SOIL SURVEY AROUND FRESNO, CAL.

By THOMAS H. MEANS and J. GARNETT HOLMES.

INTRODUCTION.

This survey was commenced April 1, 1900, at the city of Fresno, and continued until August 9, 1900, during which time about 620

FIG. 35.—Sketch map of California, showing areas surveyed.

square miles of land were surveyed. The area mapped includes the territory between the third standard parallel south of the Mount

Diablo parallel and the fourth standard parallel south, and extending from the west boundary of range 19 east of the Mount Diablo meridian to the Kings River. (See fig. 35.) In this survey is included all of the land which is irrigated by the Upper Kings River canals west of the river. This takes in the agricultural district around Fresno and covers all of the agricultural territory directly tributary to this town. Included in this survey are some of the most important fruit lands of the San Joaquin Valley, large extents of wheat lands, and along the western and southern portions of the map are great areas of alkali lands. In the northeastern corner of the map the soils of the Sierra Nevada foothills are shown, and from these foothills the soils of the plains are shown nearly to the trough of the valley at the Fresno Slough.

CLIMATE OF FRESNO COUNTY.

Fresno County lies across the center of the San Joaquin Valley, extending from the summit of the coast range to the summit of the Sierra Nevadas. The climate of the valley is arid, with a wet season during the winter and dry season during the summer. This valley, as are all of the interior valleys of California, is warm and dry in summer, with almost cloudless days and no rain. The winters are characterized by occasional cloudy days with fogs and rain. The northern end of the valley receives a larger amount of rainfall than do the central and southern parts, the increase in rainfall down the center of the valley being uniform. The rainfall on the east side of the coast range is very slight, but upon the west side of the Sierra Nevada the precipitation is heavy. The data on the climate of Fresno County, which follow, is taken from the U. S. Weather Bureau reports.

The following table shows the mean monthly temperature for a series of years at the city of Fresno, together with data upon the frost:

Climatological data for Fresno.

MEAN MONTHLY TEMPERATURE FOR TWELVE YEARS.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l.
	Deg.	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*
1888	44.1	53.2	54.1	67.1	68.6	74.1	80.6	86.3	83.4	68.9	56.0	48.6	65.4
1889	43.6	50.5	58.4	63.5	69.6	79.5	82.6	82.2	75.6	62.8	54.1	49.1	64.3
1890	42.3	41.2	54.6	61.2	69.4	73.4	82.5	80.8	74.6	64.5	56.9	43.8	62.6
1891	45.4	48.5	54.4	59.0	67.1	73.0	83.6	83.6	74.6	67.0	56.2	43.9	63.0
1892	48.5	53.2	55.6	57.6	67.2	72.8	79.4	81.4	73.6	63.9	56.4	47.4	63.1
1893	42.8	48.4	52.2	55.9	66.9	73.2	80.8	82.0	68.4	60.8	52.8	48.4	61.0
1894	43.8	46.8	53.0	62.2	67.6	68.9	82.7	82.1	74.0	64.0	58.6	47.6	62.6
1895	45.3	52.6	53.7	60.0	67.4	77.2	79.4	80.6	70.4	66.6	52.8	43.6	62.5
1896	50.6	53.4	56.3	54.7	63.9	78.6	85.0	79.8	72.6	66.7	53.2	49.5	63.7
1897	43.7	49.2	48.6	63.5	71.7	74.3	82.8	81.8	72.8	61.2	52.0	45.1	62.3
1898	41.7	53.8	52.8	65.4	65.2	72.2	83.9	81.6	72.8	64.6	52.5	45.2	63.1
1899	50.0	51.2	54.4	61.1	63.2	78.3	81.8	75.1	77.3	60.4	54.4	43.8	62.6
Means	45.2	51.5	54.0	60.9	67.3	74.6	82.1	81.4	74.2	63.4	54.7	46.3	63.0

Climatological data for Fresno—Continued.

ABSOLUTE MAXIMUM AND DATE.

Date.	Temperature.	Date.	Temperature.
	Deg.		*Deg.*
January 15, 1893	69	August 11, 1898	113
February 20, 1896	80	September 24, 1888	111
March 6, 1899	86	October 4, 1889	98
April 25, 1898	101	November 7, 1894	82
May 21, 1892	104	December 5, 1895	71
June 30, 1891	112	Annual	114
July 1, 1891	114		

ABSOLUTE MINIMUM AND DATE.

Date.	Temperature.	Date.	Temperature.
	Deg.		*Deg.*
January 1, 1888	20	August 27, 1895	51
February 6, 1899	24	September 22, 1895	44
March 1, 1888	28	October 17, 1892	36
April 5, 1895	34	November 25, 1898	27
May 1, 1899	38	December 21, 1897	23
June 2, 1899	46	Annual	20
July 8, 1891	51		

FROST.

Year.	Last light frost.	Last killing frost.	First light frost.	First killing frost.	Year.	Last light frost.	Last killing frost.	First light frost.	First killing frost.
1888	Mar. 6	Mar. 1	Nov. 7	None.	1895	Mar. 21	Apr. 5	Nov. 22	Nov. 23
1889	Feb. 20	Feb. 19	Nov. 6	Dec. 21	1896	Apr. 15	Mar. 1	Nov. 26	Nov. 29
1890	Mar. 27	Apr. 14	Nov. 9	Dec. 6	1897	Mar. 23	Mar. 30	Nov. 16	Nov. 26
1891	Apr. 8	Mar. 29	Oct. 2	Dec. 3	1898	Mar. 27	Mar. 22	Nov. 7	Nov. 21
1892	Apr. 18	Mar. 28	Nov. 15	Nov. 25	1899	Apr. 29	Feb. 7	Dec. 10	None.
1893	Apr. 13	Mar. 13	Nov. 16	Nov. 18	Average	Apr. 1	Mar. 15	Nov. 16	Dec. 1
1894	Apr. 17	Mar. 4	Dec. 14	Dec. 2					

There is very little variation in the mean annual temperature or even in the mean monthly temperature between the stations in the valley. The stations along the foothills average a little higher in winter temperature than the stations of the valley, but with that exception there is very little difference. In the mountainous districts the temperature is known to be much lower, though no records are available for publication.

With this high summer temperature there is a low relative humidity, which, with the good wind velocity, makes the sensible temperature much lower than would be supposed from an examination of the temperature data alone.

Average monthly relative humidity at Fresno for twelve years.

Month	Per cent.	Month	Per cent.
January	79	July	33
February	70	August	34
March	68	September	42
April	58	October	56
May	51	November	65
June	41	December	82

The prevailing direction of the wind in the valley is from the northwest, that is, up the valley. The winds are uniformly light; very few winds of high velocity.

Hourly wind movement at Fresno, 1895 to 1898.

Month	Miles.	Month	Miles.
January	4.6	August	6.2
February	4.7	September	5.4
March	5.5	October	4.1
April	6.5	November	3.9
May	7.3	December	3.4
June	7.5		
July	7.0	Year	5.5

Highest wind velocity per hour and direction for twelve years.

Month.	Year.	Velocity.	Direction.	Month.	Year.	Velocity.	Direction.
January	1898	32	NW.	July	1893	24	NW.
February	1894	30	NW.	August	1891	24	NW.
March	1896	38	SE.	September	1899	28	NW.
April	1894	30	NW.	October	1892	25	NW.
May	1894	30	NW.	November	1892	30	SE.
June	1891	30	NW.	December	1891	24	NW.

The details of precipitation of the valley lands are shown by the records from Fresno. The rains are confined almost entirely to the winter months and fall in gentle showers rather than in torrents. The great part of the rainfall enters the ground and does not wash over the surface.

Monthly and annual rainfall for eighteen years.

[An accurate record of rainfall was kept by Louis Enstein from August, 1881, to August, 1887; measurements were made with a standard rain gage. Weather Bureau records began in August, 1887.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
1882	0.54	1.44	1.80	1.36	0.21	0.00	0.00	0.00	0.56	1.07	1.00	0.42	7.89
1883	0.54	0.27	3.28	1.01	1.69	0.00	0.00	0.00	0.05	1.17	0.17	0.56	8.69
1884	2.54	4.35	3.77	3.42	1.43	1.25	0.00	0.00	0.00	0.46	0.08	3.93	21.23
1885	0.63	0.00	0.76	1.32	0.02	Tr.	0.00	0.00	0.00	0.11	9.54	2.06	14.44
1886	2.82	0.68	1.34	2.87	0.03	0.00	0.00	0.00	0.00	0.57	0.80	0.44	9.55
1887	0.40	3.09	0.17	2.93	0.03	0.04	0.00	0.00	0.49	0.15	0.32	1.16	8.78
1888	1.75	0.13	1.95	0.22	0.56	Tr.	Tr.	Tr.	0.06	0.00	2.38	1.71	8.76
1889	0.34	0.32	2.07	0.54	0.57	0.00	0.00	Tr.	0.00	3.17	1.39	3.87	12.27
1890	2.12	0.80	1.04	0.17	0.45	0.00	0.00	Tr.	1.26	0.00	0.22	2.30	8.36
1891	0.88	2.24	0.81	0.49	0.03	0.02	0.00	0.00	0.27	0.00	0.21	3.99	8.94
1892	0.48	1.00	1.69	0.79	1.44	0.06	0.00	0.00	Tr.	0.34	0.39	2.56	8.75
1893	1.04	2.21	4.22	0.34	Tr.	0.00	Tr.	0.00	0.01	0.02	0.16	1.40	9.40
1894	2.27	2.02	0.29	0.10	1.16	1.16	Tr.	Tr.	0.75	0.37	0.27	4.09	12.48
1895	4.14	1.70	1.84	0.99	0.52	0.00	Tr.	Tr.	0.07	0.16	0.19	0.78	10.39
1896	2.89	0.06	1.21	2.82	0.02	0.00	0.07	0.15	0.06	1.28	1.46	1.00	11.02
1897	1.93	2.65	1.64	0.30	0.00	Tr.	0.00	Tr.	Tr.	1.19	0.22	0.48	8.41
1898	0.42	1.15	0.71	0.00	0.79	0.00	0.00	0.00	1.12	0.03	0.34	0.43	4.99
1899	1.92	0.02	2.90	0.36	0.06	0.66	0.00	0.00	0.00	2.01	1.52	1.09	10.54
Average	1.54	1.34	1.75	1.11	0.50	0.18	Tr.	0.01	0.26	0.67	1.15	1.79	10.27

Greatest precipitation in twenty-four hours for each month.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
1888	0.95	0.13	1.05	0.20	0.31	Tr.	Tr.	Tr.	0.06	0.00	1.33	0.71
1889	0.29	0.53	0.55	0.32	0.33	0.00	0.00	Tr.	0.00	1.73	0.48	0.75
1890	0.74	0.30	0.33	0.15	0.43	0.00	0.00	Tr.	1.12	0.00	0.22	1.21
1891	0.54	0.50	0.26	0.29	0.02	0.02	0.00	0.00	0.27	0.00	0.21	2.10
1892	0.24	0.38	0.53	0.43	0.82	0.06	0.00	0.00	Tr.	0.32	0.22	0.66
1893	0.39	1.48	1.22	0.32	Tr.	0.00	Tr.	0.00	0.01	0.02	0.15	0.55
1894	1.28	0.62	0.20	0.07	0.94	0.74	Tr.	Tr.	0.75	0.28	0.27	1.12
1895	1.46	0.95	0.52	0.84	0.52	0.00	Tr.	Tr.	0.06	0.13	0.12	0.40
1896	1.05	0.06	0.50	1.68	0.02	0.00	0.06	0.15	0.06	1.28	1.01	0.56
1897	0.73	1.16	0.50	0.30	0.00	Tr.	0.00	Tr.	Tr.	0.48	0.13	0.25
1898	0.17	0.49	0.30	0.00	0.74	0.00	0.00	0.00	1.12	0.03	0.34	0.32
1899	0.84	0.02	0.99	0.31	0.06	0.60	0.00	0.00	0.00	0.85	0.72	0.36

Monthly precipitation, greatest and least.

Month.	Year.	Precipitation.	Month.	Year.	Precipitation.
		Inches.			*Inches.*
January	1895	4.14	January	1889	0.34
February	1884	4.35	February	1885	0.00
March	1893	4.22	March	1887	0.17
April	1884	3.42	April	1898	0.00
May	1883	1.69	May	1897	0.00
June	1894	1.16	June	Many years.	0.00
July	1896	0.07	July	Many years.	0.00
August	1896	0.15	August	Many years.	0.00
September	1890	1.26	September	Many years.	0.00
October	1889	3.17	October	1890	0.00
November	1885	9.54	November	1884	0.08
December	1894	4.09	December	1882	0.42

The rainfall varies greatly in different places in the valley. In a general way the rainfall is less as one goes south or west from Fresno. Rainfall records for a number of stations are shown in the following table:

Rainfall in San Joaquin Valley.

	Precipitation.		Precipitation.
NORTH AND SOUTH.	*Inches.*	EAST AND WEST.	*Inches.*
Stockton	15.54	Mendota	5.41
Merced	10.19	Fresno	10.12
Fresno	10.12	Pollasky	11.90
Kingsburg	8.70	Huron	4.92
Tulare	7.40	Kingsburg	8.70
Bakersfield	3.58	Sanger	10.32

The records show a variation from 3.5 inches at the south end of the valley to 15.5 inches at the north end. The two lines across the valley show a variation from 5.4 to 11.9 and 4.9 to 10.3 inches in going from the west side to the eastern edge of the east side near the foothills. There is a rapid increase of rainfall as one ascends the Sierra Nevadas. There are no records from mountain stations in Fresno County, but records collected along the line of the Central Pacific Railroad from Sacramento eastward across the mountains show a gain of 1 inch in rainfall for every 85 feet in elevation up to an elevation of about 3,500 feet. Above this elevation there is no increase in rainfall as the mountains are ascended. In fact, from the observations available the rainfall lessens above 3,500 feet in elevation.

On the east side of the mountains the rainfall is much less than on the west side. Truckee, at an elevation of 5,800 feet, receives a rainfall of 27 inches, while Cisco, on the west side, at an elevation of 5,000 feet, receives a rainfall of 48 inches.

The evaporation records are few in number; the only complete data are four years' records from Kingsburg by the California State engineers.[1]

Evaporation at Kingsburg.

Month.	1881-82.		1882-83.		1883-84.		1885-86.		Average.	
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
November	2.64	4.02	1.38	1.20	2.04	1.68	2.40	1.44	2.11	2.09
December	.60	1.44	1.02	1.08	.96	.78	2.16	1.68	1.19	1.24
January	1.08	2.40	.72	.48	1.26	.90	.12	.12	.79	.97
February	1.38	1.26	1.20	.84	.60	.72	1.68	1.56	1.21	1.09
March	2.16	3.18	3.66	3.72	1.08	1.26	2.88	2.64	2.45	2.71
April	3.12	5.22	3.24	3.12	1.92	2.16	1.92	3.24	2.56	3.43
May	3.66	10.02	1.92	3.72	3.84	4.80	4.08	7.92	3.37	6.61
June	5.70	11.28	6.00	10.20	3.56	6.06	7.92	9.72	5.80	9.31
July	7.92	12.90	9.12	11.64	4.56	8.05	8.52	10.80	7.53	10.85
August	7.98	10.50	11.04	11.64	4.44	8.04	11.16	11.16	8.65	10.34
September	5.70	6.90	8.76	8.46	3.84	6.24	7.68	7.92	6.48	7.38
October	1.62	2.34	4.80	3.48	4.20	3.72	5.64	4.32	4.07	3.47
Year	43.56	71.46	52.86	59.58	32.28	44.40	56.16	62.52	46.21	59.49

The number of clear days, cloudy days, rainy days, and fogs are shown in the following tables. The months of August and September, during which raisins are being dried, are seen to be very clear. During the winter months fogs are frequent, keeping down the evaporation from the soil.

Clear, cloudy, and rainy days, by months.

Month.	Average number of—				Month.	Average number of—			
	Clear days.	Partly cloudy days.	Cloudy days.	Rainy days.		Clear days.	Partly cloudy days.	Cloudy days.	Rainy days.
January	9	8	14	8	August	25	6	0	0
February	15	7	6	6	September	25	3	2	1
March	13	10	8	8	October	20	7	4	3
April	19	8	3	3	November	17	7	6	4
May	21	7	3	3	December	9	9	13	9
June	26	3	1	1	Annual	230	76	59	44
July	29	2	0	0					

Foggy days in twelve years, by months.

