosed minor depressions. (Pl. I, fig. 1.)

These soils differ from the related Corning series in the presence of a hardpan and its gravelly substratum distinguishes it from the San Joaquin series. The series usually is treeless, except in the more elevated areas which support a growth of oak, pine, manzanita, and brush.

One extensive group of these soils is mapped in this area, the gravelly loams.

## BEDDING GRAVELLY LOAMS.

The Redding gravelly loams group, as recognized in this survey, includes the Redding gravelly loam, Redding loam, Redding gravelly sandy loam, Redding gravelly clay loam, and Redding stony loam. Although it includes, as mapped, one nongravelly type, the gravelly soils are much more extensive than that without gravel. The stony type is indicated on the map by stone symbols.

*Description.*—The gravelly loam member of this group consists of a red, brownish-red, light-red, or dark-red loam of rather compact structure when dry and containing varying quantities of quartzose gravel. The red color usually is more pronounced than in similar types of the San Joaquin series. Moderate quantities of cobblestones also are present in places, mainly in slight depressions among hummocks. The soil varies from a few inches to about 18 inches in depth, and grades into heavier textured material ranging from a deep-red, dense clay loam to clay which usually contains less gravel than the surface soil. The heavy subsoil layer is seldom more than 1 foot thick and rests upon red, indurated iron-clay hardpan which closely resembles that of the San Joaquin series. The hardpan is generally free from gravel, but varying quantities are present in some places. It is seldom more than 1 foot in thickness, and is underlain by a brown, grayish-brown or red substratum of gravel and cobblestones which is not cemented as a rule and ranges in depth from 1 foot to many feet. The interstitial soil material usually is fine, but locally it is a sand. In places, as in the northeastern part of Stanislaus County, no distinct hardpan is present within the 6-foot profile, but the heavy, compact subsoil layer gradually passes into a somewhat firmly cemented substratum of gravel and cobbles. The soil in small depressions frequently is water-logged during wet weather, giving it a puddled structure and a dark-brown or dark-gray color. In such places the hardpan usually is nearer the surface than on hummocks and other minor elevations. The type is usually low in content of organic matter and no lime is apparent in either the soil or subsoil. It is somewhat difficult to till on account of the gravel content. The type is subject to considerable variation in color, texture, and arrangement of material in the cross section.

The Redding loam consists of a rather compact, poorly granulated soil, varying from light red to deep red in color and resting upon a subsoil and substratum quite similar to those of the gravelly loam member. In places the loam is quite difficult to distinguish in the field from the San Joaquin loam, and includes minor areas of the latter type. It is low in organic matter, is boggy and sticky when wet, and frequently forms a more or less cloddy surface when plowed. It has a somewhat more subdued topography than the gravelly types

of the group, and is more retentive of moisture and better suited to crop production.

The Redding gravelly sandy loam is rather inextensive. It is quite shallow, compact, and droughty, and much of the rainfall is lost as surface run-off. It is rather heavy and sticky, and in depth, color, and subsoil and substratum features closely resembles the gravelly loam.

The Redding gravelly clay loam is a red, compact, heavy-textured soil, containing varying quantities of gravel and cobbles distributed throughout the 6-foot section. The soil cracks somewhat upon drying and is very sticky and miry when wet. The subsoil, hardpan, substratum, and content of gravel are comparable with those of the gravelly loam. It frequently has more regular surface features than the other gravelly types, and in places contains somewhat more organic matter. It is difficult to till except within a narrow range of moisture conditions. In low, slightly depressed spots among hog wallows, the soil has a grayish or dark-grayish color and is more or less puddled.

The soil of the stony loam type is red, and at 1 to 3 feet rests upon the hardpan characteristic of the series. Its subsoil and substratum also resemble those of the other types. It is rather low in organic matter, and differs mainly from the other soils in the large quantity of cobblestones present. The type is also gravelly. It is higher and has a more uneven topography than the other members of the group. It is low in organic matter, is droughty, and in other features closely resembles the gravelly loam. In texture it varies considerably within short distances, often being a sandy loam on the hummocks and a dark-colored, heavy loam or clay loam in the depressions.

The group as a whole is quite variable in color, texture, and gravel content. The subsoil, hardpan, and substratum while generally of quite uniform character are also subject to noticeable changes within short distances, but there is a marked contrast in general features between these and corresponding soils of the San Joaquin series. The group includes a distinct reddish-brown phase which is similar in all essential features except color to the types described. This phase has quite a reddish appearance in the field but when examined in hand samples appears reddish brown. Minor areas of brown, gray, dark-gray, and black material also are locally present. If sufficiently extensive, these would be recognized and mapped with other soil series. Root development is confined to about 2 feet of the surface soil of this group, and the available moisture supply in this rather compact layer usually is inadequate for very heavy yields. In places where the gravelly substratum is not too compact and impervious,

blasting the hardpan is sometimes resorted to with good results, especially where water is available for irrigation. Where the gravel layer is dense or cemented, blasting is of much less benefit. Much of the Redding gravelly loams group in the foothills east of Stockton consists of an old-alluvial covering of widely varying depth overlying sedimentary rocks. Where the veneer is only a few feet or less in depth, no gravelly substratum is present and the subsoil rests directly upon beds of gray, cemented material.

The group as mapped in this survey includes a part of the soils recognized as the San Joaquin loam, sandy loam, and gravelly sandy loam in the earlier surveys of the Madera, Modesto-Turlock, and Stockton areas.

*Location.*—The Redding gravelly loams are relatively extensive in this survey. They are mapped on the upper valley slopes along the Sierra Nevada foothills on the east side of the valley, from the northern almost to the southern boundary of the survey. The largest areas occur from Planada northward.

*Topography and drainage.*—The soils of the group occur principally as fragments of old, high, eroded plains, a part of which has been eroded into rolling ridges and hills with moderate to steep slopes. They are generally separated from the more gently sloping plains to the west by a rather abrupt ascent of 25 feet or more, and much of the group is 100 to 200 feet above the main valley floor. The surface is covered in most places by well-developed rounded hummocks, many of which are several feet high. The general slope of this old elevated plain is toward the valley trough, and portions frequently are separated from the mountains to the east by narrow, irregular, erosional valleys. In places erosion has uncovered the underlying sedimentary rocks, causing sudden transitions from soils of this group to those of the Diablo, Altamont, or other associated series. As a result the crests of hills or ridges may differ in soil material from the lower slopes, and there are many other instances of changes in the character of the soil within short distances. The general surface features are such as to give the group good to excessive drainage, but the soil frequently is boggy in wet weather, owing to an excess of moisture above the hardpan. No alkali is present.

*Utilization.*—The soils of this group are nearly free from trees and bushes in this area, but in their native state support a moderate growth of grass and wild oats. They are utilized for grain growing and pasture, the latter being the main use. They lie above present irrigation systems and can not be used for intensive crop production until water is supplied. Irrigation would be quite expensive, and it is doubtful whether any effort will be made to develop

this land as long as extensive areas of better located, productive soils are available. With irrigation similar soils in the Sacramento Valley give moderate to good results with deciduous fruits. Under irrigation favorable slopes with deep soil and protection from severe winds should prove of value for citrus-fruit production.

Few houses are located on these soils. The land usually is held in large tracts for pasture or in connection with better agricultural soils. The roads are generally good. Shipping points are distant from most of the areas. Irrigation, deep tillage, and the incorporation of organic matter are the principal requirements in developing these soils.

#### SAN JOAQUIN SERIES.

The soils of the San Joaquin series are derived from old unconsolidated water-laid deposits, originating in most instances in a wide range of rocks. They are typically red or light red in color, but as mapped include important bodies of reddish-brown soil which appears red under moist-field conditions. At depths varying from a few inches to 3 feet or more the soil gives way to a thin, redder, heavier textured, and very compact subsoil. The subsoil rests in turn upon a red or reddish-brown indurated hardpan which may continue to a depth of 6 feet, but more often gives way at less depth to a relatively permeable substratum. In some places, instead of the typical material below the hardpan, the soft sandstones over which the soils have been deposited are encountered. The combined depth of soil and subsoil varies widely, but averages between 2 and 3 feet. The depth to hardpan ranges from zero to several feet. Typically it is encountered at less than 6 feet. The soils are low in organic matter and without apparent concentrations of lime within the soil section. They occupy sloping to undulating or rolling valley plains, usually intermediate in elevation between the foothills or mountains occupied by residual soils and the lower lying, more nearly level recent-alluvial soils. The San Joaquin areas are nearly always the remnants of previously more extensive bodies, laid down, as a rule, as older valley-filling deposits. The general topography favors good surface drainage, but subsurface drainage is retarded by the hardpan, and the characteristic hog-wallow mounds with their associated depressions interfere with the run-off in places, so that boggy conditions occur in rainy seasons. On the other hand, the soils become hard and compact during the dry season if not cultivated. Alkali typically is not present. The soils were largely without trees or shrubs in their native state, but locally supported some timber.

In this survey the series is represented by three soil groups which have a large total area. Other groups of soils contain some undifferentiated areas of these soils.

## SAN JOAQUIN SANDY LOAMS.

The San Joaquin sandy loams group includes the sandy loam, fine sandy loam, and gravelly sandy loam of the series.

*Description.*—The San Joaquin sandy loam is the dominant type of this group and probably forms more than half the included area. The soil ranges from light red to deep red, with variations of reddish brown. It is usually lighter red than the soils of the Redding series, and while it appears red under field conditions, small samples show much of it to be reddish brown. The soil generally contains medium to coarse, angular, gritty sand, and in places small quantities of fine, water-worn gravel. When dry, the type is somewhat compact, and its generally low content of organic matter causes it to form a lumpy surface when tilled. The subsoil as a rule is heavier and redder than the surface soil, and ranges from a loam to clay. The material is generally quite compact and heaviest near the underlying hardpan. This heavy subsoil is, however, sometimes absent, the surface soil continuing quite uniform to the hardpan. At depths ranging from a few inches to 6 feet a reddish-brown to red, impervious hardpan, which varies in thickness from a few inches to several feet, is encountered. Where typically developed, the substratum below the hardpan is a brown, reddish-brown, or red friable material which is permeable to roots and water. In some cases, however, as east of Escalon and Madera, the hardpan frequently rests upon a sandstone which, when exposed, weathers into soils of the Altamont and Diablo series. No concentration of lime is apparent in the soil, subsoil, hardpan, or substratum, except locally where the type adjoins areas of the Madera sandy loam.

Surplus water accumulates above the hardpan in wet weather and causes the soil to become so boggy that travel is difficult except on well-developed roads. The type is subject to considerable variation in texture and color, and sudden changes to a fine sandy loam, sandy loam, or loam sometimes occur. Where the hardpan is neither too thick nor underlain by a cemented substratum, blasting has been successful in preparing the land for crops requiring a deep soil. The hardpan is brittle, and when once broken apparently does not form again. No alkali is present, except where the type adjoins lower or more poorly drained soils. The type includes patches of undifferentiated Alamo clay adobe and Madera sandy loam.

The fine sandy loam member of this series is a red to dull-red or brownish-red, rather compact fine sandy loam. Locally, it ranges to a heavier material which approaches loam in texture and frequently contains small quantities of fine, rounded gravel and coarse, gritty sand. In one variation a few cobblestones are present, which, with the rather compact structure, increase the difficulty of tillage. The

heavier areas puddle badly if plowed when wet. This type closely resembles the sandy loam member in other features.

The gravelly sandy loam is of small extent. It consists of a compact sandy loam containing varying quantities of gravel in the soil and subsoil. The presence of the gravel adds to the difficulty of tillage. In color, depth of hardpan, and most other features the type resembles the sandy loam.

The group as a whole is quite distinct from soils belonging to the other series with which it is associated. It most closely resembles the Redding series, but lacks the gravelly substrata, is generally freer from gravel and cobbles, and has a thicker hardpan. It has a pronounced hog-wallow surface with the hardpan occurring at shallow depth in depressions. Considerable leveling, which costs from \$10 to \$35 or more per acre, usually is necessary to prepare the soils for fruits, alfalfa, and other intensive crops.

*Location.*—The soils of the group are widely distributed, but are confined to the east side of the valley trough in this survey. They are very extensive east and north of Madera and in northern Merced County and around Dickinson. Smaller areas occur west of Oakdale, south of Hickman, and in several other places.

The areas nearer the foothills have the most uneven surface, owing in part to more active erosion and in part to the weakly cemented character of the underlying sandstones. The surface over a large part has a generally level appearance, except for the hummocks and depressions. The slopes usually are sufficient to give good surface drainage, except in low spots where rain water collects and remains for long periods in wet weather. This standing water puddles the soils, frequently resulting in reduced yields of grain in such places. The group represents an old alluvial deposit which has undergone noticeable changes in mineralogical character and arrangement since the material was laid down.

*Utilization.*—The soils of this group are extensively farmed, but owing to the uneven, hummocky surface and the shallow soil, they are utilized mainly for dry-farmed grain and grain hay, with areas poorly adapted to cultivation used for pasture. Irrigation is generally necessary for intensive crops, but in areas of deeper soil fair results are obtained with grapes and certain deciduous fruits by dry-farm methods. Local irrigated areas, where water is supplied either by pumping or through gravity systems, are being utilized for a wide range of crops, and good yields are obtained. Alfalfa does well on the deeper soil, but is short-lived where the soils are shallow. Grapes, figs, olives, peaches, almonds, berries, plums, and other fruits do well when watered, especially where attention is given to increasing the organic matter of the soil. Citrus fruits are grown successfully on the slopes where the soil is several feet deep

and where climatic conditions are favorable. Blasting the hardpan has proved beneficial where it is underlain by permeable material, permitting a deeper penetration of roots and a better circulation of moisture. Much of the group is located where water for irrigation is rather difficult to obtain. Practically no commercial fertilizer is used on these soils, except for citrus fruits and some other intensive crops. Practically no crop rotation is practiced, but it is generally the custom to alternate grain crops with fallow. Deeper plowing probably would prove beneficial for the soils of this group where they are deep and unusually compact. The price of land varies considerably, depending upon location, irrigation possibilities, productivity, and degree of development. Much of the group is favorably located with reference to railroads and shipping points, and is well supplied with roads. Few homesteads are located on these soils, except where they are intensively developed. In other places they are held mainly in large tracts, and are operated either by the owner or by tenants. Irrigation and the addition of organic matter are two of the principal requisites in the handling of these soils, although best results also depend on other factors, such as depth of soil, nature of the hardpan or substratum, and methods of farming.

#### SAN JOAQUIN LOAMS.

The San Joaquin loams as mapped in this survey include the loam, stony loam, and gravelly loam types. The stony and gravelly areas are shown on the map by stone and gravel symbols. The total area of the group is much less than that of the San Joaquin sandy loams.

*Description.*—The San Joaquin loam is the most extensive type in the group. It consists of a light-red, dull-red, or red loam averaging about 10 to 12 inches in depth. The soil is red when wet, but when dry, although having a pronounced reddish appearance in the field, small hand samples are often reddish brown. The soil is sometimes smooth and silty, but it often carries considerable coarse, gritty sand and fine, water-worn gravel. There are other marked variations in texture. The higher areas often consist of a heavy fine sandy loam and the lower, flatter areas locally approach a clay loam, with adobe tendencies. The structure usually is compact, but variations in this and in the texture make tillage difficult in some places and easy in others. The subsoil is a reddish-brown to red, rather heavy, compact clay loam or clay, which is generally heaviest near the underlying hardpan. In rare instances the soil continues quite uniform to the indurated layer. The subsoil is redder than the surface material in most places, and averages 12 to 36 inches or more in thickness, resting upon a reddish-brown to red, densely cemented iron-clay hardpan which usually contains varying quantities of coarse, gritty sand. The hardpan varies greatly in thickness, and typically is underlain

by more permeable material, resembling the surface soil, though in some places the substratum consists of a feebly cemented sandstone.

The depth of soil and subsoil above the hardpan varies widely. The hardpan is exposed locally in depressions or on hummocks, but may lie more than 6 feet below the surface. It restricts subdrainage so that the soil becomes boggy and at times practically impassable. The organic-matter content is moderate to low, and no concentrations of lime are apparent in the soil, subsoil, hardpan, or substratum except locally along the contact with soils of the Madera or Fresno series. Where it is not too thick and is not underlain by a cemented substratum, the hardpan is blasted successfully for deep-rooted crops.

A few small undifferentiated areas of brown soils of the Madera series and of dark-gray to black soils of the Alamo series occur within the type, but are of little importance. The soil is somewhat slow to absorb moisture and some of the rainfall is lost as surface run-off, but where well tilled, the type is quite retentive of moisture.

The stony loam type is inextensive. It is generally compact, but variable in texture and structure and contains gravel as well as cobblestones. In most respects, as in color and subsoil and hardpan features, it closely resembles the loam member of the series.

The gravelly loam also is of minor extent, and is similar to the loam type except for its gravel content, more compact structure, and droughty nature, and the greater difficulty of tillage. It is a less desirable soil for crops, and its chief use is for pasture.

*Location.*—This group is quite extensive in the eastern part of Merced County and also occurs at Montpelier, Stanislaus County. It is mapped only east of the valley trough in this survey, and is confined to the plains between the Sierra Nevada foothills and the San Joaquin River.

*Topography and drainage.*—These soils have a gently undulating, sloping, or slightly rolling topography, occupying a part of extensive plains which extend in some places from the Sierra Nevada foothills nearly to the trough of the valley. A part of the group is smooth, but considerable areas are strongly eroded, being more or less dissected by degrading channels and having a very hummocky surface. Numerous small depressions, occurring among the hummocks, are poorly drained in wet periods. Surplus rainfall collects in such places as small ponds, which remain until the water evaporates. As a rule crops do not do well in these puddled spots. Otherwise the group is well drained. Alkali is present only locally where the soils merge with lower lying types of the Fresno series. The material forming the soils of this group has undergone considerable change in mineralogical character since deposition.

*Utilization.*—The San Joaquin loams group is used chiefly in the production of grain and grain hay and as pasture land. The shal-

low areas produce light yields of grain and a moderate to light growth of grass and wild oats. The deeper and more uniform areas are partially devoted to other crops, such as grapes and a few other fruits, without irrigation, but the yields usually are light and uncertain. The loam member is the more desirable type of the group, and when well handled and irrigated is capable of producing a wide range of crops. Under such conditions grapes, olives, figs, almonds, peaches, plums, alfalfa, and other crops do well. Only a small part has been irrigated, owing mainly to the difficulty of obtaining water and the preference for other soils more favorable for intensive crops. Little fertilizer is used except for a few intensive crops. Occasionally fields are changed from one crop to another, but no definite rotations are followed. A reduction in yields of grain resulting from continuous cropping has led to fallowing in alternate years for this crop.

The price of land of these soil types varies greatly and is dependent on many factors, mainly the possibility of irrigation and the average depth of the soil.

Roads usually are good, and shipping points as a rule are easily reached. There are few dwellings on the least favorable tracts of this group, but where intensively developed it is more thickly populated. Irrigation and an increase in the organic-matter content are the greatest needs of these soils.

#### SAN JOAQUIN CLAY LOAMS AND CLAYS.

The group San Joaquin clay loams and clays includes four types—the clay loam, gravelly clay loam, clay adobe, and clay loam adobe of the series.

*Description.*—The clay loam consists of a light-red to deep-red clay loam and includes a prominently developed reddish-brown phase. The soil of the clay loam is quite heavy and sticky when wet and compact and hard when dry. It ranges from a few inches to about 10 inches in depth, and rests upon a reddish-brown to red heavy clay loam or clay subsoil. At widely varying depths, but usually at less than 2 feet, the subsoil is underlain by a red hardpan, which is impenetrable to roots and water. Friable material generally occurs below the hardpan, but in places gray cemented beds are encountered. A small quantity of gritty sand frequently is present in the soil, subsoil, and hardpan, and small quantities of rounded gravel sometimes occur on the surface and in the soil mass. The texture varies within short distances, often approaching a loam or gravelly loam on hummocks or other elevations, with a puddled clay loam or clay in the intervening depressions. Tillage is quite difficult, and the soil usually is low in organic matter, which, with its compact structure,

causes it to absorb moisture rather slowly. When wet, however, and where well managed it remains moist for a considerable time, and the deep areas are capable of producing good yields of grain without irrigation. The virgin soil cracks badly on drying and is extremely dry during long periods in the summer. Locally the type is well supplied with organic matter and has a dark reddish-brown color when dry. No lime is apparent in the soil, hardpan, or substratum except in places where the type adjoins soils of other series. Rarely the soil and subsoil are 6 feet deep; in such places the indurated layer serves a good purpose in preventing the loss of moisture by percolation. The hardpan where not too thick and not underlain by the cemented gray beds can be blasted successfully and the land used for deep-rooted crops.

The gravelly clay loam has a rather small total area, but is more extensive than the clay loam. It consists of a dull-red to brownish-red, compact clay loam about 10 inches deep, carrying waterworn gravel. Small areas of the Montezuma clay adobe and Redding gravelly loam are included. The type has a subsoil and hardpan closely resembling those of the clay loam. The substratum usually is less favorable for the agricultural use of the type; it generally consists of red, yellowish-brown, or gray mottled clay loam, and locally contains small quantities of cobblestones. Gray cemented beds are of more frequent occurrence than in the clay loam. In other features the two types are similar.

The clay adobe is more extensive than the clay loam adobe. It consists of a dull-red or dark brownish-red, heavy, compact clay of adobe structure, 8 to 12 inches in depth. The subsoil, to a depth of about 2 or 3 feet, is a red, reddish-brown, or yellowish-brown clay of about the same texture as the surface soil. Where the soil is shallow, it may continue uniform to the hardpan, but usually there is a noticeable change before the hardpan is reached. The typical San Joaquin hardpan is present. The substratum usually is lighter in texture than the surface soil and is permeable to roots and water except locally where it consists of sandstone or gray cemented beds. The soil is moderately to well supplied with organic matter and no lime is apparent in the soil column except locally, as in slight depressions, where small streaks or seams are sometimes present. Small quantities of gravel and cobbles occur on the surface and through the soil material. The soil cracks badly upon drying and where untilled, and owing to its heavy, compact character tillage operations are difficult and much of the rainfall is lost as surface run-off. When saturated, however, the type retains moisture for long periods if cultivated. A dark reddish-brown variation of this type occurs in places.

The clay loam adobe member of this group is of very small extent. It occurs principally as small areas associated with the clay adobe, but also in minor depressions in the clay loam and gravelly clay loam areas. As a rule it is badly puddled and difficult to till. It has the same range and variations in color and structure in the soil column as the clay adobe member.

*Location.*—The soils of the San Joaquin clay loams and clays group are subject to considerable variation, and in places represent soil conditions intermediate between the Redding and Fresno series. They form a few small, irregular areas in the eastern part of Merced and Madera Counties. The gravelly clay loam is encountered around Lake Yosemite and in a few areas near the foothills east of Le Grand.

*Topography and drainage.*—This group of soils occupies gently or moderately sloping, undulating, or slightly uneven, hilly areas. Drainage usually is well developed except for minor depressions in which surface water collects in wet weather. When saturated the adobe members retain moisture well, and these types can usually be distinguished at a considerable distance in the spring by their unusually heavy growth of grass and wild oats. The soils of the group are not subject to active erosion.

*Utilization.*—The group is of little agricultural importance. Some grain and grain hay are produced on the clay loam and the adobe members, but pasture is the chief use. With irrigation a few of the fruits might be grown successfully in the deeper and more favorable areas, but these soils probably will not be intensively developed as long as more desirable soils are available. Land values usually are low, and the soils are either held in large estates or farmed in conjunction with more desirable land.

#### SAN JOAQUIN AND ALTAMONT SANDY LOAMS, UNDIFFERENTIATED.

This group includes the San Joaquin sandy loam and Altamont sandy loam, with small areas of Redding, Diablo, and Madera soils of the same textures. Some areas of heavier or lighter soils belonging to the Redding and Diablo series also are included.

*Description.*—The San Joaquin sandy loam is derived from old alluvial deposits which originally covered the lower foothills, but erosion exposed the underlying sandstones in places, and these have weathered into the Altamont sandy loam, constituting part of the soil group. Small quantities of gravel and cobbles are locally present, but have little influence on tillage and crop production. The San Joaquin sandy loam is not conspicuous on the hilltops, ridge crests, and slopes, but occurs as a rather deep and uniform soil of smoothly rolling topography. A sandstone substratum is generally

present, but otherwise the type corresponds with the description of the San Joaquin sandy loam as given in this report.<sup>1</sup>

The Altamont sandy loam is a brown, grayish-brown, or slightly reddish-brown residual soil containing some mica and a moderate to small supply of organic matter. This type varies considerably, and occasionally contains small undifferentiated patches of Redding gravelly sandy loam or Diablo clay loam adobe. In texture it ranges from a light sandy loam to a light loam; in other respects it corresponds with the description given for this type in the discussion of the Altamont sandy loams.<sup>2</sup> It is more extensive than the San Joaquin sandy loam, and probably occupies 60 per cent or more of the area of the group.

Small, unimportant areas of the Madera sandy loam are present, as are also local spots of gray, residual material from sandstone, which, if more extensive, would be mapped with the Arnold series.

The soils of the group as mapped in this area include a part of the Arnold sandy loam and loam types of the Modesto-Turlock detailed survey.

*Location, topography, and drainage.*—The group, which is not extensive, occurs in a number of irregular areas in eastern Stanislaus County. It usually occupies a position somewhat above the general elevation of the valley plains. The areas have a gently rolling and sloping to somewhat uneven, low, hilly topography, with contours rounded and without abrupt breaks. Erosion has not been severe, but there is sufficient slope to provide good drainage, and the soils are free from alkali.

*Utilization.*—Both types in this group are retentive of moisture, and rank among the best lands for dry-farmed grain, for which they are utilized almost entirely. Moderate to good yields are obtained by fallowing every other year. Where the soil is shallow and the surface uneven the land is used for pasture. The soils in favorable locations would probably prove suited to orange growing with irrigation, but the group lies above present canals, and irrigation would be expensive. The elevation and the nature of the underlying material are unfavorable for supplying water by pumping. Some grapes and deciduous tree fruits might be grown without water, but irrigation is necessary for best results with fruits and alfalfa. No fertilizer is used nor are systematic rotations practiced. Most of the areas are well supplied with roads and have convenient shipping points, but are sparsely settled.

Irrigation, good tillage, and the addition of organic matter are the chief needs of this group of soils.

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<sup>1</sup> See p. 61.

<sup>2</sup> See p. 47.

## MADERA SERIES.

The soils of the Madera series have their origin in weathered and otherwise modified, old, unconsolidated, waterlaid deposits derived from many kinds of rocks. They typically are brown in color, the lighter textured members often being light brown or grayish brown and the heavier soils reddish brown or chocolate brown. The soils are underlain by brown, reddish-brown, or red, heavier textured, very compact subsoils which typically give way at depths within the 6-foot profile to red, reddish-brown, or mottled brown and gray hardpans, in places containing seams of calcareous material. (Pl. I, fig. 2.) The hardpan usually is softer than that underlying the San Joaquin series. The substratum below the hardpan is often permeable, but as encountered in this survey may sometimes be displaced by soft sandstone. The soils are rather low in organic matter and without concentrations of limy material in the soil section, except occasional streaks or seams in the lower subsoil, hardpan, or substratum. They usually have a less pronounced hog-wallow surface than the San Joaquin soils, and in many places, where of more recent origin, have a level to sloping surface, with the hardpan lying at greater average depths. They occupy modified alluvial fans, sometimes of rolling character, or smooth-surfaced strips or terraces along streams. The surface drainage is good, but the sub-drainage is restricted by the hardpan. These soils are distinguished from the San Joaquin series by differences in color and other features.

The soils of the Madera series are mapped in this survey in six groups of types, three of which also contain undifferentiated material of other series of soils.

## MADERA SANDY LOAMS.

The group Madera sandy loams includes the fine sandy loam and sandy loam types of the series.

