

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF SOILS—MILTON WHITNEY, Chief.

IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA AGRICULTURAL
EXPERIMENT STATION, THOMAS F. HUNT, DIRECTOR;
CHARLES F. SHAW, IN CHARGE SOIL SURVEY.

RECONNOISSANCE SOIL SURVEY
OF THE SAN FRANCISCO BAY REGION
CALIFORNIA.

BY

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

MACY H. LAPHAM, INSPECTOR, WESTERN DIVISION.

[Advance Sheets—Field Operations of the Bureau of Soils, 1914.]



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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF SOILS,
Washington, D. C., April 14, 1916.

SIR: During the field season of 1914 a reconnoissance soil survey was made of the San Francisco Bay region, California. This work was done in cooperation with the University of California Agricultural Experiment Station, and the selection of the area was made after conference with State officials.

I have the honor to transmit herewith the manuscript report and map covering this area and to recommend their publication as advance sheets of Field Operations of the Bureau of Soils for 1914, as provided by law.

Respectfully,

MILTON WHITNEY,
Chief of Bureau.

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

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MAP.

Soil map, reconnaissance survey, San Francisco Bay region sheet, California.

RECONNOISSANCE SOIL SURVEY OF THE SAN FRANCISCO BAY REGION, CALIFORNIA.

By L. C. HOLMES, of the U. S. Department of Agriculture, in charge, and J. W. NELSON, of the University of California.

DESCRIPTION OF THE AREA.

GEOGRAPHY.

The area covered by the reconnoissance soil survey of the San Francisco Bay region is practically included within the parallels of 37° and $38^{\circ} 30'$ north latitude and the meridians of $121^{\circ} 30'$ and $122^{\circ} 45'$ west longitude. It is irregular in outline. The Pacific coast forms the western boundary from Santa Cruz to about 4 miles northwest of Duxbury Point. The other boundaries are straight lines, following the quadrangles covered by the topographic maps of the United States Geological Survey, which were used as base maps in the soil-survey work. The greatest length north and south is 125 miles and the greatest width east and west is a little more than 56 miles. Exclusive of the San Francisco, San Pablo, and Suisun Bays, the area is about twice the size of the State of Delaware, comprising 3,933 square miles, or 2,517,120 acres.

TOPOGRAPHY.

Topographically, the area embraces a series of elongated valleys, separated by high hills or mountains, all extending in a general northwest-southeast direction. The valleys are somewhat irregular in outline and range in extent from a few square miles to about 200 square miles. They are usually well drained and consist of nearly level to very gently sloping surfaces with occasional minor stream bottoms.

The area presents very irregular surface features. More than one-half the region consists of hilly and mountainous areas. The hills are, however, in most cases rounded in contour, and this characteristic, in conjunction with the many moderately sloping ridges and footslopes and the small extent of rock outcrop and broken stony



FIG. 1.—Sketch map showing location of the San Francisco Bay area, California.

land, makes tillage possible over about 75 per cent of the area. There are a few rugged slopes and precipitous rocky ridges. A few of the roughest and most remote mountainous tracts are inaccessible for intensive agriculture and are utilizable mainly for grazing and forestry. The range in elevation is from sea level to an average of about 350 feet for the valley lands and about 4,000 feet for the mountain tops. Mounts Hamilton, Diablo, and Tamalpais are among the highest points in the area. The elevated broken land in the Mount Hamilton section in many places reaches elevations of more than 2,500 feet and embraces the highest and roughest mountains in the area surveyed. The highest crests of the ranges between the Santa Clara Valley and the ocean are about 2,500 feet above sea level. The other elevations in the range from Golden Gate southward do not rise more than 1,500 feet above sea level. The mountains north of the bay are not quite so high, but material of igneous origin is here more prominent and rougher and rocky surfaces are more prevalent than in the areas of sedimentary rocks farther south.

The Golden Gate, which forms the entrance to San Francisco Bay, separates the Marin and San Francisco Peninsulas. The coast from the Golden Gate northward to Bolinas Bay is quite rugged and rises eastward into a series of broken hills and mountains, the most conspicuous of which is Mount Tamalpais, with an elevation of 2,586 feet. South of the Golden Gate the ocean foreland is less rugged and consists of a series of disconnected, irregular old marine terraces and foothill slopes dissected by deep ravines with almost precipitous sides. Moderately rolling hills prevail from San Francisco southward for several miles. These culminate in Montara Mountain west of San Mateo and continue southward to the boundary of the survey as a series of high, rolling ridges known as the Santa Cruz Mountains. The hilly and mountainous region along the coast varies in width from 6 miles at the Golden Gate to about 25 miles to the north and south.