Month.	Total foggy days.	Average.	Month.	Total foggy days.	Average.
January	144	12	July	0	0
February	44	4	August	1	0
March	25	2	September	4	0
April	3	0	October	15	1
May	0	0	November	75	6
June	0	0	December	160	13

[1] Physical Data of California.

GEOLOGY AND TOPOGRAPHY.

Fresno County is naturally subdivided into two portions—plains and mountains.

The plains are the bottom of the San Joaquin Valley extending from the foot of the coast range on the west to the foothills of the Sierra Nevada on the east. The trough of the valley south of Fresno has an elevation of 180 feet, Fresno has an elevation of 290 feet, and the valley, at the edge of the foothills, has an elevation of about 500 feet. The distance from the slough in the lowest part of the valley to the foothills is about 35 miles, so that the average slope is about 9 feet per mile. The greater part of this fall is between Fresno and the foothills, for the average maximum fall from Fresno to the sloughs is only 5 feet per mile.

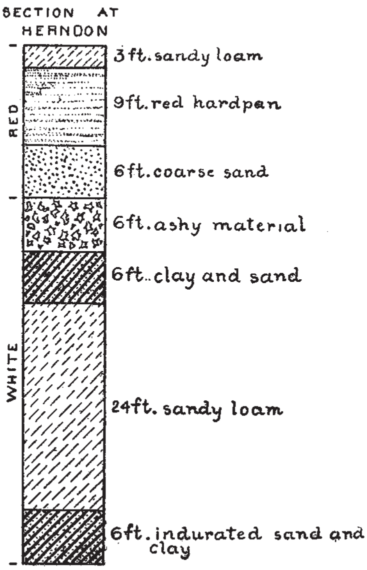


FIG. 36.—Section of bluff at Herndon, Cal.

The maximum slope is southwest, about at right angles to the main line of the Southern Pacific Railroad.

From the first foothills the rise is rapid, the mountains culminating in peaks 10,000 to 12,000 feet high. Mount Whitney, a little to the south, is the highest mountain in the United States—about 15,000 feet.

The plains are the débris from the wearing down of the mountains on both sides of the valley, but, since the eastern mountains are much higher, have a greater run-off of water, and larger drainage area, the portion of the valley which is shown on the map is entirely débris from the Sierra Nevadas.

The plains are formed of well-stratified deposits—clays, sands, gravels, volcanic ash, and sandstone—laid down under water at some time when the portion of California now included in the Great Valley was lower in elevation than at present and was an arm of the Pacific Ocean.

Typical sections of the valley deposits are exposed in the bluffs along the San Joaquin River and along the Kings River and in wells in the plain portion of the valley.

Two geologic sections are shown in figs. 36 and 37. At Herndon a vertical section of the bluff shows 18 feet of the red material from which the San Joaquin sandy loam has been derived. The soil of 3 feet in depth is underlaid by a red sandstone, which, from its presence immediately below the surface, is called hardpan. This hardpan is an indurated sand in which the cementing material is hydrate of iron and silica. Below this sandstone is found a bed of coarse red sand 6 feet in depth. Underlying the sandstone is a bed of volcanic ash 6 feet thick, and this in turn is underlaid by sandy loams, clays, and ashy material as deep as exposed in the bluffs.

At Lanes bridge, 11 miles north from Fresno, the red materials are much thicker, there being two distinct strata of the red sandstone. As at Herndon, the red materials are underlaid by the white ashy materials. On going farther up the San Joaquin, beds of gravel are encountered on top of the red sandstone. In some exposures these gravels are pumice, so light as to float when dry. Following the river still farther up, the gravel is found overlying the granite foothills, and upon the gravel is a basaltic table-land, sloping southwest at the rate of about 100 feet per mile.

A section along this line is shown in fig. 38 and another along a different line in fig. 39. The white formation is seen to be the lowest exposed strata. This is overlaid by the red formation, and in the foothills, with a few remnants out in the valley, is found the basaltic table-land.

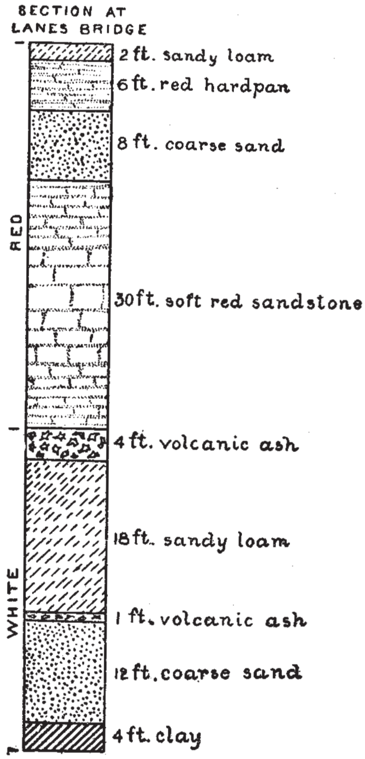


FIG. 37.—Section of bluff at Lanes Bridge, Cal.

The material comprising the red soils north of Fresno is intimately connected with the basaltic lava flow. The sandstones, as far as can

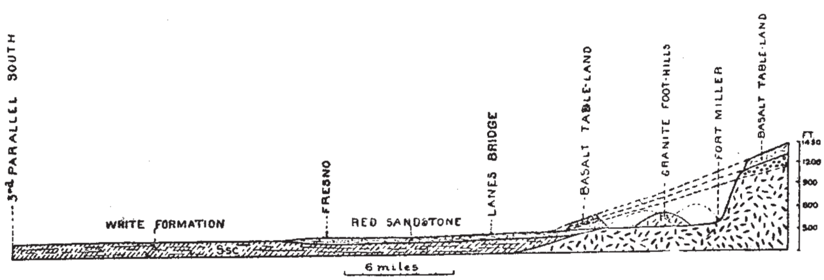


FIG. 38.—Section north and south through Fresno, across Fresno sheet to San Joaquin River at Lanes Bridge, thence northeast to foothills.

be judged from microscopic examination, were formed from the breaking down of basaltic and granitic material.

The presence of the iron in the basalt and the presence of iron in the red soils indicates a relation between these two materials, since there is no other rock from which the iron could have originated in such quantities. This basalt table-land undoubtedly extended over a much larger area than is at present covered, for remnants of the table are seen far out in the valley northwest from Millerton.

Underlying this red material are strata of white sands, loams, and clays, interstratified with volcanic ash. In places the ash becomes coarse in texture and there are exposed in the portions near the foothills gravel banks composed entirely of pumice.

These materials are well stratified and were laid down in deep water. Everywhere throughout the exposures alkali salts are found associated with the white strata in the unconsolidated material or in the white or bluish lime-magnesian hardpan which is found interstratified with the sands and volcanic ash. This is in contrast with the red strata, which are everywhere free from alkali salts. If the red materials ever contained alkali salts this has all been removed by water. The soils formed from these two formations resemble the original material

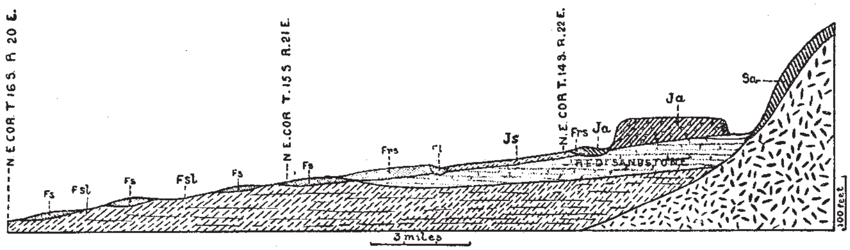


FIG. 39.—Section from foothills in northeast corner of Fresno sheet, SW. to NE. corner T. 16 S., R. 20 E.: *Fs*, Fresno sand; *Fsl*, Fresno sandy loam; *Frs*, Fresno red sand; *Fl*, Fancher sandy loam; *Js*, San Joaquin sandy loam; *Ja*, San Joaquin black adobe; *Sa*, Sierra adobe.

in this respect; the red soils are free from alkali salts and the white soils always carry alkali salts immediately at the surface or else buried at a shallow depth. These alkali salts are held by the lime-magnesian hardpan, the formation of which will be discussed later.

SOILS.

The soils have about the following area:

Areas of the different soils.

Soil.	Area.	Per cent total area.	Soil.	Area.	Per cent total area.
	Acres.			*Acres.*	
Fresno sand	163,200	40.6	San Joaquin red adobe	12,691	3.1
San Joaquin sandy loam	74,547	18.6	San Joaquin black adobe	5,664	1.4
Fresno sandy loam	69,811	17.4	Meadow	5,478	1.3
Fresno red sand	43,776	10.9	River wash	480	.1
Sierra adobe	13,376	3.3	Total	401,855	
Fancher sandy loam	12,832	3.2			

Three main physiographic and four natural soil divisions have been recognized: The foothill region, where agriculture is confined largely to grazing; the plains of the valley, with subdivisions (first, the red soils derived from the red formation and, second, the white soils derived from the sands and volcanic ash of the white formation), and the bottoms or alluvial lands along the Kings River.

Sierra Nevada Foothill Soils.

The classification of the soils as foothill soils is in name purely physiographic, though there is a physical difference in the soils themselves which warrants their separation as a class. The foothills are granitic, though the character of the granite changes greatly, and occasionally we have intrusions of volcanic material, which in many ways change the aspects of the soils. The agents which have acted in the weathering of these rocks also have caused differences. Of these agents in the higher mountains, insolation, or the action of the sun's rays on the rocks, and the grinding action of glacial ice are the most prominent. Glaciation has not extended to the lower foothills, as far as has been observed.

The action of water has caused the greatest part of the breaking down of the granites. The upper 2 or 3 feet are very thoroughly disintegrated with the formation of the surface soil of red adobe. Where this adobe material has been washed down into the valley along the stream courses patches of heavy brown or black adobe are frequently found, resulting from the growth of swamp vegetation in the normal foothill adobe.

SIERRA ADOBE.

By this title, "Sierra adobe," is designated the normal product of the weathering of the granite rocks of the foothills. The granite rock, yielding to the various weathering factors, slowly disintegrates and decomposes, the more easily attacked minerals giving way first. The result is a sandy loam filled with coarse sand grains and particles of rock in a half-decomposed state. These particles yield still more to the weather and there results an adobe with coarse sands and partially decomposed mineral fragments. This soil presents very markedly the characteristics of an adobe soil; that is, it is very sticky when wet, dries hard, and cracks badly. There is nothing in the mechanical composition which would indicate the peculiar adobe properties which are found, therefore it is reasonable to assume that this property is due to some peculiarity of the soil grains themselves rather than a property induced by any peculiar size of the soil grains or an arrangement of the grains. Analyses of soils similar in origin to this soil, published by Hilgard, show relative large quantities of soluble silica, alumina, and iron. This would indicate silicates which are easily decomposed or rendered soluble, and it may be these unstable silicates, in taking up and giving off the water of the soil, so change their character as to give the soil its adobe properties. The term "adobe" does not of necessity imply a soil which carries a large percentage of clay, but it does imply a soil in which that clay is of such a character as to absorb water and swell when moistened, and to dry hard, shrink, and crack when dried.

A mechanical analysis of an average sample of this Sierra adobe is shown in the following table:

Mechanical analysis of Sierra adobe.

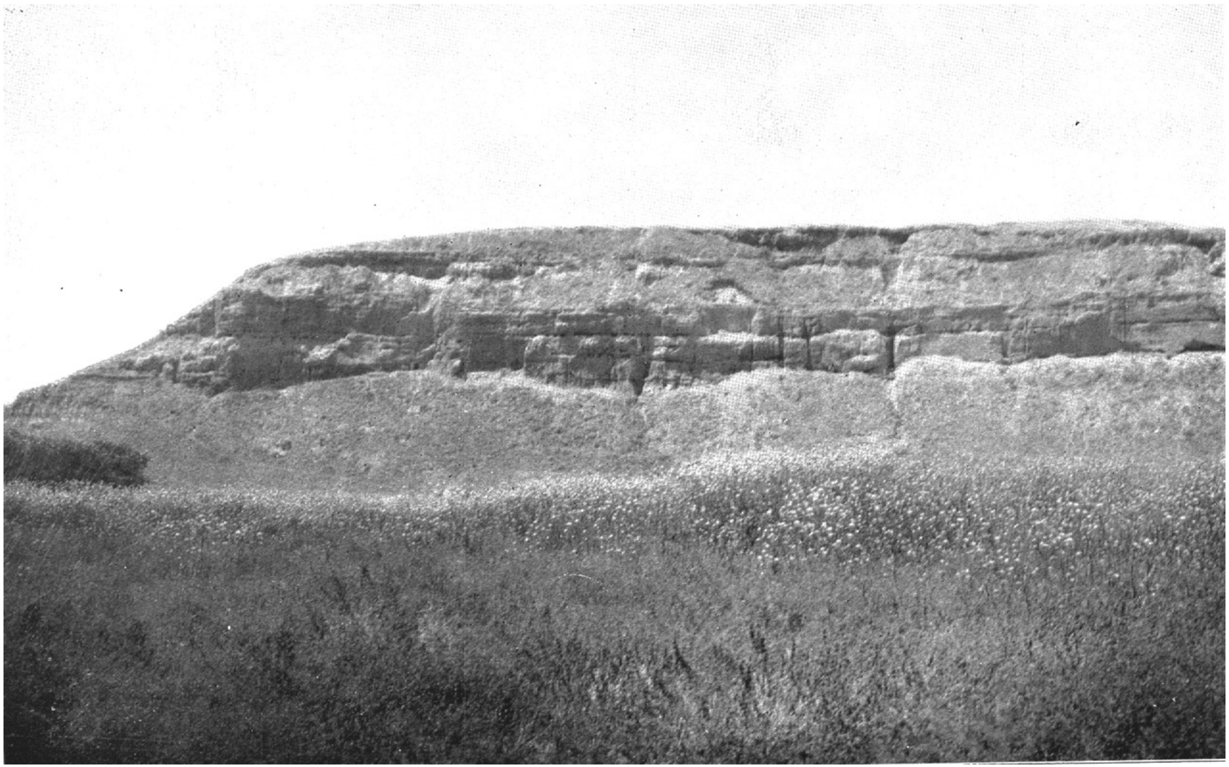
No.	Locality.	Depth.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4861	Sec. 5, T. 13 S., R. 23 E.	0 to 12 inches	2.79	2.80	3.14	7.16	24.50	31.10	19.65	8.82

This soil in the field possesses the properties of a much heavier soil than would be indicated by consideration of the mechanical analysis alone. The simple mechanical analysis indicates a sandy loam such as would result in normal weathering of a granite under humid conditions. However, the peculiar type of weathering produced by the climate of the Pacific coast results in the formation of a soil very different from a sandy loam in character. The reason for this peculiar type of weathering is not well understood at present.

The foothills in this portion of the San Joaquin Valley are not extensively farmed. The rainfall is insufficient to produce crops every year, and, moreover, the topography does not permit grain farming. The foothills are usually steep (up to 30-degree slope) and well rounded. Along the lower hills, when the soil has been carried out on the plains, this same type of soil is farmed successfully and dry grain in normal years produces a profitable yield.

SAN JOAQUIN BLACK ADOBE.

Whenever the Sierra adobe is washed down along the foothill stream courses, and serves as a soil for tule and other swamp vegetation, certain changes take place in the physical and chemical properties of the soil. The soil becomes brown to black by the incorporation of organic matter, and there is usually more complete disintegration of the mineral fragments and an increase in clay content at the expense of the coarser particles. This adobe assumes nearly the characters of the true black valley adobe of the slough country near the axis of the valley. Since it is an alluvial soil it is deeper than the Sierra adobe and often attains a depth of 6 to 8 feet.



RED SANDSTONE BLUFF ALONG SAN JOAQUIN RIVER ABOVE LANES BRIDGE.

This sandstone forms the hardpan which underlies the lands north of Fresno.

BLUFF OF WHITE FORMATION AT LANES BRIDGE ON THE SAN JOAQUIN RIVER.

This formation consists of white sands, sandy loams, and volcanic ash, interstratified with soft lime-magnesium hardpan, and always contains white and black alkali.

The mechanical analysis of this soil is given in the following table:

Mechanical analysis of San Joaquin black adobe.

No.	Locality.	Depth.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4854	Sec. 3, T. 13 S., R. 22 E.	0 to 24 inches	6.27	1.70	2.18	7.36	11.38	22.27	33.88	14.25

In some localities this soil is known as a "dry-bog" soil. This peculiarity is due to the property which the soil has of shrinking as it dries and cracking up into irregular-shaped grains. These grains vary in size from that of a small grain of sand to an inch in diameter. The soil is light in weight, and in walking over this loosely cracked material one sinks to a depth of several inches each step. This has given rise to the name of "dry bog."