*Description.*—The fine sandy loam consists of brown, light-brown, or grayish-brown, friable, open-structured fine sandy loam, in places carrying a small quantity of mica. Very rarely the color is a light reddish brown, which is intensified somewhat when the soil is wet. Often no distinct subsoil is present, but in the deeper areas the soil is underlain at 12 to 18 inches by a somewhat browner or more reddish brown, slightly heavier textured subsoil, which is heaviest and most compact near the underlying hardpan, usually present 2 to 6 feet or more below the surface. The hardpan, which is rather firmly indurated, is reddish brown, brown, red, or grayish brown in color and in places contains seams and thin layers of limy material. The hardpan varies greatly in thickness, but is usually thin

enough to be shattered by blasting. The substratum usually is friable, and is permeable to roots and water. The hardpan varies greatly in its influence on crops. In the areas of shallowest soil it is a distinct disadvantage; in its deeper occurrence it is of little effect, although of some benefit under certain conditions. The type is somewhat variable in places, and grades from a sandy loam to light loam. Tillage is not difficult.

The sandy loam is variable in depth and color, but typically consists of a brown, grayish-brown, or reddish-brown, somewhat friable to rather compact sandy loam, carrying small quantities of mica and waterworn gravel. The soil is quite uniform where it occurs in large areas, but elsewhere it may contain patches of coarse sandy loam, loamy sand, or light loam too small to map. At a depth of 12 to 15 inches the soil grades into a brown, grayish brown, or reddish brown, somewhat compact sandy loam or loam subsoil, usually heavier and redder than the surface material. Typically this subsoil is underlain at depths of less than 6 feet by the reddish-brown hardpan characteristic of the Madera series. A substratum of permeable material, which in many places closely resembles the surface soil, occurs below the hardpan. Tillage is not difficult, although fields sometimes have a cloudy appearance, largely due to surface flooding in irrigation. Gravel occurs in noticeable quantities west of Table Mountain in Madera County. The sandy loam usually has a shallower hardpan than the Madera sand, mapped in the group Oakley and Madera sands, and in places it closely resembles the Oakdale sandy loam, from which it is distinguished by the hardpan, which is absent in the Oakdale type.

*Location.*—The fine sandy loam member of this group is of small extent. It occurs in small areas, which were not mapped, between the Madera sand and heavier types, but two small bodies south of Le Grand and several others along intermittent stream ways in Madera County are shown on the map. The sandy loam occurs extensively southwest of Snelling and in several smaller areas north and northwest of Merced, with a prominent development extending eastward from Cressey beyond Amsterdam. In the last-named location the type occurs either as small, elevated, or slightly depressed areas among types of the San Joaquin series or as distinct bodies near areas of the Oakley and Madera sands, undifferentiated. The group is confined to the east side of the valley trough in this survey.

*Topography and drainage.*—The areas of this group of soils have gently undulating or rolling to nearly level topography. The western extensions are generally more uniform, but frequently become more uneven and hummocky as the eastern foothills are approached. The eastern part is dissected in places by intermittent streams which add greatly to the surface irregularities. Drainage is good in most

places, but seepage and the accumulation of alkali occur locally in the level or slightly depressed areas. The more uneven eastern areas usually have a shallower hardpan than the areas farther west.

*Utilization.*—The soils of the group are used mainly for grain and grain-hay production (Pl. II, fig. 1) and pasture, much of the rough land being poorly adapted to irrigation, which is necessary for most intensive crops. Where the soil is deep and well handled, grapes and other fruits give fair returns in favorable years without irrigation. Water is available over parts of these soils from canals and by pumping, and where irrigated they have proved well adapted to olives, almonds, alfalfa, deciduous fruits, and truck and other annual crops. Thompson Seedless grapes locally do very well. Commercial fertilizer is used for certain intensive crops, and the addition of organic matter increases crop yields. The sections in which these soils occur usually are well supplied with roads and shipping points, but they are sparsely settled where the land is owned in large tracts. Land values vary greatly, depending upon the possibility of irrigation, location, the value for intensive crops, and other factors.

#### MADERA LOAMS.

The Madera loams group includes the loam and silt loam types of the series.

*Description.*—The Madera loam is a brown, grayish-brown, or slightly reddish brown loam, which is normally friable and retentive of moisture. It is low to moderate in organic matter, but contains slightly greater quantities than the San Joaquin loam. The Madera loam is often compact when dry and sticky when wet. The soil rests upon a somewhat heavier and slightly more compact subsoil at a depth of 10 to 15 inches. The subsoil is brown, light brown, yellowish brown, grayish, or reddish brown. Typically at depths of less than 6 feet a brown, reddish-brown, or grayish-brown hardpan is encountered, which frequently contains seams or other concentrations of marly material. This hardpan varies widely in thickness and hardness, and rests upon a substratum of material closely resembling the surface soil. Lime is sometimes present immediately above the hardpan, but otherwise apparently does not occur in the soil or subsoil in this survey. The hardpan is generally near enough the surface to lower the productiveness of the soil, and in the shallow areas blasting is necessary to fit the land for deep-rooted crops. The deeper lying hardpan helps to conserve the moisture within the root zone, and this, with good tillage, frequently enables a number of crops to do moderately well without irrigation.

The silt loam is an extensive type. It has a brown, reddish-brown, or dark-brown, friable soil. As mapped, a large part of the area

is heavier than typical and closely approaches a silty clay loam or clay loam, especially east and slightly southwest of Merced. In this section the soil is compact when dry and sticky when wet, but near streams and in the region west of Le Grand it is friable and easily tilled. At 10 to 15 inches the soil grades into a somewhat lighter-colored and slightly heavier subsoil, which is underlain by a hardpan and substratum similar to those of the loam. The hardpan in the silt loam lies at a greater average depth than in the loam. The silt loam also contains more organic matter. Locally, small, hummocky areas of soils of the San Joaquin are included, and in such places the soil and subsoil section is shallow. Local areas of the Madera clay loam and clay adobe also occur within the type, but are small and of little importance.

*Location.*—The Madera loams group is extensive. It is confined to the plains region of the east side of the valley. The loam member occurs as irregular areas from the northern to the southern boundaries of the survey. The silt loam member occurs principally in Merced County, and occupies most of the large alluvial fan of Bear Creek and its tributaries. It lies on slight terraces along this creek, where the stream emerges from the foothills. An important area also occurs on the Mariposa Creek fan and smaller ones along other streams.

*Topography and drainage.*—The topography generally is smooth and nearly level to gently sloping or undulating. In places the loam is marked by hummocks and depressions, and this type as a whole is slightly more uneven than the silt loam. A number of drainage ways occur, but little active erosion is taking place. The soils as a rule are better drained than the corresponding types of the San Joaquin series. Drainage usually is good except in local flats and in depressions between hummocks where the land becomes quite boggy in the rainy seasons. In places the soils are subject to occasional overflow, and small quantities of alluvium are deposited. They are normally free from alkali, though small concentrations may occur in low areas adjoining other poorly drained soils.

*Utilization.*—These soils are largely utilized for farming and rank among the best soils of the survey. In some cases they are still held in large tracts and used for grain growing and pasture. Yields of grain are good in favorable years. The land is fallowed in alternate years. The deep areas give moderate yields of fruits and other special crops without irrigation in years of abundant rainfall, but irrigation is necessary for continued good results. Irrigation, the water being supplied both by canals and by pumping from underground sources, has made large areas suitable for fruits, truck crops, nuts, alfalfa, and other intensive crops. The addition of organic matter materially increases yields and improves the moisture-retain-

ing capacity of the soils. Commercial fertilizer is used in a small way for certain intensive crops. No regular rotations are practiced, but a frequent change of annual crops is the rule. The soils are generally well located with respect to roads and transportation facilities. Land values vary greatly and are based to a large extent upon location, quality of the soil, and practicability of irrigation. The best land frequently is held at a price of several hundred dollars an acre, but in less favorable localities much lower prices prevail. The soils are capable of a much more intensive development than at present exists.

#### MADERA CLAY LOAMS AND CLAYS.

This group of soils includes the clay loam, silty clay loam, clay, and clay adobe types of the series.

*Description.*—The clay loam is a brown, reddish-brown, dark-brown, or grayish-brown, rather compact, refractory soil, in many places showing a tendency to adobe structure. The soil is sticky when wet, and its dense structure and heavy texture make tillage difficult. It is variable in depth, but usually at 10 to 18 inches grades into a rather compact, reddish-brown or brown clay loam or clay. At a depth of 2 to 6 feet the subsoil rests upon a mottled red or grayish-brown, semicemented or indurated hardpan, often containing seams of calcareous material. Occasionally the hardpan is fragmentary, and in places it gives way to grayish, compact clay, containing calcareous nodules. The subsoil usually is heaviest just above the hardpan, and small quantities of lime are locally apparent. In some places the hardpan is not encountered within 6 feet of the surface, but clayey layers are present, and these usually interfere with the development of roots and the circulation of air and water. In poorly drained areas the soil and subsoil are gray or dark gray and the hardpan is grayish, as in the Stockton soils. Such areas are generally heavy and badly puddled. The substratum below the hardpan generally resembles the surface soil in texture, but is lighter in color.

The silty clay loam is of small extent in this survey. It closely resembles the clay loam in most features except its higher silt content. It is also somewhat more friable, and usually is better drained.

The Madera clay is a brown, dark-brown, or dark grayish-brown clay or silty clay, usually sticky when wet and compact and locally puddled when dry. The type as mapped varies widely in texture within short distances, and includes areas of clay loam on slight elevations and spots of clay adobe in minor depressions. At a depth of 10 to 12 inches occurs the subsoil, a brown, yellowish-brown, or grayish-brown clay of about the same texture as the surface but usually of more compact structure. The hardpan and substratum

resemble those of the clay loam. The soil contains more organic matter than the clay loam.

The Madera clay adobe is a dark-brown, brown, or dark grayish-brown clay of pronounced adobe structure. It is quite high in organic matter and at a depth of 12 to 20 inches rests upon a heavy, plastic clay subsoil of brown, reddish-brown, or dark grayish-brown color. This is underlain by the characteristic hardpan of the Madera series at depths ranging from 3 to 6 feet below the surface. The type is difficult to till, but where well handled forms a friable seed bed. It conforms to the description given for the clay loam in other features.

*Location.*—Of this group of soils, the inextensive clay loam occurs in Madera County; the silty clay loam is found in small bodies associated with the clay, north of Merced and south of Bear Creek in Merced County, and the clay, which is confined to Merced County, lies mainly north and east of Merced, with a few small areas scattered over the Bear Creek fan. The clay adobe is of very small extent and occurs in association with other soils of the series.

*Topography and drainage.*—The areas of these soils have a nearly level, very gently sloping or slightly depressed surface, which is marked in places by shallow stream ways, but is in general smooth enough to be prepared easily for crops and for irrigation. A few small hummocks, generally occupied by lighter soil types, are included. The soils are less subject to the accumulation of alkali than some of the other soils, but drainage to remove surplus water in wet periods and to improve aeration is necessary over a large part of their extent.

*Utilization.*—The Madera clay loam and silty clay loam, where free from alkali, are the best farming soils of the group. Their small extent and unfavorable drainage features, however, have somewhat retarded their development. They are used mainly for grain, grain hay, and pasture. A considerable part of the clay north of Merced has been leveled and planted in part to alfalfa and figs, although low, poorly drained areas are not well suited to these crops. Alfalfa has been short-lived, and in some fig orchards several replantings of trees have been necessary before a full stand could be obtained. Grain promises to continue for some time the best crop for these soils, although local areas may successfully be used for more intensive crops. Irrigation is necessary for the best results with crops. Most of the soils are well located with reference to towns and shipping points. The price of land of this group varies widely, depending upon location, possibility of irrigation, alkali conditions, and the depth of the soil.

MADERA AND SAN JOAQUIN<sup>1</sup> SANDY LOAMS, UNDIFFERENTIATED.

The group Madera and San Joaquin sandy loams includes the San Joaquin sandy loam and the Madera sandy loam, the latter being much the more extensive. The soils usually are variable, and transitions and gradations from one to the other are so numerous that separate mapping on the scale used in this survey is not feasible. The crests of hummocks frequently are occupied by material of the San Joaquin series, and the intervening depression and more nearly level areas by soils of the Madera series. Such spotted conditions are very noticeable in places, but can not be indicated satisfactorily on the map. Small areas of fine sandy loam and gravelly sandy loam are also present, but these are of minor extent and resemble the other soils of this group, except in texture and gravel content.

*Description.*—The soil recognized as belonging to the San Joaquin series is mainly a red, light-red, or brownish-red sandy loam, with a distinct subsoil, usually of redder color and heavier texture, which rests upon a red or reddish-brown hardpan at varying depths below a few inches. The hardpan layer, which is variable in thickness, overlies a brown, yellowish-brown, reddish-brown, or red substratum which is friable and permeable to roots and water. Locally the substratum is sandstone or gray, cemented material. The combined depth of soil and subsoil averages about 2 feet or somewhat less, but in exceptional cases has a depth of 6 feet or more. The soil, subsoil, and hardpan frequently contain a larger proportion of coarse, angular sand than the Madera soil.

The part of the group recognized as the Madera sandy loam is brown to grayish brown or slightly reddish brown, with included dark-brown or dark grayish brown spots. The soil is a sandy loam and rests upon a brown to reddish-brown, heavier textured subsoil at a depth of 8 to 12 inches. At depths varying from a few inches to 6 feet or more, a brown, grayish-brown, or reddish-brown hardpan is encountered. It closely resembles the hardpan of the San Joaquin sandy loam, except that it often carries seams and incrustations of limy material and is slightly lighter in color. The organic-matter content and the combined depth of the soil and subsoil in the Madera sandy loam is also usually somewhat greater than in the San Joaquin type. The soil of both types contains some gritty material, but the Madera sandy loam is usually more friable and has a slightly wider range in texture than the San Joaquin sandy loam.

This group includes much of the material mapped as the San Joaquin sandy loam in the survey of the Modesto-Turlock area and a small part similarly mapped in the Madera area. Fuller descriptions of the types of this group are given elsewhere in this report.

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<sup>1</sup> See p. 60 for description of San Joaquin series.

*Location.*—The soils of this group, which are quite extensive, are confined to the east side of the San Joaquin Valley. Important areas occur in eastern Stanislaus and San Joaquin Counties, and another near Fairmead. Several smaller bodies lie along the foothills of the Sierra Nevada Mountains. Most of the areas represent parts of old alluvial fans which extend in many places nearly to the valley trough.

*Topography and drainage.*—The types in the group have quite similar topographic features. They occupy gently sloping, slightly hilly, or undulating areas, the San Joaquin sandy loam ususally predominating on slight elevations of more thorough drainage and better oxidation. The soils are generally well drained, except locally.

*Utilization.*—These soils are mainly utilized for grain and grain-hay production, with light yields in the shallow areas and moderate to good yields in the deeper areas. The poorer land is used for pasture, but most of it is tilled. Intensive cultivation has been retarded by the uneven, hummocky surface and the difficulty of obtaining water for irrigation. In places, however, land has been leveled and irrigated and is producing moderate to good yields of deciduous fruits and other special crops. Fair returns from grapes are obtained on the deeper soil without irrigation, but water is necessary for best results. Where the hardpan is not too thick and is not underlain by a cemented substratum, blasting has proved beneficial for deep-rooted crops. The land used in the production of grain crops is fallowed every other year. No regular rotations are followed, but the annual crops are changed frequently. These soils are much better supplied with roads and shipping facilities than the gravelly members of the San Joaquin or Redding series. Land prices vary considerably, depending on the degree of development, location, depth and quality of soil, and irrigation possibilities, the last often being the most important factor.

#### PLEASANTON SERIES.

The soils of the Pleasanton series, as mapped, are the weathered, altered products of old, unconsolidated water-laid deposits, originally derived mainly from sedimentary rocks. The types usually occur along the sides of the main valley as remnants of more extensive beds. The soils are typically brown or light brown in color, but there are grayish-brown or reddish-brown variations. They typically rest upon a heavier textured subsoil, more compact and less permeable than the soils and usually of lighter brown color. The subsoil typically is underlain at depths less than 6 feet by substrata composed of rounded quartzose gravel mixed with smaller quantities of finer materials. The soils are apparently low in organic matter and con-

tain no concentrations of lime within the 6-foot section. They occupy smooth, elevated terraces, or rolling or hilly areas, and are well drained except in the rainy season, when their dense subsoils interfere with the downward movement of water.

The soils of the Pleasanton series encountered in this survey occur greatly mixed with material of other soil areas, but well-defined areas are typical of the series as mapped in other surveys.

PLEASANTON AND ANTIOCH<sup>1</sup> LOAMS AND CLAY LOAMS, UNDIFFERENTIATED.

This group, Pleasanton and Antioch loams and clay loams, has a rather wide range in character of soil material. In addition to soils of the Pleasanton and Antioch series, it includes some Corning material. There are also small areas of residual material (Altamont). For the most part, however, the brown soil in connection with the subsoil features indicates that the Pleasanton and Antioch soils predominate. Where there is no distinct gravelly substratum, but the subsoil is heavy, compact, and calcareous, the soil is recognized as belonging to the Antioch series, and where there is a distinct gravelly subsoil or substratum, to the Pleasanton series. It is probable that less than 10 per cent of the area of the group is occupied by soil of the Corning series. The remainder is about evenly divided between the Pleasanton and Antioch.

*Description.*—The Antioch loam in this survey has about the same range in color as in other parts of the State but includes more dark-brown or slightly reddish brown variations. A grayish-brown variation occasionally occurs in the poorer drained spots, or where some of the more calcareous, deeper substrata have been exposed by erosion. The type is rather friable but, like many other upland soils, becomes baked and compact when exposed to dry weather without cultivation. It is normally free from gravel, but quantities sufficient to affect tillage occur in small areas. At depths ranging from 12 to 36 inches a compact clay loam usually is encountered, and this extends, with some variation, to a depth of 6 feet or more. The subsoil on exposure cracks and is more or less streaked and marked with calcareous seams and nodules. It merges gradually into the noncalcareous gravel substrata typical of the Pleasanton series. In some instances, instead of the gravel-free clay loam subsoil a gravelly clay loam or clay subsoil is encountered, in which there occur lime-encrusted pebbles or semicemented calcareous layers.

The Antioch clay loam consists of a brown, dark-brown, or slightly reddish brown clay loam, which has about the same depth as the loam. It also has gravelly variations similar to those of the loam. The subsoil is not often distinctly different in texture from the surface

<sup>1</sup> See p. 82 for description of Antioch series.

soil but differs in structure, being more compact and having a tendency to crack upon exposure. As in the other soils of the series, calcareous seams or nodules occur in variable quantities in the subsoil and the deeper substrata.

The Antioch clay loam adobe occurs in some important areas and differs from the clay loam in but two essential features, the adobe structure and the prevailing darker color.

The Pleasanton loam consists of a brown loam which is normally friable. Like nearly all the other soils derived from old valley-filling material it is easily tilled when moist, but is hard and baked in uncultivated areas. Dark-brown variations are more common than the lighter brown or slightly yellowish brown variations prominent in other surveys. There are also variations in which gravel occurs. The soil usually is underlain at depths ranging from 12 to 30 inches by a thin layer of compact heavier textured material, which upon exposure develops an adobelike structure. The substratum is subject to wide variations. In its extreme development it consists of a mass of medium sized, waterworn fragments with small quantities of interstitial fine soil material, extending to a depth of 6 feet or more. When partially cemented, as is sometimes although not typically the case, the substratum is not favorable to water storage or root development. There are all gradations in the group between this extreme and the normally gravel-free subsurface layers of the associated Antioch series. Gravel streaks or beds sometimes alternate with finer textured layers, and this, with other variations, gives rise to differences having direct bearing on the value of the soil.

The Pleasanton clay loam ranges in color from medium brown to darker or more reddish brown, and consists of a clay loam or, in some places, gravelly clay loam. The gravel may be confined to the surface few inches or distributed throughout the soil mass. The gravelly substratum typical of the series is found at various depths from a foot or more downward. The soil immediately overlying the gravelly beds usually is adobelike and more compact than the surface material. The gravelly substratum varies as in the loam.

The Pleasanton clay loam adobe is similar to the Antioch clay loam adobe except in subsurface conditions.

The subsoil and substrata of the soils of this group are distinctly less permeable to roots, water, and air than those of the recent-alluvial soils of similar texture. The relatively shallow depth of the friable surface material is unfavorable to the storage of water for the use of plants.

*Location.*—The soils of this group occur in several areas in the southwestern part of the survey, along the margins of the valley between the upland mountain soils and the smooth, gently sloping sides of the valley. They are nearly always bordered on the side facing

the mountain by soils of the Altamont series and on the opposite side by the Yolo soils. One or two detached areas occur within the valley floor. Other areas are included with the alluvial soils of the valley slopes, but their total extent is small. It is possible that some areas exist in the area of Altamont loams and clay loams lying west of Patterson and Crow's Landing.

The area of soils of this group represents remnants of old, water-laid deposits. Some of the bodies, like those southwest of Dos Palos, represent old-alluvial fans which have been only slightly altered by erosion and merge with the lower-lying recent soils of the Yolo series from which they are rather arbitrarily separated. Other parts, like that west of Los Banos, occupy rather distinct shelves or benches which break rather sharply on their eastern margins into the lower valley floor and pass on the opposite side more or less abruptly into the higher-lying residual soils. This same position of intermediate elevation marks most of the soils included with the group west of Newman and Gustine, although arbitrary lines sometimes separate them from adjoining soils.

*Topography and drainage.*—The original surfaces are indicated by the even-crested ridges or extensive flats. Minor streams and washes are numerous, but the rounded slopes are tillable. Drainage is good in all the rolling areas, and only intermittently poor in the flatter parts, where the water after heavy rainfall sometimes disappears slowly owing to a dense subsoil. Depressions among hummocks or hog-wallow mounds in places collect surface water.

*Utilization.*—Where tilled the group is used for the production of dry-farmed hay or grain. Probably 50 per cent of it is untilled and used mainly for pasture. These soils are not so well adapted to dry-farming methods as the deep, recent-alluvial soils, nor do they yield so well under irrigation. Where properly supplied with moisture, however, they produce profitable yields of a wide variety of crops. Owing to the light rainfall and the lack of water for extensive irrigation there seems little likelihood of more intensive use. Most of the group is accessible and near shipping lines.

#### CORNING SERIES.

The soils of the Corning series are derived from old water-laid deposits, composed of the wash from many kinds of rocks, but in this area mainly from sedimentary formations. The soils are typically red, but vary to yellowish or light red. The subsoils are red to deep red and heavier and more compact than the surface soils. The subsoil rests within the depth of 6 feet upon gravelly beds generally consisting mainly of rounded quartzose gravel mixed with a smaller quantity of fine soil material. The soils are deficient in organic

matter and typically are without apparent concentrations of lime. They usually occupy regions of intermediate elevations along valley margins, being flanked on their upper side by residual soils and on the lower side by alluvial soils. The areas usually are remnants of more extensive old valley-filling deposits, altered and modified by erosion. Topographically they vary from undulating or hilly on the uplands and elevated terraces to sloping on valley plains. There are some hummocks and associated minor depressions, with local poorly drained flats. Owing to the dense subsurface layers the depressed areas and flats collect surface water in the rainy season and the soils become boggy. During the remainder of the year the soils are rather droughty.

This series resembles the Redding series except that the hardpan of the latter is not present; it differs from the Pleasanton series in color.

The Corning series is represented in the present survey by one group. Patches of these soils too small to be shown separately on the map may be found in areas of other soils.

#### CORNING AND PLEASANTON<sup>1</sup> LOAMS, UNDIFFERENTIATED.

This group contains the loam and gravelly loam types of the Pleasanton and Corning series. The members of the Pleasanton series predominate.

*Description.*—The Pleasanton loam, as mapped in this group, consists of a brown or light-brown loam, underlain at depths of 10 to 30 inches by a heavier textured, more compact subsoil, which checks upon exposure. The subsoil ranges in color from light brown to yellowish or reddish brown, and normally is rather free from gravel. It is only a few inches thick, and overlies compact gravelly substrata which often contain layers of silty or clayey material relatively free from gravel. Except in color the soil, subsoil, and substrata of this type are similar to those of the Corning loam. The gravelly substrata vary in character, and the quantities of fine and coarse material change within short distances. One extreme is represented by gravel beds carrying little fine interstitial material, while the most favorable part of the type is that in which the fine material predominates, with small quantities of embedded gravel.

The Pleasanton gravelly loam is the most extensive member of this group. It differs from the Pleasanton loam chiefly in having a higher gravel content, although the two types merge gradually in many instances. The gravel is waterworn and usually of quartzose character.

The Corning loam consists of a red loam, which is fairly friable under moderate moisture conditions, but which bakes and becomes

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<sup>1</sup> See p. 76 for description of Pleasanton series.



S6129

**FIG. 1.—TREELESS VALLEY PLAIN ADJACENT TO THE SIERRA NEVADA FOOTHILLS.**  
This plain is occupied mainly by soils of the Redding series. The illustration shows the general topography and the hogwallow surface typical of the series.



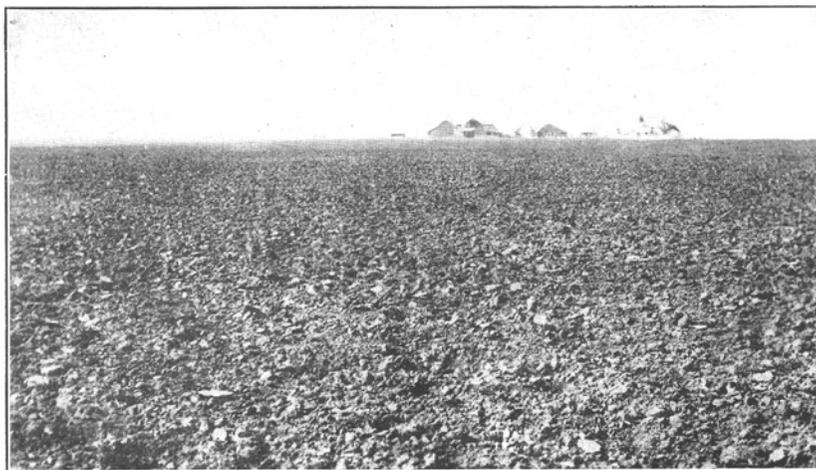
S8038

**FIG. 2.—HARDPAN OF THE MADERA SERIES EXPOSED IN STREAM BED NEAR STOCKTON.**  
Much of this material is, in this locality, superficially covered by soils of the Honcut series.



S7722

FIG. 1.—GRAIN STUBBLE ON SOILS OF THE MADERA SERIES EAST OF WATERFORD.  
Rounded hills in distance occupied by soils of the Altamont and Diablo series.



S8044

FIG. 2.—PLOWED FIELD ON YOLO CLAY LOAM, NEAR WESTLEY.

compact and hard upon drying. When wet the soil is boggy. It is normally free from gravel, but in places where it merges into the associated Corning gravelly loam some gravel is present. The soil varies considerably in depth, but generally grades at 10 to 30 inches into a more compact and heavier textured subsoil, which, upon exposure, cracks like adobe. Where most compact the subsoil is unfavorable for plant growth. It merges gradually into a gravelly substratum, which varies widely in compactness and in the proportions of gravel and clay, but in general is more permeable than the hardpan underlying the Redding soils.

The Corning gravelly loam is essentially similar to the Corning loam except that it carries sufficient waterworn gravel in the surface soil to influence tillage. It is of small extent in this survey.

This group of soils includes some variations in texture other than those mentioned, chief among which are local areas both of more sandy and of more silty nature than typical. Some exposures of the deeper substrata indicate that a few rather well cemented and impervious gravelly beds occur, but these are not continuous nor typical. The soils and subsoils as a whole do not contain apparent concentrations of lime. They have a moderate to low content of organic matter and are not very well adapted to dry farming. Tillage usually is easy when the soil is in proper condition as regards moisture.

*Location.*—This group is inextensive, being confined to several moderate-sized areas along the western margin of the survey. The most important occur west of Romain and southwest of Los Banos. The Corning soils are most extensive west of Dos Palos, along the southwestern margin of the survey. In places the soils merge with the more subdued areas of soils of the Altamont series, the Corning and Pleasanton material occurring as a thin veneer over areas underlain by rocks yielding the Altamont.