Paralleling this highland on the east is an elongated depression varying from a few miles to about 20 miles in width. A great amount of alluvium has been deposited in this trough, forming a broad valley floor. Santa Clara Valley constitutes the southernmost part of this depression included in the area surveyed. San Francisco and San Pablo Bays cover about 400 square miles and occupy the greater part of this valley basin from San Mateo northward to the mouths of the Napa River and Sonoma and Petaluma Creeks. Beginning at San Pablo Bay and extending north along the above-named streams are three definite valleys, separated from each other by hilly and mountainous country. These valleys vary in width from 1 to several miles, are more or less marshy in their lower approaches to San Pablo Bay, and give way to canyons or a

series of ravines toward the northern part of the area. Napa Valley, lying north of San Pablo Bay, is separated from Vaca Valley on the east by high hills and rough elevated masses, the main crest of which is known as the Vaca Mountains. These mountains extend to the northern boundary of the surveyed area and with their foothills form the eastern boundary at this place. North of the town of Petaluma is the Santa Rosa Valley, a nearly level basin of considerable extent.

The Berkeley Hills, averaging about 15 miles in width, separate San Francisco Bay from the Ignacio and San Ramon Valleys to the east. These two small valleys are bounded on the east and southeast by the Mount Diablo group of elevations, which attain a maximum height of 3,849 feet. South of Mount Diablo and separated by a range of hills from the Santa Clara Valley is the Livermore Valley. This is a well-defined structural basin or valley of considerable extent, bordered on the east by a range of rounded hills and low mountains which, with their outer slopes, extend to the eastern boundary of the area. The highlands to the south of Livermore Valley consist of a series of prominent high, rough mountain blocks, drained to the northward. Mount Hamilton, about 13 miles east of San Jose, is one of the notable peaks of this group of mountains. It reaches a height of 4,209 feet above sea level.

DRAINAGE.

The region included in the survey is in general well drained, except for Tidal marsh and small basinlike depressions a few square miles in extent south of Santa Rosa and a number of others of less extent elsewhere. With the exception of the drainage of the Santa Rosa Valley, which is carried directly to the ocean through the Russian River, most of the drainage of the area reaches the sea through San Francisco Bay. A number of minor streams carry the drainage waters of the Santa Clara Valley and surrounding elevations to the bay. Alameda Creek drains the Livermore Valley and discharges into the bay west of Niles. Walnut Creek and a few other creeks empty into Suisun Bay after draining the San Ramon and Ignacio Valleys. Napa River and Sonoma and Petaluma Creeks flow southward and drain the three valleys north of San Pablo Bay. The extreme eastern part of the area borders the Great Interior Valley and is drained by minor intermittent streams which either lose themselves on the valley floor or reach the Sacramento or the San Joaquin River. Practically none of the streams in the area surveyed are perennial, except in their upper courses, where there is usually a small flow during most of the year.

Tidal marsh areas of considerable extent occur along San Francisco Bay on the south and along San Pablo and Suisun Bays on the north. These comprise lowland, much of which is subject to inundation at high tide. These marshes receive much flood water during the winter season and are slowly building up through the deposition of sediments by the streams. The scarcity of tree and brush growth on much of the hill land permits a rapid run-off, and during rainy periods the streams overflow, causing damage to bridges and roads and to cultivated fields.

VEGETATION.

The hills and mountains over much of the area present a generally treeless appearance (see Pl. I and Pl. II, fig. 1). The rather shallow and droughty nature of the mountain soils has had a tendency to restrict tree growth. In places, however, especially in the deeper canyons and on eastern and northern slopes, there is a heavy growth of timber. The great timber belt of Mendocino and Humboldt Counties extends into the northwestern part of the area as a few rather thickly wooded slopes. There is a remarkably wide range of trees and bushes native to the area, chief among which are Douglas fir, coast live oak, valley oak, redwood, species of pine, red alder, willow, laurel, buckeye, California walnut, manzanita, ceanothus, blackberry, wild rose, and poison oak. The forest growth decreases as the Great Interior Valley is approached. The vegetation of the salt and fresh water tidal marshes consists principally of salt grass, sedges, and tule. A moderate to heavy growth of wild grasses is found in all parts of the area. Wild legumes grow abundantly in most of the canyons and ravines and upon the forested slopes. Along the coast the vegetation differs somewhat from that prevailing elsewhere, consisting principally of trailing plants and shrubby growths.

POPULATION AND CITIES.