A second phase of this soil occurs in one area on the map. This area is a remnant of an old delta from Kings River. The soil occupies the mesa directly north of Centerville. The mesa is from 30 to 50 feet higher than the plain of the valley immediately surrounding it. The soil is very dense and black and exceedingly stiff when dry. Throughout the surface soil are found occasional large gravel and at a depth of 3 to 4 feet the gravel is abundant.

The following mechanical analysis shows this phase of the soil to carry about twice as much clay as the Sierra adobe and about 10 per cent more clay than the normal black adobe, yet it does not indicate the stiffness and tenacity which were found in the field:

Mechanical analysis of second phase San Joaquin black adobe.

No.	Locality.	Depth.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4856	Sec. 29, T. 13 S., R. 23 E	0 to 18 inches	3.76	0.70	2.40	4.48	8.78	13.88	46.06	24.42

This one area in places assumes a dry-bog character, as does the normal San Joaquin black adobe.

The area is farmed exclusively to dry grain without irrigation, since from its position water can not be obtained for irrigation except by very expensive works or by pumping.

In the recent extensive progress in citrus-tree cultivation along the foothill border in the San Joaquin Valley this black-adobe soil has been selected as one of the most favorable soils for orange trees. The orchards are yet young and the best soils for orange culture is largely a matter for experiment, but if the experience of southern California is a guide, these soils are adapted to such culture. As dry-grain soils they are not so successful, since the cracking of the surface permits such rapid evaporation of the moisture that grains do not have sufficient time to develop before the soil dries out. This criticism, however, does not apply to a crop which can be cultivated, for this cracking is largely prevented by cultivation.

RED FORMATION SOILS.

Under this head are included the soils derived from the red sandstone formation, which has been described. The red sandstone formation, which has been called the red formation for convenience, is believed to have been formed from the mixed granitic and basaltic débris from the mountains, and the soils are of the same origin.

FRESNO RED SAND.

The Fresno red sand, which is the lightest product of the weathering of this formation, occupies ridges and plains between the foothill creeks which leave the mountains north and east of Fresno.

The soil is very light and porous, deep generally, and uniform in character, to a depth of 6 feet. The results of mechanical analyses are shown in the following table.

Mechanical analyses of Fresno red sand.

No.	Locality.	Depth.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4699	S. 27, T. 13 S., R. 20 E.	0 to 24 inches	2.11	10.13	13.20	32.75	26.72	9.90	3.82	1.35
4702	S. 32, T. 13 S., R. 20 E.	.....do	1.15	Tr.	11.82	40.38	35.69	6.70	1.99	1.69
4823	S. 4, T. 14 S., R. 21 E.	Clod	2.20	.74	11.96	26.68	27.02	13.06	12.28	5.17
4691	S. 31, T. 13 S., R. 20 E.	0 to 36 inches	2.26	6.47	14.55	16.44	21.35	21.12	10.24	7.26
3396	S. 3, T. 14 S., R. 21 E.	0 to 24 inches	2.03	.24	5.12	20.96	41.39	18.11	4.97	7.50

The mechanical analyses show the soil to be very light in texture. Fine sand is the predominating grade, with small quantities of very fine sand, silt and clay on one side and rather large quantities of

GANG PLOW PREPARING LAND FOR WHEAT UNDER DRY FARMING, SAN JOAQUIN SANDY LOAM.

medium sand and gravel on the other side. Such a texture indicates a very open, porous soil, one in which the natural drainage is good. Such is found to be the case in the field. The soil occupies ridges where it is deep and well drained by the beds of the foothill streams.

No chemical analyses of this soil are available, though from the field observations some facts can be gleaned. The soil is apparently well off in plant foods, with the exception of nitrogen. As in all of the plains soils around Fresno, this important plant food is not abundant.

The soil is in a well decomposed condition, that is, the soil grains are soft and easily crushed, and even though in some cases presenting apparently fresh mineral fragments, these fragments are rapidly breaking down. This decomposition undoubtedly renders available all of the plant food for the crops grown at the present time.

This soil originated in the granitic and volcanic rocks in the mountains to the eastward. The disintegrated materials were swept down to the plains of the valley by the foothill streams. These streams have built up sandy banks of red sand, and this has been still further distributed by the winds. At present the sands occupy low ridges running northeast to southwest, principally along the south sides of the foothill streams.

Fruit crops generally are grown on this soil with success. Large areas of raisin grapes are located upon it north, east, and west of Fresno, and though the soil can not be considered to be the best grape soil in the country, yet good results are obtained from its cultivation. The elevated position adapts the soil to such fruits as require specially good drainage. Figs, peaches, apricots, nectarines, plums, and prunes are the fruits best adapted to this soil, and they can be recommended in the order named. Grain is not as successful as on heavier soils, but melons of all kinds thrive and produce abundantly. North of Fresno large fields are planted in watermelons and the product shipped to the cities. The trucking industry, which is not great and which is confined to supplying the local markets, is largely located on this soil.

This light character makes cultivation easy, but the porosity of the soil renders irrigation difficult. Irrigating canals and laterals passing over areas of this soil lose large quantities of water through seepage. This water is not only lost to all good, but it is a serious menace to lands lying in the lower parts of the valley. Also in irrigating much larger quantities of water are used in flooding these porous sands than are necessary to the life of the growing crops. All this excess of water accumulates in the deeper subsoil, and runs underground to raise and make swampy some lower soil.

The irrigation of such a soil should be in small lands or small checks. Wherever furrow irrigation is possible, and in the growing of fruit crops it is always possible, this soil should be watered by the furrow method. Short furrows in which the water runs only a few hours are much perferable to long furrows requiring several days to irrigate. Ditches, laterals, and canals should all be protected from leakage. It is believed that over one-half of the water applied to this soil is lost by seepage. If this water were saved, twice as great an area could be covered with the present supply of water, and, moreover, none of the leaching away of plant food would result and the harm to the lower lands from seepage waters would be obviated.

This soil never carries alkali salts in sufficient quantity to be harmful to vegetation.

SAN JOAQUIN SANDY LOAM.

The San Joaquin sandy loam occupies great areas of land north, northwest, northeast, and east of Fresno. The soil as typically developed is seen on the "hog-wallow" lands which are found between Fresno and the San Joaquin River at Herndon. When the foothill streams are approached the same character of soil is formed by the intermixing of the Fancher sandy loam of the creek bottoms and the Fresno red sand of the ridges.

In its mechanical composition, as shown in the following analyses, the soil does not differ greatly from the red sand. The lighter phases show 5 to 6 per cent clay, and by uniform gradation the clay content increases to 14 per cent in the heavier phases. An average soil carries from 9 to 10 per cent clay.

Mechanical analyses of San Joaquin sandy loam.

No.	Locality.	Depth.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4697	Sec. 4, T. 13 S., R. 19 E.	0 to 24 inches	1.77	7.59	11.30	19.26	21.01	22.60	10.33	5.94
4695	Sec. 29, T. 13 S., R. 19 E	do	1.59	12.47	15.53	14.40	12.31	22.33	13.15	7.22
4696	Sec. 10, T. 13 S., R. 19 E	do	1.81	10.22	12.95	14.18	13.98	25.51	12.55	7.95
4703	Sec. 1, T. 13 S., R. 19 E.	do	3.00	1.58	3.59	5.45	7.85	44.14	25.52	8.34
4705	Sec. 9, T. 13 S., R. 20 E.	0 to 6 inches	3.66	2.87	5.80	7.80	13.03	32.06	24.77	10.13
79c	Sec. 12, T. 14 S., R. 20 E	0 to 24 inches	2.74	1.29	4.34	13.70	22.89	19.45	25.01	10.24
327	Sec. 4, T. 14 S., R. 21 E.	do	4.86	.60	2.99	9.05	15.70	26.04	31.06	11.00
3394	Sec. 3, T. 14 S., R. 21 E.	0 to 36 inches	4.13	.43	3.40	16.14	30.95	15.90	14.30	14.60

This mechanical composition indicates a light sandy loam soil of easy tillage and drainage. In this case, as in many other soils of the western districts studied, the mechanical composition does not show the true properties of the soil. It has in a measure true adobe properties, and when dry is very hard and difficult of cultivation. This property is particularly true of the hog-wallow lands. Here, when dried, toward the latter part of the dry season, the soils are exceedingly hard; clods plowed up in the fields remain hard and unpulverized even after careful cultivation. Just the reason of this hardening is a problem yet to be solved, though it is deemed possible that the explanation will be found in the easily decomposed silicates, which are so abundant in soils of this adobe-like class.

This soil originated much in the same way as the red sand soil, except that the greater part of its area is much older than the red sands. The larger areas are sedentary soils derived from the weathering of the red sandstone of the red formation, which underlies the soils; but since this red formation is to be regarded as wash from the mountains the soils have the same ultimate origin. Thus, the chemical and mineralogical properties of the soils should be the same. The sandy loam, however, being more finely divided, has suffered greater weathering than the sand, and in this regard should have more plant food in an available form.

Large areas of this soil are underlaid by the red sandstone hardpan. In such areas only unirrigated grain crops are grown. Wherever the hardpan is below 2 feet in depth the grain crops are fair or good; but where the hardpan approaches the surface nearer than 2 feet very little profit is obtained from the cultivation of the soil in any crop. This is seen in the cultivation of the hog-wallow lands, for on the top of the hog-wallow mounds, where the soil is usually deeper than between the mounds, the crops grow and mature grain, but between the mounds, where the soil is shallow, the crops in the early spring start well, but the shallow soil soon dries out, and before the grain matures the moisture from the soil all evaporates and the grain suffers or dies.

On the deeper soils fruit crops are grown with great success. Wherever the soil is well drained the same recommendations can be made as were made for the Fresno red sand soil, but when the land is low lying and wet drainage is necessary before fruit produces the best results. In several areas northeast from Fresno drainage is found to be necessary for fruit lands.

The areas of shallow depth to hardpan on this soil cover large extents of land which otherwise would be very valuable. No cheap or easy method of removing this hardpan has been devised, and this is one of the most serious and difficult problems of the country. A more complete discussion of the hardpans will be found later in this report.

No large areas of alkali lands are found in this soil. This is to be expected from what has been said of the alkali in the red formations from which it is derived.

FANCHER SANDY LOAM.

Along the foothill streams and around the sinks where these streams disappear in normal flow are found areas of a heavier sandy loam, in some cases approaching a loam in texture. These soils occupy the low-lying tracts along the streams between the ridges of Fresno red sand. Since Fancher Creek has produced the most typical areas of this soil the name Fancher sandy loam has been adopted.

The mechanical analyses following show this soil to be only a little heavier than the San Joaquin sandy loam; it contains 11 per cent of clay as compared with 9 per cent in the San Joaquin sandy loam. The difference in texture is not so much due to the difference in the amount of clay as the difference in the amounts of silt and very fine sand, both of which are greater in the Fancher sandy loam.

Mechanical analyses of Fancher sandy loam.

No.	Locality.	Depth.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4830	Sec. 17, T. 14 S., R. 19 E.	0 to 24 inches	2.62	1.30	1.58	3.74	29.06	34.80	18.76	7.97
4824	Sec. 5, T. 14 S., R. 21 E.	do	3.41	.91	2.32	7.72	16.68	31.98	28.16	9.01
4845	Sec. 8, T. 14 S., R. 21 E.	do	3.22	Tr.	2.75	19.99	28.46	19.51	16.86	9.55
4841	Sec. 25, T. 14 S., R. 18 E.	0 to 12 inches	4.34		2.18	8.12	24.52	19.60	30.67	10.32
4825	Sec. 21, T. 14 S., R. 20 E.	0 to 24 inches	2.41		1.34	15.10	24.48	22.56	21.39	12.29
4700	Sec. 21, T. 13 S., R. 20 E.	do	3.83	3.99	10.57	14.20	12.66	17.43	21.24	15.87

This soil is considered to be of the same origin as the two red soils of the San Joaquin formation, which have been previously described. It is, however, directly the result of stream depositions, and for that reason carries small quantities of gravel and coarse sand. The soil areas are found along the flood courses of the foothill streams. Dry Creek, Dog Creek, Red Bank Creek, Fancher Creek, all have areas of this soil along their courses. The soil deposited by Dry Creek is typically a red, fine-grained, micaceous sandy loam of great depth. Fancher Creek deposits a soil of a heavier type, darker in color and with less mica.

Since the soil is further weathered than either of the red soils described, the plant foods should be in a more available form. The soils contain more organic matter than do the other soils of the valley, and in this way perhaps are richer in nitrogen.

This soil is the best soil for grapes found in the Fresno sheet. Large and excellent vineyards are located on it. This soil has been examined by Hilgard, chemically, and at the World's Fair at Chicago, in 1893, a section of this soil was exhibited as a typical raisin-grape soil.

The soil is deep, generally more than 6 feet, and is easily drained. Some of the areas suffer from nearness of underground water so much that drainage has been found necessary. The soil, however, is so

HEADING GRAIN ON SMALL TRACTS. GROWN WITHOUT IRRIGATION.

HARVESTING GRAIN WITH COMBINED HARVESTER AND THRASHER ON LARGE TRACTS. GRAIN GROWN WITHOUT IRRIGATION.

porous that tile drains every three or four hundred feet are all that have been required.

No alkali areas of great size have been found in this soil with the exception of the area in the south half of T. 14 S., R. 19 E. There the soil has been pushed out across an area of alkali soil, and the alkali salts have raised in the Fancher sandy loam so as to render part of it barren. Small areas of alkali, mere spots, seldom as large as an acre, have been found along the old streams and sinks east from Fresno. These spots are not getting larger; in fact, an examination of the land around them shows no alkali in the subsoil which would make them grow larger. Such spots are merely local accumulations of alkali from the prolonged subirrigation of that particular spot of ground. Constant subirrigation, even if by a good water, will in time result in an accumulation of alkali at the surface of the ground, and since it appears that alkali salts move up much faster than they move down subirrigation leads to accumulation of the salts at the surface very rapidly.

There is no reason to fear that these spots in the Fancher sandy loam will spread or that there will be new spots formed in fields which at present are free from alkali salts. A careful study of the conditions warrants the prediction that as long as the water surface is kept down to its present level no more damage will result.

SAN JOAQUIN RED ADOBE.

In the northeastern corner of the map, along the margin of the foothills and extending for 5 or 6 miles along the ridges between the foothill creeks, are areas of a bright, red soil which has been called San Joaquin red adobe upon the soil map. Red Bank Creek receives its name from the exposures of this bright red soil along the banks.

Mechanical analyses following show very little difference between this soil and the Fancher sandy loam. In fact the average of the six samples of sandy loam is so nearly like the average of three analyses of the adobe that the differences are all within the limit of error of the method of analysis.

Mechanical analyses of San Joaquin red adobe.

No.	Locality.	Depth.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4846	S. 22, T. 13 S., R. 22 E.	0 to 12 inches	2.29	0.97	5.01	12.65	23.29	21.71	24.83	10.05
4848	S. 23, T. 13 S., R. 22 E.	do	2.65	1.56	3.66	10.52	23.80	26.04	21.10	10.48
4850	S. 22, T. 13 S., R. 22 E.	do	3.03	.70	4.90	13.16	22.34	18.78	25.90	11.18
4851	Subsoil of 4850	12 to 24 inches	3.07	Tr.	4.17	10.86	18.92	17.36	26.27	18.86

The analyses of these two soils types, the Fancher sandy loam and the San Joaquin red adobe, serve to illustrate the fact that the mechanical analysis alone can not be relied upon to tell the character of the soil in the field. Here we have analyses so nearly the same that the soils might have been taken from the same bottle, and yet in the field these soils are very different in appearance and in action under the plow. There is also another difference which is not brought out in the table, and that is a difference in the subsoil. The Fancher sandy loam is the same to a depth of 6 to 10 feet, while the San Joaquin red adobe becomes heavier below. One analysis of the second foot is given in the table, showing the heavier subsoil. All of the samples, with one exception, were collected to a depth of 12 inches.

This soil originated in the foothill adobe, and is the finer portions of that soil washed down on the plains, and more thoroughly disintegrated. Undoubtedly, the material comprising the grains is the same, the difference being in the degree of comminution.

Very little of this soil has been irrigated. Almost the entire area is planted to grain crops without irrigation. The heavy character of the soil makes it retentive of moisture, and being close to the foothills the soil receives a greater amount of rainfall than do the soils farther out in the valley, hence the grain production is a little greater per acre than in the sand and sandy loams of the red formation.