*Topography and drainage.*—In nearly all instances the soils of this group lie along the margin of the valley at elevations slightly greater than those of the adjoining alluvial soils of the valley slopes, but lower than the residual soils on the opposite side. In some places the surface is quite irregular, owing to erosion. Parts of the original surface remain, and the topography is comparatively smooth. Some of the areas lying at low elevations merge with areas of recent-alluvial soils, and are separated from them with difficulty. Even in the latter instances, however, there usually is a slight unevenness of surface not characteristic of the recent-alluvial soils. Drainage is adequate except for short periods during the wet season, when the escape of water is retarded by the compact subsurface layers.

*Utilization.*—About one-half the total area of this group is tilled and the remainder is used for pasture. The cultivated land is used mainly for the production of grain and grain hay. Crop yields are moderate. The low rainfall and the moderate moisture-conserving power of the soils render them poorly adapted to the production of special crops without irrigation. Owing to the elevation of these soils, water must be supplied by pumping, and it must be brought from considerable distances, so that the prospect for extension of irrigation is not bright. Nearly all the areas are moderately well located with respect to shipping facilities. Land prices are generally lower than for the recent-alluvial soils of the valley slopes.

#### ANTIOCH SERIES.

The soils of the Antioch series are derived from old unconsolidated, water-laid, valley-filling deposits made up of material of mixed origin but coming mainly from sedimentary rocks. The soils are brown, but variations of light brown, grayish brown, or even dark brown are included. The subsoil typically is heavier and more compact than the surface soil, although this difference is less marked in the heavy textured types. It also is lighter colored, being typically a light brown or yellowish brown. The soils carry medium quantities of organic matter, and the subsoils typically contain concentrations of lime. The substratum below a depth of about 6 feet is lighter in texture and less compact than the subsoil and contains less concentrations of lime.

Soils of this series lie at an elevation greater than that of the recent-alluvial soils, but lower than that of the residual soils. The surface is sloping, slightly rolling, or has the form of a modified terrace. A hummocky surface occurs in some places. Drainage is good except in some flat areas or in small depressions that retain water in the rainy season.

These soils differ from those of the Pleasanton series in having calcareous subsoils and in the absence of gravelly substrata. They usually are treeless or support only a sparse forest growth.

The Antioch series is represented in this survey by one inextensive group and a part of one other group.

#### ANTIOCH CLAY LOAM AND CLAY.

In the group Antioch clay loam and clay the latter predominates. There are small included areas of loam.

*Description.*—The Antioch clay loam consists of a brown or dark grayish brown clay loam, which is compact and very hard when dry. It has a granulated or slightly adobelike structure in some of its variations and usually is free from gravel. The subsoil, encountered normally at 12 to 30 inches, is lighter colored than the surface soil,

ranging from light brown to yellowish or slightly reddish brown. It is more clayey than the surface material, in places a clay, is compact, and has a more pronounced adobe structure upon exposure. The subsoil contains calcareous streaks, seams, or small nodules, although distinct hardpan layers are not typical.

The Antioch clay forms a small part of the group. The soil consists of a heavy adobelike clay, underlain by a lighter colored subsoil of about the same texture as the surface material, but more compact and calcareous. The subsoil cracks upon exposure to the air.

Besides the two soils described small areas of the loam and silty clay loam of the series occur throughout the group.

*Location.*—The soils of this group are mapped in several inextensive areas in the western part of the survey. The largest of these occurs at San Joaquin City, the others near Westley and Byron Hot Springs.

*Topography and drainage.*—The areas of this group have a topography intermediate between that characteristic of the recent-alluvial soils and that of the elevated old valley-filling soils. The surface is slightly uneven or marked by hog wallows and occasionally is undulating. It is more uneven than is typical of the associated recent-alluvial soils of the Yolo series, but, on the other hand, is smoother than that of much of the Antioch series located at greater elevation. The soils for the most part border the lower lying valley trough. Streams of the valley slope have become slightly entrenched in the material. Drainage usually is good, except in the flatter, heavier areas or in the hog-wallow areas where the run-off may be sluggish in the wet season. Injurious quantities of alkali occur in some minor areas.

*Utilization.*—The soils in this group are used principally for the production of grain and grain hay and for pasture. Some of the land is being developed under irrigation, the water being supplied by pumping, but the production of intensive crops has not yet become established.

#### OAKDALE SERIES.

The soils of the Oakdale series are typically brown or grayish brown. The surface soil, which is often very gritty, may continue to a depth of 6 feet or more without marked change in texture, but typically it gives way at less depth to a more compact and usually slightly heavier textured subsoils of lighter brown or reddish-brown color. This series is derived from old water-laid deposits. The soil column to a depth of 6 feet or more is much more permeable than in many of the other old valley filling soils, yet it shows differences between the soil and subsoil not characteristic of the recent alluvial soils, and lenses of incipient hardpan occur locally. Moderate to small quantities of organic matter are present. Neither soil nor

subsoil show lime as seams, nodules, or other concentrations. The series usually lies on smooth or gently undulating terraces or upland plains lying considerably above the alluvial bottoms of present streams. Drainage usually is good.

One group of these soils, including several types, is mapped in this survey.

#### OAKDALE SANDY LOAMS.

The group of Oakdale sandy loams includes the coarse sandy loam, sand, sandy loam, and gravelly sandy loam of the series.

*Description.*—The Oakdale coarse sandy loam has a total area much greater than that of all the other types of the group combined. It consists of a brown, grayish-brown, light-brown, or rarely a dark-brown, coarse, gritty, sandy loam, often micaceous and with local areas containing small quantities of fine quartzose gravel. Relatively large quantities of fine sand and silt give the soil a very loamy texture and cause it in places to clod when plowed. Most of the surface soil, however, is quite incoherent and loose when dry, though sticky when wet. In areas containing noticeable quantities of fine gravel, and where the texture approaches a coarse sand, the type is leachy and droughty. The dark-colored soil contains moderate quantities of organic matter, but the areas of lighter color contain very little. These variations, together with differences in texture, influence the moisture-retaining capacity of the soil. At a depth of 12 to 18 inches a lighter colored or browner, more compact and heavier textured subsoil usually is encountered, although in places the soil continues uniform to depths of 6 feet or more, being in such areas more nearly like the older areas of the recent-alluvial Hanford material. No hardpan is present in typical areas, but intermittent lenses or sheets occur locally. The substratum resembles the subsoil quite closely and continues uniform for many feet except where semi-stratified. Constant tillage and irrigation tend to develop a heavier layer at about 1 foot or more below the surface, which checks the downward movement of moisture.

The Oakdale sand, a type of small extent, consists of a brown, light-brown, or grayish-brown, rather smooth, micaceous sand locally carrying small quantities of fine gravel. The type contains varying amounts of fine material, which is often sufficient to give it a pronounced loamy texture. The soil ranges in depth from 18 to 36 inches, and in typical areas rests upon a subsoil of slightly heavier texture and of more compact structure. Areas occur, however, in which the material is uniform in color and texture to a depth of 6 feet or more. In addition to being heavier, the subsoil usually is somewhat browner than the surface material, and occasionally hardpan, which resembles that of the soils of the Madera

series, is encountered. The substratum is similar to the subsoil except that in places it shows some stratification. The type usually contains little organic matter, and does not retain moisture well. The soil works into a friable seed bed, and may be tilled under a wide range of moisture conditions. It is developed principally on old elevated terraces along the larger streams entering the area from the east.

The Oakdale sandy loam also is of small extent. It consists of a brown to grayish-brown, or rarely dark-brown, friable, micaceous, sandy loam. The content of coarse sand is often relatively high, and there are local areas of finer texture. Typically the soil at a depth of 12 to 20 inches grades into a more compact and slightly heavier subsoil, of brown to slightly reddish brown color, which continues quite uniform throughout the profile, and in many places to a depth of 10 feet or more. The type occurs locally as an overwash several feet deep resting on a hardpan and substratum similar to those of the Fresno and Madera series. It absorbs water readily, and is retentive of moisture wherever the subsoil is typically developed, though where the subsoil is porous the type is droughty. This is the best agricultural soil of the series in this survey. In case of tillage and certain other respects it is similar to the Oakdale sand.

The Oakdale gravelly sandy loam is a type of very small extent and occurs principally as local areas or meandering strips which mark remnants of old stream channels through other types. It is variable in character, but usually is a light grayish brown to brown, micaceous, incoherent, sandy-loam soil, approaching in texture a coarse, gravelly sand. It is easily tilled, but is droughty, water passing rapidly downward beyond the reach of plant roots. It is lower in organic matter than the other soils of the group and an inferior soil for farming.

*Location.*—The Oakdale sand is confined principally to the lower side of the terraces, and is most prominently developed in a number of areas along the Stanislaus, Tuolumne, and Merced Rivers. The most important body lies south and east of Oakdale. The sandy loam, coarse sandy loam, and gravelly sandy loam are associated with the sand, but usually occupy the higher parts of the terraces. The group is confined to the east side of the valley in this survey.

*Topography and drainage.*—The areas of this group have a comparatively uniform topography, usually nearly level and smooth, but with sufficient fall for good drainage. Moisture is absorbed readily by most of the soils and their proximity to deeply intrenched streams gives them a low water table and freedom from seepage and alkali. Typical areas usually are quite retentive of moisture, but those having open, porous subsoils are droughty.

*Utilization.*—The coarse sandy loam is not only the most extensive type of this group of soils but is also the most important agriculturally. Almonds are a very important crop in the region about Oakdale and are grown quite successfully without irrigation. The soils of this group are devoted in part to peaches, olives, grapes, figs, bush and vine fruits, and truck crops. Some oranges are grown on the north side of the Stanislaus River east of Oakdale. Some alfalfa is produced where irrigation water is available, but much of the group is still used in the production of dry-farmed grain. Areas having an uneven surface are used for pasture. The less favorable parts are rather unproductive. The soils are well located with reference to transportation and towns.

The price of land composed of soils of this group ranges above \$100 an acre for the better areas and below for less desirable areas. Where water is available these soils are capable of producing good yields of intensive crops, but for continued high yields the addition of organic matter is necessary.

#### FRESNO SERIES.

The soils of the Fresno series typically are gray or light gray to light brownish gray, but as mapped in this area include variations of light brown to brown. The subsoil is of similar or lighter gray color and in its typical development has an ashy appearance. It is heavier in texture and more compact than the surface soil and usually contains more or less firmly cemented layers, forming a gray to yellowish or light-brownish hardpan. The hardpan is sometimes rather irregularly developed and may consist of a single layer or of several successive layers with intervening and underlying material of more friable character. In places it is calcareous and frequently is associated with calcareous nodules or concretions. In the areas of browner soil the hardpan may lie below the depth of 6 feet or be entirely lacking.

The soils of this series are derived from old unconsolidated valley-filling deposits occupying extensive alluvial fans and valley plains. The surface is level to gently undulating and the lighter textured members and browner variations frequently are modified somewhat by wind action. Drainage is retarded by the compact subsoils and hardpan, except in the lighter and deeper soils. The heavier members usually occupy flat valley plains of poor drainage, and usually contain more or less alkali.

The series is extensive and important in this survey. The map shows two types, two groups of types, and undifferentiated parts of two other groups.

## FRESNO SANDY LOAM.

*Description.*—The Fresno sandy loam consists of a gray or brownish-gray sandy loam, having a light grayish brown variation which quite closely resembles the lighter and more poorly drained parts of the Fresno sandy loam, brown phase. The type is variable in color and texture, with surface hummocks which are often occupied by a light-brown or brown, loose, or moderately compact sandy loam, and intervening depressions, which usually constitute 60 per cent or more of the surface, of gray or ashen-gray, compact, puddled heavy sandy loams to light loams. The surface often bleaches to almost white, and this condition has given rise to the popular term “white-ash lands.” The color changes quickly below the surface to a light brownish gray or light grayish brown, which continues to a depth of 8 to 10 inches, below which in places it gradually becomes somewhat browner. The texture below 10 inches becomes heavier. At depths ranging from 18 inches to 3 feet a silty layer of varying thickness is encountered, which is very compact and in places semicemented or indurated. This hardpan layer usually is calcareous and generally harder, thicker, and nearer the surface than in the Fresno sandy loam, brown phase. The substratum usually consists of semicemented beds of material somewhat resembling the subsoil. In places it is mottled or has the bluish cast typical of poorly drained areas in this region. The soil is low in organic matter. The gray color and puddled condition is caused by water which stands on the surface in periods of wet weather.

The Fresno sandy loam is less friable and usually less retentive of moisture than the Fresno sandy loam, brown phase, from which it is differentiated by its more compact structure, lower organic-matter content, shallower soil, thicker, and harder hardpan, and poorer drainage. Cultivation of the typical soil is more difficult than of the phase.

*Location.*—The typical soil is not extensive. It occurs in a number of irregular areas east of the trough of the valley in San Joaquin, Stanislaus, and Merced Counties.

*Topography and drainage.*—The topography of this type is nearly level to very gently sloping. In detail the surface frequently is hummocky. Occasional sloughways or remnants of old abandoned stream channels occur, but most of the type has the appearance of an extensive nearly level plain with slight relief. The greater part of the type is droughty in the summer. Where adjoining higher soils which are heavily irrigated there is a high water table and areas affected by seepage. Surface drainage is poor, and in wet weather water stands for weeks on the slight depressions and flats. In gen-

eral, the drainage is so poor that injurious accumulations of alkali are common.

*Utilization.*—The type is used principally for pasture and generally supports a moderate growth of salt grass. The better areas are dry farmed to grain, with moderate to low yields. Some of the uneven parts have been leveled and where the soil is of moderate depth give fair yields. The type usually is held in large tracts or is farmed in connection with more desirable soils. The prices of land vary widely, depending on location, character of the soil, and irrigation possibilities. It is of relatively low agricultural value, owing to its poor drainage and low organic-matter content, the presence of alkali, and the shallowness of the soil. The type is generally well supplied with roads but frequently is remote from shipping points.

*Fresno sandy loam, brown phase.*—The Fresno sandy loam, brown phase, is one of the most extensive and important soils of the area. It consists of a grayish brown, light-brown, or brown, light, friable sandy loam, usually grading at about 12 to 18 inches into a lighter colored and somewhat heavier grayish-brown, light-brown, or brown, heavy sandy loam to a rather silty loam or, rarely, silty clay loam. In places, the soil and subsoil are apparently stratified, giving a varied profile. At a depth of 2 to 6 feet a gray or light grayish brown, silty, compact layer is encountered, which in places is indurated. This layer, or hardpan, as it is popularly called, usually is dense enough to check the free movement of roots and water. It frequently softens under irrigation. It varies in thickness from a few inches to several feet. Locally, it is only semicemented and contains many small, calcareous nodules and lime casts. It generally is calcareous, although important areas contain no visible lime. The areas near the valley trough seem to be more marly than those nearer the foothills. Wide differences in the quantity of calcareous material occur within short distances.

The substratum in many places closely resembles the material above the hardpan, but locally may be of either lighter or heavier texture. It generally is quite permeable, and where the cemented layer is not too thick blasting is beneficial for fruits and other deep-rooted crops. Over large areas, the hardpan is below the depth of 6 feet, and does not interfere with farming.

Small, rather flat, slightly depressed areas of grayer appearance and heavier texture than typical sometimes occur. These spots are compact and more or less puddled, water standing on the surface for periods in wet seasons. They also have more compact subsoils and the hardpan is nearer the surface than usual. Such areas quite closely resemble the typical gray Fresno material which is much more

extensive near the trough of the valley. Locally and near abandoned stream ways noticeable quantities of fine gravel and coarse, angular sand particles occur. Mica is present in varying quantities in the soil over considerable areas. The phase is variable in surface features, texture, and drainage, but is quite uniform over the extensive areas of nearly level surface. It is locally subject to slight reworking by wind, and in such places is sometimes slightly undulating. The organic-matter content usually is low, but tillage is not difficult at most seasons of the year, except in the low areas of irregular surface, with shallow, puddled soils.

This phase is distinguished from the grayer Fresno soils located farther out in the valley on the basis of color and because of its better drainage, deeper and more friable soil, and greater freedom from alkali. In earlier detailed mapping the phase was not shown separately. In places the soil closely resembles soils of the Madera series, from which it is distinguished by the lighter color of the soil and the gray color of the hardpan. Much of the material mapped south of the Tuolumne River is of light texture and in places closely approaches a sand, but extensive areas of the sandy loam material occur west and southwest of Ripon, around Salida, north of Modesto, between Ceres and Hickman, south of Keyes, and west of Waterford.

*Location.*—The Fresno sandy loam, brown phase, is confined to the east side of the valley trough, where it occurs as large areas throughout the central part of the survey. It lies on the more gently sloping or more nearly level parts of the valley slopes formed by the larger streams entering the area from the east, and is associated with soils of the Madera and San Joaquin series.

*Topography and drainage.*—This soil has a very gently sloping, slightly undulating to nearly level topography. Occasional shallow drainage ways, segments of old abandoned stream channels, and slight depressions occur. Low places frequently are poorly drained and usually affected with alkali. The western part of the areas of this soil has poorer drainage and more alkali than that farther east. The deeper areas have few, if any, hummocks and are well drained, while the shallower and flatter parts are frequently hummocky, with inclosed puddled depressions, are poorly drained and require reclamation before they are suitable for cultivation.

*Utilization.*—Practically all the better parts of this phase are under cultivation. The soil is adapted to a wide range of crops, chief among which are grapes, peaches, almonds, walnuts, olives, figs, truck crops, alfalfa, beans, sunflowers, and grain. Moderate yields of some of these crops are obtained in favorable years without irrigation, but water is necessary for consistent returns and long

lived trees. Yields are noticeably increased by applying organic matter. The shallowest and most uneven parts of the phase and areas held in large tracts are used mainly for grain production and pasture. Considerable areas are now under irrigation. Water is supplied mainly by canals, although some is pumped from underground sources. The soil warms up rapidly in the spring and matures its crops soon after the Fresno and Oakley sands. Some commercial fertilizer is applied for certain of the intensive crops, but little definite information is available as to the fertilizer requirements of this soil. Annual crops are changed from year to year, but no definite rotations are followed. The soil is well located with reference to towns, and is well supplied with transportation facilities. The roads usually are in good condition, but become somewhat cut by ruts in the summer.

Land prices vary greatly. Some areas are held at several hundred dollars an acre, but the usual price is much below \$100 an acre for the less desirable land, which usually requires considerable outlay for leveling, drainage, or alkali reclamation before it can be highly developed. Irrigation and organic matter are the chief requirements of this soil.

#### FRESNO FINE SANDY LOAM.

*Description.*—The Fresno fine sandy loam is friable to compact, and has a gray or brownish-gray color. It includes noticeable variations of light grayish-brown color, which resembles its brown phase and the Fresno loam. The type is variable in its smaller areas, and ranges from a grayish brown or brown light sandy loam on hummocks to a heavier, ashen-gray fine sandy loam or light loam in the associated depressions. Where extensively developed, as in Madera County, however, the type is quite uniform. A small percentage of fine gravel or coarse sand occurs along stream ways. At a depth of 8 to 12 inches the soil rests upon a compact gray or grayish-brown, heavy sandy loam, loam, or clay loam. At 18 inches to 4 feet the subsoil is underlain by a fine-textured hardpan, ranging from compact beds to semicemented or indurated layers. This is generally gray or grayish brown, and varies greatly in thickness. It is usually thicker and more firmly cemented than that beneath the Fresno fine sandy loam, brown phase, and frequently contains small calcareous nodules. The substratum resembles the subsoil quite closely, although locally it may be mottled and of darker color. In low and poorly drained areas, near the heavier types of the series, the typical hardpan is displaced in places by a dark bluish gray clay loam or clay. The soil is low in organic matter, is not retentive of moisture, and is somewhat more difficult to till than the Fresno sandy loam.

*Location.*—The Fresno fine sandy loam is confined to the east side of the valley, where it occurs on the lower parts of large, gently-sloping old-alluvial fans. It usually occupies a position nearer the valley trough than the brown phases of types of this series. A few small, irregular bodies occur near the San Joaquin River in San Joaquin and Stanislaus Counties, and more important areas are located in Merced and Madera Counties.

*Topography and drainage.*—The type has a uniform surface, forming a nearly level plain, with a slight slope westward. A few minor stream ways occur, and small areas are nearly flat or slightly depressed. Drainage is generally deficient and varying quantities of alkali usually are present in the soil and subsoil. Most of the type is well drained in summer, but small ponds of water occur in the depressions in winter. The water table is high in many places, and alkali accumulation has resulted locally through seepage from near-by, higher lying soils.

*Utilization.*—The Fresno fine sandy loam is used almost entirely for pasture on account of its puddled and alkali condition and because of its ownership in large tracts. Small areas are sown to grain, of which the yields are light to moderate. Leveling and alkali reclamation usually are necessary to fit the land for intensive crops. Much of the type is rather remote from towns and shipping points. Land prices vary, often being below \$100 an acre. The main type is much less desirable than the brown phase.

*Fresno fine sandy loam, brown phase.*—The brown phase of the Fresno fine sandy loam, to a depth of 12 to 36 inches, consists of a grayish-brown, light-brown, or brown, smooth, friable fine sandy loam, in places containing varying quantities of mica. The soil may extend to a depth of 6 feet or more without variation, but typically it has a distinct subsoil and a variable hardpan. The subsoil often consists of a heavy fine sandy loam, silt loam, or rarely a silty clay loam usually somewhat lighter in color than the surface soil, being light brown, brown, or grayish brown. It is more compact than the surface material but usually is readily penetrated by roots. It is retentive of moisture. At 2 to 6 feet or more the subsoil typically rests upon gray, grayish-brown, or brown, compact silty layers which in places are more or less indurated, constituting a hardpan. This usually is rather impervious to roots and water but in many instances softens under irrigation. It varies greatly in thickness and rests upon a rather friable substratum, which continues to considerable depths. The soil, subsoil, and substratum frequently are semistratified, causing considerable variation in the profile. Where the hardpan is of good depth it sometimes assists in holding moisture within the root zone, especially where the subsoil and substratum are very porous, but under most conditions the occurrence of the hardpan is

unfavorable to agriculture. The soil rarely contains visible concentrations of lime, but some is present in the lower subsoil and in the hardpan. It occurs usually as streaks or seams and forms nodules and lime crusts. In places it gives the soil material a mottled-gray appearance. The soil usually is low in organic matter. It is easily tilled at nearly all times of the year and where well handled is very retentive of moisture. Locally, and where it merges into other types, it is quite variable and ranges in texture from a loamy fine sand or sandy loam to a light silt loam. The lighter textured soils drift somewhat when freshly exposed, giving the land a slightly undulating appearance. Small quantities of coarse sand or fine gravel sometimes occur near streamways, and minor flat or slightly depressed areas of the typical gray, rather poorly drained Fresno fine sandy loam are included.

*Location.*—The brown phase of the Fresno fine sandy loam is not extensive. It is confined to the east side of the San Joaquin Valley and occupies a number of irregular areas in the smoother parts of the old alluvial fans. It lies below the Redding soils and is associated with types of the Madera and other closely related soil series. It has a very gently sloping or slightly undulating to nearly level topography, and except for occasional streamways and segments of abandoned stream channels has a uniform, smooth surface. Locally there is a tendency toward the formation of hummocks, but this is less pronounced than on the typical soil. The phase usually is well drained, except in local flat or slightly depressed areas where seepage from irrigation on higher lands causes a rise in the ground water. In such areas also there is usually an injurious accumulation of alkali.

*Utilization.*—The Fresno fine sandy loam, brown phase, though much less extensive than the similar phase of the sandy loam, is an important agricultural soil. It is utilized for a wide range of crops and is intensively cultivated except where held in large tracts. Grain and grain hay are the principal crops grown on the large holdings, and fruits, alfalfa, and other crops similar to those grown on the brown phase of the Fresno sandy loam are produced in the more highly developed areas. Grain yields normally are high where the land is fallowed in alternate years. A few other crops are grown without irrigation, but the returns are more or less uncertain and dependent upon the rainfall. Irrigation, both with water from canals and from underground supplies, has proved very successful and has greatly widened the range of crops grown. Some commercial fertilizer is used for certain crops, and organic manures are added where available. Interplanted crops are sometimes grown in the young orchards and give good returns where water is plentiful. Most of the phase is well located with respect to roads and shipping points,

and where used for intensive crops is well settled. The price of land varies greatly and ranges up to several hundred dollars an acre for the better parts.

#### FRESNO LOAMS.

The Fresno loams group of soils includes the loam and silt loam types of the Fresno series. Unimportant areas of the Stockton adobe soils are included with the group as mapped.

*Description.*—The Fresno loam, to a depth of 8 to 12 inches, consists of gray or brownish-gray, rather compact material, which when wet is quite sticky and, in flat or slightly depressed areas, puddled. Light grayish brown and dark grayish brown variations occur locally. The lighter material usually is confined to slight elevations and hummocks, and the darker material to the flat and slightly depressed areas. The more nearly level areas have a very light gray or ashen-gray appearance when dry, but are browner at shallow depths. The texture is quite variable, and ranges from a light loam or sandy loam in the higher areas to a heavy loam or light clay loam in depressions and flat areas. Mica is sometimes conspicuous in areas bordering soils of the Hanford series or where streams have overflowed their banks. The subsoil is quite variable, and ranging from a silt loam to silty clay loam or clay loam, with a slight tendency toward stratification in places. In the more poorly drained parts of the type it is dark gray or dark brown in color and quite compact, while with better drainage it is gray or light grayish brown, and more or less friable and retentive of moisture. At a depth of 18 inches to 4 feet a compact, semicemented or indurated, silty hardpan occurs. This layer varies greatly in thickness. It is usually gray or grayish brown and frequently more or less calcareous. The beds are sometimes non-continuous. They usually are quite impervious. At varying depths the hardpan gives way to a gray, brown, or dark-gray loam to clay loam substratum. Where no definite hardpan is encountered within 6 feet, rather compact soil layers usually are present. The type is normally low in organic matter and the soil packs into a rather refractory mass where water stands on the surface in wet weather. The higher and better drained parts are tilled without great difficulty, but the lower parts usually have a rough surface where plowed and are difficult to put in good physical condition.

The silt loam is much less extensive than the loam. It is rather compact, and occurs in small bodies either within the loam areas or as narrow margins between the loam and heavier types. In color, texture, and structure of soil, subsoil, hardpan, and substratum, and in other features it closely resembles the loam.

Areas of this group lie in the vicinity of the San Joaquin River north of Modesto and in the southern part of Merced County. They

occupy a slightly lower position than the San Joaquin soils, with which they are sometimes associated. Small, undifferentiated areas, too small to map separately in this survey, are present as spots or narrow border strips in areas of other soils in San Joaquin and Madera Counties.

*Location, topography, and drainage*.—The soils of this group occur on very gently sloping, treeless plains, only slightly elevated above the heavy phase of the Fresno clay loams. They have in most places an uneven or hummocky surface. Poorly drained and puddled flats and slight depressions are common, and drainage is in general defective, with indications of alkali. A number of sloughs occur, and water collects in these and in low places in wet weather. In the summer the soil is naturally droughty, but it is greatly improved by the addition of organic matter and by good tillage. The soils of this group, like the heavier members of the Fresno series, contain numerous barren white spots, which usually contain injurious quantities of alkali.

*Utilization*.—The Fresno loams are utilized for grain growing and pasture. Where untilled they support a growth of salt grass. Yields of grain are moderate to light. Intensive crops have been tried only locally. An underground supply of water for irrigation usually is available at moderate depths, but removal of the alkali frequently is necessary before intensive crops can be grown. Land of these types usually is held in large tracts or is farmed in connection with more desirable soils. The location with respect to roads and shipping points is not very favorable, and land prices are generally low. Reclamation from alkali, drainage, the addition of organic matter, good tillage, and irrigation are necessary on much of these soils before intensive crops can be produced successfully.

#### FRESNO CLAY LOAMS.

The group Fresno clay loams includes the clay loam and silty clay loam and heavy phases of these soils. Areas of Merced and Dublin clay are included, but these are so small they may be disregarded.

*Description*.—The Fresno clay loam type is compact and rather fine textured. It is typically gray or brownish gray in color, but as mapped includes variations which range from a brownish-gray or light grayish brown heavy loam or clay loam on minor elevations to a heavy, dark-colored clay loam or clay in depressions or flat areas. In some places the soil approaches the Stockton clay loam in general character.