The population of the 11 counties¹ lying wholly or partly in the area included in this survey, according to the 1910 census, is 1,002,579. Nearly half the aggregate area in these counties is within the boundaries of this area. These 11 counties show an average increase in population of 48.1 per cent for the decade 1900 to 1910. There are 12 cities in the area of over 5,000 population, their total population being 714,559. The rural population for the counties, exclusive of San Francisco, averages 28.3 persons per square mile. The foreign-born population in these same counties averages 25 per cent of the total population. Of the foreign population, Germans rank first,

¹ Alameda, Contra Costa, San Francisco, San Mateo, Marin, Napa, San Joaquin, Santa Clara, Santa Cruz, Solano, and Sonoma.

and Italians, Japanese, Chinese, Irish, Portuguese, Austrians, and Scandinavians constitute the principal other foreign nationalities. The native settlers are mainly from the North Central and New England States.

San Francisco, a world port and a place of first importance on the Pacific, is the principal city of the area. It is an important commercial center and a point of great interest to tourists. San Francisco is located on the peninsula between San Francisco Bay and the ocean, on the south of the strait known as the Golden Gate. Oakland, across the bay on the east, is the second city of importance in the area. It is the terminus for several transcontinental railroads, and with its advantageous situation for industry and shipping carries on an extensive trade. Berkeley adjoins Oakland on the north, and is the third city in size. Berkeley is an attractive residential city. It is also the site of the University of California. San Jose, in the heart of the highly developed Santa Clara Valley, ranks next to Berkeley in size. Alameda is located just south of Oakland Harbor, across from Oakland City. Santa Cruz, with its attractive beach, is a well-known resort city on the ocean front south of San Francisco. The Leland Stanford Junior University is located at Palo Alto, between San Jose and San Francisco. Richmond, Vallejo, Santa Rosa, Napa, Petaluma, San Rafael, Livermore, and other important towns or cities, ranging in population from a few hundred to 10,000 persons or more, are located in fertile valleys throughout the area or on the bays and navigable streams. At Richmond there are Pullman-car shops and a large petroleum refinery.

INDUSTRIES, TRANSPORTATION, AND MARKETS.

A beet-sugar factory has been in operation in the Santa Clara Valley for a number of years. The manufacture of salt is carried on extensively by several large companies and a number of smaller concerns along the shores of San Francisco Bay, particularly in the vicinity of Alvarado, southward to the Coyote Hills. Many thousands of tons of salt are annually obtained by evaporation from the bay waters and refined. Powder works, a shot factory, shipbuilding yards, a United States naval training station, and a number of other smaller factories and institutions are located along the shores of the San Francisco and San Pablo Bays, or on some of the islands. There are numerous wineries, cooperage cellars, packing houses, processing plants, and canneries in various parts of the area, where the type of agriculture demands their maintenance.

Orcharding, trucking, wine production, dairying, and poultry raising are the main interests of the people in the rural districts, while commerce and manufacturing are of first importance in the larger cities.

Practically all the dairy, meat, hay, poultry, and truck products produced in the area are consumed in the larger towns and cities. Other products, such as tree fruits, nuts, hops, and seeds, are used in large quantities locally, but are also shipped fresh and as cured products to eastern markets and Alaska, and in a small way to Europe and Asia.

Three trunk lines—the Southern Pacific, the Atchison, Topeka & Santa Fe, and the Western Pacific—terminate at Oakland and San Francisco. With the numerous branches of the systems and lines of the Northwestern Pacific, the Oakland, Antioch & Eastern, and the Ocean Shore Railroads, as well as several other steam and electric lines, nearly all points within the area are well supplied with transportation facilities to San Francisco, Oakland, and other towns and cities. Petaluma Creek and Napa River are navigable for small boats as far as Petaluma and Napa, respectively, and vessels of shallow draft pass through San Pablo and Suisun Bays to points along the Sacramento River as far as 300 miles inland. Besides various steamboat lines, ferries operate across the bays and large rivers.

Much attention has been given recently to road construction, and excellent highways, with numerous well-graded feeder roads, now reach practically every important town and point of interest, radiating from all the cities to outlying points. The improvement of the public-road system has been of much importance in the marketing of fruits and other intensive farm crops.

CLIMATE.

The climate of that part of the Bay Region included within this survey varies greatly and has a marked influence upon the distribution of crops. Marked variations which appear to be due largely to elevation and exposure occur within short distances. Along the coast and on the western slopes of the Berkeley Hills from Oakland to Carquinez Strait the climate is too cool and damp for the best development of tree fruits, but truck crops thrive.

The year is divided into a wet and a dry season, which coincide with winter and summer.

PRECIPITATION.