Should water ever be obtained for this soil, grapes, and in the protected places citrus fruits, would undoubtedly be profitable.

The soil is high. Standing water is far down, generally 30 feet or more, and there is no danger from alkali. Hardpan underlies large areas of this soil, and whenever it approaches the surface of the ground it offers the most serious obstacle to cultivation.

White Formation Soils.

Underlying the red formation and extending to an unknown depth are sands, sandy loams, and volcanic ash interstratified, and frequently containing thin layers of indurated material. The breaking down of this formation, assisted by the washing and distributing action of the streams, has resulted in the formation of the white soils south of Fresno.

FRESNO SAND.

The Fresno sand covers great areas of land south of Fresno, extending from the Kings River westward to the boundary of the map. This area is cut up by strips and areas of the Fresno sandy loam. The area is a uniform sloping plain, with shallow depressions and drains following the same general trend as the strips of sandy loam. As a rule, the sandy loam strips are lower lying than the sand soils, they having the same relation to the sand soil as do the red sandy loams to the red sand.

Typically, the soil is a loose white sand with no coherence. When plowed or cultivated the surface breaks up on drying to a deep, loose mulch, as there is not enough clay to bind the grains together. Along Kings River for a distance of 2 or 3 miles from the river the white sand is a little heavier in texture and soft clods form on plowing. These, however, are so soft that they easily break up.

Mechanical analyses are given in the following table:

Mechanical analyses of Fresno sand.

No.	Locality.	Depth.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4874	S. 11, T. 15 S., R. 22 E.	0 to 24 inches	.82	1.98	14.10	32.70	26.60	16.24	5.10	1.94
4887	S. 27, T. 16 S., R. 22 E.	do	1.21	.90	15.68	30.92	22.30	17.86	8.10	2.91
4875	S. 28, T. 15 S., R. 23 E.	do	.86	......	3.68	11.66	28.36	37.72	14.99	3.16
328	Central Colony		1.30	1.56	22.96	26.19	14.96	17.33	12.91	3.60
4884	S. 32, T. 15 S., R. 22 E.	0 to 24 inches	1.01	......	2.44	14.92	25.88	26.94	23.43	5.62

This soil in mechanical analysis is not far different from the Fresno red sand. The red sand carries a slightly greater amount of clay, but the white sand carries more of the silt and very fine sand, so that the texture alone would indicate a very little difference. In the field, however, there is found considerable difference both in appearance and in working properties. The white sand never becomes compact or hard, does not bake or crack upon drying, and never plows up in clods. The red sand, on the other hand, does all of these. Wherever the two soil types adjoin, the difficulty of distinguishing them becomes great, the two soils grade very gradually from one to the other, there being a zone at least a mile wide possessing the properties more or less of both soils.

These white sands ultimately originated in the rocks of the Sierra Nevada Mountains, but directly they have originated in the white formation underlying the strata of the red formation.

Instead of being entirely sedentary soils from the breaking down of this white formation, the soils have been greatly modified by the flood waters from the foothill streams and from Kings River, and particularly along that river have been modified by the sediment of that stream. Since these soils have been laid down, Kings River has cut a deep channel from the point of exit from the foothills to the trough of the valley, and no longer sweeps over the sand soils. There are well-defined channels, however, which, starting in the immediate vicinity of the river, can be traced nearly across the soils, and moreover the arrangement of the areas of white sandy loam in this sand show evidence of having been caused by stream action. Wind has played a great part in modifying the conditions which existed when Kings River left the upper plains and cut the deep channel which it occupies at the present. Many of the old channels and drains have filled in with drifted sand and at present are but shallow swales in the plain. Large areas of the white sandy loam have been buried by the drifting sands, and their presence is only known from the records of borings

This soil is typically 6 feet or more deep, there being scarcely an appreciable variation in the texture for the depth. Around the borders of the area and in some low swales a subsoil of white sandy loam is encountered at a depth of 3 to 6 feet.

The drainage of this soil upon the plains is good. It is very porous and permits the ready downward flow of water. In the swales, sinks, and drains very often the ground water approaches the surface and bears enough alkali to cause serious damage to tender crops. A great many of these sinks and drains are filled with water by seepage during the irrigating season, and in the autumn upon turning the water from the canals the water in them promptly lowers and they sometimes dry up completely. The soil in these low places is often seeded to alfalfa where it is not alkaline and where the water never actually comes to the surface. There is more or less uncertainty about such cultivation, since the level of the underground water varies so much during an irrigation season that the alfalfa stands either the chance of being drowned out or of being killed for want of water.

The uplands being well drained are, as a rule, free from harmful quantities of alkali salts within 6 feet of the surface. This is quite contrary to the popular opinion of some areas of the soil. A comparative examination of the alkali and salt maps will show, as a rule, that the white sand is free from harmful quantities of alkali salts. Below the depth of 6 feet, however, in nearly every place examined, this soil carries alkali salts, generally in the white hardpan or in the white sandy loams which underlie the sand. The uplands, however, will never suffer from this alkali if proper precautions are taken. The natural mulch formed by the soil lessens greatly the surface evaporation, and the accumulation of the alkali at the surface is, therefore, not naturally rapid. As long as the subsurface water is not permitted to come close to the surface, there need be little fear of accumulation of alkali. In the swales and drains where the water comes close to the surface alkali salts are likely to accumulate. In a few instances this accumulation has already taken place, but in all of these cases if adequate drainage is supplied this accumulation can be prevented. Wherever the lands have already become alkaline reclamation is possible and easy if an outlet can be found for the water.

A great deal of this sand soil is not irrigated at present, though canals have been dug and over much of it water was once applied.

Years of low water and lawsuits over the right to use water have been the cause of the abandonment of many farms in this soil.

In former years wheat and barley were extensively grown without irrigation. The uncertainty of crops in the dry years and the low yield in normal years have caused a great decrease in this industry, and the area around Caruthers, which once was a great wheat-growing center, is now largely abandoned. This soil is well adapted to some classes of fruit; peaches, nectarines, and apricots do very well. Some of the best peaches seen in the valley were grown in this soil. Wherever it is well drained peaches are a great success, and the reclamation of this arid land and the building up of a great fruit industry waits but the development of an adequate water supply.

FRESNO SANDY LOAM.

This is the soil which is locally known as "white-ash" land. There are great areas of this land southwest and west of Fresno and other areas around Fowler, Selma, and Kingsburg.

The soil lies flat in a perfect position for irrigation in the colony lands south and southwest of Fresno, and was, at the time of the laying out of the colonies, considered the most desirable land for fruit. Around Selma, in the long strips of the soil, it is yet considered a very valuable fruit land. This soil is derived almost entirely from the white loams, sands, and volcanic ash of the white formation. This, from the ashy nature, imparts an ashy feel to the soil and has given rise to the local name. In some places the soil is almost entirely a product from the volcanic ash, and there the ashy nature is very evident. In other places more of the sandy elements are mixed with the soil and the ashy nature in a measure is masked.

The mechanical analyses of this soil follow:

Mechanical analyses of Fresno sandy loam.

No.	Locality.	Depth.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
4831	Sec. 3, T. 15 S., R. 19 E.	0 to 12 inches	2.41	......	0.66	9.98	33.00	33.42	16.25	4.54
4832	Subsoil of 4831	12 to 24 inches	1.36	......	1.38	9.90	36.78	29.90	16.06	4.15
4833	do	24 to 36 inches	1.15	......	1.48	6.08	40.00	33.40	13.48	3.98
4834	do	36 to 48 inches	.95	......	1.12	10.54	36.82	29.53	15.25	5.19
4878	Sec. 23, T. 16 S., R. 21 E.	0 to 12 inches	1.74	......	.78	7.55	30.76	34.72	18.69	5.85
4882	Subsoil 4878	48 to 60 inches	1.84	0.76	.83	3.67	11.39	19.35	49.53	12.07
4683	Sec. 23, T. 15 S., R. 20 E.	0 to 24 inches	2.22	Tr.	.93	3.51	20.28	27.44	21.63	6.18
3400	4 miles SE. of Fresno	0 to 15 inches	2.65	.27	4.29	10.36	15.88	38.11	22.03	6.70
3398	3 miles S. of Fresno	12 to 24 inches	1.68	.18	3.76	7.75	16.86	43.93	19.25	6.73
4826	Sec. 28, T. 14 S., R. 20 E.	0 to 12 inches	1.97	......	1.36	4.92	27.28	25.95	29.78	8.77
4827	Subsoil of 4826	12 to 36 inches	2.11	1.12	1.40	2.26	14.94	39.22	31.85	6.89

The mechanical analyses of this soil show large percentages of fine sand and silt, with about 6 per cent of clay. Such a composition would be interpreted to mean a soil very loamy in character and of great capillary powers. In the field this interpretation is borne out, and in addition to that the soil is found to work well, clods very little, and takes water easily. When puddled, however, water penetrates but slowly, and in such condition when dry the soil forms dense, hard clods.

The subsoil becomes heavier below a depth of 2 feet and, on an average, at a depth of 3 feet bluish clay is encountered. This material is found to be a lime-magnesian hardpan which has been softened by water. In some small areas this material is still hard, but is so disconnected and broken up by the action of water as to be of little obstruction to the growing roots. The analysis of sample 4882 shows the mechanical composition of a sample of the bluish clayey matter. Analyses of the subsoil are given to show the great uniformity of the soil to a depth of 2 feet.

The subsoil clay in the original condition of the soil contained alkali salts, or, in other words, the hardpan is an alkali hardpan.

Irrigation has changed the location of these soluble salts, in some cases washing them down, but more generally causing them to rise. The reasons for and extent of this alkali movement will be discussed in the consideration of the alkali, and the hardpan will be considered later under its proper heading.

Though this was considered very choice soil thirty years ago experience since that time has unquestionably demonstrated that mistakes are very often made in its selection. Nearly the entire area of this soil has to a certain extent suffered from alkali salts, and very much of the land which was once in valuable orchards or vineyards is now seeded down to Bermuda grass for pasturage. The land in good condition was worth $200 an acre. As Bermuda grass pasture it is not worth $25 an acre. This loss of $175 an acre has extended over perhaps a thousand acres of land south of Fresno, and a great deal more land which was originally not so valuable has been damaged. Altogether, upon the area as mapped, there are about 28,500 acres of land which have been so badly damaged by alkali as to be abandoned.

The reclamation of all this alkali land is believed to be possible and profitable. This matter will be discussed in more detail later.

Alluvial Soils.

The term "alluvial" is here used to mean those soils which have been laid down by the rivers in their present condition. No doubt in a strict sense all of the soils are alluvial, since they were laid down by running water, but for the purposes of soil classification the term is confined to those river-bottom soils which are still flooded at times of very high water, or bear evidences of very recent flooding. Two types of this character of soils were recognized and mapped.

MEADOW.

The meadows, as they have been called, include the bottoms of the Kings River so far as they were mapped. The soil is the sediment dropped by the river waters in flood and in part the material cut down from the banks, sorted over and laid down again.

The soil is a fine-grained micaceous sandy loam, with little true clayey matter and very little coarse sand or gravel. Analyses of three typical samples are shown in the table:

Mechanical analyses of meadow.

No.	Locality.	Depth.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4864	Sec. 30, T. 14 S., R. 23 E	0 to 24 inches	4.22	......	Tr.	1.26	10.94	51.70	27.78	3.86
4871	Sec. 24, T. 14 S., R. 23 E	....do	5.09	......	0.82	2.50	10.61	42.50	32.60	5.03
4888	Sec. 9, T. 17 S., R. 22 E.	....do	3.90	......	.10	1.82	8.82	43.74	34.20	7.08

The samples are given in the order of their deposition, Nos. 4864 and 4871 being near Sanger, and No. 4888 being about 4 miles south of Kingsburg. The last sample contains more clay than do the others, as would be expected, since it has been carried farther.

This soil lies low, water is found at an average depth of about 3 feet, and in cases of very high floods most of the land is flooded. A greater part of the area is given over to pasture, but below Sanger there are some fine truck farms, orchards, and large fields in corn.

The native vegetation is rather dense and the expense of clearing the land is great, but the class of crops adapted to the conditions are profitable and warrant the expense. Along the foot of the bluffs in the west side the seepage water from the irrigated plains above has subirrigated a narrow strip of land and in spots alkali has accumulated. This is easily drained away if the proper outlet for the water be supplied.

RIVER WASH.

The area of this soil comprises a narrow draw southwest from Herndon, in the northwest corner of the map. The draw heads in the San Joaquin River at Herndon, and is an old channel of that river which has been abandoned owing to the cutting down of the present channel below the mouth of the old one. The area is so small that there are no special uses to which it has been put, but it is farmed with the surrounding soils.

The mechanical analysis following shows the soil to be a coarse gravel and sand with not enough clay to render it plastic:

Mechanical analysis of river wash.

No.	Locality.	Depth.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4698	Sec. 7, T. 13 S., R. 19 E.	0 to 12 inches	1.23	6.50	13.84	10.90	21.14	32.64	10.55	2.92

SOIL MAP.

The areas occupied by the above soils have been indicated by colors upon the map which accompanies this report. Upon the side of the map an average section of the soil to a depth of 6 feet is given.

HARDPAN.

Hardpan is a very prominent feature of the lands in this part of the San Joaquin Valley. The greater part of the land is underlain by hardpan of some kind, though very much of the hardpan is below the zone of rapid root growth, and so does no harm.

Two kinds of hardpan are found, very different in their origin and nature, and at the same time very different in their effect upon the crops grown on the land.

RED HARDPAN.

The most prominent kind of hardpan is a red hardpan. The material is really a red sandstone which lies so close to the surface of the ground as to be called hardpan by the farmers. This material is exposed in the bluffs along the San Joaquin River at Herndon and above. The maximum thickness that has been observed is about 40 feet, though this is not one continuous layer of indurated material. Thin layers of hard sandstone, generally less than a foot thick, alternate with layers of rotten sandstone and loose sand. These layers of hard material are not always continuous, but run gradually into softer material and here and there are broken down altogether.

The cementing material of this hardpan has been found to consist largely of ferric hydrate with some lime carbonate and probably silica. In most cases examined small quantities of lime were extracted from the hardpan. The lime is not considered a necessary feature of the hardpan, since in some samples very little or no lime was found.

RED SANDSTONE HARDPAN IN BOTTOM OF FOWLER SWITCH CANAL.

ABANDONED PEACH ORCHARD ON IRRIGATED LAND WHERE RED HARDPAN IS LESS THAN 2 FEET FROM SURFACE.

Water fails to soften the cementing material. Hot, moderately concentrated hydrochloric acid easily removes the cementing material, causing the hardpan to fall down to sand. Erosion by water is very slow. The bottom of the Fowler's Switch Canal is upon hardpan for long distances; the water of the canal has a high velocity, yet the erosion has not been great.

Wherever this hardpan is less than 3 feet from the surface of the ground the trees or vines which are planted are not able to send their roots as deeply as is necessary for the healthful growth of the plant. Moreover, the hardpan prevents the water from sinking and acts as a shallow evaporating pan in which the rainfall is soon lost into the air by evaporation. Since water does not dissolve the cementing material, the hardpan does not soften after irrigation, hence there is but one remedy—to loosen up the hardpan so that the roots and water can penetrate to lower depths. This loosening can be done by blasting with blasting powder or dynamite. The practice is to dig a pit 3 feet in diameter down to the hardpan, then drill down 2 feet into the hardpan, well tamp a stick or half stick of dynamite, and fire the dynamite before filling the pit. This loosens up the hardpan for a distance of 2 feet around the point at which the plant will be rooted, and gives ample room for the underground development of the roots. Several large vineyards have been treated in this way with apparent success. The hardpan never seems to re-cement after being once loosened up. The cost of this treatment of a vineyard is said to be about $50 per acre. The cost of blasting for orchards would be less, since the number of blasts would be smaller.

The areas of the shallow hardpan, or the areas in which the hardpan is less than 3 feet from the surface of the ground on the average, are shown upon the alkali and hardpan map which accompanies this report. There are about 85,000 acres of land with the hardpan less than 3 feet from the surface. Much of this land, while it is not adapted to fruit growing, raises unirrigated wheat. In fact, the presence of the hardpan, if not extremely shallow, seems to benefit the growth of the wheat, for the hardpan prevents the escape of any of the water from the rainfall by seepage, and thus holds all of the water for the use of the wheat plants. The wheat matures before the hot dry months come on, and thus the plants have advantage of all the moisture before it is evaporated. When the hardpan is less than 18 inches, or 2 feet even, the wheat seems to suffer. This is well shown in the hog-wallow mound country, where wheat can be seen growing upon the tops of the mounds when hardpan is 3 feet down, while in the hollows between the mounds, where the hardpan is a foot or 18 inches down, the soil has dried out and the wheat is dead.