The subsoil, which lies at depths of 1 to 4 feet or more, usually consists of a heavy, compact clay loam or a clay. It is brown to

light grayish brown in color in the better drained areas and gray, dark brown, or dark gray in lower and flatter areas. The subsoil usually is dense, poorly aerated, and comparatively unretentive of moisture. At various depths the silty hardpan layer common to the series appears. It is quite variable, being lightest in color in the more elevated areas and darkest in low places. It is 1 or 2 feet thick, and underlain by material resembling the subsoil. Lime occurs as seams, streaks, and nodules in the hardpan and in places in the lower subsoil. The soil typically has a low content of organic matter, but the lower lying areas grading into dark-colored soils of other series are relatively high in this constituent. In some places the soil bleaches to a very light gray when dry. This seems to be the result of poor drainage. In such places the soil absorbs water rather slowly and cracks more or less when dry. Tillage operations are quite difficult, and can be performed only within a narrow range of moisture conditions, a very cloddy condition of the surface soil resulting if the type is handled too wet or too dry.

The silty clay loam is a gray to rather dark gray, heavy, silty clay loam from 10 to 18 inches deep. The dark-colored part of the type is a gradation toward the Stockton adobe soils, and where hardpan is absent, as is locally the case along streams, and approaching the Merced or Dublin types. This subsoil is dense and variable, and overlies a hardpan and substratum similar to those described as occurring in the clay loam. In its puddled condition, organic-matter content, moisture-retaining properties, and other features this type is similar to the clay loam. The type is subject to variations near the boundaries, and sometimes contains noticeable quantities of mica near areas of the Hanford soils.

*Location.*—The main occurrence of the group is in western Madera County and in southern Merced County, on that part of the plains near the trough of the valley. Small spots and border strips of these soils of too small extent to be shown on the map occur within areas of the other heavy-textured types of the Fresno series.

*Topography and drainage.*—Broadly, the group occupies a very gently sloping to nearly level plain, but it has many minor depressions, 1 foot or more below the general level of the surface, and low hummocks which make the surface irregular. A number of sloughs and abandoned stream ways which carry water only in flood periods traverse the type. The group has stagnated drainage, and the presence of alkali is indicated over much of the surface by white, barren spots, although there is, in general, a moderate growth of salt grass and other alkali-resistant plants.

*Utilization.*—Land of this group is used mainly for pasture. The better parts produce some grain and grain hay, but the returns are

uncertain. The cultivated areas usually are farmed in conjunction with better soils. The land used for pasture is held in large tracts. An underground supply of water is available for irrigation in many places, but is little used. Drainage and reclamation from alkali are necessary for effective utilization of the soils of the group. They are not well located with respect to shipping points, and are held at relatively low prices.

*Fresno clay loams, heavy phase.*—The Fresno clay loams, heavy phase, consist of heavy, plastic material of gray, bluish-gray, or brownish-gray color. It frequently is darker gray than the lighter textured types of the series, and includes many small, undifferentiated depressed spots or strips of dark gray, dark-brownish gray, or black soils of the Stockton series. The soil usually is more or less puddled and typically differs little from the subsoil in texture, but the color of the latter usually is dark gray, dark bluish gray, or dark brownish gray, and locally it is somewhat mottled. The subsoil is very compact, and has poor moisture-retaining properties. At a depth of 12 to 48 inches a gray, silty hardpan is encountered. This is of variable thickness, and generally contains calcareous nodules or streaks and seams of marly material. The hardpan is semi-cemented or indurated and usually is impervious to roots. The substratum in low places closely resembles the subsoil, but elsewhere it frequently is a gray or light grayish brown clay loam or clay. The soil is higher in organic matter as a rule than the lighter types of the same series. It is subject to greater modification of the surface by overflow waters. When dry it cracks badly, and it is droughty in the summer.

*Location.*—Fresno clay loams, heavy phase, occur near the San Joaquin River in western Merced County. Other small patches, not shown on the map, lie in western Madera, Stanislaus, and San Joaquin Counties. The phase is confined to rather low, flat areas near the valley trough and is associated with heavy soils of other series in a region of greatly mixed soils, influenced to a considerable extent by flood waters.

*Topography and drainage.*—There is little variation in topography. The soil usually occupies the outermost extensions of the old alluvial fans that extend nearly to the trough of the valley. The surface is nearly level to slightly uneven with many low, rounded hummocks. Small sloughs dissect the surface in places, and carry water in flood periods. The soil is poorly drained and frequently is water-logged for long periods each year. Alkali is present over much of the surface.

*Utilization.*—The phase is of low agricultural value at present on account of its puddled and periodically water-logged condition. It

is difficult to handle, and crops are uncertain. It is used mainly for pasture, with one or two areas devoted to grain. This land is remote from shipping points and towns and is supplied with but few roads, which become almost impassable in wet weather. The land is held in large tracts. Prices are generally low. The phase is not well suited to intensive development.

#### STOCKTON SERIES.

The soils of the Stockton series are formed from modified water-laid deposits, derived from many different kinds of rocks. The soils typically are dark gray to black and underlain at variable depths, usually less than 3 feet, by a brownish, yellowish, or grayish calcareous subsoil. The subsoil contains seams and concretions of lime and a calcareous hardpan, or a compact, semicemented layer. The soils are high in organic matter. The surface usually is smooth, with slight slopes. Most of the areas are subject to intermittent overflow. Much of the material giving rise to this series has been laid down as deposits in depressions in areas of sluggish drainage.

The Stockton soils are mapped in this survey in one group and parts of two other groups. Important areas properly belonging to the Merced or Dublin series are included.

#### STOCKTON ADOBE SOILS.

The group Stockton adobe soils includes the clay adobe and clay loam adobe types.

*Description.*—The Stockton clay adobe is typically dark gray to black, the lighter-colored parts being darker when wet. Local spots of dark-brown soil which become almost black when wet occupy slight elevations or strips along stream ways. Light-gray or ashen spots are locally prominent where the surface is flat. The soil also varies in texture, being lighter than typical, approaching a clay loam adobe in some places, and heavier in others. It contains very little coarse material and is uniformly heavy throughout. It is very sticky when wet, and upon drying, without cultivation, assumes a pronounced adobe structure. Cracks from 4 to 6 inches in width and 2 to 4 feet in depth form, and blocks between these jagged cracks check into hard fragments. The soil is well supplied with lime and organic matter.

At a depth of 2 to 4 feet a light-brown, yellowish-brown, or grayish, calcareous subsoil is encountered. This, in texture, may be similar to or somewhat lighter than the surface soil. Typically a hardpan occurs at a depth of about 2 to 4 feet. This layer is not continuous under the group as mapped, but normally is sufficiently dense and compact to affect the development of roots and the movement of

water. The hardpan layer varies greatly in character. It is frequently most pronounced at the level at which the soil grades into the subsoil. Upon exposure it becomes compact and hard, but it seems to soften somewhat when wet. When the hardpan is absent the subsoil material approaches in character that of the Dublin, Merced, or Sacramento soils, and intermittent lenses of cemented material or calcareous nodules of small size are common. When dry, the calcareous material of the subsoil is white or light gray in color, but when wet yellowish or brownish colors predominate.

The Stockton clay loam adobe is almost identical with the clay adobe except in its slightly lighter texture. It is of slightly brownish color in places and has a less pronounced adobe structure.

*Location.*—The Stockton adobe soils occur most typically and extensively in the vicinity of Stockton, and cover the greater part of the plains east and southeast of that city. An important area lies near Dos Palos on the west side of the valley.

*Topography and drainage.*—The surface is level or very gently sloping and remarkably smooth and even, except in some parts, as about Dos Palos, where slight irregularities occur. Stockton Channel and others near by meander through these soils and, together with the protecting levees, constitute the greatest surface irregularities. The soils characteristically occupy positions intermediate between the plains on the one side and the river bottoms on the other. Surface drainage and subdrainage are restricted over most of the soils of the group, and this is especially true of the lower parts adjacent to the delta lands of the San Joaquin River. Much of the group is subject to periodic overflow, but water does not stand on the surface for long periods. Alkali occurs in minor spots in the lower areas, but rarely is found in the typical black soils.

*Utilization.*—Extensive grain fields, dotted with occasional trees or small groves of valley oak, cover almost the entire area of these soils. The land has been cropped to grain without irrigation for many years, and yields are not very heavy. Small tracts have been planted to alfalfa, walnuts, pears, and other fruits and to intensive crops, irrigation in such cases usually being practiced. Vineyards produce satisfactorily without irrigation. The alfalfa fields appear to preserve only a medium stand, and the plant does not seem to be as long-lived as on lighter textured soils. The soils are undesirable for some fruits and vegetables but well suited to many others. Rice culture is receiving attention as a possibility for these soils. The introduction of this crop in other parts of California has proved successful, and it is being grown profitably on similar soils in Butte County.

STOCKTON AND FRESNO<sup>1</sup> SOILS, UNDIFFERENTIATED.

The group of Stockton and Fresno soils, undifferentiated, comprises extremely complicated soil conditions. Soils of various colors and textures and having variable subsoils occur in very small and intimately associated bodies. The Merced, Dublin, and several other series are represented to a small extent.

*Description.*—The Stockton and Fresno soils, undifferentiated, occur in the valley trough, extending northwest from Firebaugh to a point about 4 miles northeast of Newman. They occur on both sides of the San Joaquin River for a considerable part of this distance, but in their northern extension are confined to the east side. The principal area occupies a somewhat basinlike or rather flat region with the meandering course of the San Joaquin River only slightly intrenched within it. The group is subject to occasional overflow by both the main stream and other streams tributary to it. Numerous sloughs leave the San Joaquin River and, paralleling its course, divert water from it in times of flood. These intermittent waterways often have a number of small tributaries and generally reunite with the river. In addition to overflow from the San Joaquin River, considerable water enters the soils laterally from the valley slopes. The area so affected is composed mainly of sediments or alluvial deposits which are principally of altered, aged, or weathered character. They properly belong to the old valley-filling rather than with the recent-alluvial soils, but some soils of recent-alluvial character are included along the river or occur as strips where intermittent stream action has altered, veneered, or entirely removed the older, somewhat modified original sediments.

The soils of the series making up this group do not differ distinctly in elevation or proximity to streams. The small included areas of the alluvial soils of the Dublin series may occupy either slightly elevated stream-built ridges or slightly lower strips bordering some of the sloughways which are eroding rather than building up land surfaces. Probably more than 50 per cent of the area of the group as mapped is covered by soils of dark-gray, drab, or black color. An important part of this dark-colored area seems to be comprised of material of the Stockton series. The Stockton clay adobe, described elsewhere in this report, comprises possibly 25 to 35 per cent of this area of dark soils, but does not usually occur as broad, typically developed bodies. It rather occupies irregular-shaped, lower-lying areas, dotted with numerous slight elevations or hummocks of soils of lighter color. The Stockton clay loam and the Stockton clay loam adobe are included within the group as detached

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<sup>1</sup> See p. 86 for description of Fresno series.

areas associated with the clay adobe. The clay loam and clay loam adobe types are practically similar, except for the adobe structure of the latter. Like the clay adobe, they have very calcareous subsoils, which usually influence the agricultural value of the land.

The soils of the Fresno series occur as irregularly shaped patches throughout the group, chiefly on the east side and in the northern extension of the group on the west side of the San Joaquin River. Both the brown phase and the typical gray material are represented, with textures ranging from a fine sandy loam to a clay loam.

Closely associated and mixed with the Stockton series of soils are irregular areas of material similar to the Merced soils, described elsewhere in this report. The group as mapped includes the Merced silty clay loam of the Merced area which was inaccessible because of its flooded condition when that survey was made. This type is pre-eminently a dark-gray or drab to black, smooth silty clay loam, with a high content of organic matter and with variations of both lighter and heavier texture. Some mica is present, but in smaller quantities than in the Hanford series. The dark color of the soil may extend to a depth of 6 feet or the surface soil may be underlain by a lighter colored subsoil. The subsoil is calcareous, containing lime nodules or concretions, may be accompanied by thin, soft calcareous seams or crusts, and is often compact. It resembles the typical subsoil of the Stockton series. The group also includes some dark-colored soils which possess subsoils showing no appreciable changes in chemical or textural features and which are considered as recent-alluvial soils very similar to those of the Sacramento or Dublin series. The material in the somewhat basinlike positions is of mixed origin and is similar to that of the Sacramento series, but does not appear much different in a cross section from the soils of the Dublin series. The texture ranges from loam or clay loam to clay or clay adobe. The color of the soil is dark gray to black, while the subsoil is light brown or grayish brown. The subsoil is similar to the surface soil in texture or is irregularly variable, as with all recent alluvial soils.

There are two other soils included with this group. The first consists of small strips of soils of brown color having the typical cross section of recent-alluvial soils. Some of this soil is micaceous and is recognized as belonging to the Hanford series. Certain other portions probably represent material of the Yolo series. The second soil is similar in color to the Fresno, but is without the hardpan typical of that series.

*Topography and drainage.*—The soils of this group have but little slope and are not markedly different in topography from adjacent

soils. The basinlike or flattened surface appears quite even when viewed broadly, but is very irregular in detail. Hummocks, slight ridges, and depressions, the result of water action, occur over much of the area of the group. The irregularity of the surface has a direct influence on the drainage and agricultural value of the land and a somewhat consistent relation to the distribution of the various soils. Many of the flat and slightly depressed areas are occupied by soils of the Stockton or Merced series, while the strips bordering the sloughways or main river channel often comprise soils of recent-alluvial character belonging to the Sacramento, Dublin, or Hanford series. The knobs, ridges, and similar slightly elevated areas are more often occupied by soils of brown or gray color. In all the minor depressions among hummocks and the more continuous ones among the gentle ridges excess surface water accumulates in the rainy season. This is either supplied by local rainfall or by surplus surface waters escaping from the river channel or entering laterally from the upper valley slopes. In this manner a single acre often contains several bodies of soil having very different drainage conditions. The small knolls and ridges, by reason of their compact subsoils, shed the rainfall into the adjoining puddled areas. These minor inequalities are reduced somewhat by leveling for irrigation, although the expense is greater and the results are less favorable than on most of the recent-alluvial soils. The sloughs, remnants of stream channels, and swampy depressions sometimes support a growth of tule. Much of the group is flooded for considerable periods in seasons of heavy rainfall, or, if not covered by water, is isolated by flooded areas bordering the main slough ways. A large part has a high-water table and contains alkali in injurious quantities. The dark-gray to black areas rarely contain much alkali, but many of the slightly higher ridges or knobs with brown or gray soils carry excessive concentrations.

*Utilization.*—This group of soils has two main uses, the first and probably the most extensive being for pasture, while the second is the production of irrigated alfalfa on a very extensive scale. Most of the land is held in large tracts, more than one-half of it being under one ownership. The soils are not very well located with respect to shipping points and main roads. Yields of alfalfa vary greatly, owing to the local differences in soil. Some parts have been leveled, seeded to alfalfa, and then allowed to revert to pasture grasses because of the effect of alkali on yields. Other parts are being leveled and prepared for an extension of the alfalfa industry. Water for irrigation is obtained from canals tapping the San Joaquin River.

STOCKTON AND MADERA <sup>1</sup> SOILS, UNDIFFERENTIATED.

The group Stockton and Madera soils, undifferentiated, includes the Madera loam and clay loam and the Stockton clay loam adobe and clay adobe, the types being greatly mixed in occurrence.

*Description.*—The soil material is variable, and transitions from the dark-colored soils of the Stockton series to the brown soils of the Madera series are so frequent that differentiation is not feasible in this survey. The included Stockton types are more fully described elsewhere in this report as being typically dark gray to black, heavy textured soils of adobe structure with lighter colored subsoils, ranging from grayish brown or gray to reddish brown, more compact than the surface material and overlying light-colored hardpan or semicemented layers. The material of the Stockton soils included in this group departs from the typical material of that series in that it often overlies a stratum of soft sandstone or gray, cemented beds. The soils are high in organic matter. Near their margins they are dark brown or dark grayish brown. The clay adobe usually occupies the flatter and lower areas of the group.

The Madera loam and clay loam, as previously described, are brown, dark-brown, or slightly reddish brown soils, occupying about the same topographic position as the associated Stockton types. As included in this soil group they depart from the typical in having a usually smoother surface, with a cemented substratum of sandstone or other consolidated material immediately underlying the hardpan.

These soils appear to contain more material derived from sedimentary rocks than is characteristic of the Madera and Stockton series. They are quite retentive of moisture and the hardpan and cemented substratum prevent the loss of water by percolation. The types of the Madera series probably constitute the greater part of the group.

*Location.*—This group of soils is confined to small areas in the valleys west of Warnersville and southwest of La Grange. The soils occupy nearly level to very gently sloping areas, and are bordered by upland soils of the Altamont and Diablo series. The soils become very miry when wet, but the drainage is sufficient to prevent accumulation of alkali.

*Utilization.*—Until recently these soils were used almost entirely for grain, grain hay, and pasture with only moderate returns. Considerable plantings of rice have recently been made, and heavy yields obtained. Irrigation is necessary for this crop. Other crops, including alfalfa, do well with irrigation. The land is held in large tracts, and water is generally scarce. The soil areas are remote from towns, but are well supplied with roads. They are sparsely settled,

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<sup>1</sup> See p. 69 for description of Madera series.

and land prices are lower than for similar soils better located. The greatest need of this group probably is irrigation.

#### MERCED SERIES.

The soils of the Merced series consist of unconsolidated water-laid deposits derived from a wide variety of rocks. They typically are dark gray to black and are underlain by lighter colored subsoils of brownish or grayish color. The subsoils of the heavier textured types may be lighter in texture than the surface material, but the opposite is true of the other members of the series. The subsoils typically carry concentrations of lime as seams or nodules and are intermediate in this characteristic between the subsoils of the Dublin series and those of the Stockton series. The substratum below a depth of about 6 feet frequently is mottled. The soils are high in organic matter. They occupy flattened or slightly irregular areas and are sometimes overflowed. These soils are differentiated from the associated dark-colored soils on the basis of subsoil differences and other features such as drainage. They usually are treeless.

The Merced soils are represented in this survey by one type and an undifferentiated part of one group of soils.

#### MERCED CLAY LOAM.

*Description.*—The Merced clay loam, to a depth of 10 to 18 inches, consists of a friable to rather compact, heavy-textured clay loam of dark-gray or slate to black color. The soil as mapped includes variations in texture, due to varying velocity of currents depositing the materials, and ranges from a light loam or sandy loam on minor elevations to a silty clay loam or clay in slight depressions. The subsoil also varies considerably, but in typical areas is a dark-gray or dark-brown heavy clay loam or silty clay, usually of quite compact structure and containing varying amounts of lime either as nodules or as noticeable gray discolorations at greater depths. The subsoil is, however, often lighter in color than typical. No continuous or well-developed hardpan is present, but occasional small areas have a noncontinuous quite firmly cemented layer several feet below the surface, such areas being somewhat similar to the Stockton soils. The subsoil often continues uniform to depths of more than 6 feet, and is generally permeable to roots and water. The soil, subsoil, and substratum are variable in places and a tendency toward stratification is common. At a depth of about 6 feet the underlying material is lighter in color, usually brown to grayish brown and locally somewhat mottled. Low, heavy spots usually are quite cloddy when plowed, but the better drained soil forms a mealy or granulated surface. Small areas of the Hanford loam are included

with this type, as are also local hummocky areas of the Fresno loam and clay loam.

*Location.*—The largest area of this type occurs in western Madera County, where it forms an irregular body parallel to the San Joaquin River for more than 20 miles. Small unmapped bodies occur in many places along the trough of the valley in Merced and Stanislaus Counties.

*Topography and drainage.*—The type has a rather uniform surface and occupies a position intermediate between the lower extension of the valley slopes and the recent-alluvial deposits along the San Joaquin River. Slight undulations, low flattened ridges, and minor depressions are common, but the differences in elevation are seldom more than a few feet. A number of winding sloughs and segments of abandoned stream channels serve as drainage ways for the type in wet weather. Drainage is moderate to good. The water table usually is within 6 to 10 feet of the surface. Where not protected by levees, a large part of the type is subject to overflow in the winter months. Small accumulations of alkali are present, but, except in occasional spots, the alkali does not seriously affect most of the crops grown.

*Utilization.*—Only a small part of this type is utilized for crops. Where protected from overflow, alfalfa gives very good yields, and this crop, grain, and grain hay are the principal products. Leveling and irrigation are usually necessary in growing alfalfa and intensive crops, and where alkali occurs in injurious quantities its removal is necessary. The type is of little agricultural importance, largely on account of its small extent and unfavorable location with reference to shipping points, roads, and towns. Land prices vary greatly, and are governed largely by the availability of water for irrigation, alkali conditions, leveling necessary in preparing the land for irrigation, uniformity of soil, state of improvement, and location.

#### ALAMO SERIES.

The soils of the Alamo series are derived from unconsolidated water-laid deposits. They typically are dark gray to black in color and underlain at a depth of 2 or 3 feet by compact, brownish or reddish-brown subsoils. At less than 6 feet, usually at 15 to 36 inches, a hardpan of red or mottled red, brown, and gray color occurs. The substratum below the hardpan usually is lighter textured than the subsoil. The soil appears high in organic matter, and the subsoil, hardpan, and substratum often contain concentrations of limy material as seams or nodules. The soils usually are rather flat and occupy somewhat depressed positions among the surrounding soils. Drainage is often stagnated in the rainy season and overflows from

adjoining slightly higher soils may occur. The soils usually are treeless.

The series is represented in this area by one inextensive soil type.

#### ALAMO CLAY ADOBE.

*Description.*—The Alamo clay adobe as recognized in this survey occurs essentially as mapped in the included earlier soil survey of the Merced area. As described in the Merced area report it consists of a dark-gray to nearly black clay with a pronounced adobe structure, 2 to 4 feet deep, resting upon a red, ferruginous hardpan.

*Location and origin.*—The Alamo clay adobe is confined to a few areas in the northeastern and eastern parts of Merced County, where it is closely associated with the San Joaquin soils, and many areas too small to be shown on the map are scattered through bodies of the latter series. The soil is composed in part of material washed from the higher lying San Joaquin soils.

*Topography and drainage.*—The type is normally smooth or nearly level and slightly depressed below the surrounding soils. Both the surface and subsurface drainage usually are restricted in the rainy season, but the soil is free from alkali. A well-drained phase of this type was recognized in the survey of the Merced area, but is not differentiated in this survey. The phase was described as having a reddish-brown or a brownish tinge in places with better surface drainage than the main type. It is probable that this better drained phase includes considerable material of the Montezuma, Altamont, and Diablo series.

*Utilization.*—The Alamo clay adobe is used for pasture or grain production. It occurs mainly in small bodies, and is farmed as a rule in conjunction with the surrounding soils. Crop yields are fair. It is said that the grass is more abundant and persistent on this type than on the adjoining San Joaquin soils. Irrigation broadens the adaptation of the type, but the soil is, by reason of unfavorable drainage conditions and texture, unsuited to the production of most fruits.

#### MONTEZUMA SERIES.

The soils of the Montezuma series are derived from old, unconsolidated water-laid deposits. They typically are dark gray to black, but often include minor variations of brownish color. The soil typically is underlain by lighter colored, grayish-brown, yellowish-brown, or gray subsoils which extend with minor variations to depths of 6 feet or more. The subsoils usually are heavier textured and less permeable than the surface material, although the difference is not so marked in the heavy types. The soils seem relatively high in organic matter, and the subsoil bears seams and nodules of limy material. The entire soil column is rather retentive of moisture, and

normally no true hardpan is present. The surface is rolling to hilly, with generally rounded contours, and but few steep-sided gullies. Drainage is well developed, and the surface run-off is rapid. The low, flat areas are sometimes separated with difficulty from the dark-colored recent-alluvial soils. This series differs from the Diablo series mainly in the consolidated character of the parent material in the latter. Most of the soils originally were not wooded, but supported a heavy growth of grasses.

One soil type of this series is mapped in this survey, and it is rather inextensive.

#### MONTEZUMA CLAY ADOBE.

*Description.*—This type is mapped in this survey essentially as recognized in the included detailed soil survey of the Merced area. As described in that report, it typically is a dark-gray or black clay, 24 to 36 inches deep, being very sticky when wet and having all the tendencies to check, crack, and assume an open structure upon drying, characteristic of adobe soils. Although the prevailing color is very dark gray or black, there is in this survey a pronounced reddish or brownish shade in some parts of the type. These brown or reddish-brown patches, which are recognized as approaching or even as being material of the San Joaquin series, usually are lighter in texture and less pronounced in adobe structure than the typical areas. As typically developed, the soil is underlain by a subsoil varying from a loam or silt loam to clay in texture, and ranging from yellow to gray in color. This subsoil is very calcareous, and in places is semicemented although it is rarely a true hardpan. Below 6 feet, in a few places, a substratum very similar to that of the adjoining San Joaquin or Redding soils is encountered. In places waterworn gravel and cobbles are scattered over the surface and through the soil. Calcareous nodules are sometimes abundant both on the surface and in the soil and subsoil. The content of organic matter apparently is high. Owing to its heavy texture, this soil is very difficult to cultivate unless worked when moisture conditions are favorable, and considerable skill is required to handle it to best advantage.

*Location, topography, and drainage.*—The Montezuma clay adobe occurs near Planada and southeast of that town as far as Le Grand. It lies just above the Madera soils and at about the same elevation as the San Joaquin soils. The topography is level to gently undulating, and the surface usually is well adapted to furrow irrigation. The lower lying areas are sometimes differentiated from the clay adobe type of the Alamo series with difficulty. The surface drainage is generally good.

*Utilization.*—This soil produces good yields of small grains when moisture conditions are favorable, and much of it is devoted to these

crops. A part of the type is used for pasture. A part has been divided into small holdings for growing alfalfa and fruit of various kinds. It is planned to provide water for irrigation by pumping.

#### SOILS DERIVED FROM RECENT-ALLUVIAL MATERIAL.

##### YOLO SERIES.

The soils of the Yolo series are recent-alluvial deposits which, so far as mapped, are derived mainly from upland regions occupied largely by sedimentary rocks and their derivative soils. They typically are brown in color, but light-brown or grayish-brown variations are common. The subsoils are lighter colored, ranging from yellowish brown to light brown, and may be similar to the surface soil in texture or consist of strata of variable texture. Hardpan or similar compact strata do not occur typically, and the soil column usually is friable and retentive of moisture. The soils contain moderate quantities of organic matter, and the soil column normally is free from concentrations of lime. They occupy alluvial fans (Pl. II, fig. 2), stream bottoms, or low recent terraces of moderate to gentle slope, with occasional slight unevenness due to the occurrence of low, stream-built ridges. Drainage usually is good, except for intermittent overflow affecting parts of the type. The series is differentiated from the related Dublin series on the basis of color, and organic content.

This series is one of the most important in the State. In the present survey it is mapped in three groups and a part of a fourth group. Some of the soils in this survey, however, approach the old valley-filling soils in character, and the included variations of dark-colored soil material if of greater extent, would be recognized as material of a distinct series.

##### YOLO LOAMS.

The Yolo loams group includes the silt loam, loam, and gravelly loam. A dark-gray phase of this group is separated in this survey.

*Description.*—The Yolo silt loam typically consists of a light-brown, brown, or light grayish brown, smooth-textured silt loam, about 18 to 30 inches in depth, underlain by a subsoil which is a little lighter brown or more yellowish brown in color than the surface material. The texture of the subsoil is variable, and may be similar to that of the surface or may range from a silty clay loam to a fine sandy loam. The Yolo silt loam is the heaviest member of the group, and even it is friable or only occasionally compact. The soil column usually is free from compact or relatively impervious layers which might retard root development and water movement. The soil column sometimes contains gravelly streaks, but these are less pronounced than in the lighter textured soils of the series.