The irregular line drawn across the alkali map shows the southern limit of the red hardpan. All land north of this line can be said to be underlaid at some depth by the red hardpan, and all of the land south of this line is free from the red hardpan. The areas on which hardpan is less than 3 feet from the surface are shown by shading.

WHITE HARDPAN.

South of the line drawn across the alkali-hardpan map the soil is everywhere underlaid by a white hardpan. This material is a true hardpan, since it has been formed in place by the action of water upon the soils overlying the hardpan. Meteoric waters always carry carbonic acid gas in solution, which dissolves the calcium and magnesium carbonates as bicarbonates from the upper layers of the soil. These bicarbonates are washed down as deep as the rainfall penetrates the soil. Here the aeration of the soil, caused by the temperature changes and changes in barometric pressure, slowly carry away the excess of carbonic acid gas and the lime and magnesium are precipitated as carbonates in a coating around the soil grains. The absorption by the soil grains of carbonic acid gas and the carbonates themselves also assists in the deposition of the lime and magnesium. Small amounts of clay from the upper layers of soil are also washed down, and gradually there is formed at the maximum depth of rainfall penetration a more or less clayey hardpan. In the San Joaquin Valley this mode of hardpan formation is modified by the presence of alkali salts within the soil, and to a certain extent, no doubt, the precipitation of the calcium carbonate was caused by the presence of sodium carbonate and bicarbonate. The presence of the large amounts of dissociated acid ions of the sodium salts in a measure drives back the dissociation of the lime salts, and therefore causes the precipitation of the lime upon the soil grains.

Another point of importance in the formation of the hardpan is that the alkali salts accumulate in the hardpan layer. These alkali salts are washed down by the rain water, but since the greater part of the rainfall in the valley is returned to the air by evaporation it would be natural to suppose that the alkali salts would return to the surface of the ground as the waters come back to the surface by capillary action. There are several reasons why the salts accumulate in the subsoil. First of all, more water moves down through a soil than moves up. This is because a small amount of the water at least escapes downward by seepage. In the San Joaquin Valley this is reduced to a minimum, since the rainfall upon the sandy lands is very largely returned to the surface by evaporation. Plants growing upon the surface of the ground draw water up from below without necessarily absorbing all of the salts which the water contains. There is no question but that part of the evaporation from a soil takes place from the lower depths, the water being carried out and up by gaseous diffusion and by convection caused by changes in temperature and pressure. Again, as the soil waters move down the most concentrated water is in the front of the wave of downward-moving water. The first films of water largely dissolve the salts and carry them down, while the water which follows carries the more difficultly soluble salts and the absorbed salts. When this water returns to the surface the more dilute solutions are first evaporated, and the more concentrated salts sometimes remain behind. Then again, the salts in solution in the water undoubtedly form double compounds and easily decomposable but scarcely soluble silicates as a film around the soil grains. In this way part of the salt is retained in the lower depths, but upon the drying out of the soil the silicates are decomposed and the alkalis are again liberated. But by far the most important agent in the accumulation of the alkali salts within the subsoil is the absorption of the salts by the surface of the soil grains. Very little is known about the causes or magnitude of these phenomena. The soil grains have the property of concentrating upon their surfaces the salts which are in solution in the soil water. These salts are slowly yielded up to solution in the continuous leaching of a soil, hence when the subsoil is continually washed the alkali salts again appear. They in a way move slower than the water which carries them.

All of these phenomena have an important bearing upon the accumulation of the alkali in the hardpan. No one of the agencies can account for all of the facts observed, hence it must be concluded that all have their bearing upon the movement and retention of the salts.

Since the cementing material of this hardpan is almost entirely lime and magnesium carbonate, water slowly softens the hardpan, and after a few irrigations the hardpan becomes so soft as to permit the roots to penetrate. Thus, though the entire area of land south of the red line across the alkali map is underlaid by hardpan material, there are no areas of any great size where the hardpan is within 3 feet of the surface of the ground, or so close as to harm tree or vine growth. This material, though it is not hard, is often rather impervious to water, and it does much harm in some areas by shutting off rapid drainage into the deeper subsoils. The greatest damage, however, which has been done has been to furnish alkali salts to the soils after irrigation has commenced, for though the tendency of alkali salts is to accumulate in the subsoil in well-drained soils, yet in soils which have been water-logged by irrigation the movement of the salts is toward the surface of the ground.

THE HOG-WALLOW MOUNDS.

Over great areas of land in the San Joaquin Valley, and in a general way throughout California, are found districts in which the ground is covered with small rounded hillocks or mounds. (See fig. 40.) Typically, these mounds are 1 to 3 feet in height and almost round, with a diameter at the base of 10 to 50 feet—on an average about 25 feet. The material of which these mounds is composed is the same as the material of the surrounding soils, except that in gravelly areas very little gravel is found in the mounds. These mounds occur on several types of soils, but are generally found upon the red soils. Plains and foothills alike are covered with the mounds, and so far as can be learned there is no relation between topography and elevation to the mounds.

Several writers have noted these peculiar mounds and have given theories as to their origin. Whitney, in his Geology of California, volume 1, describes the mounds and calls attention to their resemblance to the mounds produced in eastern forests by the uprooting of large trees by the wind.

Barnes in 1879 (American Naturalist, 1879, p. 565) describes the mounds of San Diego County, and ascribes their formation to the agency of vegetation and wind erosion. At the same time he recognizes that burrowing animals assist in the upbuilding of the mounds.

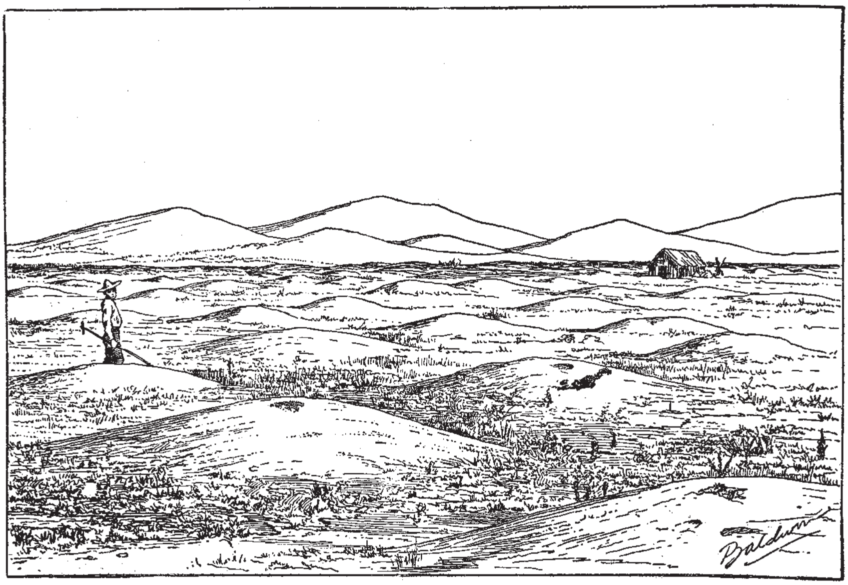


FIG. 40.—Hog-wallow mounds in red hardpan area.

Hilgard, in the Tenth Census report on Cotton Production in California, mentions the hog-wallow lands. He says they are "evidently the result of erosion, but precisely under what condition it is difficult to explain."

Le Conte, in describing the prairie mounds of eastern Oregon (Proc. Calif. Acad. Sci., vol. 5, p. 219), considers the formation of the mounds as due to erosion under peculiar circumstances. The circumstances necessary are a bare country and a drift soil, which is movable above and less movable below. In the erosion, the surface has been removed in part, leaving the top in spots, and the rounded hillocks the result from the spots upon which the vegetation grows, protecting them from further erosion.

The "pimpled prairies" of western Louisiana are very similar in appearance to the hog-wallow mounds. Harris and Veatch (Geological Survey of Louisiana, 1899) give a résumé of the theories for the formation of these mounds. Though in appearance the mounds of the pimpled prairie and the mud lumps of the Mississippi delta resemble the hog-wallow mounds, yet when the two are more nearly compared, certain differences are found to exist. The main difference is that the material composing the mounds is different from the material on which the mounds rest. And in the case of the Louisiana mounds the material has been traced to underlying strata. In the San Joaquin Valley the underlying material to a great depth is often similar to the material forming the mounds, so that the mounds may have been brought up from great depths, without being possible to determine the fact. None of the accepted theories as to the origin of the Louisiana mounds are hardly applicable to California conditions, for the mounds are located upon plains and upon hillsides where the soil is only a few inches in depth.

Turner (17th Ann. U. S. G. S., pt. 1, p. 681), in a brief description of the hog-wallow mounds of Mariposa and Merced counties, calls attention to the similarity between these mounds and the mounds built by the ground squirrels along the Coast Range. He concludes that the mounds were formed by the squirrels in the San Joaquin Valley.

The present writer, after a careful consideration of the possible methods of formation of the mounds, is also of the opinion that the mounds were built by the squirrels or animals of similar habits. Several important points in the characters of the mounds seem never to have been observed, and these are all in a measure important for a complete consideration of the cause of their formation. First of all, though the mounds are not restricted to one type of soils, they are restricted to a class of soils which have the property of hardening on the surface, forming smooth surfaces or hard clods when plowed, and in this way resisting erosion from the surface. This property of the soil enables mounds once thrown up to much longer resist the erosion by rain than would a looser soil, one which does not cement into a hard surface on drying. Good hog-wallow mounds have never been observed in the Fresno white sand or the similar loose soils of the valley, but the Fresno red sand, which has a pronounced tendency to run together and bake, and especially San Joaquin sandy loam, have been frequently observed in hog wallows. Furthermore, the lands in hog-wallow mounds are almost always underlain by hardpan or some hard layer, such as rock. The soil covering the rock or hardpan is not of sufficient depth to suit the tastes of the squirrel, so he throws up a pile under which his dwelling lies, and where the material is hardpan he scratches through the hardpan and brings up soil from below. Squirrel holes through the hardpan have been observed repeatedly immediately under the mounds. It is hardly supposed that one squirrel or one generation of squirrels would build one of these mounds, but that the process of formation has been one of ages. The squirrels seem to like to dig holes on elevated portions of ground, such as ditch banks, levees, or even railroad tracks, so instead of building for himself an entirely new mound the tendency has been to start digging at the top of some old mound and thus increase its height. On the foothills, where the soil is thin, the mounds are often higher and are no doubt thrown up to serve as a substitute for a deep soil.

These mounds offer serious obstacles to the cultivation of the land. Before irrigation can be thorough each mound must be leveled down. And even should irrigation not be needed, the farming of dry grain on the mounds is hard on the machinery. Nearly the entire area underlain by the red hardpan is or was covered with these mounds.

THE IRRIGATION WATER AND CANAL SYSTEMS.

The irrigation water of this area is all taken from the Kings River. There are two places from which canals take water direct from the river—at the point of exit from the foothills just northeast of Centerville, and at other places along the sloughs below Kingsburg. The upper canal systems are the most important; very little of the water from the lower canal system is used upon the area of the sheet.

The Kings River at its point of exit from the mountains varies in flow from 30,000 second-feet to a minimum of 250 second-feet. High water occurs from April to July, with the lowest stage during November.

The water of Kings River is very pure. Since it comes from the rain and melted snow almost altogether during the early summer, the water has little opportunity of taking up saline matter in solution. Very few analyses of the water are available for publication. Two analyses by Hilgard, published in the report on cotton production of the Tenth Census, show 7.08 parts mineral matter in solution in June at presumably high water, and 8.62 parts in November at low water. No analyses were made during the summer of 1900, but determinations of the total solids by the electrical bridge, in every case, the water contained less than 8 parts solid matter per 100,000 parts water. This is perhaps as pure a water as could be obtained for irrigation. Rivers in humid climates seldom contain less matter in solution.

The canals which convey the water to the lands of the valley have all been constructed since 1870. The first canals were taken out by private parties near Centerville. These have been extended and enlarged, until the present canal systems taken together would aggregate 150 miles of main canals, with perhaps 2,000 miles of smaller canals and laterals in actual use. Canals run parallel to canals, and water from one canal is carried long distances in laterals, crossing other canals to reach land, which could much more easily be watered from a nearer canal.

The great duplication of canals and laterals has been the result of the slow development of the system. At the present time it is recognized that such a system is very wasteful of water. Changes in the methods of handling the water will be slow in being introduced. These changes are much needed and undoubtedly will come with time. Very little in the way of special effort to remedy the troubles can be seen on the part of the canal owners and managers. If the losses of the present systems could be clearly pointed out, no doubt a much greater effort would be put forth to remedy the conditions.

The canals of the upper systems are: (1) Kings River and Fresno Canal; (2) Fresno Canal; (3) Fowler Switch Canal; (4) Centerville and Kingsburg Canal.

These canals are shown upon the soil and alkali maps. During ordinary seasons all of the canals, except the Fowler Switch Canal, have sufficient water to irrigate the land covered by them, but during dry seasons the greater part of the water goes directly to the country around Fresno through the two canals first named. As a result, this country is very often supplied with an excess of water, while other districts in the valley are suffering for want of water. The amount of water which passes by Centerville in the Kings River, if uniformly distributed over the valley, if properly handled and protected from losses by seepage, would cover a much greater area than is at present irrigated. There are large areas of valuable fruit land which await a supply of water, and which would be profitable investments if water could be furnished them.

One of the greatest sources of loss of water is from seepage through the bottoms and sides of the canals. From the mechanical analyses of the soils which have been given, it will be seen that most of the soils are very porous. Canals, constantly running ditches, and laterals therefore lose quantities of water which could otherwise be applied to the useful purpose of irrigating dry lands. No new data upon the losses from the canals are at hand, but tables published by Grunsky in Water Supply and Irrigation Papers No. 18 show that the losses are great. In a distance of 20 miles the Kings River and Fresno Canal lost 64 cubic feet per second, or a little more than 3 cubic feet per mile of the canal. This would be equivalent to 0.9 feet in depth per day of twenty-four hours if the canal has a wet perimeter of 60 feet. Of the 23.5 miles of the Fresno Canal measured, the loss was 104.5 cubic feet per second, or 4.4 cubic feet per second per mile. This would amount to a loss of 1.2 feet in depth per day of twenty-four hours. The upper 12.5 miles of the canal loses 8.5 cubic feet per second per mile, or a depth of 2.3 feet per day. The Centerville and Kingsburg Canal loses 138.3 cubic feet per second in the first 7 miles, or at the rate of 19.7 cubic feet per second per mile. This would equal an average depth of 5.3 feet. The seventh mile of this canal loses 52 cubic feet per second, or 14 feet in depth.

The loss by evaporation is negligible when compared with these losses by seepage. The maximum daily average evaporation would never equal 1 inch.

These great losses have caused the level of subsurface water to raise from a depth of 100 feet or more to the present level of 10 feet. The amount of water lost would irrigate large areas of land, and, should this leakage be stopped, the ground water over much of the area would lower sufficiently to permit the reclamation of the alkali lands without underdrainage.

THE UNDERGROUND WATER.

When irrigation first commenced in the country around Fresno ground water was first found at a depth of from 70 to 150 feet. At present water can be obtained anywhere in the irrigated portion at from 10 to 20 feet, while over the country immediately around Fresno, during the irrigating season, water can be found at from 3 to 10 feet.

This great filling up of the subsoil with water points toward great waste of water in some manner. All water which passes below the depth of root penetration is lost to all good at the point applied, and is a serious menace to land lying lower. There are two ways in which water is wasted in irrigation: First, by seepage and evaporation from the canal; and, second, by excessive irrigation.

Both of these losses are common in the Fresno area, and in the earlier days of irrigation, no doubt, were much more prominent than at present. The first applications of water to the new lands were largely taken up by animal burrows and underground channels in the hardpan. Sinks were formed, and for days at a time water would be poured into holes. In many places the ground would sink perceptibly after the first few irrigations. Cases have been known when water to a depth of 10 or 12 feet has been used in one irrigation. All of this excessive water has gone to raise the level of standing water in the subsoil, and the present losses are just about sufficient to keep the level in its present position.

Quite marked variations occur at the present time in the level of the water. As soon as the irrigating ditches are filled in the spring the level of the water in the wells begins to rise. Immediately the water is turned out of the ditches and canal the level begins to lower. There is a prompt drop as soon as the water is turned out. The drop is as much as 8 or 10 feet in some of the wells of the district, and as far as can be found the average drop south of Fresno would be 4 or 5 feet. This indicates a rapid natural drainage.