The Yolo loam is a light-brown, brown, or slightly grayish brown loam, 20 to 36 inches in depth, overlying a subsoil of lighter brown or yellowish-brown color. The subsoil is similar to the surface material in texture, or may be either more silty or more sandy. It is not unusual for the Yolo loam to carry considerable quantities of rounded gravel in the soil and subsoil, but the entire soil column typically is rather fine, friable, and retentive of moisture. The main areas of the type are often quite uniform in texture but small undifferentiated bodies of fine sandy loam, gravelly sandy loam, or even sand, are included. These occur along streamways or form the old filling at stream channels. The subsoils where they differ from the surface material may be more gravelly or of variable light textures. The more porous variations are very different agriculturally from the average of the Yolo loam, owing to the markedly different capacity to hold water.

The Yolo gravelly loam as occurring in this survey is variable, and while usually a heavy gravelly loam it is associated and mixed with a gravelly fine sandy loam or gravelly sandy loam. The color of the soil ranges from brown to light grayish brown, and there is less difference in color between the soil and subsoil than in other members of the group. The soil section shows more variations in texture, however, with more porous or gravelly substrata. Some of the most gravelly areas, of small extent, and occupying positions along streams near where they leave the foothills or forming the beds of broad intermittent washes, are much like Riverwash.

The types of this group sometimes have a slightly reddish-brown color, which may represent more weathered areas of older deposition.

The substratum underlying the Yolo loams differs but little in general features from the subsoil. Gravel may occur in distinct layers in the soil, subsoil, and substratum or may be mixed with the finer material composing the type. The gravel content generally increases as foothills or stream ways are approached. The soils in their occurrence northwest of Patterson are underlain at depths of about 6 feet or more by cemented masses of gravel.

The soils included in the Yolo loams group are more friable than the heavier types of the series. While the silt loam and loam members are moderately compact, the gravelly areas and the lighter soils usually are open and porous. The subsoils, while generally friable, are in some instances compact. The silt loam and loam are retentive of moisture, but the lighter areas are much less so. The organic-matter content is lower than in the Yolo clay loams, but tillage is easier owing to the lighter textures. These soils often represent the most recently deposited material of the series and have less concen-

trations of limy materials in the subsoils and substrata than the heavier types of the series.

*Location.*—The group Yolo loams is most important on the west side of the valley. Areas of considerable size are numerous in the latter region, and one elongated area lies along Dry Creek east of Modesto on the east side of the valley. The main bodies occur along the foothills as fan-shaped areas broadening as they descend the valley slopes or extend into the valley along the principal streams. The soils decrease in extent and merge with the heavier soils as the trough of the valley is approached.

*Topography and drainage.*—The Yolo loams typically occupy broad alluvial fans of gentle gradient and rather smooth surface. The areas nearest the foothills have the most pronounced slope, while the surface becomes more nearly level near the lower, heavier soils. The soils often lie slightly higher than adjoining types of the same series, particularly where deposited as stream-built ridges. They sometimes occur about intermittent drainage ways as intrenched stream bottoms, but this position is not general in this survey. Intermittent overflow is a factor in such places and may extend to the smoother parts farther from the stream in exceptional floods. The soils are free from alkali except in a few spots, such as the area several miles west of Volta. The surface of the Yolo loams is well adapted to irrigation in all typical occurrences.

Some of the materials mapped as these types southwest of Los Banos and also northwest of Patterson differ from the typical soils in that they apparently are older and have been more modified by weathering since deposition. This has given rise to a hog-wallow or hummocky surface and the more distinct change from soil to subsoil. Irrigation is more difficult on this variation than on the greater part of the group, as more or less leveling is necessary to give a uniform surface.

*Utilization.*—The Yolo loams are important agriculturally. They are in part irrigated and devoted mainly to alfalfa, with smaller acreages of other crops, such as kafir. The largest part under cultivation, however, is used for dry-farmed grain and grain hay.

*Yolo loams, dark-gray phase.*—This phase of the Yolo loams includes material of silt loam, silty clay loam, and clay texture usually darker in color than the typical soils. If more extensive, this phase would be classed as types of the Elder series. The first two members are of about equal extent; the area of the clay is small.

The silt loam of this phase consists of a gray to dark-gray silt loam, 2 or 3 feet deep, underlain by a subsoil of the same texture but a little lighter in color. Occasionally thin beds of gravel are encountered in the soil and subsoil, especially in the lower part of the

profile. There seems to be a fair percentage of organic matter in the soil, and it is friable and easy to cultivate.

The silty clay loam is a dark-gray or drab, silty clay loam, in places of rather low silt content and approaching a clay loam. It is underlain at about 3 feet by a subsoil of the same texture but slightly lighter in color. Like the silt loam, it sometimes carries gravelly layers in the lower part of the soil section. It is fairly high in organic matter and easily tilled.

The clay is quite different in texture and structure from the silt loam and silty clay loam but is mapped with them because of its small extent. It is a dark-gray or drab clay, compact and occasionally adobelike in structure. The soil often extends to a depth of 6 feet or more with no distinct subsoil. It is sticky when wet and is easily puddled. It bakes and checks upon drying where untilled and is difficult to work, though under favorable conditions it can be maintained in good tilth.

*Location.*—The dark-gray phase of the Yolo loams covers a comparatively small area. It is confined to a number of narrow areas along intermittent streams in the northeastern part of Merced County. The soils usually are level and well drained except after heavy rainfall, when they may be flooded for a short time. The clay member is poorly drained in part. The lighter-textured members are well adapted to irrigation wherever water is available.

*Utilization.*—The silt loam is used mainly for grain and grain-hay crops, with very satisfactory yields. Some small spots of black alkali occur, but aside from this it is very valuable soil. The silty clay loam is used for pasture and grain crops, and produces good yields. The clay is used mainly for pasture, with small areas cultivated to grain.

#### YOLO CLAY LOAMS.

The group Yolo clay loams includes the silty clay loam, clay loam, and clay types of the series.

*Description.*—The Yolo silty clay loam, the most important type of the group, consists of a brown to dark-brown or dark grayish brown, silty clay loam, 18 to 24 inches deep, underlain by a slightly lighter, usually yellowish-brown subsoil somewhat lighter or heavier in texture than the soil. The subsoil extends to a depth of 6 feet or more. The structure of both soil and subsoil is rather compact.

The Yolo clay loam consists of a clay loam of brown to dark-brown or dark grayish brown color, and at a depth of 20 to 30 inches is underlain by a subsoil very similar to that of the Yolo silty clay loam. The type is of small extent.

The Yolo clay represents poorly defined areas, usually zones of gradation between the other types of this group and the Yolo adobe

soils. It typically is a brown, dark-brown, or dark grayish brown clay or silty clay, 18 to 30 inches deep, underlain by a lighter colored and lighter textured subsoil. The type varies from a silty clay to a heavy, compact clay of adobelike structure, the heavier material being almost identical with the Yolo clay adobe. Several areas of this adobelike part of the type occur near Patterson. The type is sticky when wet and puddles if improperly handled, but is generally friable for a soil of its heavy texture and, under proper moisture conditions, is tilled without great difficulty.

Many variations from the typical necessarily occur in an extensive group of soils such as this, and numerous small bodies are included which differ considerably from the main development. Essential differences often occur where the soils adjoin other soils. In such places both the soil and subsoil may resemble those of the adjacent types. Narrow strips of soils of lighter texture sometimes parallel the courses of small streams. The subsoil frequently is reddish brown or red near the areas of old valley-filling material or of residual soils, and small bodies of soil belonging to these other provinces are included with this group. The substratum may differ little from the subsoil or may carry interbedded gravelly layers. The subsoil, while usually fine textured, occasionally contains streaks or thin layers of gravelly soil.

The structure of the material is slightly compact, but under proper moisture conditions tillage is moderately easy. The soil, subsoil, and substratum are more favorable to root development than in the lighter types of the group. The organic-matter content is moderate; it is highest in the heaviest-textured areas and aids in the retention of moisture. The subsoil and substratum often carry lime, which occurs in seams or as local discolorations. This feature, together with a recurring tendency for the subsoil to become compact and to check on exposure, indicates that much of the soil has been modified by weathering processes and is approaching in character the old valley-filling soils. Areas near Byron Hot Springs and Grayson show these evidences of age more clearly than other parts of the group.

*Location.*—The Yolo clay loams are the most extensive and important soils of the west side of the valley. They are distributed throughout that region and frequently extend from the foothills on the west to the trough of the valley. The clay loam and silty clay loam are by far the most extensive. The clay occurs chiefly in the vicinities of Brentwood and Patterson on the lower extensions of the alluvial fans, where they border the San Joaquin River, or in local flats or surface depressions.

*Topography and drainage.*—The surface of the Yolo clay loams is similar to that of the Yolo series in other parts of the State. The

group occupies uniform broad alluvial fans, with but few surface irregularities. The valley slopes, which are formed by a succession of these merging fans, often have rather pronounced gradients near the foothills but become more nearly level as the trough of the valley is approached. Shallow depressions and gentle undulations are of rare occurrence. The general surface is favorable to irrigation. The drainage is generally adequate. The slopes are favorable to surface run-off, and the subsoil and substratum do not restrict the internal movement of moisture. The water table usually is many feet below the surface, but adjacent to areas of poorly drained soils it may lie at shallow depths, and in such places accumulations of alkali occur.

*Utilization.*—Practically all the Yolo clay loams group is used for agriculture, though only a small part is under irrigation. Dry-farmed grain and grain hay are the most important crops. Grain constitutes the only crop of importance on these soils from near Patterson northward to the northern boundary of the survey. Southward from the vicinity of Patterson grain is important, but irrigated alfalfa, kafir, peaches, and walnuts are also grown. Irrigation water in the vicinity of Patterson and of Newman, Gustine, and Los Banos is supplied both by pumping and by gravity canals. Dairying and hog and cattle raising are important industries in these sections. The moisture-retaining power of these soils makes them well suited to the production of grain by dry-farming methods, and very good yields are obtained except in the southernmost areas, where the rainfall is light. The yield of alfalfa is good where the crop is irrigated. Considerable areas are devoted to the grazing of cattle and horses.

#### YOLO ADOBE SOILS.

The group Yolo adobe soils includes the Yolo clay adobe and the Yolo clay loam adobe.

*Description.*—The Yolo clay adobe consists of a brown or dark-brown, compact heavy clay of adobe structure, underlain at a depth of about 24 to 36 inches by a lighter brown or light yellowish brown subsoil which varies in texture from a clay to a silty clay or silty clay loam. The subsoil extends with some variation to a depth of 6 feet or more, and usually is underlain by a substratum of variable, but permeable, material. The type locally departs from its typical color and texture, but usually is very uniform throughout the large areas. The color is typically darker brown than in the group of Yolo clay loams, but is sometimes similar to that of the clay loam soils.

The Yolo clay loam adobe is a brown to dark-brown clay loam of adobe structure, 18 to 24 inches deep. This is underlain by a subsoil of lighter brown, more yellowish brown, or slightly reddish brown color which extends to 6 feet or more and ranges in texture from a clay loam or silty clay loam to a clay. Rounded to subangu-

lar cobbles or gravel frequently occur on the surface, especially where this soil adjoins the gravelly phases of other groups. The subsoil is underlain by variable strata, often carrying large quantities of waterworn gravel.

The Yolo adobe soils are sticky when wet, compact when dry, and typically crack deeply where allowed to dry without tillage and assume a minutely checked adobe structure. The adobe character is most pronounced in the case of the clay adobe soil, and is most apparent in well-drained or hillside areas. The material in poorly drained positions frequently becomes baked and hard upon drying. These soils absorb moisture slowly, but are retentive of moisture when tilled. The first rains of the season sink readily through the cracks in the material, although percolation is otherwise slow. A good supply of organic matter usually is present, but improper handling puddles the surface. Concentrations of lime occur occasionally in the subsoil. These soils are not generally affected with alkali, though slight concentrations occur in some of the depressions and flat areas west of Firebaugh.

*Location*.—The Yolo adobe soils occur mainly on the west side of the valley, where both extensive and small areas are mapped. The most important areas lie north of Crows' Landing, west and south of Tracy, and near Bethany. Smaller areas lie near Westley, south of Romain, southwest of Gustine, and in the northwestern part of the area. One small area is encountered about 2 miles south of Paulsell, on the east side of the valley.

*Topography*.—These soils occupy extensive alluvial fans or occur in minor valleys among the low hills bordering the valley. The surface usually is smooth and ranges from gently sloping to nearly level as the trough of the valley is approached. While usually smooth, the surface may be more undulating than is characteristic of the Yolo clay loams or Yolo loams. Slight ridges and shallow depressions are of frequent occurrence, but in general the surface is suitable for irrigation without leveling.

*Drainage*.—Near the foothills and in slightly elevated areas elsewhere the soils are well drained, but the depressions and flats near the trough of the valley sometimes have a high water table and restricted drainage. Some of the lower lying areas are subject to periodic overflow, the surplus water remaining on the surface until evaporated or removed by percolation.

*Utilization*.—Owing to their heavy and unfavorable texture the Yolo adobe soils are not easily cultivated, except within a very narrow range of moisture conditions. The physical condition of the soil is easily impaired by improper tillage or by careless irrigation, especially in the low areas. A large part of the group is under cultivation,

grain and grain hay being the principal crops. Alfalfa is grown in a small way, but the soils are not so suitable for this crop as the lighter textured soils of the series. Rice, recently introduced, is grown in the southern part of the survey in a flat area having compact soils and subsoils, and good yields are obtained. Grain, mainly barley, is the leading crop and seems to yield well. It is generally grown without irrigation. The greater part of this group in the southern part of the survey is used for pasture.

#### PANOCHÉ SERIES.

The soils of the Panoche series are typically gray, but grayish-brown variations exist. The series is recent alluvial in origin and composed of materials washed from sedimentary rocks. The subsoil is usually browner in color, more compact, slightly heavier in texture, and more calcareous than the soil, though in places the soil and subsoil are similar. The soil generally contains enough lime to effervesce freely. The content of organic matter is low. The soils are well drained, except on the lower and flatter parts of the valley slopes. In such places alkali is frequently present. The Panoche soils occupy gently to moderately sloping alluvial fans with smooth or slightly irregular or hog-wallow surfaces. They occupy a position in age midway between the soils of the Antioch and Yolo series and differ from the former in having less well-defined subsoils and a more uniform distribution of lime, and from the latter in being lighter in color, having a lower content of organic matter and a higher content of lime. They resemble the Laguna soils in most features except content of lime, which is much lower in the Laguna.

#### PANOCHÉ LOAMS.

The group Panoche loams includes the loam and silt loam of the series. Locally small areas of somewhat gravelly soils occur, but these are not of sufficient importance to make necessary the recognition of gravelly types.

*Description.*—The Panoche loam typically consists of a gray to light-gray friable loam. The subsoil usually is similar in color and other essential features to the surface soil, but varies somewhat and may consist of stratified stream-laid deposits either somewhat coarser or finer in texture than the soil. Both soil and subsoil are calcareous, the latter generally effervesces freely with acid. The content of organic matter is low.

In places the color of the soil is brownish. This is most pronounced in the zone of transition between this group and the Yolo soils. Another variation consists of small areas of gravelly soil.

The soil of the Panoche silt loam is gray to light brownish gray in color, low in content of organic matter, of friable structure, and

usually calcareous. The subsoil is like that underlying the loam. Both soil and subsoil are permeable to moisture and easily penetrated by roots. Minor variations in texture of the surface and subsoil material occur and local gravelly areas exist. The brown variations approaching the Yolo in character are found in the silt loam as in the loam.

The substratum of these types differs little from the subsoil, but may include a stratum of gravel, sand, or silt. In some localities considerable weathering has taken place in the deeper material, with concentration of the lime as nodules, concretions, or seams.

*Location, topography, and drainage.*—The group Panoche loams is inextensive. It is confined to the extreme southwestern part of the survey, south of Firebaugh, where it forms parts of broad gently sloping alluvial fans. In a few places the areas are traversed by intermittent streams. Drainage is usually good and the soils are free from alkali. Some of the flatter and lower portions may be subject to occasional overflow.

*Utilization.*—The surface of these soils is generally favorable to cultivation and to irrigation where water is available, which is the case in only a portion of the types. Owing to this, to the low rainfall, and to the small extent of the soils, they are of little importance in this survey. They are used for pasture, and where irrigated for the production of alfalfa, small grain, and the grain sorghums.

#### panoche clay loams.

The group Panoche clay loams includes the silty clay loam and clay loam, and small areas of clay of the series.

*Description.*—The Panoche silty clay loam probably predominates. It is a gray or light-gray to brownish-gray silty clay loam of smooth texture, rather low organic-matter content, and relatively high lime content. The subsoil resembles the surface soil in essential features. In some localities it is slightly browner or a lighter gray in color and noticeably more compact or heavier in texture than the soil. It is calcareous, effervescing freely with acid, and lime in many places is concentrated in seams, veins, and nodules. The deeper subsoil and substratum sometimes includes strata of small gravel, sand, and finer sediments. In places it appears to have been considerably weathered, with the development of a compact, roughly columnar structure. It is, however, free from hardpan or material offering resistance to movement of soil waters or to development of roots. A brown variation of this type approaching the Yolo in general characteristics occurs. When moist, the browner variations are most pronounced, and such areas frequently approach in color and character or merge with adjacent bodies of similar soils of the Yolo series.

The Panoche clay loam is a gray or brownish-gray clay loam, similar to the Panoche silty clay loam in all essential features except texture. The subsoil which occurs at a depth of 18 to 30 inches is similar to that of the silty clay loam.

The Panoche clay is represented by only a few poorly defined areas of soil of somewhat darker color, heavier texture, and more compact structure than the Panoche silty clay loam and Panoche clay loam. Some of the material is rather silty and of low clay content, while other variations are high in clay, puddle when wet, and check and crack when dry. These merge with the heavier adjoining Panoche adobe soils.

The Panoche silty clay loam and clay loam types are of moderately compact structure and have a tendency to puddle when wet and to bake under unfavorable field conditions, but become granular and quite friable when in a favorable moisture condition. The concentration of lime in the subsoil, with a tendency to compactness in the deeper subsoil indicates modification by weathering and an approach in character to the older valley-filling soils.

*Location, topography, and drainage.*—The Panoche clay loams group is confined to a single area south and west of Dos Palos, in the southwestern part of the survey. The group occurs upon broad, nearly level to gently sloping alluvial fans. Much of the surface is marked by hog wallows and other minor surface irregularities characteristic of the older valley-filling soils. Surface drainage and subdrainage are usually good, except in parts lying on the lower slopes. Here drainage is restricted and accumulations of alkali occur.

*Utilization.*—The soils of this group are retentive of moisture, but they lie in a region of low rainfall, and though dry farmed to some extent, results are uncertain. Under irrigation alfalfa and the grain sorghums are grown. Both irrigated and unirrigated areas are used as pasture for cattle, sheep, and hogs. Where irrigated, free from alkali, and well drained, the soils are productive. Dry-farmed areas are of comparatively low value.

#### PANOCHÉ ADOBE SOILS.

The group Panoche adobe soils includes the clay adobe and the clay loam adobe of the series.

*Description.*—The Panoche clay adobe is a gray to rather dark or dull brownish gray compact clay of adobe structure. The subsoil is usually similar to the surface soil, but in places it varies slightly in color and texture, sometimes consisting of a silty clay or silty clay loam. It is underlain by a substratum of similar appearance, including in places stratified layers of variable but usually fine texture. The soil, subsoil, and substratum are calcareous and accre-

tions and nodules are often present, but there is no cemented hardpan. A brown variation resembling the soils of the Yolo series is found.

The Panoche clay loam adobe is a gray to brownish gray soil of clay loam texture and adobe structure. In all features except texture it resembles the clay adobe, with which it is generally closely associated. Field differences in the two soils are slight and the types are distinguished with difficulty.

*Location, topography, and drainage.*—This group of soils is confined to the southwestern part of the survey where it occurs in an extensive area near Firebaugh and Dos Palos. It occupies the lower and flatter portions of broad alluvial fans of uniform gentle slope or nearly level surface. The area is marked in places by low hog-wallow mounds, shallow basinlike depressions, and other minor irregularities. The flatter areas are poorly drained and in places show accumulations of alkali.

*Utilization.*—The soils of this group are difficult to cultivate on account of their heavy, sticky structure. They can be handled effectively only under a narrow range of moisture content and even then heavy implements and teams are required to do the work satisfactorily. The physical condition is easily impaired by improper tillage or careless irrigation. When handled under favorable moisture conditions they break down into a fairly friable and granular seed bed. They absorb moisture slowly, but absorb much water and retain it well when properly managed. They support a growth of grasses and desert shrubs and are utilized mainly for pasture in connection with stock raising.

#### HANFORD SERIES.

The soils of the Hanford series are of recent-alluvial origin, the materials being derived predominantly from upland or mountain areas occupied by granitic rocks. They are brown, but with many variations such as light grayish brown or buff, the lighter brown shades predominating. They typically are micaceous, usually friable and permeable, and may extend to depths of 6 feet or more without change, although in places the profile may be made up of a number of differing strata. The subsoil may be similar to the surface soil in color, but usually is slightly lighter colored. The entire soil column typically is free from compact layers or hardpan interfering with penetration by roots or water, and ordinarily does not contain concentrations of lime. The organic-matter content usually is low. The soils occur on alluvial fans, stream bottoms, and low recent terraces. On the fans the surface varies from slightly to steeply sloping, while in the stream bottoms and on the terraces usually it

is practically level. Drainage usually is good except in local areas having a high water table or where overflows occur. Where the water table is high alkali may accumulate in injurious quantities. The overflowed areas originally supported a brush and timber growth.

The series is represented by three groups of types and one type mapped separately, but their total extent in this area is small, as compared with some parts of southern California.

#### HANFORD SANDS.

The group of Hanford sands includes the coarse sand, sand, and fine sand of the series.

*Description.*—The coarse sand, the most extensive member of the group, consists of a light-brown, grayish-brown, or brown, coarse, gritty sand. Typically the soil is uniform to a depth of 6 feet or more, is very micaceous, and in places contains varying quantities of fine quartzose and feldspathic gravel. Like other recent-alluvial soils it is more or less stratified. In places the soil material may vary from fine sand or sandy loam to gravelly sand and may consist of a wash of 1 foot or more of Hanford material over material of the Fresno or Madera series. The type is low in organic matter and of loose, porous structure, and much of the rainfall is lost by percolation. It apparently contains no lime in the soil or subsoil. In some parts the soil contains relatively large quantities of fine sand and silt which are gradually translocated to a subsurface zone under cultivation and irrigation, increasing the moisture-retaining power of the type. The substratum below 6 feet usually is of heavier material and frequently is stratified, containing compact layers which check the downward movement of water, though they generally lie too deep to have much influence on the crops.

The Hanford sand is of small extent in this area, and usually occurs as small bodies within areas of the coarse sand, fine sand, and sandy loams of the series. It is brown, grayish brown, or light brown, the lower part of the soil being somewhat browner than the surface material. The material is often uniform to 6 feet or more, but in places is stratified, the beds varying from gravel or coarse sand to fine sandy loam. The type usually is browner than the coarse sand, and with its slightly higher organic-matter content and larger content of fine material is more retentive of moisture and better suited to crop production. In character of substratum, mica content, variability, and other features it resembles the coarse sand.

The fine sand member consists of a uniform, smooth, open-structured, micaceous fine sand often 6 feet or more in depth. It ranges from brown to buff or grayish brown in color, being generally some-

what browner than the other types of the group. It is more retentive of moisture and usually contains more organic matter and silty material than the other types. Moisture is readily absorbed, and is retained by the soil, except where coarser and more porous subsoils are present. Locally along the San Joaquin River the subsoil consists of gravelly layers, but areas of this kind are small and very irregular in occurrence. The type is not extensive, but where favorably located is the most important member of the group for agriculture. It generally requires less water to mature crops than the sand or coarse sand, and also requires less frequent fertilization.

*Location.*—The soils of this group, which are not extensive, occur mainly in Merced and Madera Counties. The coarse sand forms a narrow, elongated strip along the Chowchilla River and, with the sand and fine sand, occupies small, irregular areas west and southwest of Chowchilla and Madera. A few small bodies of the sand and fine sand lie along the San Joaquin, Fresno, Merced, Tuolumne, and Stanislaus Rivers, many of which are too small to be mapped separately in this survey.

*Topography and drainage.*—The Hanford sands are confined to those parts of the area in which the soil material is derived from the Sierra Nevada Mountains. In the stream bottoms the surface is smooth to uneven, depending upon the velocity of flood waters. It is more uniform on the plains, where the material has been laid down by water spreading over nearly level to very gently sloping areas. Drainage is good in most places and usually excessive in the coarse sand. In local depressions and where the soils merge with soil of the Fresno series there is some seepage, and small quantities of alkali have accumulated in the sand and fine sand.

*Utilization.*—The small, irregular areas of the group frequently occurring along stream courses support a growth of willow and vines. They are subject to overflow and have not been developed to any great extent. The coarse sand member requires considerable water for crop growth. Where cleared and irrigated, the sand and fine sand give good yields of alfalfa, grain, corn, truck crops, and deciduous fruits. The coarse sand is also utilized for these crops, but yields are light and uncertain. The group as a whole is rather deficient in organic matter and responds well to the use of green manure crops and stable manure.

The land usually is owned in large tracts and used mainly for pasture and growing general farm crops, although irrigation by pumping would be relatively inexpensive in the stream bottoms. Land prices vary widely, being influenced largely by the general character of surrounding types, overflows, proportion of land cleared, the leveling required for and the cost of irrigation, and other factors.

## HANFORD SANDY LOAMS.

The group Hanford sandy loams embraces two types of the series, the sandy loam and coarse sandy loam.

*Description.*—The Hanford sandy loam, to a depth of 6 feet or more, consists of a brown, light-brown, grayish-brown, or buff-colored, smooth, micaceous sandy loam. It is usually friable and open in structure, but in places a somewhat heavier redder subsoil is present. The soil and subsoil are quite uniform except where the material is stratified, and in such places the 6-foot soil section may contain several strata varying in texture from silt to gravel. This variability in texture of soil and subsoil is due to the deposition of the material by currents of different velocities, and the range usually is greater near the foothills, where the gradient is greater and the stream valleys are comparatively narrow. Local gravelly strips and small areas of sand, which appear to be filled-in water courses, occur in the type. These are small and too irregular to be shown on the soil map. The type has a moderate organic-matter content, is quite retentive of moisture, and is easily tilled. Where it occurs on small alluvial fans in the valley plain, it is subject to much variation, owing to a mingling of soils of other series. In such places it may be uniform to a depth of 6 feet, while at others it occurs as a deposit a few feet thick over material giving the Fresno or Madera soils. Some of the areas lying along the San Joaquin River north of Firebaugh depart from the typical in many features. The texture is variable, ranging from a fine sandy loam to loam, and the color is darker than usual, being similar to that of the related Foster series mapped elsewhere in the State. Some parts also contain less mica than the Hanford soils usually do.

The Hanford coarse sandy loam on the average is slightly lighter in color than the sandy loam. It is coarse, gritty, micaceous, and where uniform in texture and structure to depths of 6 feet or more is somewhat droughty. It is low in organic matter and even in the better areas is not very retentive of moisture. In other respects it resembles the sandy loam. No visible concentrations of lime occur in the soil, subsoil, or substratum of the typical areas. The Hanford fine sandy loam occupies a few areas along streams of the valley trough, but such areas are too small to be shown satisfactorily on the map.

*Location.*—The soils of this group in this survey are largely composed of material brought from the Sierra Nevada Mountains, and occur principally along the large streams or on the alluvial fans of the plains west and southwest of Chowchilla and Madera.

*Topography and drainage.*—The topography is nearly level, slightly undulating, or gently sloping. The surface is generally smooth, but locally may be somewhat uneven, owing to the existence of overflow channels and sloughs. Some small streams traverse it. The soil typically is well drained and free from alkali, although in stream bottoms the water table frequently is encountered at less than 10 feet. Where the soil is shallow or associated with soils of the Fresno series, it frequently is subject to seepage and the accumulation of alkali, the sandy loam type being more subject to these unfavorable conditions than the coarse sandy loam. The group consists of recent-alluvial material and new materials are annually added over parts of the group. Some areas are subject to erosion and redistribution of material.

*Utilization.*—The sandy loam is of considerable importance agriculturally, being used in the production of alfalfa, deciduous fruits, truck crops, and grain. Corn is an important crop in the river bottoms. Fair yields of certain crops are obtained in favorable areas without irrigation, but the greater part of the land of the valley plains requires irrigation for most of the intensive crops. Some areas contain enough alkali to make reclamation necessary before they are suitable for cropping. The coarse sandy loam is of less importance than the sandy loam. It usually requires more water to mature crops.

The soils of the group are highly developed, and rank among the best soils of the area. They are well supplied with roads and usually are well located with reference to towns and railroads. Land in the best parts of the group, well located, sells for \$100 to \$200 or more an acre. In less favorable areas it may be bought for \$50 or less. Irrigation is possible over most of the group, water being supplied either by canals or by pumping.

#### HANFORD FINE SANDY LOAM.

*Description.*—The Hanford fine sandy loam is a loose, friable, open-structured soil containing moderate to large quantities of mica. It is brown, light brown, light grayish brown, or slightly reddish brown in color, and usually continues uniform to depths of 6 feet or more. The areas of most recent deposition usually are lightest in color. In places there is some stratification, and several layers of sand, silt, or gravel may be present in the 6-foot soil section. Locally, and in areas near the foothills where streams enter the valley, gravel deposits of varying thickness occur in places at depths of a few feet. The soil is smooth and velvety to the feel and is moderately well supplied with organic matter. Locally in the river bottoms meandering strips of gravel and patches of sand and fine sand which were too small to map in this survey occur at irregular

intervals. The open structure of the type and its permeable subsoil make it absorptive and retentive of moisture. Tillage is not difficult at any time, except in small depressions where deposits of silt occur. Where the type lies on alluvial fans of the valley plains in Merced and Madera Counties it is somewhat less uniform. In marginal areas it blends with types of the Fresno and Madera series, and in a number of places it occurs as an overwash of smooth, micaceous material several feet deep over the Fresno or Madera hardpan. In such places, and especially in the proximity of the Fresno soils, there is some seepage and accumulations of alkali occur.

*Location.*—The type occurs in several well-defined areas and as narrow belts paralleling the stream courses in western Madera County. A large area extends along the flood plain of the Merced River from Merced Falls to west of Livingston in Merced County, another lies east of Newman, and several smaller areas in the southern part of Merced County, paralleling the Chowchilla and San Joaquin Rivers. The type is largely derived as alluvial wash from the Sierra Nevada Mountains.

*Topography and drainage.*—The type varies only slightly in elevation and is nearly level or gently undulating with a slight slope westward. One or more low terraces occupied by this type flank some of the recent stream valleys, and range in age and position from recent products annually affected by overflow to material of considerable age on the more elevated terraces. In the latter areas the subsoil is beginning to show a compact structure and locally is becoming slightly heavier in texture. The surface is smooth and uniform except where cut by segments of old stream channels or by small streams. The type also occurs as several small alluvial fans. In places small terraces along the larger streams gradually merge into alluvial fans. Some areas have a high water table, and these with local seepage areas are sometimes affected by accumulations of alkali. In the stream bottoms a number of small depressions occur which remain wet for long periods, rendering them of little value for crops. In other places drainage is well established, the open structure of the subsoil and substratum being favorable to the rapid removal of surplus water.

*Utilization.*—The greater part of the Hanford fine sandy loam is valuable for agriculture. Much of the type is intensively cultivated, but rather large areas are still used for grain growing and for pasture. In areas of deep soil along stream bottoms corn and alfalfa give moderate to good yields without irrigation. Figs, peaches, prunes, bush and vine fruits, potatoes, and truck crops do well both with and without irrigation, yields being greatly increased, however, by applying water. The higher-lying areas are more difficult

to irrigate than the low areas and generally require more water on account of their more thorough drainage. Water for irrigation usually is available. It is supplied both by canals and by pumping from underground sources. The cost of irrigation usually is less in the river bottoms. All crops yield well when given good care, and little commercial fertilizer is used. Much of the type situated in moist stream bottoms supports a moderate to heavy growth of willow, native vines, and cottonwood, and this adds considerably to the cost of preparing the land for crops.

The Hanford fine sandy loam is generally well situated with reference to shipping points and roads. Land prices range from \$50 an acre or less for the least desirable parts of the type to \$200 or more for the most favorable areas. Considerable areas are capable of intensive development.

#### HANFORD LOAMS.

The group Hanford loams includes the silt loam and loam types of the series.

*Description.*—The Hanford silt loam, occupying about 90 per cent or more of the area of this group, consists of a brown, grayish-brown, yellowish-brown, or rarely a slightly reddish brown, smooth, micaceous silt loam. Typically the soil is open, friable, and uniform in texture to a depth of 6 feet or more. The subsoil below 12 or 18 inches is frequently browner or more reddish brown than the surface soil. Most of this type lies sufficiently above the river to escape ordinary overflows. Where it is lower, as near the stream channels, and is overflowed almost every year, it is much more variable and contains narrow, irregular strips of gravelly material and patches of sand, clay loam, or material of other texture. In such places the subsoil lacks uniformity, and may consist of semistratified deposits of gravel, sand, or sandy loam. Those areas near the bluffs, which include the alluvial bottoms of deeply entrenched streams, have soils and subsoils noticeably heavier in texture, often being a heavy loam or light clay loam. Such areas are slightly affected by seepage from the adjacent plains and frequently carry alkali in injurious quantities. An included variation occurring in the valley trough along the San Joaquin River is unusually variable, and sudden transitions, as from a fine sandy loam to silt loam or clay loam, occur within very short distances. The average texture, however, is that of a silt loam. Near the river and along parallel sloughs and segments of old drainage ways the soil and subsoil are much more variable than in the flatter areas somewhat removed from them. Parts of the type in the valley trough exposed to more constant currents are more uniform, and frequently have a dark-gray to black clay loam or clay subsoil at a depth of 10 to 18 inches, which may

continue uniform to depths of 6 feet or more or may grade into a silt loam or fine sandy loam at 4 or 5 feet. The soil over a part of this low-lying section is mottled with red and yellow in the surface few inches. Water several feet deep stands over the surface of such areas for a month or more in wet weather, and this has a tendency to pack the soil in places and to puddle it in the heavy, low spots. The more recently deposited soil is lighter in color and texture than that of the more elevated and older areas and contains less organic matter. The soil is tilled without difficulty, and where typically developed contains a moderate percentage of organic matter. It absorbs and retains water well. No hardpan and apparently no concentrations of lime are present.

The loam member of this group is a type of small extent. It has the same range and variability of material as the silt loam, from which it differs only in its lighter texture. It occurs as local spots and small depressions within areas of the silt loam.

The group as mapped in this survey includes the soil recognized as the Sacramento silt loam in the survey of the Modesto-Turlock area, and also several small areas of dark-brown or dark-gray soil high in organic matter. The latter, if more extensive, would be mapped as a distinct type.

*Location.*—The soils of this group are prominently developed in the bottoms of the large streams crossing the area, and also in the trough of the valley along the San Joaquin River. In the latter position it is less uniform than where more typically developed, as along the Merced, Tuolumne, and Stanislaus Rivers. Along the latter streams it occurs 20 to 100 feet or more below the general level of the plains, but in or near the trough of the valley there frequently is no distinct break in elevation between this type and adjoining soils.

*Topography and drainage.*—In places the group has a variable topography, but where the soils are typical the surface is uniform. The bottoms along the large streams are smooth, though they may be more or less dissected close to the stream. In such places they are nearly flat with a gentle slope westward, or the areas may occupy several low terraces parallel to the stream. In the areas lying in the trough of the valley the surface is uniform and smooth, except near the San Joaquin River, where a number of winding sloughs and erosion by flood waters give it a more or less uneven and pitted appearance. Depressions occurring in such places contain standing water and support a growth of tule through much of the summer.

*Utilization.*—The soils of this group rank among the best in the survey for the production of intensive crops. The well-drained and more uniform areas are easily tilled and productive. Large areas, especially where held in single ownership, have been used for grain growing for many years, with good yields. Alfalfa and corn do

well. Several cuttings of alfalfa are obtained each year without irrigation. Some of the oldest orchards in the area are on soils of this group. Where given proper care, peaches, apricots, prunes, pears, grapes, and bush fruits give good yields. These fruits generally require little or no irrigation except in the higher-lying areas, where light applications of water give best results. Trucking is highly developed locally. The soils are very productive, and a wide range of highly intensive garden crops are grown. Several successful crops are obtained from the same field in a single season. Irrigation is employed and the yields are heavy. Large areas along the trough of the valley and a margin along the streamways support a growth of willow and are used for pasture. Protection from overflow and considerable expense in clearing such areas are necessary before they can be highly developed. Owing to the low-lying position of the soils of this group the crops are more subject to injury by frost, and extensive plantings of almonds and citrus fruits are usually not advisable.

Except along the San Joaquin River, nearly all the land of this group is easily accessible and is well located with respect to towns and shipping points. The price of land ranges from a few dollars an acre in the least desirable areas to several hundred dollars for the better areas. As a rule alkali is not a serious factor. Locally, however, appreciable quantities of sodium carbonate or black alkali are present.

#### HONCUT SERIES.

The soils of the Honcut series are derived from recent alluvial deposits of heterogeneous origin. The surface soils typically are reddish brown, but as mapped in this survey red variations are included. The subsoil usually is similar to the surface material in color and texture, though it may be redder and of variable texture. Soil and subsoil to a depth of 6 feet or more typically are permeable to roots. No hardpan or compact subsurface layers occur, although these may in places lie below 6 feet. The soils have a medium or low organic-matter content. Concentrations of lime are uncommon. Soils of the Honcut series occupy alluvial fans or stream bottoms. The surface, except where slightly furrowed by present or abandoned stream channels, is comparatively smooth. Much of the land is subject to overflow; otherwise the drainage usually is good. Most of the types are forested, mainly with valley oak.

The series is represented in this survey by only one group of soils.

#### HONCUT LOAMS.

The group Honcut loams consists mainly of the Honcut loam and silt loam, with small bodies of the fine sandy loam and clay loam,

*Description.*—The Honcut loam of this area is not typical and consists of brown, light-brown, or grayish-brown phases, and sometimes, in small areas, reddish brown. In places near the Stockton soils the color may be dark brown or dark grayish brown. The type also is subject to considerable variation in texture, ranging from sandy loam on the one hand to clay loam on the other, the transitions being rather abrupt. The soil is practically free from gravel. In places, at a depth of 24 to 36 inches, it passes into semistratified layers of coarser or finer material frequently of lighter brown color than the surface soil. In some places the subsoil is a yellowish-brown or reddish-brown clay loam or silty clay loam, continuing to a depth of 6 feet or more. The soil is friable, and as a rule is easily tilled, though the heaviest areas frequently are compact and difficult to handle, especially when dry. The substratum resembles the subsoil, and in areas somewhat removed from old stream channels a brown to reddish-brown hardpan of considerable thickness frequently is encountered at 8 or 10 feet below the surface. The type is moderately well supplied with organic matter and absorbs and retains moisture well. It is not so well drained in places as the silt loam member and often remains water-logged for a month or longer in wet seasons.

The surface soil of the Honcut silt loam is a brown, grayish-brown, or light-brown, friable, rather smooth textured silt loam. In texture the underlying material to a depth of 6 feet in many places closely resembles the surface soil, but is quite variable and may consist of irregular layers of semistratified material of lighter or heavier texture. Some mica is present in places. Below a depth of about 18 inches the subsoil usually is lighter brown, occasionally approaching reddish brown in color. No gravel or coarse sand is encountered in the type, except locally along stream ways. The silt loam usually contains less organic matter than the loam and is on the average somewhat lighter in color. It is better drained and probably for this reason more easily tilled than the loam.

The group includes small bodies of clay loam and silty clay loam which occur in low, flat, or slightly depressed areas. Small bodies and strips of fine sandy loam and sand, in places highly micaceous, also occur locally along the larger streams. These soils are of small extent and of little importance in the agriculture of the area. The group includes also a few patches of red to reddish-brown soil derived from old valley-filling deposits which appear to be remnants of originally larger areas of soils of the San Joaquin series. Such areas usually have reddish-brown or red, heavy subsoils and a hardpan within a depth of 6 feet. The soils of the group are locally subject to the addition of fresh material deposited by streams in

periods of overflow. Other areas, somewhat removed from streams and occurring where the soils merge into older deposits, are developing heavier subsoils and approach the old valley-filling deposits in this and other features.

*Location.*—This group of soils is not extensive. It is confined to the region east and northeast of Stockton and occurs as a rather smooth plain west of the higher and more uneven Redding soils. It extends along the Calaveras River and Mormon Slough, and continuing westward merges into soils of the Stockton series.

*Topography and drainage.*—The Honcut loams occur in gently sloping to nearly level areas. The soils have been deposited in their present position by the streams mentioned above and by a few others of less importance. They have a smooth, even surface except locally, where shallow, old streamways occur. These drainage ways have rounded banks and bottoms, and some carry water in periods of heavy rains. The soils are generally well drained and free from alkali. In some slightly depressed and nearly level spots, however, the drainage is restricted at times and some alkali is present.

*Utilization.*—There was once a conspicuous growth of valley oak on these soils, but this has largely been removed. The remaining trees are large and spreading and of scattered occurrence. Nearly all this group is highly developed to agriculture, the soils being among the most productive of the area. They are used in growing a large number of crops, chief among which are peaches, almonds, walnuts, cherries, olives, figs, bush and vine fruits, vegetables, alfalfa, corn, and small grains. Yields are heavy, and the products are of good quality. Irrigation is necessary for the best results with a number of the crops, water being supplied by pumping from an underground source. The lift is not great as a rule, and the supply is adequate. The physical properties of the soils are such as to make them quite retentive of moisture, and a deep hardpan, which is present in many places, is beneficial in preventing the loss of water by percolation. The deep, uniform soil permits of extensive root development.

Commercial fertilizers are not generally used for most of the crops grown. Irrigation frequently tends to pack the surface material and locally gives it a puddled appearance, but an increase in the organic-matter content greatly improves this condition. The price of land, which varies considerably, is usually more than \$100 an acre. The areas for the most part lie near shipping points and are well supplied with good roads. Some parts are still held in rather large tracts, and here development has been retarded.

#### CAPAY SERIES.

The soils of the Capay series are dark brown or dark grayish brown, the latter color predominating under dry field conditions

and the brown tint being more pronounced when the soil is moist. The subsoils are generally brown or light brown and in many places of heavy texture and compact or adobelike structure. The series consists of low-lying, recent alluvial fan deposits, occupying the flatter extensions of the fans or valley basins. The parent material is derived mainly from sedimentary rocks, and the soils are often associated with soils of the Yolo series. Material from a variety of sources, however, has entered into the formation of this series. In subsoil characteristics the series approaches the soils derived from old valley-filling. The surface is generally smooth. Drainage is restricted, and accumulations of alkali occur in places. The Capay series is differentiated from the Yolo by its slightly darker color and its poorly developed drainage.

The Capay series is mapped in this survey in one group, including also soils of the Merced series.

CAPAY AND MERCED<sup>1</sup> CLAYS, UNDIFFERENTIATED.

The group of Capay and Merced clays is rather uniform in some of its features and extremely variable in others. Practically all the soil is very heavy in texture, of compact or puddled structure, possesses an uneven or hog-wallow surface, and is affected by injurious accumulations of alkali. Aside from these general features the soils are variable especially in color and in subsoil characteristics, and variations rather than typical Capay and Merced soils prevail. The group includes also some small areas of Yolo material.

*Description.*—The Capay clay consists of a brown or grayish-brown compact clay extending to a depth of 12 to 36 inches. It is generally free from gravel or grit and in places cracks upon drying until it approaches an adobe structure, although it is more often puddled or poorly granulated. The subsoil is a compact, yellowish-brown or light-brown clay loam. It is in many places mottled, and is calcareous, the limy material occurring as seams, nodules, or similar concentrations. Hardpan or distinct gravelly substratum does not occur, but the subsoil becomes adobelike in structure on exposure. This change of structure in the subsoil, together with the modified, calcareous nature of the soil material and the uneven surface, indicates that the type is approaching with age the character of the old valley-filling material. There is some clay loam of the Capay series present in this group; it differs little from the clay except in texture.

The Merced clay consists of a dark-gray, slate-colored, or black clay of variable structure. In the slightly better drained localities it cracks and crumbles upon drying, closely resembling adobe in

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<sup>1</sup> See p. 103 for description of Merced series.

structure, but the larger areas are puddled or soggy when wet and cracked or flinty when dry. At a depth of about 12 to 36 inches, the soil is underlain by lighter colored and occasionally lighter textured, compact subsoils. True hardpan and gravelly substrata are not typical. The subsoils where mottled grayish, brownish, and yellowish contain seams, streaks, or nodules of calcareous material in sufficient quantity to indicate that the soil column has undergone alteration since deposition. The clay loam member of the Merced series, described elsewhere, occurs in small areas.

In this group the Capay and Merced clays are mixed in such manner that their separation even on a detailed map would be very difficult. Over broad areas the brown Capay clay occupies the small mounds or ridges of hog-wallow areas and the dark-colored Merced clay occupies the intervening depressions or flats, so that many soil bodies occur within a single acre. The soils do not always exhibit this consistency in relation to topographic position, as both mounds and depressions are sometimes occupied by brown soils and sometimes by dark-gray or black soils. Much of the material is neither brown nor black, but of the peculiar dark-grayish cast often identified with uncultivated clayey soils which are alternately water-logged and air-dry. Some areas depart from the prevailing heavy texture. Some of the material just west of Dos Palos consists of a loamy sand, sandy loam, or fine sandy loam. The lighter textured soil in places is confined to the low mounds or ridges with intervening heavier soils or it may constitute more than 50 per cent of the surface. The general region east of Gustine and Newman includes some of the sandier soils.

*Location.*—The soils of this group are confined to the west side of the valley and, excepting the small area west of Firebaugh, are included in a single large body. This extends southeastward from a point a few miles northeast of Newman for nearly 40 miles, or within a few miles of the southern boundary of the survey. The northern extension of the group reaches to the San Joaquin River, in the trough of the valley. The group is bordered on the west by soils of the Yolo series.

*Topography and drainage.*—The Capay and Merced clays have generally flat or slightly sloping surfaces, though along their western boundary they are somewhat irregular. Hummocks varying in height from a few inches to 2 feet or more are present. These range in diameter from a few feet to 50 feet or more, are sometimes closely set, and occupy more than 50 per cent of the surface. In places they are scattered and subordinate to the flatter, puddled intervening areas. In places the surface is slightly ridged, as a result of erosion. The drainage of these soils is sluggish during the rainy season. Surplus water from the foothills collects in the depressions

or escapes slowly to the valley trough through meandering drainage courses. In addition, the small depressions receive the surplus water from the hummocks, so that much of the surface is covered with standing water, which finally evaporates or is slowly removed by percolation. In the summer the soil gradually dries, and a droughty condition ensues. The hummocks and ridges are never inundated, so that widely different drainage conditions sometimes occur within very small areas. The group as a whole is distinctly affected by alkali. Some parts are relatively free from injurious accumulations, but most of the type contains injurious quantities. Some of the land is nonagricultural under present conditions. The salts seem to be largely sodium chloride and sodium sulphate, with little evidence of sodium carbonate (black alkali), which is an injurious constituent of the alkali soils on the east side of the valley. The percentage of alkali in the surface soil may be less in low, depressed areas and greater on the hummocks. In certain areas the surface soils apparently are rather free from alkali, but indications are that their subsoils carry heavy concentrations.

*Origin.*—These soils consist of water-laid deposits, which have been somewhat modified and aged. The hog-wallow surface and the character of the subsoils are evidences of some of the changes that have taken place through weathering.

*Utilization.*—Most of the group is untilled and used for pasture, although adjoining soils frequently are cultivated. The alkali content is sometimes reduced and crop yields improved by irrigation. In some cases, owing to the low yields obtained, crop production has been discontinued and the land has reverted to pasture. Important areas are being leveled for irrigation, to be used for alfalfa production or for growing pasture grasses. Extensive areas are irrigated by flooding from canals without much leveling or other preparation of the surface.

#### DUBLIN SERIES.

The soils of the Dublin series are derived from recent alluvial deposits, composed of wash from upland areas occupied mainly by sedimentary rocks. They typically are dark gray to black, with variations of dark brownish gray. The subsoils, which are lighter colored than the soil, are gray, dark gray, or brownish gray in the more poorly drained areas and grayish brown or brown in the better drained parts. The subsoil may be similar to the surface soil in texture or may consist of alternating strata of varying textures. Typically hardpan or hardpanlike layers do not occur. The soils are high in organic matter. Both the soil and subsoil are normally free from concentrations of lime, but some of the flatter areas the subsoil may carry nodules and seams of calcareous material.

The Dublin soils occupy alluvial fans, stream bottoms, or low recent terraces. The drainage usually is good, except in flat or depressed areas, in which water may stand on the surface during the rainy season. Much of the land is subject to overflow. The Dublin series is distinguished from the Yolo series on the basis of its darker color; it differs from the Stockton and Merced series in character of subsoil. Most of the areas originally supported a scattered tree and brush growth.

The Dublin soils are mapped in this area in one group of small extent and a part of one other group.

#### DUBLIN ADOBE SOILS.

The group Dublin adobe soils includes the clay loam adobe and clay adobe types.

*Description.*—The clay loam adobe consists of dark-gray, dark brownish gray, or black clay loam of pronounced adobe structure. The soil is sticky or plastic when wet, and when dry becomes compact and cracks, crumbling into small cubes or pellets if trampled or otherwise disturbed. In typical, untilled areas the cracks are numerous, with many several inches wide and a number of feet deep. The soil is generally uniform in texture to a depth of 6 feet or more, but at 12 to 36 inches the color usually becomes lighter, ranging from dark gray or gray to grayish brown. Lime is often present in the subsoil, giving it in places a marly appearance. Where the lime is most abundant it is beginning to concentrate in seams, encrustations, or nodules, the soil in such places closely resembling the younger parts of the Stockton types. Concentrations of lime in the subsoil are not typical and such areas would be mapped as of another series in a more detailed survey. The type is high in organic matter, but tillage usually is difficult on account of its dense structure, its compactness when dry, and its stickiness when wet. Where stratification occurs the subsoil and substratum usually are somewhat lighter in texture than the surface material.

The group includes small spots of the Dublin clay adobe, and sloping areas not subject to inundation have browner subsoils with occasional narrow strips of loam or silt loam along streamways. The type absorbs water slowly when dry, but when saturated and well tilled it retains moisture for long periods. The clay adobe is about equal in extent to the clay loam adobe and usually occupies the more nearly level or slightly depressed parts covered by the group. It has the same range in color and structure as the clay loam adobe, but usually the brownish cast common to parts of the latter type is not so marked in the clay adobe. It is generally more difficult to till, absorbs moisture more slowly, and is more poorly drained than the lighter member. In other respects it closely resembles that type.

*Location.*—The soils of this group, which are not extensive, occur in a number of small, irregular areas along or near the valley trough in the northwestern part of the survey northeast of Oakdale, and to a less extent in other sections. The soils occupy gently sloping to nearly level alluvial fans or basinlike depressions. The surface is smooth and uniform except for occasional minor slough ways, and little or no leveling or clearing is necessary to prepare the land for irrigation. The more elevated parts of the alluvial fans are well drained; many of the low depressions are inundated for short periods in the winter. The soils are, however, poorly drained only in the winter, and crops suffer for lack of moisture in the summer unless irrigated. Alkali is present locally, sometimes in quantities sufficient to affect crops.

*Origin.*—The material forming the soils of this group consists of recent alluvial deposits derived principally from sedimentary rocks occurring in the Coast Range or in the lower hills along the base of the Sierras from the Calaveras River southward. Some material is annually added to the overflowed areas, but the more elevated parts of the group are coming to resemble the soils from old valley-filling deposits by reason of chemical and physical changes in the soil mass.

*Utilization.*—Grain farming is the main use of this group of soils in this region, and moderate to good yields are obtained where the soil is well prepared. Some deciduous fruits have been tried, but fruit growing has not been successful except in the best drained areas. Alfalfa is grown to some extent, but is short-lived and yields are uncertain. Other crops, such as beans, are grown locally and do well. The soils are cold and crops are slow to start in spring, and it is likely that the lower areas will continue to be utilized for general-farming crops. Parts of the group are rather remote from shipping points or towns. For best results with these soils they must be drained, protected from overflow where necessary, and irrigated.

DUBLIN AND YOLO<sup>1</sup> LOAMS AND CLAY LOAMS, UNDIFFERENTIATED.

The group Dublin and Yolo loams and clay loams, undifferentiated, includes variable material, ranging widely in color and texture, with transitions from one extreme to another within short distances.

*Description.*—Of this group of soils the Yolo loams and clay loams have been fully described elsewhere. These types form the greater part of the present group.

The soils of the Dublin series in this group have about the same range in texture and depth as the Yolo types, but are dark gray to

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<sup>1</sup> See p. 107 for description of Yolo series.

black in color and higher in organic-matter content, and the heavier material has an adobe structure. They occur as small spots within the Yolo types or as larger areas of sufficient extent to be differentiated in a detailed survey. The heavier types of the Yolo series often gradually merge into soils of the Dublin series, from which they are separated principally on the basis of color and organic-matter content. In other respects the types of the Dublin series correspond to the description given the members of the Yolo series. Areas of the group occurring within the foothills east of Farmington include a few small areas of Madera and San Joaquin soils, which here occur as local remnants of larger areas. They are of much greater age and can be distinguished from the dominant soils of the group by the presence of red or brown hardpans.

*Topography and drainage.*—This group of soils occurs in a belt less than 2 miles wide following Little Johns Creek and its tributaries east of Stockton. West of Farmington the soils occupy a position on the plains similar to that of the Madera, Stockton, and Honcut series, but east of this point they occur as stream bottoms or as a series of low, gently sloping recent terraces. The surface is gently sloping to nearly level. The material has not been transported very far and is derived mainly from the sedimentary formations in the hills between Farmington and the lower Sierra slopes. Good surface drainage and subdrainage prevail, except in the western extension of the group near the Stockton adobe soils, where the surface has less fall and the soils are locally more or less saturated in wet weather. In such places and in others along streams slight overflows sometimes occur. No alkali is present.

*Utilization.*—The soils of this group are well located with respect to roads and shipping points, and are well suited to the production of a wide range of deciduous fruits and general farm and truck crops. They usually are held, however, in large tracts and are mainly utilized for the production of grain, the yields of which are moderate to good. In the more favorable areas certain fruit and other crops are successfully grown without irrigation, but irrigation is necessary for best results, except with grapes and grain. The group has about the same crop possibilities as the Honcut loams. Land prices vary according to location, state of development, and the possibility of irrigation. The better areas usually are held at more than \$100 an acre. No clearing is necessary and very little leveling is required to fit the land for irrigation.

#### SACRAMENTO SERIES.

The soils of the Sacramento series are recent water-laid material, generally deposited under semilacustrine conditions in basinlike areas and derived from a wide range of rocks. They are dark gray,

drab, or black in color and often 6 feet or more in depth, but are generally underlain by lighter colored and sometimes variable-textured strata. The structure of both soil and subsoil usually is quite friable and permeable, considering the prevailing heavy texture of the material. The soils usually are high in organic matter. The subsoil in some places contains calcareous seams or nodules, although this is not typical. The series generally occupies flat or depressed areas, which are subject to overflow and may be under water for long periods where not protected by levees. Alkali occurs in some marginal strips, but is not widespread over typical areas. Most of these soils originally supported a growth of tule, with willow and other trees in slightly elevated areas.

The series is represented in this survey by one group, which is comparatively extensive.

#### SACRAMENTO CLAY LOAMS.

The group Sacramento clay loams includes the clay loam and silty clay loam of the series.