The character of this underground water is uniformly good where it is not concentrated by evaporation. In the areas of red soil, that is, the soils from the red formation, the wells are generally good; the water never carries more than 25 parts of solid matter in 100,000. In the white soils, however, the well waters often carry a higher quantity of total solids in solution. These wells vary from 25 to 100 parts of salt per 100,000 parts of water, though very few of the wells examined go over 50 parts. Black alkali or sodium carbonate is not a conspicuous salt in the well waters. Very few of the well waters carry more than 10 parts of sodium carbonate per 100,000. Most of the waters, however, carry bicarbonates in solution. From the average of a few determinations the wells can be said to carry, on an average, about 20 parts bicarbonates, calculated as sodium bicarbonate.

When the surface of the ground water is high ponds are formed in many of the sinks and draws in the white soil. Here the evaporation causes the waters to concentrate, and in part drives away the carbon dioxide from a sodium bicarbonate in the water. Thus, the pond waters are very often concentrated and contain much black alkali. The sodium carbonate acting upon the vegetation around the ponds dissolve organic matter and gives the water a brown or black color. Ponds have been examined which carry as much as 3 per cent sodium carbonates and 2.6 per cent sodium bicarbonates, with a total salt content of about 8 per cent. The water which enters these ponds, however, is not concentrated; there is no reason to believe that the water is any more concentrated than the well waters. The examination of a few samples of fresh seepage water showed practically the same salt content as the well waters.

ALKALI IN THE SOILS.

As has been stated, a careful examination was made of the formations from which the soils were derived, to determine, if possible, the origin of the alkali in the soils. The red formation, or those deposits derived from the basaltic rocks, in all places examined failed to show any large quantities of alkali salts; neither in the bluffs exposed in the open wells nor in the soil were great quantities of alkali salts found. A few spots of alkali were noticed in the bottom of the old stream channels east from Fresno, and one area of alkali land was found in the long tongue of Fancher loam running southwest from Fresno. This area is surrounded by alkali soils of the white formation, and the salts are derived from the white formations immediately underlying the red soils rather than from the red soils themselves.

The white formation from which the white soils were derived was found generally to be impregnated with alkali salts. In the bluffs along the San Joaquin and Kings rivers salts were found crystallized out upon the sides of the banks, alkaline waters were found seeping out from the foot of the bluffs, and in the wells in the soils the water carried larger quantities of alkali salts than did the well waters from the red formation. The soils were found everywhere to be more or less alkaline.

Upon the breaking down of the white formations to soil, the alkali salts which are present remain in the soil in part. The rainfall is not sufficient to wash the soils free from alkali to any great depth. There is, however, sufficient of rain to wash the upper parts of the soil so that the alkali in the virgin condition of the soil very seldom shows upon the surface. It is never safe to judge from the surface conditions alone whether a soil contains alkali or not, nor is an examination to a depth of 2 or 3 feet sufficient. In the examination made around Fresno, borings were made to a depth of 6 feet in nearly all cases, and occasionally the soils were examined to a depth of 12 or 15 feet. An average boring in land which has been very little disturbed by irrigation shows the alkali of the soils to be buried at a depth of from 3 to 8 feet. In the sandy loams where the rainfall penetrates but a short distance the depth to the zone of accumulation of the alkali is generally about 3 to 4 feet. In the sands the rainfall penetrates deeper, and here the alkali is found deeper. In all cases the alkali is in greatest quantity in the blue lime-magnesium hardpan. This is to be expected, since the hardpan is formed by the same agents which cause the accumulation of the alkali in a zone beneath the surface. This hardpan can therefore be called an alkali hardpan. The following tables show the results of several borings in the soils as nearly unaffected by irrigation and cultivation as was possible to find:

Alkali in Fresno sand, unirrigated.

No. 164, S. 35, T. 14 S., R. 20 E.				No. 853, S. 35, T. 15 S., R. 21 E.			
Depth.	Soil.	Total alkali.	Na_2CO_3.	Depth.	Soil.	Total alkali.	Na_2CO_3.
		Per cent.	*Per cent.*			*Per cent.*	*Per cent.*
0 to 1 foot	Sand	0.06	0.00	0 to 1 foot	Sand	0.06	0.00
1 to 2 feet	do	.10	Tr.	1 to 2 feet	do		
2 to 3 feet	do	.24	.07	2 to 3 feet	do	.06	0.00
3 to 4 feet	do	.29	.10	3 to 4 feet	do	.11	0.00
4 to 5 feet	Soft hardpan	.11	.16	4 to 5 feet	do	.11	Tr.
5 to 6 feet	do	.09	.06	5 to 6 feet	Soft hardpan	.12	.03
				6 to 7 feet	do	.11	.03
				7 to 8 feet	do	.09	.02
				8 to 9 feet	Sand	.08	Tr.
				9 to 10 feet	do	.05	Tr.

Alkali in Fresno sandy loam, unirrigated.

No. 177, S. 35, T. 14 S., R. 20 E.				No. 286, S. 30, T. 14 S., R. 19 E.			
Depth.	Soil.	Total alkali.	Na_2CO_3.	Depth.	Soil.	Total alkali.	Na_2CO_3.
		Per cent.	*Per cent.*			*Per cent.*	*Per cent.*
0 to 1 foot	Sandy loam	0.09	0.00	0 to 1 foot	Sandy loam	0.11	0.00
1 to 2 feet	do	.15	Tr.	1 to 2 feet	do	.14	.10
2 to 3 feet	do	.16	.10	2 to 3 feet	do	.14	.10
3 to 4 feet	Soft hardpan	.30	.14	3 to 4 feet	do	.12	.12
4 to 5 feet	do	.32	.09	4 to 5 feet	Soft hardpan	.11	.14
5 to 6 feet	do	.16	.06				

First Appearance of Alkali in Vineyard.

In none of these cases could it be positively stated that the soils were unaffected by irrigation. Even though the soil at the point examined had not been irrigated, the rise of the level of standing water by the irrigation of the surrounding country has in a measure changed the location of the zone of accumulation of the alkali.

MOVEMENT OF ALKALI SALTS.

Within a soil there are three ways in which the alkali salts move: (1) By diffusion in the soil moisture; (2) by the force of gravity in moving the soil moisture downward; (3) by surface tension or capillary action, which moves the soil moisture in any direction.

(1) *Diffusion.*—Though diffusion must be recognized as an important factor in the movements of the dissolved salts of soil moisture, yet the diffusion in capillary spaces has never been studied. The diffusion for salts or mixture of salts in the water is so slow that compared with the movement by gravity and surface tension the effects of diffusion are practically negligible.

(2) *Force of gravity.*—When water is applied to the surface of the ground the force of gravity, assisted by surface tension, pulls the water down into the capillary spaces. Soils will hold a certain percentage of water by capillary forces alone, and any excess over this per cent will drain away. Such excess of water over the amount which will be held by surface tension is called gravity water, and the dominating force in its movement is the force of gravity. So that when the surface of the ground is flooded both surface tension and gravity act in pulling the water downward. The force of gravity is much the more intense force, hence the true gravity movement is greater than the purely capillary movement. The rate of flow of water through capillary spaces depends upon the size of the space. The rate varies inversely as the fourth power of the diameter of the space. Therefore the flow through the large capillary spaces, the root holes, worm borings, and animal burrows is very much greater than through the true capillary spaces. When water is applied the downward movement by gravity is almost entirely through the larger noncapillary spaces, while the true capillary spaces are filled by surface tension from the noncapillary spaces. Briggs has shown in Bulletin No. 10, Division of Soils, that the fine capillary spaces fill with water at the expense of the larger spaces. In this way the salt which is dissolved by the descending water is drawn back into the capillary spaces where there is very little downward movement and remains there, only escaping out into the channels of downward movement by diffusion. The amount of salt which is washed downward by a heavy flooding of the land is therefore small. Lands have been examined before and after a foot in depth of water had been leached through them, and the amount of salt leached out was scarcely noticeable.

Thus, it is possible to heavily flood a soil, have good underdrainage, and yet get rid of the alkali salts very slowly. The downward movement of the salts, therefore, is very slow, and is not directly dependent upon the amount of water run through the soil.

This fact, however, points to a method of removing the salts by flooding which is efficacious, and that is frequent flooding with small quantities of water rather than by one or a few heavy floodings. By frequent floodings with an inch or more of water the downward movements are largely capillary, and the amount of salt removed by capillary movements is much greater than where the movement is gravitational alone.

(3) *Movement by surface tension.*—When water moves by surface tension the film around the grains moves. As soon as the gravity water has drained away the movements become entirely by surface tension, for changes in temperature or concentration of the solution change the tension of the water films and starts a capillary movement toward the point where the evaporation takes place or away from the place of higher temperature. But when the water moves by capillary action it is the water in the smaller spaces that moves, and not the water which was in the larger noncapillary spaces. Therefore, the water which was drawn back into the capillary spaces and carried the alkali salts as it flowed down into the soil, starts upward and carries with it the salts which are in solution. The evaporation of an inch of water from the surface of the ground accumulates on the surface all alkali salts which were contained in that inch of water, while on the other hand the same volume of water leached down through the soil would perhaps only wash the salt out of a few of the larger soil spaces. From this it will be seen that the tendency of the alkali salts under irrigation is to move upward more rapidly than to move downward. Were the tendency and the rapidity of movement the same in both directions, the rise of alkali salts would never be possible if a little more water was added to the surface of the ground than evaporates each year from the surface. In the Fresno area we know that in many cases a great deal more water has been added to the surface than could possibly have been evaporated from the surface; in other words, more water flowed down than has flowed up; and yet the alkali salts have come up. This is readily understood when we consider that the downward movement is through the larger, noncapillary, spaces, while the upward movement is through the smaller, the capillary, spaces.

This goes to show that surface tension or capillary attraction, as it is often known, is the most important agent in the movement of the alkali salts toward the surface of the ground. Therefore, a soil which would permit the most rapid movements would be the most likely to accumulate alkali salts upon the surface of the ground. If two soils with different capillary powers were placed side by side, with the level

LAND TOO ALKALINE FOR FRUIT CROPS, SEEDED TO BERMUDA GRASS FOR PASTURAGE.

of standing water the same, the soil which raised the water to the surface the more rapidly would the sooner accumulate an alkali crust.

South of Fresno there are examples of such soils—the Fresno white sand (loose and coarse grained) and the Fresno sandy loam (fine grained and compact). The rate of capillary rise and the height to which water will rise in the sandy loam are both much greater than in the sand; consequently the sandy loam will accumulate an alkali crust much more rapidly than the sand. Such has been found to be the case throughout the area. The sandy loam or white-ash land is nearly always troubled with alkali, and is very often heavily crusted with alkali salts, while the sand is very seldom sufficiently charged with alkali as to be worthless. It is true that the alkali salts are more abundant under the sandy loam, and that it is accumulated in a zone nearer the surface than in the sand, but in areas side by side where the conditions could not have been far different originally, the sand is found free from alkali in the surface, while the sandy loam has an accumulation of alkali at the surface. The washing of salts out of the open porous soils and the accumulation in the heavier soils is very well illustrated in the alkali lands in T. 15 and 16 S., R., 19 E. Here the original conditions are very little affected by irrigation. The draws and low places are generally of the sandy loam, while the ridges between the draws and the higher plains are of sand. The sand soils are free from alkali salts in the upper 5 or 6 feet, while the sandy loams are invariably alkaline, and even when the soils are side by side at the same level the alkali is found in much greater quantity in the heavier soil. Here we have a beautiful example of the Briggs movement of capillary water from a light soil to a heavier soil, the moving water in this case taking with it the alkali salts. Some of the causes for the movement of alkali salts in soils have been shown; the special causes for their accumulation in the Fresno soils now remain to be considered.

When the colony lands south and southwest of Fresno were first settled, very little of the land was alkaline on the surface. After a few years' irrigation and when the subsurface water had been raised high enough to permit constant upward movement by capillarity, the alkali salts began to accumulate. In the soils of most rapid capillary movement the damage occurred most rapidly, and this sometimes with frequent and copious irrigation from the surface. After this accumulation has gone on for a while the greater part of the alkali salts is found at or near the surface of the ground. The same accumulation is observed in the unirrigated soils where the subsurface water is close enough to the surface to permit continuous capillary movement upward. Such soils are said to be subirrigated. When, however, the subsurface water is down so far that there is no capillary movement continuously upward, or when the rainfall does not penetrate to the subsurface water, the alkali salts do not accumulate at the surface, but in a zone beneath the soil, as has been previously described.

Therefore, if the subsurface water had never been allowed to approach the surface of the ground, as was done in the colonies south of Fresno, the alkali salts would never have been accumulated at the surface. This is seen in the two long strips of Fresno sandy loam east of Selma. Here the water surface never comes higher than 6 to 8 feet from the surface of the ground. Capillary movements through 8 feet of soil are not rapid; hence the salts have very slowly moved upward, or else have not moved at all. The subsoil, however, contains alkali, perhaps as much as did the colony lands south of Fresno, and if ever the level of standing water around Selma rises to within 3 or 4 feet of the surface a great part of the now valuable fruit land will become alkaline. On the strip of land south of Selma the water surface is already near the surface of the ground during part of the year and the alkali has accumulated so that nothing but salt grass will grow.

CHEMICAL COMPOSITION OF THE ALKALI.

A large number of chemical analyses of the alkali salts from the Fresno area have been made in the Division of Soils. A general discussion of the results is given by Cameron.[1] The accepted classification of the alkali salts has been heretofore black alkali when the salts contained sodium carbonate, and white alkali when the salts did not contain sodium carbonate. Cameron has considered a new classification, in which the types are defined by the principal salts found in the crusts. This classification is certainly a more rational one and deserving of further study. The general type of the alkali salts in this district is called the Fresno type by Cameron, and he considers the predominating salts to be sodium or potassium chloride reacting with calcium or magnesium carbonate. As accessory salts, we have small quantities of sulphates and occasionally traces of phosphates.

The analyses are given in the tables on pages 373 and 374. For convenience, the analyses which showed no sodium carbonate are given in one table, while those analyses which showed sodium carbonate are given in a second table.

[1] See paper by Cameron in this report.

Chemical analyses of alkali salts containing no sodium carbonate.

Constituent.	4872. Sec. 19, T. 14 S., R. 22 E., crust.	4841. Sec. 25, T. 14 S., R. 18 E., 0 to 12 inches.	4871. Sec. 7, T. 14 S., R. 23 E., 0 to 24 inches.	4681. Sec. 22, T. 14 S., R. 19 E., 0 to 12 inches.	4835. Sec. 22, T. 14 S., R. 19 E., 0 to 12 inches.	4676. Sec. 20, T. 14 S., R. 20 E.	4682.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ca	18.71	12.59	17.25	1.60	9.51	15.96	2.76
Mg	8.21	5.26	5.59	.74	3.30	9.33	.56
Na	5.34	15.56	7.93	31.11	21.28		33.33
K	.92	1.15	3.50	2.63	1.86	9.33	1.55
SO_4	1.00	1.60	2.33	25.84	4.54	8.66	7.56
Cl	64.60	60.40	55.71	33.39	54.55	56.66	53.00
CO_3						Tr.	
HCO_3	1.31	3.44	7.69	4.69	4.96		1.24
PO_4							
$CaSO_4$	1.38	2.28	3.27	5.43	6.40	12.00	9.40
$CaCl_2$	50.64	34.61	44.75		21.08	34.66	
$MgSO_4$				3.66			1.14
$MgCl_2$	32.75	20.49	21.91		12.81	35.99	1.34
K_2SO_4							
KCl	1.74	2.05	6.53	4.97	3.51	17.34	2.96
Na_2SO_4				28.25			
NaCl	12.32	35.77	13.05	51.23	49.39		83.46
Na_2CO_3							
$NaHCO_3$	1.77	4.79	10.49	6.46	6.81		1.70
PO_4							
Per cent soluble	4.61	.87	.86	3.50	.97	.30	8.23

Chemical analyses of alkali salts containing sodium carbonate.