*Description.*—The Sacramento clay loam is dark gray, drab, or black, in some places having a brownish cast. As encountered in this survey, the clay loam is not typical except in local areas where it continues quite uniform in texture to 6 feet or more in depth. In such places the subsoil may be dark grayish brown in color and contain a relatively large proportion of silt. Over most of its area, however, the type approaches Muck in texture and consistency, and the material usually is light in weight, indicating a relatively small content of the mineral soil constituents. The soil is very irregular both in the texture of the surface soil and in its cross section. The organic matter usually is well decomposed, except locally, where it is somewhat fibrous. At a depth of about 12 to 30 inches the subsoil is encountered, and the upper foot or less is frequently a yellow, yellowish-brown, or grayish-brown, smooth silty loam or silty clay loam. In places this light-colored layer appears to be the residue of a deposit of Muck or Peat, which has been burned. Below this layer the material is variable, and may consist of a fine sandy loam, a light-colored, loose sand, a silt loam, or clay, or may be similar to the surface soil. One or more of these layers may be present in a 6-foot section. In places there is some concentration of lime in the subsoil, giving it a marly appearance, but this is not general. The substratum usually resembles the subsoil, but it is more poorly drained and may be somewhat mottled and of lighter color. Locally the subsoil and substratum may contain one or more layers of mucky or peaty material separated by seams of material varying from a sand to a clay. In other places the soil may continue uniform to a depth of 3 or 4 feet and rest upon Muck or Peat, which may extend to a

depth of many feet. The type is most uniform in level areas, but most irregular where the surface is uneven, sudden transitions from light to heavy texture occurring in very short distances. No gravel is present in the soil or subsoil. The surface usually is quite sticky when wet, but more or less friable under tillage. A few spots of clay occur in minor depressions, but they have little influence on crop growth. Tillage usually is not very difficult, owing to the high organic-matter content. In uniform areas the soil is quite retentive of moisture, but where the type is variable, and especially if loose sandy layers are present, it may be quite droughty in the summer.

Only a small area of the silty clay loam of this group occurs in the survey. It occurs as gradational material between types rather than in well-defined areas. It is somewhat more friable and easily tilled than the clay loam, but in texture, color, variability, and other features closely resembles that type.

*Origin.*—The mineral material of the soils of this group has been laid down as alluvial deposits over areas of nearly level or slightly depressed topography. It has come from a wide range of rocks, principally in the Sierra Nevada Mountains, and during its transportation to its present position has been well assorted. The soils lie at or slightly above sea level in this survey.

*Location.*—This group is rather extensive, occupying a number of large areas in the island region southwest of Stockton. Smaller areas occur between the lower extension of the alluvial fans and the Muck and Peat areas, and in one low, flat area on the lowlands adjoining the San Joaquin River near Tuolumne City. Parts of the area on Roberts Island, southeast of Holt, were separated in the Stockton detailed survey and shown in the map as Peat.

*Topography and drainage.*—The surface of the areas of this group is nearly level, very gently sloping, slightly undulating, or, in small areas, depressed. It is smooth except where former streams have left low, irregular, winding ridges. In such places more or less leveling is necessary before irrigation can be successfully practiced. In areas having no outlet and little or no slope the soils remain water-logged for long periods in the winter. Locally the water table is near the surface, and in such places there was formerly a growth of tule. Some of the land requires drainage before it can successfully be used for crops, and this usually is accomplished by ditching and pumping the water over levees into the main drainage channels. Locally, where seepage occurs and there is a high water table, some alkali has accumulated, but it is confined principally to marginal areas and rarely occurs in sufficient quantity to injure crops.

*Utilization.*—This group of soils is agriculturally one of the most important in the survey. The soils produce heavy yields when well handled, but the yields decline where continuously used for a single

crop. Deciduous fruits and alfalfa do well in the well-drained areas, and beans, corn, truck crops, grain, and grain hay give heavy yields. The soils are well suited to dairying and produce an abundance of grass and other feed crops. Dry-farmed grain and grain hay are, however, the principal crops grown at present. Dairying and hog raising are increasing in importance. Little irrigation is necessary, except in the higher and better drained areas. Formerly the same crops were grown continuously in the same fields, but at present crop rotation is common.

Areas of this group are well located with respect to towns and shipping points and are moderately well supplied with roads. Practically all of the land is under cultivation. The price ranges usually from \$100 to \$200 an acre, or more for the most desirable areas.

#### SOILS DERIVED FROM WIND-DEPOSITED MATERIAL.

##### OAKLEY SERIES.

The soils of the Oakley series are composed of wind-laid material. They are brown and usually sandy. The soil and subsoil typically do not differ essentially in color or texture, and both are very permeable. The soils usually are low in organic matter and without concentrations of lime in either soil or subsoil. The surface is undulating, uneven, or hummocky and shows the effects of wind action nearly everywhere. The areas include some distinct dunes. Drainage is good, the rainfall being removed rapidly by percolation. Some areas of this series originally supported a growth of brush and oak.

Soils of this series are mapped in the present survey in one group and as parts of two other groups.

##### OAKLEY SANDS.

The group Oakley sands includes the sand and loamy sand of the series, the former being much the more extensive.

*Description.*—The Oakley sand consists of a light-brown, brown, or grayish-brown sand of medium texture, extending to a depth of more than 6 feet. The color and texture vary little throughout the areas mapped, the chief variation being where the type adjoins soils of heavier texture, in which case the marginal soil is heavier than the average and is also shallower. But little difference is apparent in the soil, subsoil, and substratum. The type has a porous structure but retains moisture well for a soil of such light texture. The sand grains are sharp rather than rounded, and the material packs and is favorable to crop growth. Little organic matter is present in the soil.

The sand member gives way in places to a loamy sand. The quantity of fine material is in places sufficient to form a light sandy loam. It has a greater water-holding capacity than the sand. In most essential features, except texture, it resembles the sand.

*Location.*—One relatively large body of this group of soils and a number of smaller areas are mapped in the extreme northwestern part of the area, but their total extent is not great. The soils are an extension of similar soils mapped in the adjoining surveys covering the Sacramento Valley and the San Francisco Bay region.

*Topography and drainage.*—The surface of the Oakley sands is smooth, uneven, or gently rolling, and in some places hilly. Some drifting occurs, but in the main it is not serious. Drainage usually is good, owing to the easy removal of water by percolation.

The group is intensively farmed over most of its extent. Almonds are the principal crop, which, with grapes, peaches, and apricots, is grown without irrigation. Alfalfa and grain are not important crops on these soils. The soils need organic matter. Irrigation, while desirable, is difficult, and good returns are obtained without it.

#### OAKLEY AND FRESNO<sup>1</sup> SANDS, UNDIFFERENTIATED.

The group Oakley and Fresno sands, undifferentiated, includes types of sand, coarse sand, loamy coarse sand, and fine sand of the two series, and small areas of fine sandy loam and sandy loam of the Fresno series. The included Fresno material is for the most part too brown to be typical, and may be considered a brown variation of the series.

*Description.*—As mapped the Fresno sand consists of a grayish-brown, light yellowish brown, or brown, porous, incoherent sand of medium texture. The subsoil is of similar color or slightly browner than the soil, is similar in texture and is slightly more compact than the soil, and typically is underlain at a depth of less than 6 feet by gray or light grayish brown, silty strata, varying greatly in structure and quantity of lime present, though they are usually calcareous. They are quite compact when dry or in local areas of sufficient hardness to be considered hardpan. In important parts of the areas mapped, however, the presence of lime in the hardpan is not indicated by tests with acid. In marginal areas and near the western extension of the soils of this group, and sometimes locally within the main areas, the hardpan occurs within a depth of 3 feet, but usually it lies at sufficient depth not to interfere with the growth of trees and deep-rooted crops, and may be beneficial in preventing the loss of irrigation water through percolation. The thick-

<sup>1</sup> See p. 86 for description of Fresno series.

ness of the hardpan varies greatly, ranging from a few inches to several feet. In many areas it softens under irrigation. The material below the hardpan is permeable and resembles that above.

The deeper substratum usually consists of alternating beds of silt, fine sand, and clay to considerable depths. Several compact or semicemented layers, separated by layers of open, permeable material, may occur within a depth of 50 feet, and these have a direct influence on the cost of obtaining irrigation water from an underground source. The subsurface layers usually are of sufficient porosity and the surface of sufficient slope to give good drainage, except locally and near the trough of the valley, where the subsoil and substratum are more compact and usually heavier in texture, retarding drainage and causing local accumulations of alkali.

The surface soil usually is quite loose when dry, making the roads heavy for hauling. The organic-matter content in this soil is low, but tillage is easy. The soil contains a relatively large quantity of fine material, which makes it somewhat loamy when wet and greatly increases its power to hold water. Small quantities of gravel occur locally, but have little effect on crops or tillage. When cultivated the surface soil drifts readily, and injury to young crops may result. Constant cultivation at a uniform depth and irrigation tend to form a compact layer a few inches below the surface.

A body of this soil south of Turlock, near the Merced River, is somewhat lighter in color and has been more influenced by wind action than the rest of the group. Southwest of Livingston the type closely resembles the Madera sand, from which it is separated mainly on the basis of a difference in color and the presence of hardpan in the latter. Small areas of coarse sand, usually porous and leachy, occur locally within the sand areas, and crops grown in such places frequently suffer for lack of moisture.

The Oakley sand is light brown or brown in color and medium in texture, and does not differ essentially from the Oakley sand as mapped with the Oakley sands group and described elsewhere in this report. It occurs in intimate association with the Fresno sand, with which it is practically identical in surface features, and from which it differs in having no distinct subsoil or hardpan within the 6-foot depth, although the Oakley material is underlain by Fresno material in some places below this depth.

The Fresno fine sand as mapped in this group is smoother in texture, possesses a somewhat more compact subsoil, and packs more firmly when wet than the Fresno sand. Locally it closely approaches a fine sandy loam in texture, and in places it is somewhat darker than the sand and the surface usually is more nearly level. With proper cultivation it retains moisture well. It is slightly more subject than

the sand to poor drainage conditions and alkali accumulation, but in other respects is similar to that soil.

Most of the material of this group of fine sand texture probably belongs to the Fresno series, the area of Oakley material being small. The Oakley would be mapped only where heavier subsoils or hardpan lie at greater depths than 6 feet. It does not differ essentially in other respects from the brown variation of the Fresno fine sand.

The brown variation of the Fresno coarse sand consists of light grayish brown, light-brown, or light yellowish brown, coarse-textured, porous, gritty sand, having the Fresno substrata and hardpan within 6 feet of the surface. Occasionally the subsoil below 2 feet contains more fine sand and usually is somewhat browner than the surface material. A high quartz content frequently gives the surface soil a noticeably grayish cast.

The small area of material of coarse sand texture which may properly be classed as Oakley is similar in surface features to the Fresno and differs from that soil only in having no hardpan or other distinctive subsurface layers within the 6-foot depth.

The loamy coarse sand included with this group of soils ranges from 1 to 6 feet or more in depth, and is light brown or light grayish brown, with a grayish cast at the surface when dry. It is coarse textured but contains much more fine material than the associated coarse sand, and in places it closely approaches a coarse sandy loam. The subsoil below about 12 inches usually is browner than the surface material, and it generally rests upon a semicemented, grayish, silty hardpan at varying depths. Sudden transitions in the depth and thickness of the hardpan are common. The soil is low in organic matter and excessively drained. Areas in which the hardpan or similar layers occur within the depth of 6 feet represent material of the Fresno series, while the soils having a greater depth belong to the Oakley.

*Location.*—This group includes the soils recognized in the earlier detailed surveys of the Stockton, Modesto-Turlock, Merced, and Madera areas as the sand, fine sand, coarse sand, and loamy coarse sand of the Fresno series. It is the most extensive and one of the most important groups of soils in the survey. The sand types occupy most of the area covered by the group, the fine sands occurring only as long, narrow strips south and southeast of French Camp and as minor areas of more subdued topography in other places. The sand and fine sand material is extensive around Manteca, south and west of Escalon, and south of Modesto. It occupies most of the region south of Turlock to the Merced River and extends southwest and west of Livingston in Merced County. A large area southwest of Madera with several other large bodies occur in the western part

of Madera County. Small areas occur on the plains east of the trough of the valley. The surface has a gentle slope westward approximating that of the plains.

The coarse sands of the group occur principally as narrow strips from Greenleaf to Irrigosa. The loamy coarse sand is scattered over broad areas in the southwestern part of Madera County. Both the coarse sand and loamy coarse sand in places occupy old abandoned stream ways.

*Topography and drainage.*—The soils of the group are confined to the plains region between the lower rolling foothills to the east and the valley trough. They have a nearly level to undulating topography, the relief chiefly being the result of wind action. In the southwestern part of Madera County, southeast of Manteca, in the vicinity of Delhi, and northwest of Merced, low, dunelike or billowy areas occur, but in all cases the topography is favorable to agriculture. The soils generally have good drainage, due largely to their loose structures, open subsoil, and the absence of continuous layers of dense hardpan. In parts of its westward extensions and in small shallow depressions, the heavier underlying subsoils and hardpan sometimes prohibit the free movement of water and cause some accumulation of alkali.

The material giving rise to this group of soils is derived from a wide range of rocks in the Sierra Nevada Mountains and their western foothills. It was spread over extensive alluvial fans by the larger streams before they developed their present well-defined channels. A part of the material has been drifted from the stream channels during periods of low water, and a large part has been modified by wind action.

*Utilization.*—The soils of this group rank among the most important of the survey for intensive crops, and are highly developed where favorably located and where water is available for irrigation. Nonsaccharine sorghums, peaches, grapes, beans, melons, sunflowers, and a few minor crops are grown successfully without irrigation; but most crops give best returns with irrigation. The soils are capable of growing a wide range of cover crops, and respond readily to the incorporation of organic matter. On account of a lack of irrigation water extensive areas are still utilized for pasture or grain and hay production. The soils warm rapidly and mature crops early in the season. Watermelons, cantaloupes, casabas, and some Persian melons are grown. Heavy yields are obtained and the products are of high quality. Hoed crops are successfully grown in orchards until the trees come into bearing. Tomatoes, beans, and corn are favorite crops for this purpose. Sweet potatoes yield well where given good care.

The soils are very easily tilled, and a surface mulch is not difficult to maintain. Special systems of irrigation which reduce the loss of water by percolation are necessary for best results with crops. No special rotations are practiced, but it is recognized that a change in crops is highly advantageous. The soils are well located with reference to towns, shipping points, and improved main roads, but most of the side roads are sandy and hauling is difficult. The price of land varies greatly, depending on location, degree of development, uniformity of surface, and availability of water. It is seldom less than \$100 an acre or, where irrigated, \$150 an acre. An underground source of water irrigation is available over much of the group. This supply has not been extensively developed, but important areas are watered by gravity systems. The soils usually respond well under irrigation; their greatest needs are irrigation and the addition of organic matter.

OAKLEY AND MADERA<sup>1</sup> SANDS, UNDIFFERENTIATED.

The group Oakley and Madera sands, undifferentiated, consists mainly of the sand, coarse sand, and loamy sand of the two series. The group is separated from the Fresno mainly on the basis of its color, structure, and the character of its hardpan.

*Description.*—The Oakley material included with this group consists mainly of the sand, with minor variations, and does not differ essentially from this material occurring in the group Oakley and Fresno sands, undifferentiated. In character of the surface soil and upper subsoil it does not differ materially from the associated material of the Madera series, except that hardpan is wanting in the Oakley sand.

The Madera sand consists of a grayish-brown, light-brown, or brown, loose, open-structured sand, which varies somewhat in texture and locally is coarse and slightly gravelly. It usually is low in organic matter. The depth to hardpan varies from about 2 to 6 feet. Often no distinct subsoil is present, though the soil frequently is somewhat browner at lower depths. The type carries varying quantities of fine material, giving it a loamy appearance in places and causing the surface to become firmer when irrigated. Hardpan usually is encountered within a depth of 6 feet. The hardpan is generally light brown, brown, or reddish brown and closely resembles that of the San Joaquin series, except that in the Madera material seams or incrustations of lime frequently occur. Locally the hardpan consists of grayish-brown or nearly gray, semicemented layers of silty material quite similar to that occurring in the Fresno series of soils. The hardpan under this type usually lies at sufficient depth to have little influence

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<sup>1</sup> See p. 69 for description of Madera series.

on the soil, and may, in certain instances, be an advantage rather than a hindrance to agriculture. The material below the hardpan usually resembles that above, but in the more nearly level areas it may be noticeably heavier textured. No concentration of lime is apparent in the soil or subsoil, but lime casts and calcareous seams are common in the hardpan layer. Tillage is easy, and the type is retentive of moisture, often more so than the heavier types.

The coarse sand, which is much less extensive than the sand, consists of 4 to 6 feet of light-brown, grayish-brown, or brown coarse sand. In some places the color is dark gray or dark brown, owing to the presence of larger quantities of organic matter than typical; normally the soil is very low in organic matter. Fine waterworn gravel is sometimes present. The soil is quite uniform in texture to the underlying hardpan, except in local areas where gravel is present, but the deeper material frequently is slightly reddish brown. The hardpan characteristic of the Madera series is present. In some parts of the coarse sand areas hardpan occurs within the depth of 6 feet, and the soil may be correlated with the Madera series. In other localities the hardpan occurs below the 6-foot depth, and the soil is recognized as Oakley material. A slightly heavier-textured layer occasionally overlies the hardpan.

The loamy sand, which is less extensive than the coarse sand, consists of material intermediate between a sand and a sandy loam. In texture, structure, and moisture-retaining properties it is superior to both the sand and coarse sand, but otherwise it closely resembles these types. Both the Oakley and the Madera loamy sands are represented in this group.

Small areas of the Madera fine sand occur locally. Except for a different texture and a slightly more compact structure they closely resemble the loamy sand.

*Location.*—This group of soils is very extensive. It occurs about Livingston and Atwater, in several minor areas in Merced County, and southwest of Ryer, north of the Merced River. It occurs also in the vicinity of Berenda, and as long, narrow strips along stream washes just north of this point in Madera County. These strips lie mainly along the south side of the streamways, from which much of the material has been blown. The coarse sand is confined mainly to the eastern half of Merced County, and occurs in scattered, small areas either as narrow strips along intermittent streams as knolls or low ridges between them and as patches within areas of other types of the Madera and San Joaquin series.

*Topography and drainage.*—The group has an undulating to nearly level or very gently sloping topography and locally is slightly dune-like. Sand heaps several feet high frequently border fences and

roads. The lightest and deepest soil is on the ridges which frequently surround minor depressions of somewhat heavier texture and poorer drainage. The group usually is well drained, and all the rainfall is readily absorbed. Occasionally small quantities of alkali are present in the shallow areas where the type overlies heavier material containing an excess of alkali salts.

*Utilization.*—The soils of this group formerly were dry farmed to grain. Continuous cropping has greatly reduced the yields. Large areas are now devoted to intensive crops such as peaches, grapes (Pl. III, fig. 1), figs, sweet potatoes (Pl. III, fig. 2), truck crops, and almonds, some of which yield well without irrigation. Alfalfa does well with irrigation, the fields lasting for several years before reseeding is necessary. The land is irrigated by gravity from the Merced River, and considerable areas are watered by pumping from underground supplies.

In plowed fields and freshly planted areas the soil drifts considerably in dry springs, young plants frequently being injured. Windbreaks are planted in many places. The coarse sand is generally the least desirable type for farming, but it is productive with proper methods of cultivation. The soils of the group warm up quickly in the spring, mature crops early, and respond readily to applications of organic matter.

A surface mulch is easily maintained. Considerable leveling is necessary in places before water can be applied, but the use of movable pipe lines for irrigating eliminates the necessity for much of this work and results in a more economical use of water. Commercial fertilizer is used for some of the crops. No systematic rotations are followed. The group is well supplied with roads, but most of these are very sandy, and hauling usually is difficult. Straw is applied to make the roads firm while the bulk of the crops are being moved to shipping points. Land values vary widely, depending upon the opportunity for irrigation, the character of the soil, the location, and other factors. The group is thickly settled and intensely developed in some places, but large areas are still used for grain farming or pasture. This is an important group of soils, and is capable of producing a very wide range of valuable crops if properly handled. Water for irrigation and the incorporation of organic matter are its most important requirements.

#### MISCELLANEOUS.

##### MUCK AND PEAT.

*Description.*—The group Muck and Peat consists of brown, dark-brown, or black soils in which the decayed and semidecayed roots and stems of tule and other aquatic plants constitute a large part of the

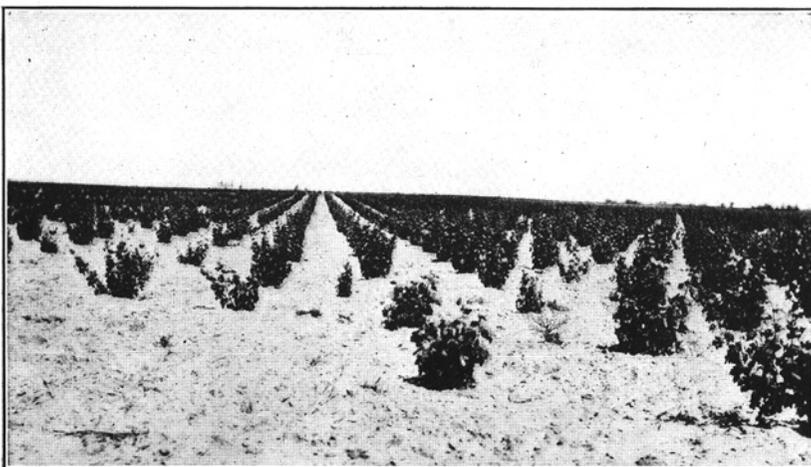
material. This organic material is mixed with mineral matter which varies from a negligible quantity in the most typical areas to relatively large quantities where the group merges with alluvial soils. The typical areas have the peculiar spongy and more or less fibrous structure and texture which are characteristic of Muck and Peat material. The nature of the soil depends largely on the stage of decomposition of the organic material. Where it is slightly decomposed the soil is brown and fibrous, and is less desirable for agriculture than where the material is well rotted. The latter is black in color and of fine texture and friable structure. Under natural conditions the fibrous material breaks down into the decomposed muck, and it is the aim in reclaiming these lands to hasten the decomposition of the coarser material.

In those areas which have been brought under cultivation the surface soil is sufficiently coherent to bear the weight of work stock and of specially devised farm machinery, but the underlying material is in a soft, semifloating condition and lacks coherence or the ability to sustain any considerable weight. This surface crust is flexible and gives under the weight of pedestrians and very noticeably undulates with the passage of teams or farm machinery. Below the surface the decomposed muck becomes less coherent until the semifloating, saturated, coarse peat is reached, usually at a depth of 1 to 3 feet. It is generally possible to force the handle of a hoe or pitchfork through the surface soil and, with the slightest pressure, into the ground to its full length. The soil material is very light in weight, and much of it will float.

The character of this soil material is very favorable to agriculture in many features. It never puddles, and yet has a high water-holding capacity. When the material becomes ignited, however, it burns, and there remains only a bed of ash full of pits or holes.

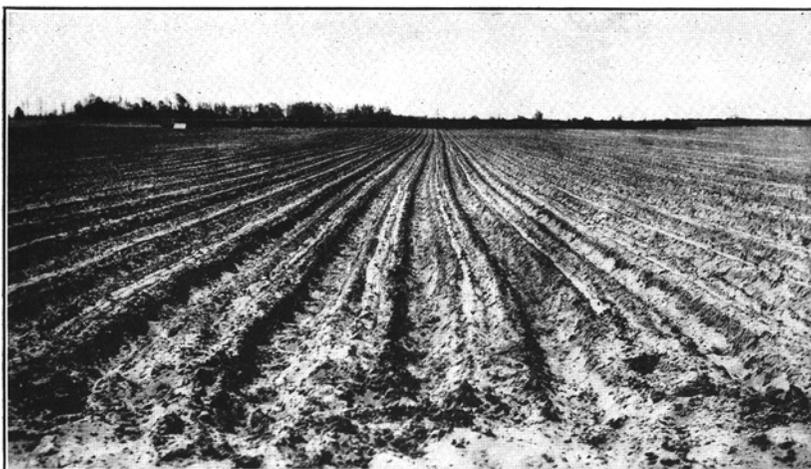
Much of the material of this group varies from the typical in containing large quantities of sediments, in places more than half the soil mass. In some places these sediments have been deposited over the surface, while in others the typical Muck and Peat is but a shallow layer over the mineral or alluvial material. These variations occur along the margins of the typical areas; they are absent in the central islands of the San Joaquin delta region, in which the Muck and Peat material occurs. The nature of the soil in these modified areas depends on the proportion of the organic and mineral constituents. An increase in mineral matter makes the material heavier and alters the capillarity of the soil and its moisture-holding capacity.

Muck and Peat in the marginal localities is less than 15 feet deep, but it is of much greater depth over broad areas. It is underlain by varicolored sediments. Conditions in the marginal areas are too



S6139

FIG. 1.—YOUNG VINEYARD ON OAKLEY AND MADERA SANDS, UNDIFFERENTIATED, NEAR MERCED.



S6131

FIG. 2.—SWEET POTATOES ON OAKLEY AND MADERA SANDS, UNDIFFERENTIATED.  
The plants have just been transplanted and the land prepared for irrigation. Note the friable character of the soil.



variable for accurate description. Silts and clays may cover a part of the surface or may entirely displace the organic material at varying depths below about 2 feet. Gravel is absent in the soil column, but strata of sand or fine sand are sometimes encountered.

*Location.*—This group of soils covers the region known as the river delta, an extensive area of low elevation around the lower course of the San Joaquin River to the west of Stockton. It adjoins a body of similar character which occurs along the lower Sacramento River and is mapped in the reconnoissance soil survey of the Sacramento Valley. The two bodies make up a geographic and agricultural unit, and together are known as the "delta lands" or the "island country." The region is marked by a flat topography and in its virgin state is very poorly drained or covered with water. Originally it was a tule marsh, inundated by the waters of the rivers and smaller streams. Numerous winding channels divide the region into islands of a few hundred to several thousand acres.

*Utilization.*—Utilization of these soils is dependent upon their reclamation. This is done by building protecting levees around the islands and draining them by means of pumping. Much of the surface of the reclaimed areas is below water level in the surrounding channels and is often below tide level, so that the areas are without natural drainage. The most general system for controlling the water is to supply irrigation water through gates in the levees by siphons or pumps, drainage being effected by pumping the water back into the streams. The land is subirrigated, the water being allowed to flow through ditches about 2 feet deep and 60 to 80 feet apart. This method is very successful on these soils. The marginal areas, where the soils consist largely of mineral material, are subject to accumulations of alkali.

The reclamation of the Muck and Peat lands has generally been accomplished through the organization of reclamation districts. The earlier work was quite expensive, but the use of improved machinery to build the levees has materially reduced the cost. Difficulty is sometimes experienced through settling of levees, and frequently they require building up and strengthening.

The soil of this delta region has become one of the most widely known in the State, because of its remarkable productiveness of certain special crops. Large expenditures have been made for reclamation, and the extensive areas rendered tillable. They are devoted largely to the production of asparagus, potatoes, beans, onions, and celery. Rotation is essential, especially for potatoes, and barley, clover, and other crops are grown for the purpose. Alfalfa is not grown extensively, owing to the high water table, a condition unfavorable for this deep-rooted crop. Corn yields heavily. The large

amount of manual labor required in producing the crops is performed principally by Chinese, Japanese, and Hindus.

Dairying is a very important industry on Muck and Peat, but is best developed on the marginal portions of the group, where the water table is lower than the average. Many sheep are pastured on these lands after the crops are harvested.

Some of the islands are accessible only by water, and water transportation is available for nearly all the area. Much of it is well supplied with good roads.

#### ROUGH BROKEN AND STONY LANDS.

This group includes the types of miscellaneous material recognized individually as Rough broken land and Rough stony land. It comprises areas of soils of various series in which the surface is too rough and broken, steep, or stony for tillage under the prevailing forms of agriculture. The group includes some local flats, ridge crests, and slopes of less than average steepness or stone content which have some value for farming.

*Description.*—Rough broken land consists of areas of rough broken topography, unsuited to tillage. It differs from Rough stony land in not having the stony character of the latter. It is relatively free from rock outcrop, and in places is covered with grass.

Rough stony land comprises rough, broken, and stony areas, most of which have numerous rock outcrops and are too uneven and steep for tillage. The surface is rocky and rough, and supports only a sparse growth of grass. Wherever small, open areas occur the soil is very shallow and stony, and soon loses its moisture in the summer. Table Mountain in eastern Madera County is classed as Rough stony land in a detailed survey of that region. This is an elevated table-land whose rocky exterior faces are precipitous and clifflike and whose interior is cut by steep, rocky ravines. This area and another to the southeast include patches of tillable land which might be differentiated in more detailed mapping.

*Location.*—This group of soils is not extensive in the present survey, and is confined to scattered areas within the hill lands along its boundaries. The soil usually is similar to that of associated areas. There are several small bodies west of Byron in the northwestern part of the survey, within large areas of the Altamont adobe soils. In this locality the Altamont soils cover the steep slope of the Rough broken land, although some of the ridge and hill crests are more sandy, while in other places the soils of the Diablo series occur. Most of the areas of the group farther south, along the western margin of the survey, represent rough, broken areas of Altamont loams and clay loams. Differentiation between material of this group and

various residual soils is often rather arbitrary. For this reason it is necessary to include some undifferentiated bodies of Rough broken and stony lands in many of the groups of residual soils.

*Utilization.*—The areas of this group are characterized by excessive drainage and sufficient erosion to remove soil almost as rapidly as it forms. Barren, eroded areas occur, and the land at best supports only a stunted growth of oak, brush, and grass. The land usually is held in large tracts and is utilized only for pasture. It usually is isolated and is valued only for grazing and for the small amount of oak available for firewood.

#### RIVERWASH AND TAILINGS.

The group Riverwash and Tailings includes undifferentiated areas of nonagricultural materials laid down along streams.

*Description.*—Riverwash consists of prevailing coarse-textured but variable material, ranging from sand to gravel. It usually is flood-swept, though it may lie slightly above present overflows. The sandy areas are loose and incoherent to a depth of several feet, or they may be stratified with gravel or silt layers. The texture ranges from fine sand to coarse sand or gravel within very short distances. The movement of the material by winds in sandy areas exposed during periods of low water sometimes results in the sand being spread over parts of the adjoining plains. Gravel and cobblestones prevail near the foothills, but farther out in the valley these give way to deposits of sand with some silt or other fine material. Riverwash is restricted in this survey to the beds of streams and adjoining local areas subject to annual overflow.

Tailings consist of uneven heaps of cobblestones and gravel which have resulted from placer mining. Dredgers are still at work on the Merced and Tuolumne Rivers and are continually increasing the extent of this class of material. Hydraulic mining has been carried on over some of the hillsides, and has left a class of material quite similar to that left in dredging. The broad, gravelly beds and bars of rivers and the valuable alluvial areas adjoining them have been worked over to considerable depth, leaving the cobblestones and gravel originally underlying such areas in irregular heaps, usually at an elevation noticeably greater than that of adjoining areas. Varying quantities of sand, silt, and clay were present in the original mass, but as the débris is disposed of in the dredging operations the fine material is washed out.

*Location and utilization.*—The main bodies of Riverwash lie along the Merced and Tuolumne Rivers. An inextensive development occurs southwest of Tracy. Many areas of this material too small to be mapped separately in this survey are included with other soils. Riverwash in places supports a growth of willow, cottonwood, brush, and

vines. Some eucalyptus has been planted in favorable places, and where once started does moderately well.

Areas of Tailings occur only on the east side of the valley, principally along the larger streams and near the foothills of the Sierra Nevada Mountains. It is practically nonagricultural except very locally, where an appreciable quantity of fine interstitial soil material is present. Such parts may be leveled and used for a few purposes, such as forestry. Leveling, however, is very expensive.

#### IRRIGATION.

In the area covered by this survey irrigation water is obtained by diversion from rivers or reservoirs, by pumping from wells or streams, and, in small quantities, from flowing wells. Nearly all the water available for irrigation has its source in the Sierra Nevada Mountains, the run-off from the Coast Range to the west being small and confined to small, intermittent streams. The four main rivers entering the area, the San Joaquin, the Merced, the Tuolumne, and the Stanislaus, furnish the greater part of the irrigation water. Their greatest discharge occurs in the months of May and June and their lowest in the fall months, the average discharge for each of the streams being reported as less than 400 cubic feet per second during September and October. The mean annual discharge in acre-feet for the San Joaquin River is reported as 2,060,000; for the Merced, 1,230,000; for the Tuolumne, 2,080,000; and for the Stanislaus, 1,400,000. Chief among the smaller streams entering the valley from the east are the Fresno River, Mariposa Creek, Chowchilla River, Calaveras River, and Bear Creek. These smaller streams rise in the lower Sierra foothills and their flow is intermittent, almost their entire discharge occurring in February, March, and April. Their beds usually are dry during August and September and generally through October. The Calaveras is the largest of these streams, carrying an average of 370,000 acre-feet per year. The average for the other streams is much lower. The streams of the west side of the valley are relatively unimportant and valuable chiefly as possible sources of water for local storage.

The most important development of irrigation in the area is in the Modesto and Turlock irrigation districts, where the water used is drawn from the Tuolumne River. In these two districts a total of 135,147 acres was irrigated in 1912.<sup>1</sup> The further development of irrigation from the Tuolumne River may be restricted by plans of the city of San Francisco, which proposes to store water in the Hetch Hetchy Valley for municipal purposes. The more recently organized Oakdale and South San Joaquin irrigation districts utilize water from

<sup>1</sup> Irrigation Resources of California and Their Utilization, Bul. No. 254, Office of Expt. Sta., U. S. Dept. of Agr.

the Stanislaus River by direct diversion, and further development, including some storage, is contemplated. About 8,000 acres have been irrigated in the Oakdale and 20,000 acres in the South San Joaquin districts. The Crocker-Huffman Canal, taking water from the Merced River, irrigates between 25,000 and 50,000 acres in the region between Merced and Livingston. In this section small additional areas along the stream bottom are independently watered from the same river. The present systems use only a small part of the annual flow of this river, and large supplies of water probably could be stored. Little water is diverted from the San Joaquin River in this area along its upper part, but a number of canals tap it at different places along its course through the valley. The largest of these is the San Joaquin and Kings River Canal, irrigating about 130,000 acres of land on the west side of the valley south of Crows Landing. About 15,000 acres in western Madera County and about 12,000 acres at Stevinson Colony, east of Newman, in Merced County, are irrigated with water from this stream, besides about 125,000 to 175,000 acres of pasture land, much of it affected by alkali, in the center of the valley in Merced and Madera Counties. Water also is pumped from the river along its lower course, notably on the Patterson project, where somewhat less than 19,000 acres are irrigated. Other areas on the valley floor are similarly irrigated, but on a smaller scale. The East Contra Costa Irrigation Co. has constructed a large system for pumping water from the San Joaquin River near its mouth for the purpose of watering about 22,000 acre-around Brentwood, although up to the present time very little of this land has been irrigated. The waters of the San Joaquin River are used also to irrigate the low-lying delta lands bordering its lower course. About 75,000 acres of such land are irrigated in this survey.

Irrigation by pumping from an underground supply is practiced in some places, and the indications are that this supply will be much more extensively used. The water is obtained at depths sufficiently shallow for pumping over much of the lower part of the east side. There are a number of pumping plants in Madera and San Joaquin Counties which furnish water for small ranches. In the former county especially the development of irrigation by pumping from wells has recently increased very rapidly. In the part of San Joaquin County within the survey about 5,000 acres are irrigated in this way.

Artesian water usually is available in the lower valley trough on the east side, and in Merced and Madera Counties, particularly, a number of wells are used in part for irrigating. They are generally less than 400 feet deep, and have an average flow of about 10 miner's

inches. The supply from these wells is used chiefly for stock on the large ranches rather than for irrigation. Artesian water does not seem so available on the west side of the valley.

There are many subirrigated areas in the stream bottoms and on the slopes of the valley trough. The stream-bottom lands are naturally subirrigated by the streams, while the water table in the valley floor has been raised by seepage water from higher irrigated lands. The delta lands are subirrigated under a novel plan. They are lower than the water in the adjoining slough ways, from which they are protected by levees. The water table is very near the surface, and its height is controlled by pumps.

The quantity of water used during the season for irrigation in the valley varies with the crop and the soil. For alfalfa in the Modesto irrigation district it is about 4 feet; on the heavier soils of the Patterson project and on the alfalfa lands of the lower west side, irrigated by the San Joaquin and Kings River Canal, it is 2 to 3 feet, and where the water is supplied by pumping from wells it is 30 to 40 inches. For rice culture the amount used varies from 5 to 10 feet, the smaller quantity on fields carefully leveled and cared for and the larger in less carefully prepared areas. About 3 feet of water is used in growing sweet potatoes. Melons are grown on subirrigated soils, or under irrigation with an application of 1 to 2 feet of water. Fruits and vines are grown in favorable locations without irrigation, but on less favorable soils they require 1 to 3 feet of water. In general, irrigation is desirable for best results with most of the crops grown in the area.

The cost of water varies. Under the State irrigation district law the original cost of the irrigation system is paid for by bonds which are held against the land, and the cost of maintenance is assessed proportionately among the farmers. The annual charge for maintenance is from \$1 to \$2 an acre. In the case of the Crocker-Huffman Canal in Merced County, water rights were sold for \$10 an acre, with an annual charge of \$1 per acre, but the price has recently been doubled. The Patterson project allots one share of stock with each acre of land, and the water system is to be operated ultimately on a mutual basis. The minimum water cost is \$3 an acre for 2 acre-feet and an additional acre-foot is supplied, if desired, at proportionate cost. The cost of pumping from wells in the valley varies with the depth and the power used. Pumping with electricity is usually more costly, but is more convenient than with gas engines. It is generally preferred, gas engines being used chiefly where electricity is not available. Water is free on the delta lands, and the only expenses connected with irrigation are for the distributing ditches, for operating the drainage pumps, and for leveling.

The soils best adapted to irrigation in the area are the deep, friable sandy loams or fine sandy loams, with light surface soils and somewhat heavier subsoils. Hardpan at shallow depths is unfavorable to irrigation, but where it is 5 feet deep or more it is sometimes beneficial in preventing water from sinking below the root zone. Where hardpan is near the surface and also where the soil is deep and very light textured, frequent light applications of water are necessary, but on deep soils of finer texture larger quantities of water are added at less frequent intervals. Clay soils, because of their impenetrability, are not so well adapted to irrigation as lighter-textured soils, except for rice culture. Muck and Peat are particularly well suited to irrigation. Good drainage is necessary to prevent the accumulation of alkali, and in some places in the survey artificial drainage is required. The recent-alluvial soils and the soils of the old valley-filling material are in this survey best adapted to irrigation and the most extensively utilized for irrigation farming. Steeply sloping soils are more costly and difficult to irrigate than those of moderate slope.

Irrigating alfalfa from gravity ditches usually is done by the check system. The checks are flooded and the surrounding levees keep the water well distributed. The border system also is used; under it the field is separated into long strips, the water being introduced at the higher end and allowed to flow the length of the strip. Simple flooding of unleveled fields, or "crude flooding," also is practiced, but this is wasteful of water and is not productive of the highest returns from the land. High prices of land and water have had a tendency to encourage the efficient and economic use of water, especially in the highly developed districts. In pumping for irrigation movable pipes commonly are used to convey the water to various parts of the field. Grain land and pastures where irrigated usually are watered by "crude flooding," but rice fields are leveled and checked with great care. Most other crops are irrigated by the furrow system. On nearly level soils, the furrows usually are straight and conform with the crop rows. In steep or rolling areas the furrows are made to conform to the topography, care being taken to avoid erosion. For fruits and vines deep furrows are most efficient. Vines are often irrigated by the basin and by the furrow method.

The number of irrigations and time of application depend largely on the soil and the season. Alfalfa commonly is irrigated once to the cutting, under the gravity ditch system or pumping. Vines, where irrigated, usually receive one application of water a season. Fruits are generally irrigated the first year after planting. Melons commonly are irrigated two or three times where not grown on sub-irrigated land. The practice is not to irrigate while the melons are

maturing. Sweet potatoes are irrigated about three times, but usually are not watered after they attain considerable size. The nonsaccharine sorghums are irrigated once or twice in some cases; in other cases they are not irrigated.

The best practice seems to be to cultivate as soon as possible after irrigation to prevent evaporation, and cover crops are sometimes grown successfully in orchards after the last irrigation, where an adequate supply of water is available. Rice usually is germinated and grown for the first 30 days in moist soil, after which the field is kept submerged to a depth of 4 or 5 inches until the heads are well turned down, when the water is quickly withdrawn. On alkali soils the rice seed is germinated under water.

The future agriculture of the area surveyed depends largely upon the extension of irrigation. Recent State legislation is designed to remove many hindrances in the way of irrigation development, and to enable a full utilization of the water resources of the area. Proposed storage reservoirs would render water available along the smaller creeks where there is now none during the late growing season. The foothills along the valley margin contain many small natural reservoir sites which might be utilized. Some of the water diverted to the higher lands becomes available again for pumping at lower levels. When steps are taken to utilize this and other underground sources fully and conservatively, the available water supply not only will bring under irrigation large additional areas of land, now without water, but also serve to regulate seepage and prevent injury from alkali accumulation by lowering the water table. The wasteful use of water in parts of the survey has retarded the development of areas of valuable land. The present tendency is to discontinue this extravagance. Further development of the present irrigation projects in the area awaits capital and the adjustment of certain legal difficulties.

#### ALKALI.

Careful studies of the occurrence, character, and reclamation of alkali lands embraced within this survey have been made in the detailed soil surveys in the area and in other investigations by the United States Department of Agriculture<sup>1</sup> and the University of California.<sup>2</sup>

A separate alkali map was not made in this survey, but boundaries inclosing affected lands, as determined by the earlier surveys, on the

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<sup>1</sup> Bul. No. 35 and Bul. No. 42, Bureau of Soils, U. S. Dept. of Agr.; Soil Survey of the Stockton Area, Cal., Field Operations of the Bureau of Soils, 1905; Modesto-Turlock Area, 1908; Madera Area, 1910; and the Merced Area, 1914. See also Drainage of Irrigated Lands in San Joaquin Valley, Cal., by S. Fortier and V. M. Cone, Office of Expt. Sta., U. S. Dept. of Agr., Bul. No. 217.

<sup>2</sup> Alkali Soils, Nature and Reclamation, by E. W. Hilgard, Univ. of Cal., Bul. No. 83; Alkali Soils, Nature and Reclamation, by E. W. Hilgard, Univ. of Cal., Bul. No. 128.

east side of the valley are shown on the accompanying soil map and areas not previously covered by soil surveys but containing alkali also are approximately outlined. In this manner the main bodies of alkali land are shown, but no attempt is made to indicate the relative quantities of salts present, and small areas of affected land may not be outlined.

In some of the areas outlined the alkali salts occur in injurious amounts only in scattered local spots distinguishable by surface incrustations of salts, by the barren surface, or by the yellow and unhealthy appearance of the crops grown. In such areas more than 50 per cent of the area may be free from injurious amounts of salts, but the conditions are such as to mark the land as associated with alkali conditions which limit its value and utilization and which in most cases must be regarded as indicative of danger of further concentration of the salts. In other cases the areas outlined may consist of soils having uniformly an alkali content sufficient to render impractical the production of cultivated crops in any portion of the tracts. Such areas are generally used for pasture. Other areas represent intermediate conditions in alkali concentration, and in a more detailed survey the various degrees of concentration of the alkali salts in the soils would be indicated upon the map.

The alkali consists of an excessive accumulation of various mineral salts which occur in varying proportions and quantities in all the soils and in the rocks from which they are derived. These salts are soluble in water, and when dissolved are transported readily in soil or surface waters. Under conditions of ample rainfall and good drainage they are leached from the soils and removed in the regional drainage. With light rainfall and poor drainage they remain as residual products or find their way to the lower lands where they accumulate as residues left by evaporation. The lavish use of water for irrigation in parts of the valley, principally on the plains of the east side, has aided the accumulation of alkali. This has added a large acreage to the vast expanse of alkali land formed before the settlement of the valley.

The salts commonly occurring in excessive quantities in the valley are sodium sulphate, or Glauber's salts, sodium chloride, or common salt, and sodium carbonate, or sal soda. In local areas other chemical compounds may be prominent. The sodium sulphate and sodium chloride are neutral in reaction or noncaustic and are known as "white alkali," while the sodium carbonate is caustic or corrosive and is known as "black alkali," owing to the dark-colored deposit formed when organic matter is present in solution. The amount of alkali present varies from small quantities in occasional barren or unproductive spots of minor importance to excessive and widespread concentrations, which render the land worthless except for grazing.

The areas that are affected by alkali are confined almost wholly to the flatter slopes and to basins lying adjacent to and along the trough of the valley, with some small areas in the bottoms of the larger streams and occasional bodies on some of the smaller alluvial fans. On the east side of the valley the alkali soils occur in a belt of irregular width and outline and are confined principally to the region between the San Joaquin River and the Southern Pacific Railway from just south of Stockton to the southern boundary of the area. The alkali occurs mainly in the soils of the Fresno and Merced series, with considerable areas in those of the Hanford series and a few occurrences in the soils of the Madera series. The salts present are mainly those forming white alkali, with some local spots or in places more extensive areas of black alkali. Affected areas are spreading in some localities, owing to the steadily rising water table. In Stanislaus County this extension of the poorly drained and alkali area has been met by the formation of a drainage district, and the construction of drainage canals and ditches is under way. In Merced and Madera Counties, where large alkali areas occur, concerted action has been delayed, but some surveys and plans have been made to reclaim or to prevent the extension of the affected areas.

On the west side of the valley the alkali occurs in a more irregular and narrower belt, though in places, notably south of Dos Palos, there are very extensive areas of alkali soils. The affected soils lie in the flat basin bordering the San Joaquin River, and on the lower slopes of adjoining alluvial fans. Some small areas occur in the flood plains of some of the smaller streams entering the valley from the west, with occasional areas on the alluvial fans formed by these streams. The alkali land on the west side of the valley occurs mainly in the soils of the Stockton series and the Capay and Merced clays, undifferentiated, with considerable areas in the heavier members of the Dublin and Yolo series. The salts appear to be well distributed through the soil column, and should increased irrigation cause a rise in the water table, a considerable increase in surface accumulation may occur. The alkali in this part of the valley consists almost entirely of white alkali, black alkali occurring only to a small extent. Concentrations of alkali also occur in local restricted spots in the soils of the island, or delta, region of the northern part of the survey.

Where sufficient water is available for irrigation to keep the salts leached from the soils by periodical surface flooding, and where drainage by natural or artificial means is favorable to the control of the water table and the removal of excess subsurface waters, the concentration of the salts in injurious quantities can be prevented.

Where the concentration of the salts is so great that cultivated crops are unprofitable the alkali lands are generally utilized for

pasture. Intensive crops are sometimes grown where slight concentrations are present, the degree of success varying with the crop and character of the soil.

The various crops differ in resistance to alkali. Sugar beets and sorghum are considered quite resistant field crops and are, in the presence of moderate quantities of salts, sometimes grown where other crops fail. The growing of alfalfa is often possible in the presence of small concentrations of the salts if the plants once become well established, but difficulty is often experienced in obtaining a stand. Most of the fruits, grapes, berries, and truck crops are very susceptible to injury by alkali. Present indications are that rice can be grown on land containing a greater accumulation of salts than could be withstood by most crops, and the cultural methods employed with this crop tend to remove the salts rather than to increase their accumulation.

In the reclamation of alkali lands artificial drainage supplemented by leaching the salts from the soils by surface flooding has proved the most practicable and effective method. Where the value of the lands so improved will warrant, the installation of underground tile drains is advantageous. Some success has been attained on the lower lands of some part of the valley, where a large supply of water is available, by simple flooding without artificial underdrainage, but where practiced on a small scale and where water for flooding is limited the process has proved less effective. In certain places in the Modesto and Turlock districts the accumulation of alkali has been checked by the installation of drainage ditches. Reducing evaporation by the maintenance of a surface mulch tends to decrease the rate of salt accumulation.

#### SUMMARY.

The reconnoissance soil survey of the Lower San Joaquin Valley covers 4,760 square miles, or 3,046,400 acres in the lower or northern part of the San Joaquin Valley. The Great Interior Valley, made up of the San Joaquin and Sacramento Valleys, is an enormous trough filled to great depths by material washed from the adjoining mountains. The area covered by this survey consists of a broad, basinlike valley. For the most part the valley slopes are less than 250 feet in elevation. Some elevations of 1,000 feet or more occur in the lower foothills along the margins of the survey. Some of the northwestern part is below tide level.

The area is drained almost entirely by the San Joaquin River and its tributaries, most of which empty from the east side.

Most of the area is well supplied with transportation facilities. It is served by the Southern Pacific Railroad, Atchison, Topeka & Santa Fe, and the Western Pacific Railroad. Other railroads of less

importance, such as the line which connects Merced with the Yosemite Valley and two electric lines, are in operation. Stockton and points to the west are supplied with water transportation for boats of shallow draft. The area is well supplied with roads.

The climate is similar in essential features to other parts of the Great Interior Valley; it is marked by a cool, wet winter season and a warm, dry summer season. Temperatures are favorable for the production of a wide range of crops, but the precipitation is unfavorable in both amount and distribution. The rainfall on the west side of the valley is lighter than for the points on the opposite side, and in general the precipitation decreases toward the southern part of the area.

The area surveyed is very important from an agricultural standpoint.

The soils of the region may be classed, on the basis of derivation, in five general groups: (*a*) Residual soils, or those derived in place from consolidated rocks; (*b*) old valley-filling soils, consisting of the weathered and otherwise altered products of unconsolidated water-laid deposits; (*c*) recent-alluvial soils, or those recently deposited by streams and without appreciable alteration since deposition; (*d*) wind-laid soils; and (*e*) miscellaneous materials. The old valley-filling and recent-alluvial groups are the most extensive and comprise the greater part of the area of this survey.

The residual soils of the area are of moderate extent and of minor agricultural importance. They are derived from both crystalline and noncrystalline igneous and from sedimentary rocks. Soils of the Aiken, Sierra, Holland, Mariposa, Altamont, Kettleman, and Diablo series are identified.

The old valley-filling soils occupy the higher and older surfaces of the valley plains. They are characterized by compact subsoils which are generally heavier than the surface soils and are frequently accompanied by indurated or cemented hardpan layers. They include soils of the Redding, San Joaquin, Madera, Pleasanton, Corning, Antioch, Oakdale, Fresno, Stockton, Merced, Alamo, and Montezuma series. Of these the Fresno, Madera, San Joaquin, and Stockton are the most extensive and important. The Fresno soils consist of gray to light-brown soils with gray hardpan, the Madera of brown soils with brown hardpan, the San Joaquin of red to brownish-red or reddish-brown soils with red to brown hardpan, and the Stockton of black soils with brown to yellowish subsoils and calcareous hardpan.

The recent-alluvial soils occupy stream bottoms and flood plains with low recent terraces and broad, extensive alluvial fans superimposed on the older materials of the valley plains. They are

correlated with the Yolo, Panoche, Hanford, Honcut, Capay, Dublin, and Sacramento series of soils, of which the Yolo, Hanford, and Sacramento are the most extensive and important. The Yolo soils are brown. They are derived mainly from material washed from sedimentary rocks and occupy the greater part of the slopes of the west side of the valley. The Kettleman soils are gray and calcareous. They resemble in other respects the soils of the Yolo series. The Hanford series consists of brown, micaceous soils derived mainly from granitic material. These soils occur on the east side of the valley. The Sacramento series consists of dark-colored soils derived from materials of varied rock origin. The soils occupy low, flat, poorly drained basins subject to overflow. This series is encountered in the northern part of the area along the larger streams.

The wind-laid soils are represented by the Oakley series of brown soils. This series is of moderate extent, but of widespread occurrence.

Miscellaneous materials are mapped as Muck and Peat, Rough broken and stony lands, and Riverwash and Tailings. Of these only the Muck and Peat group is of agricultural importance.

Irrigation is the controlling factor in growing many crops in the valley, and its use is rapidly increasing. Several large streams supply irrigation water, but the total amount available is not so great as would be possible with better means of storage and more conservative use of water. Considerable areas of land affected with alkali, some of which is easily reclaimed, occur in the area. The most severely affected areas are used as pasture; the less affected parts may be farmed.



[PUBLIC RESOLUTION--No. 9.]

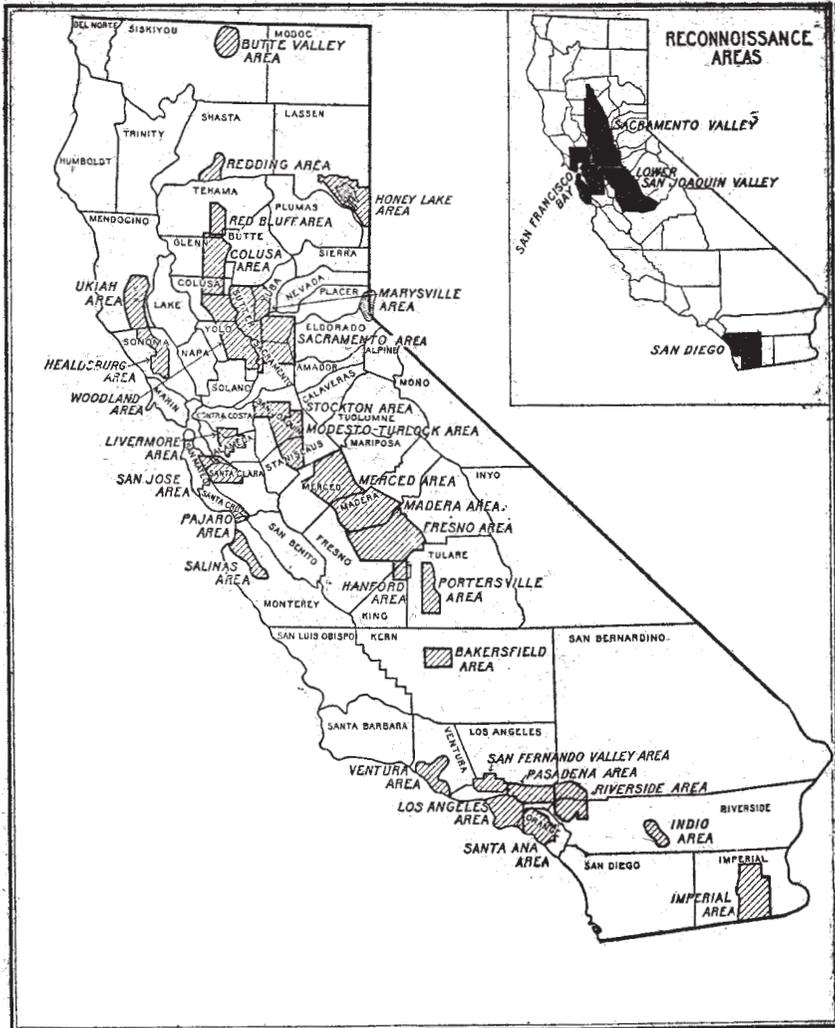
JOINT RESOLUTION Amending public resolution numbered eight, Fifty-sixth Congress, second session, approved February twenty-third, nineteen hundred and one, "providing for the printing annually of the report on field operations of the Division of Soils, Department of Agriculture "

*Resolved by the Senate and House of Representatives of the United States of America in Congress assembled,* That public resolution numbered eight, Fifty-sixth Congress, second session, approved February twenty-third, nineteen hundred and one, be amended by striking out all after the resolving clause and inserting in lieu thereof the following:

That there shall be printed ten thousand five hundred copies of the report on field operations of the Division of Soils, Department of Agriculture, of which one thousand five hundred copies shall be for the use of the Senate, three thousand copies for the use of the House of Representatives, and six thousand copies for the use of the Department of Agriculture: *Provided,* That in addition to the number of copies above provided for there shall be printed, as soon as the manuscript can be prepared, with the necessary maps and illustrations to accompany it, a report on each area surveyed, in the form of advance sheets, bound in paper covers, of which five hundred copies shall be for the use of each Senator from the State, two thousand copies for the use of each Representative for the Congressional district or districts in which the survey is made, and one thousand copies for the use of the Department of Agriculture.

Approved March 14, 1904.

[On July 1, 1901, the Division of Soils was reorganized as the Bureau of Soils.]



Areas surveyed in California.

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