Constituent.	4689. Sec. 2, T. 15 S., R. 19 E., 0 to 12 inches.	4670. Sec. 9, T. 15 S., R. 20 E.	4831. Sec. 3, T. 15 S., R. 19 E., 0 to 12 inches.	4690. Sec. 7, T. 15 S., R. 19 E., 0 to 1 inch.	4668. S. 22, T. 14 S., R. 20 E.	4684. Sec. 26, T. 14 S., R. 20 E., 0 to ½ inch.	4839. Sec. 21, T. 14 S., R. 19 E., 0 to 1 inch.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ca	Tr.	1.81	2.31	Tr.	3.65		1.15
Mg	Tr.	1.64	Tr.	Tr.	1.99	Tr.	Tr.
Na	33.78	19.34	32.41	35.27	23.80	35.26	36.16
K	1.86	19.43	1.85	1.01	10.86	.68	.83
SO_4	11.97	12.09	5.55	24.03	10.20	12.31	18.91
Cl	29.92	41.28	36.49	27.11	39.64	22.40	24.50
CO_3	3.19	4.40	5.00	4.99	9.87	10.58	14.90
HCO_3	19.28		16.29	7.59		18.67	3.55
PO_4	Tr.			Tr.		.10	
$CaSO_4$		6.13	8.13		12.36		3.91
$CaCl_2$							
$MgSO_4$		8.12			1.82		
$MgCl_2$					6.46		
K_2SO_4		2.33					
KCl	3.46	35.05	3.51	1.93	20.65	1.30	1.56
Na_2SO_4	17.69			35.57		18.23	23.91
NaCl	46.68	40.59	57.31	43.23	41.30	35.93	39.42
Na_2CO_3	5.72	7.77	8.68	8.82	17.42	18.72	26.34
$NaHCO_3$	26.45		22.37	10.45		25.72	4.86
PO_4						.10	
Per cent soluble	1.50	2.32	1.08	8.30	2.41	24.00	9.19

Chemical analyses of alkali salts containing sodium carbonate—Continued.

Constituent.	4688. Sec. 36, T. 14 S., R. 19 E., 0 to ½ inch.	4829. Sec. 31, T. 14 S., R. 20 E., 0 to 12 inches.	4680. Sec. 30, T. 14 S., R. 20 E., 0 to ½ inch.	4677. Sec. 28, T. 14 S., R. 20 E., crust.	4877. Sec. 8, T. 17 S., R. 21 E., 0 to 12 inches.	4886. Sec. 17, T. 17 S., R. 21 E., crust.	4686. Sec. 19, T. 14 S., R. 20 E., 0 to ½ inch.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ca	Tr.	3.52	Tr.	2.55	0.48	0.20	Tr.
Mg		Tr.	Tr.	.50	.16		Tr.
Na	36.46	28.74	36.23	31.03	33.77	34.90	36.03
K	.98	.59	.73	5.96	1.81	1.15	.41
SO_4	8.22	3.81	8.93	17.84	5.44	17.09	5.17
Cl	24.97	4.99	15.58	21.86	8.06	2.50	5.81
CO_3	15.26	16.71	20.26	20.31	22.63	23.56	26.30
HCO_3	13.61	41.64	17.81		27.65	20.60	26.01
PO_4	.50		.46				.27
$CaSO_4$		5.28		8.32	1.60	.67	
$CaCl_2$		*a* 8.21					
$MgSO_4$				2.46	.75		
$MgCl_2$							
K_2SO_4				13.28			
KCl	1.86	1.17	1.37		3.47	2.19	.79
Na_2SO_4	12.16		13.20	3.96	5.50	24.69	7.65
NaCl	39.73	7.04	24.64	36.04	10.72	2.39	8.95
Na_2CO_3	27.02	29.62	35.81	35.90	39.96	41.67	46.51
$NaHCO_3$	18.73	48.68	24.52		38.00	28.39	35.83
PO_4	.50		.46				.27
Per cent soluble salts	6.76	.68	9.92	3.99	3.75	28.22	26.07

Constituent.	4862. Sec. 34, T. 13 S., R. 23 E., crust.	4679. Sec. 22, T. 14 S., R. 20 E., 0 to ½ inch.	4669. Sec. 34, T. 14 S., R. 20 E., crust.	4888. Sec. 9, T. 17 S., R. 22 E., 0 to 24 inches.	4678. Sec. 18, T. 14 S., R. 20 E., crust.	4889. Sec. 11, T. 17 S., R. 21 E., crust.	Standard solution.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ca	4.58	Tr.	1.75	3.01	0.48	0.04	0.10
Mg	Tr.	Tr.	.42		.21		
Na	31.46	37.26	30.66	34.19	35.03	41.85	34.24
K	.76	1.12	9.87	.63	7.85	1.26	5.33
SO_4	5.34	2.31	9.80	7.24	7.13	2.35	18.92
Cl	3.05	11.99	15.75	2.41	5.82	1.15	29.75
CO_3	30.84	28.71	31.71	33.85	43.48	52.79	11.59
HCO_3	23.97	18.44		18.66		.56	
PO_4		.17					
$CaSO_4$	7.48		5.88	10.28	1.62	.10	.32
$CaCl_2$	*b* 6.11						
$MgSO_4$			2.03		1.00		
$MgCl_2$							
K_2SO_4			7.35		9.43		
KCl	1.37	2.13	12.67	1.15	6.89	2.41	9.77
Na_2SO_4		3.42				3.36	27.74
NaCl	3.97	18.12	16.03	3.04	4.20		41.63
Na_2CO_3	48.09	50.76	56.06	59.85	76.88	93.35	20.53
$NaHCO_3$	39.98	25.40		25.68		.77	
PO_4		.17					
Per cent soluble salts	1.31	16.42	2.86	1.91	5.81	54.24	

a $Ca(HCO_3)_2$. *b* $CaCO_3$.

The alkali salts normally contain sodium carbonate, but in special cases, which cover but a small part of the total area of alkali lands, sodium carbonate is wanting. The analyses given in the first table show the composition of the soluble portions of a number of such soils. All of the samples, except 4681, instead of showing sodium carbonate, show large quantities of chlorine, which must be largely combined with lime and magnesium as chlorides. The accumulation of calcium and magnesium chlorides is the result of the action of sodium chloride upon calcium carbonate. Both being in solution at the same time, calcium chloride must exist in the solution. Calcium chloride is a salt which moves very rapidly in a soil. Some experiments made with various chlorides (Yearbook, 1898, p. 498) showed that calcium chloride could be washed from a soil in one-half the time required to leach the same quantity of sodium chloride. As the water moves through the soil the tendency is for the calcium chloride to move more rapidly than the other salts, and hence it accumulates in the place when these waters have evaporated. The extent of these white alkali spots is not large.

Sample 4681 was collected from a spot which had been treated with gypsum; therefore the large amount of sulphates found in the salts.

The second table contains analyses of samples of alkali crusts which contained sodium carbonate. The analyses are arranged according to the content of sodium carbonate, which varies from nearly 6 per cent to over 93 per cent of the soluble portion of the soil. The principal constituents of the soil are seen to be chlorides and carbonates with bicarbonates. Lime and magnesium are low, so that the salts are largely salts of sodium and potassium. Potassium forms an average of 5 per cent of the soluble matter within the soil. Sulphuric acid is always present, but rather variable, and on the average constitutes 6 per cent of the total alkali salts. The relation between the carbonates and bicarbonates varies greatly as found in the field. The drying out of the samples in transit to the laboratory so changes the relative proportion of these two salts that a laboratory examination gives no idea of the relations which exist in the undisturbed soil. Field examinations were made in the many samples for the relation between carbonates and bicarbonates, and even here the relative proportion is found to vary greatly. Carbonates of sodium and potassium have been generally considered the most harmful salts found in the alkali of the soils. Researches in this laboratory show that the bicarbonates are themselves not as harmful as the carbonates, so that a simple statement of the carbonates and bicarbonates from the laboratory determinations does not suffice for a discussion of the field conditions.

These alkali crusts containing sodium carbonates occupy almost the entire area of the alkali lands. (See fig. 41.) White alkali lands are found in very small spots only. Gypsum has long been known as a chemical correction for black alkali. Hilgard has recommended its use, and wherever it has been tried the reclamation has been a success, if enough gypsum were applied. Gypsum, it must be remembered, does not remove the black alkali from the ground, but simply changes it over into white alkali, which is a less harmful form; so if there is already an excess of white alkali in the soil the application of gypsum is of little value, since even the changing of the black to the white only serves to add to the total percentage of white alkali. But wherever the total percentage of white alkali is small gypsum will greatly improve the land.

RECLAMATION OF ALKALI LANDS.

The areas of the various grades of alkali soils, as determined from the map areas, are as follows:

Areas of the different alkali soils.

Grades of alkali soils.	Acres.	Per cent.
0 to 0.2 per cent alkali	336,300	83.8
0.2 to 0.4 per cent alkali	26,300	6.6
0.4 to 0.6 per cent alkali	10,150	2.5
Over 0.6 per cent alkali	28,500	7.
Total area	401,250	

These percentages of alkali are based upon a column of soil 5 feet deep, as determined by the electrical method for the determination of salt in soils as used in this Division.

Upon the first grade of land, with 0 to 0.2 per cent total alkali, all classes of plants will grow.

Upon the second grade of land, 0.2 to 0.4 per cent of alkali, all but the most sensitive plants will grow, but near the higher limit of the percentage of alkali all classes of plants except the truly alkali-resistant plants show signs of distress, and if the conditions remain unchanged the death of the plants will result. Alfalfa, if well started, grows on this class of land, but seed are difficult to germinate. Fruit trees show the presence of alkali by dropping the fruit before ripening. Grapes will grow, but not with the vigor of the plants on good land. Pomegranates, pears, date palms, all do well. Beets, onions, and asparagus also are unaffected by the presence of the alkali.

The third grade of land, 0.4 to 0.6 per cent alkali, contains a little too much salt for the common crops. Alfalfa will seldom grow and can never be seeded on the land. Fruit trees all suffer or are killed, with the exception of pomegranates and date palms. Only the truly alkali-resistant plants do well, such as beets, onions, asparagus, date palms, Bermuda grass, Johnson grass. The land is worthless for ordinary fruit farming, and is in the Fresno country either allowed to lay as waste land or is seeded down to Bermuda grass for pasturage.

The fourth grade of land is that with more than 0.6 per cent of alkali, and is practically worthless for general farming or fruit raising. Salt grasses, Australian saltbush, and a number of wild or native saltbushes will grow, but, aside from pasturing, these lands are not used. Date palms would grow upon these lands, and in some cases sorghum and sugar beets could be grown, but these have not been tried to any great extent.

There are two problems which confront the irrigator farmer: First, to prevent lands becoming alkaline; second, to reclaim lands which

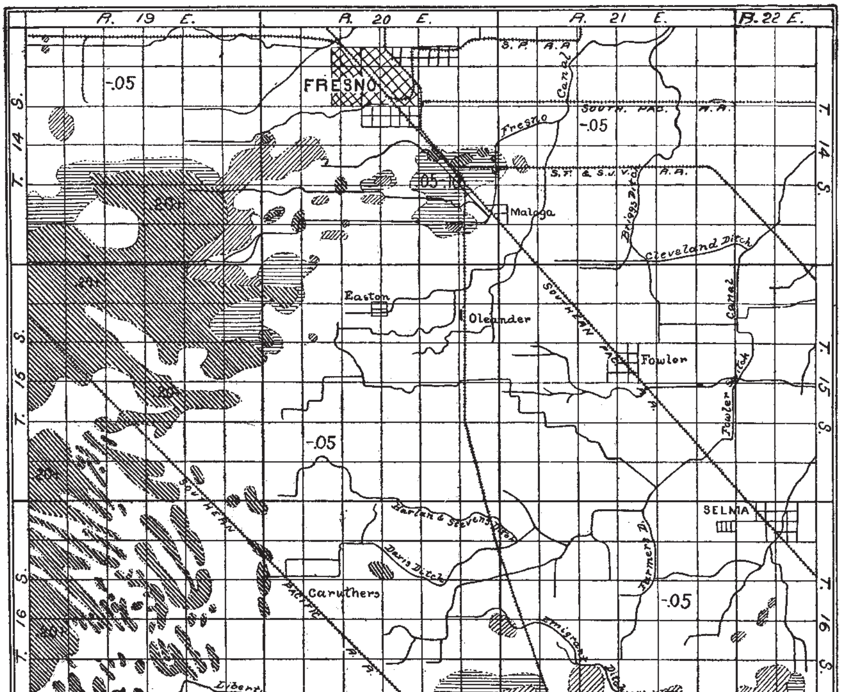


FIG. 41.—Black alkali lands of Fresno sheet, showing lands less than 0.05 per cent, from 0.05 to 0.10 per cent, from 0.10 to 0.20 per cent, and over 0.20 per cent sodium carbonate.

have already become alkaline. These two problems, while they are closely related, will be discussed separately.

PREVENTION OF THE RISE OF ALKALI.

In the discussion of the formation of the hardpan and the alkali in the soils the reasons for the movements of the alkali have been shown. The main factor in the rise of the alkali is the capillary rise of the water and the evaporation of this water at the surface. If the capillary rise of the water is slowed down or prevented and the evaporation at the surface is reduced to a minimum, the accumulation of the alkali salts at the surface will be greatly retarded and often prevented entirely.

There are two ways of lessening the upward movements of the water: First, by lowering the level of standing water; second, by cultivating the soil and breaking up the capillary spaces into large non-capillary openings.

If the level of standing water is down 5 or 6 feet, the upward movement is slow and very little can be done toward further lowering the level of the water; but if the level of the water is within 3 feet of the surface or nearer, underdrains should be dug to lower the level of the standing water. Except in the case of lands which are entirely free from alkali, the level of standing water should never be allowed to come closer than 3 feet from the surface.

Deep cultivation of the soil breaks up the fine capillary spaces and cuts off the upward movements of the water. At the same time the cultivation dries out a surface layer, which prevents the upward movement also, since the capillary movement through a dry soil is much slower than through one slightly moist. Continued shallow cultivation forms this dust mulch and prevents surface evaporation.

Mulching either with a dust mulch or with straw, leaves, or manure all aid in preventing evaporation, and the use of these means of lessening the loss of water from the surface of the soil is to be strongly recommended. An orchard was studied near Selma where stable manure was used as a mulch. Very little of the alkali had approached the surface, and no trees had been killed, although there was enough alkali in the subsoil to entirely ruin the orchard if it were allowed to rise to the surface. Orchards near by and in apparently exactly similar conditions originally, and on which no mulch was used, were found to be suffering from alkali.

RECLAMATION OF LANDS ALREADY ALKALINE.

Alkali lands which grow only salt grass and salt weeds are worth very little when compared with lands free from alkali. Ten dollars an acre is the average price fixed on alkali lands, though the land is not worth half so much. Land free from alkali and with water is worth at least $100 an acre, and if in fruit it is worth $200 to $500 per acre, and will pay good interest on that amount.

Land which will only grow certain crops is partly damaged and would not be considered as valuable as land free from alkali, therefore all of the classes of alkali land are not so valuable as the land free from alkali.

The researches of this Division have shown that the reclamation of alkali lands is a practical business proposition. The increase in value of the lands after reclamation in nearly all cases is greater than the cost of reclamation. The land when once reclaimed is known to be rich, strong land, in better condition than the land originally free from the salts. Part of the alkali is plant food in an available form,

ALKALI LAND TOO STRONG FOR FRUIT CROPS OR BERMUDA GRASS, WITH VOLUNTEER GROWTH OF SALT GRASS.

Lands once exceedingly fertile. Fresno sandy loam.

and hence the presence of small quantities of alkali always stimulate plant growth.

There are a number of ways in which alkali lands can be reclaimed, all of them deserving of use in special cases—(1) growing of alkali-resisting plants; (2) chemical correction for black alkali; (3) cultivation and flooding; (4) underdrainage.

(1) *Growing of alkali-resisting plants.*—The growing of alkali-resistant plants of some sort is nearly always possible, for there is very little land which would be farmed which is too strongly impregnated with alkali for some kind of growth. For the strongest alkali soils, the wild saltbushes, salt grass, and Australian saltbush are available. Such lands can only be used as pasture. Lands less strongly impregnated will frequently grow sorghum or beets, which withstand considerable alkali. The growth of these plants alone is a very slow and uncertain method of reclamation, but if this method is taken in conjunction with heavy flooding and thorough cultivation complete reclamation is possible.

(2) *Chemical correction for black alkali.*—Gypsum is a chemical correction for black alkali. Well-drained and aerated soil is necessary before gypsum is efficient. The action of gypsum is to react upon the sodium carbonate with the formation of sodium sulphate. If there is 0.1 per cent of sodium carbonate within the soil, 3¼ tons of gypsum are required to neutralize the carbonate, and at the present market prices the gypsum would cost $19.50 per acre, and this would reclaim only the first foot. Should the reclamation of the entire 5 feet of surface soil be desired, the cost would be $97.50 per acre for the gypsum alone. And after all this expense the land would still contain white alkali, perhaps in quantity sufficient to do harm. There are very few areas on the Fresno sheet which have an excess of black alkali and do not at the same time have an excess of white alkali. Gypsum applied to such areas is largely wasted. It is true that gypsum assists in changing the physical conditions of a heavy soil so that water flows through it more easily, but at Fresno there is very little heavy soil. Gypsum can not be recommended as of general use in reclaiming the alkali lands of the Fresno sheet. The use of gypsum where there is but a small quantity of alkali present is often of value, but at the present price of the material it is not economical.

(3) *Cultivation and flooding.*—Whenever the level of standing water is down so far as to prevent rapid capillary movements to the surface of the ground, cultivation and flooding offer one of the most ready means of reclaiming alkali lands.

Deep cultivation breaks up the root holes and cavities which are followed by water in leaching downward through the soil. In this way a heavy flooding carries downward into the subsoil much more alkali than would be carried if the land were irrigated before plowing. If some alkali-resistant plant which can be cultivated is then planted and properly attended to, frequently cultivated and irrigated, and this kept up for two or three years, much will be done toward the reclamation of the land; and if a proper kind of alkali-resisting plant is selected and the product handled intelligently the land will pay for the care in attending to it, so that the increase in value due to reclamation is clear profit.

This all presupposes a good and rapid underdrainage, that is, some place to which the alkali can go. If such is not present naturally, the only remedy is underdrainage.

(4) *Underdrainage.*—Well-drained lands never become alkaline. Therefore if lands have become alkaline it is evident that the drainage has been poor.

With good underdrainage the alkali salts are washed out and away into the stream channels, and are never of harm to the land from which they came. There are several ways of underdraining land, all of which are applicable to conditions under irrigation. A discussion of the subject of farm drainage is found in Farmer's Bulletin No. 40, of this Department.

To sum up the matter of reclamation of alkali lands: Two requisites must be had before attempting reclamation. They are a supply of water with which to irrigate and good underdrainage to the land. See that both are right, then plow deep, irrigate heavily, and plant an alkali-resisting crop. Sugar beets and sorghum are both good. Cultivate frequently to a depth of 4 inches, and irrigate often. Keep this up for three years, and then try alfalfa. If alfalfa can be gotten to stand well, the land is nearly reclaimed.

AGRICULTURE ABOUT FRESNO.

The agricultural lands about Fresno are divided into two classes—the irrigated and nonirrigated lands. These divisions are not merely accidental, but in most cases are decided by some peculiarity of the land itself, either in its location or inherent properties or by the amount of water in the streams. For example, nearly all of the San Joaquin sandy loam is dry farmed to wheat and barley, because here, as a rule, the hardpan comes so close to the surface as to exclude any deep rooting plant or tree, and in like manner the sandy land near Caruthers is also dry farmed or else left idle, the limiting cause here being location, rather than any inherent property of the soil, all of the water of the river being diverted for irrigation before reaching this point; so that in general it may be stated that the great bodies of land that are now unirrigated are so because of the difficulty or impracticability of bringing them under irrigation, and that they are liable to thus remain indefinitely, or until the present methods of obtaining and applying water undergo a radical change.

The area mapped about Fresno comprises about 401,250 acres; of this amount about one-third is now irrigated and planted to fruit trees and vineyards, one-third dry farmed to wheat and barley, and the remaining one-third includes the land sown to alfalfa; the alkaline

Raisin Grapes, pruned and receiving Winter Cultivation.

RAISIN GRAPES, IN EARLY SUMMER.

Raisin Grapes, Harvest Time.

Wine and Seedless Raisin Grapes, showing pruning and Winter Cultivation.

lands, and the land which, on account of its sandy nature and the scant rainfall, is left idle. A part of the alkali land comes under the irrigation ditches, so about two-fifths of the area is irrigated, while the remainder is dependent solely upon the rainfall.

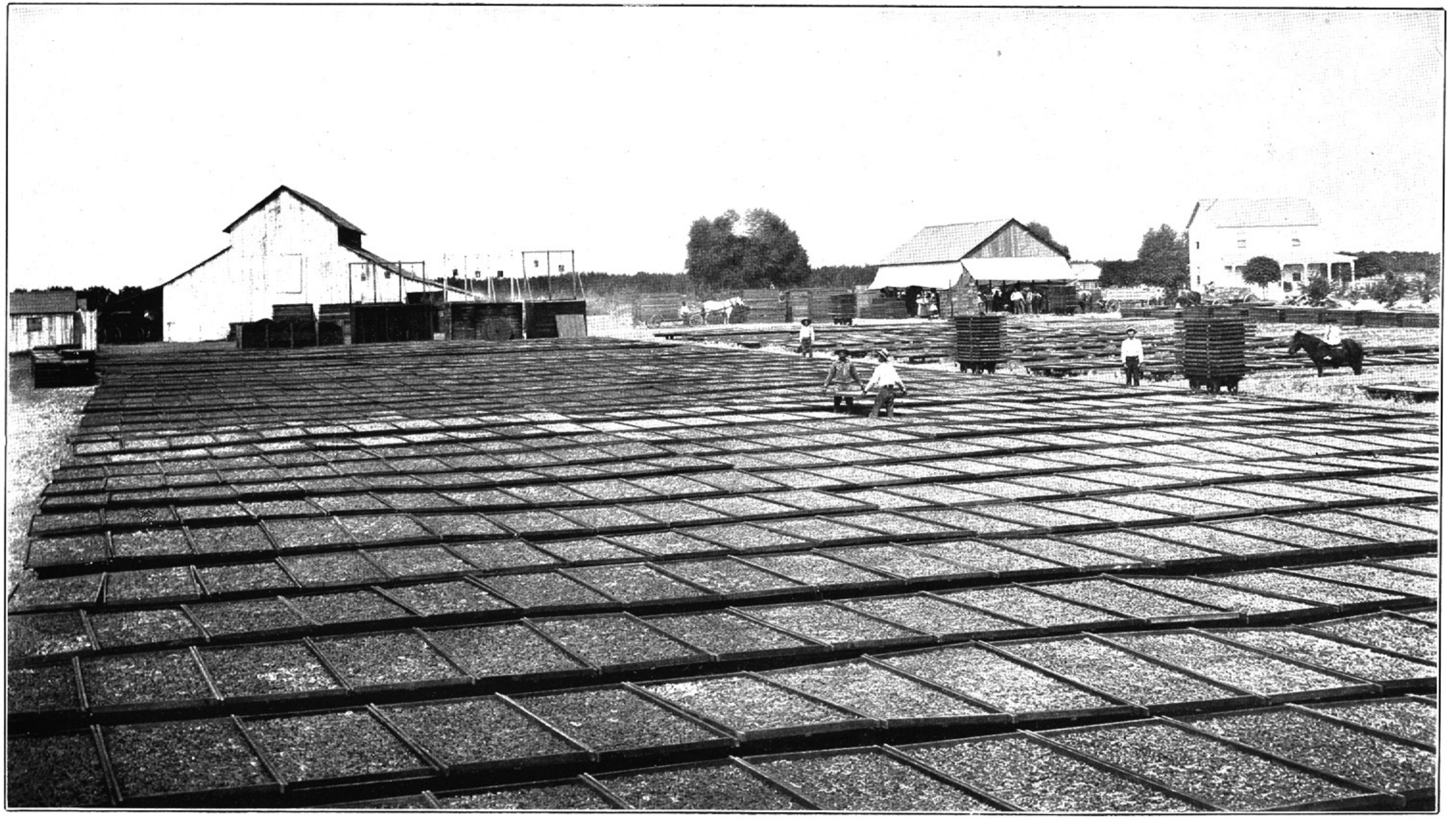
All the irrigation of this country is of very recent date. Thirty years ago the first ditch was built to divert water from Kings River to irrigate a small tract near Centerville, and from this first effort, which was considered highly experimental, has grown an agricultural community based wholly upon irrigation which counts its assets in the millions. Heading the list of irrigated crops in importance and value are the grapes, the products of which are two of the principal sources of the revenue of the county.

The grapevines are started from slips or cuttings 18 inches or 2 feet long, which are pieces of the trimmings of the old vines. These are placed very close together in a trench, with one end protruding a few inches above the ground, and irrigated copiously for one year until they have developed a few branches and a root system. They are then taken up and planted in the vineyards, the distance apart varying with the kind of grape and the judgment of the planter, from 6 feet apart each way to 10 or 12 feet, the average distance being 8 by 10 feet. The vineyards are then carefully cultivated and pruned, producing their first crop the third or fourth year. The pruning of the vines is of great importance, the object being to gain the maximum yield for the space occupied by the undivided vines and at the same time permit of cultivation between them. With this end in view all varieties are found to occupy as small space as possible. The Muscat, Malaga, Seedless Sultana, and Thompson Seedless are raisin grapes, of which the two first named are the most important, only small plats of the seedless grapes being grown. The Muscat and Malaga vines are each winter pruned back to a stump or very short trunk about a foot high, and as the vines get older these trunks increase in size, often being a foot or more in diameter. The cultivation is so managed that it is finished before the new vines grow to such length as to interfere with the cultivation; in other words, the grapes are annually "laid by," just as the Eastern farmer lays by his corn. The cultivators used are usually drawn by 2 horses and have a great number of small teeth which tend to form a mulch and at the same time destroy any growing weeds. The methods of cultivation for these varieties apply to the others also, the principal difference in the culture being in the methods of pruning. The Thompson Seedless, Seedless Sultana, and most of the wine grapes are either staked, that is, a stake driven down by the plant for a support and the vine tied to it, or they are pruned with a large stem 4 or 5 feet high, which supports its own weight of vines and fruit. In either case the result is the same, the object being to raise the grape-producing branches above the level they would occupy if pruned closer, as in the case of the Muscats. In ordinary seasons the farmer is not troubled by weeds after his vines are laid by, but when late spring rains occur and destroy the mulch that has been prepared and again wets the surface much added expense must be charged to cultivation. In some limited localities much harm may be anticipated from the spread of Johnson grass. This is a stiff, coarse grass which grows from 3 to 6 feet tall and spreads very rapidly, both from the seed and underground runners or roots, which push out laterally in every direction. When once it gains a foothold it is wellnigh impossible to destroy it without at the same time destroying the crop which it menaces. It attacks all irrigated plats that come within its range, so that it not only is a menace to grape culture, but to all agricultural industries where irrigation is practiced. Its favorite haunts seem to be along the ditch bank, where its ripening seed fall into the running water and are carried to the fields below. This is a matter which should command the immediate and urgent attention of every irrigator in Fresno County, as even now large vineyards and orchards, sometimes of a hundred or more acres in extent, have been practically abandoned on account of this grass alone, and the damage in the future promises to be much greater. Since the raisin and wine industries are greater than any others here, it would seem that the grape grower should be the one to take the initiative in the matter and seek to devise methods of relief from this pest.

The grapes begin to ripen about the 1st of August, and soon after the wineries, of which there are a great number in the county, are running at full capacity, buying the grapes from the growers and reducing them to wine. About the 10th of August the raisin grapes are ripe and picking begins. They are picked, placed on trays to dry in the sun, and after drying placed in boxes that hold about 100 pounds and "sweated." They are now taken to the packing houses, where they are sorted, the Muscat bunches being packed on the stems, while the others are stemmed and some seeded, and packed in boxes of 20 pounds each ready for shipment. The price to the grower the past season was on an average of about 4 cents per pound for dry raisins. An average production per acre is 1 ton, so that the gross receipts per acre from the raisin crop are $80. To this must be added the receipts from the second crop, which ripens later and is sold to the wineries at $10 per ton for the fresh grapes. Chinamen and other cheap laborers are generally employed in the culture and harvesting; so it can readily be seen that the grape growers' net returns or profits are great. But it has not always been thus; for a few years ago only wine grapes repaid in any great measure the efforts of the grower. But within the last two years the growers have organized what is known as the Raisin Growers' Association, which has practically doubled the profits of all raisin growers.

Not all of the soils of the irrigated lands will produce grapes in paying quantities, the most notable example being the Fresno sand. On this soil peaches are planted, so that this crop has come to be the

PICKING PEACHES FOR DRYING.



DRYING PEACHES.

second in importance to the grape. The Fresno sand seems to be especially adapted for peach growing, and for the first few years requires no fertilization, but after this the yield begins to lessen and fertilizers are needed. The peaches are planted about 30 feet apart, and cultivated and irrigated after the manner of all the orchards of this region. There are a great many differences of opinion as to the best methods of pruning, the matter being decided by the man in charge of the orchard. When the peaches are ripe they are either cut in halves and dried in the sun on trays or carted to the cannery to be canned in tin cans. The profits from a peach orchard in full bearing are about the same as from a vineyard, and since the greater part of the land now without water is the Fresno sand, the peach industry may be expected to grow as the development of water increases.

There are a great many other varieties of fruit grown in this irrigated area about Fresno. In fact, it is one vast orchard and vineyard. The two mentioned crops, however, are the principal ones. Pear trees are grown quite extensively on land that has become too badly alkaline for the less resistant crops. Fig trees are usually planted along the edges of vineyards, bordering the roads and drives. These are the variety of figs which produce a fruit whose seeds are not fertile and which are called mule figs. Attempts to grow the Smyrna fig at the Fanches Creek nursery have now met with success, however, and the past season a crop was matured with the aid of the fig insects, a few of which were imported from Smyrna by the Department of Agriculture and the insects grown and attended to, just as they are in Smyrna, under the direction of the Department.

Along the base of the foothills near Centerville is a belt of land where citrous fruits may be grown. As yet, however, the industry has been only small, but in the near future a great many acres will be planted to oranges and lemons, since it has already been demonstrated that they are a commercial success.

Prunes, plums, apricots, and the smaller varieties of fruits, such as blackberries, strawberries, etc., are successfully grown, but of these the apricot only is of commercial importance. These are dried or canned, and in some localities are quite extensively grown.

Several hundred acres of irrigated land in the Kings River bottom southeast of Sanger are devoted to truck crops, some of which are shipped to the San Francisco market and the remainder sold in the markets of Fresno.

The alfalfa that is grown is either in small patches on the fruit farms to furnish feed for the family cow, or else is on land which, because of the accumulation of alkali, is unfit for the culture of fruits. In some cases these latter areas are large, but because of the alkalinity of the soils upon which it is grown the fields are usually spotted and the crops are in no case as large as in other regions where alfalfa is grown from choice rather than necessity. The foxtail grass which covers this whole area greatly injures the first crops of alfalfa, and in some cases the entire crop is burned to destroy the seed of this grass. After the first cutting is disposed of no further trouble occurs from this grass until the next year's first crop.

In the low, swampy Fresno slough country quite a little dairying industry has been built up in the past few years, but its influence is limited as yet, so the principal crops of the irrigated region are the fruits, since other crops are grown only where fruits are for some reason excluded. When irrigation first began the ground water was from 50 to 100 feet below the surface over all this irrigated area, but now the whole country is so filled with water that some of the deep rooted crops require no irrigation, but obtain their water wholly by subirrigation, in some places the water coming within 3 or 4 feet of the surface.

On the lands uninfluenced by irrigation waters only wheat, barley, and rye are grown, and these are grown with only the slight rainfall of the region. The common practice now is to summer fallow the land and in this way hasten nitrification and also carry over some of the moisture of one year which, added to that of the actual growing season, is sufficient to mature the crop.

Wheat is now sown during the fall and winter months, usually after the first rains, and completes its growth by the latter part of May. The last two months of its growth are entirely without rain, its only supply of water being the moisture stored in the soil. Because of the long period of no rainfall including, as it does, the time of the ripening of the wheat, peculiar methods of harvesting are employed. The old method was to head the grain and then thresh it, but now, large combined harvesters are being used in the larger tracts with great success. These require from 24 to 36 horses to draw them, and cut, thrash, and sack the grain ready for shipment. From this machine the sacks are dumped three in a place and afterwards are collected and drawn to the large warehouses, where it is stored awaiting shipment. For the drawing of this wheat, 10 horses, with 2 wagons, one a trailer, are employed. In this way one driver controls the whole and thus cuts the labor expense. Fifteen bushels per acre is now about the average yield for wheat, and from this yield at the average market price the wheat farmer realizes a fair profit on his labor and money invested.

Much of the wheat raised in this valley is shipped to the parts of the State where wheat is not grown; some is made into flour for home consumption, while the poorer class is made into a cheap grade of flour, which is sold in China.

The country is well supplied with transportation facilities. Both the Santa Fe and Southern Pacific lines traverse the county, furnishing ready means of outlet both to the markets of the East and San Francisco, and also communicating with the steamship lines which transport the products to foreign markets.

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