The rainfall varies greatly from place to place, with difference in elevation, exposure, and location. The greater part of the precipitation falls from November to March, inclusive. Little or no rainfall occurs during the growing season, but where the soil is deep and retentive many crops can be matured without irrigation. Rainfall is quite well distributed during the winter months. Rainy periods seldom last more than three or four days, and gentle showers inter-

persed with clear and foggy weather are the rule. Hail, severe thunderstorms, and cloudbursts are rare. Snow very rarely occurs in the valleys, but there are light falls on the mountains, the snow remaining for short periods only.

Owing to the slow and gentle nature of the rains, precipitation is mostly absorbed by the soil, and only on bare and exposed slopes is there erosion. Considerable damage, however, occurs locally from landslides or creeps, which are quite numerous in the hilly and mountainous districts, in places where the soil becomes saturated and loosened by the deep percolation of water and yields to the pull of gravity. These slides may affect a single body of land covering one to several acres or more, or may be made up of a series of land movements affecting a number of small areas. In places they disfigure the land surface to a great extent and seriously hinder the use of the land for agriculture.

The following table gives the approximate average annual precipitation for places located in different parts of the area, the data for this and the following tables being obtained from official reports of the Weather Bureau.

Mean annual precipitation for stations in the San Francisco Bay area.

| Station. | Precipitation. | Station. | Precipitation. |
|--------------------|----------------|-----------------|----------------|
| | <i>Inches.</i> | | <i>Inches.</i> |
| San Francisco..... | 23 | Santa Rosa..... | 32 |
| San Jose..... | 15 | Santa Cruz..... | 28 |
| Livermore..... | 16 | Suisun..... | 20 |
| Oakland..... | 24 | Berkeley..... | 26 |
| Napa..... | 24 | Kentfield..... | 49 |

These amounts represent the rainfall for points in the various valleys and lower lying portions of the area. As the elevation increases the rainfall also increases, in many instances being two or more times as much in the high hills and mountains as in the valleys.

TEMPERATURE.

That part of the area immediately along the coast and surrounding the bay is coolest. Elsewhere the temperatures generally rise as the Great Interior Valley is approached. Temperatures seldom fall below 32° F. in that part of the area west of the Berkeley Hills, and while east of these hills it is a few degrees cooler in winter. little damage is done to crops, and hardy vegetables grow throughout the winter. Late spring frosts on the low, flat portions of the valleys sometimes cause damage to early blooming fruits and nuts.

The depressed or nearly flat areas, especially in the valley floors, are much more subject to freezes than the foothill slopes surrounding them. Within short distances the difference is so marked that farmers on the slopes are able to mature the more tender crops from 1 to 3 weeks earlier than those in the lower parts of the valley. For these reasons the footslopes, where the soil and moisture conditions are favorable, afford better sites than the valley floors for orchards of the early blooming fruits and nuts. September and the first half of October are the warmest parts of the year at San Francisco and bay points. The following table gives the temperature at stations located in different parts of the area:

Mean annual and absolute maximum and minimum temperatures for the San Francisco Bay area.

| Station. | Mean maximum. | Mean minimum. | Highest. | Lowest. | Mean annual. |
|--------------------|---------------|---------------|----------|---------|--------------|
| | °F. | °F. | °F. | °F. | °F. |
| San Francisco..... | 61 | 50 | 101 | 29 | 55 |
| Santa Cruz..... | 70 | 43 | 108 | 22 | 58 |
| San Jose..... | 70 | 45 | 108 | 18 | 58 |
| Livermore..... | 74 | 45 | 113 | 23 | 60 |
| Oakland..... | 65 | 49 | 106 | 30 | 56 |
| Berkeley..... | 63 | 49 | 101 | 29 | 56 |
| Suisun..... | | | 110 | 22 | 60 |
| Napa..... | | | 110 | 18 | 56 |
| Santa Rosa..... | | | | | 58 |

The prevailing cool weather during the growing season in proximity to the bay from Oakland northward makes the production of commercial tree fruits in this portion of the area difficult. Average dates of killing frosts at stations distributed over the area are indicated in the following table:

Dates of killing frost in the San Francisco Bay area.

| Station. | Latest in spring. | Earliest in fall. | Average latest in spring. | Average earliest in fall. |
|--------------------|-------------------|-------------------|---------------------------|---------------------------|
| San Francisco..... | Mar. 27..... | Dec. 18..... | Jan. 25..... | Dec. 10. |
| Santa Cruz..... | Apr. 1..... | Nov. 11..... | Mar. 10..... | Dec. 9. |
| San Jose..... | Apr. 9..... | Oct. 22..... | Feb. 6..... | Nov. 27. |
| Livermore..... | Feb. 23..... | Dec. 2..... | Apr. 12..... | Nov. 9. |
| Oakland..... | Feb. 15..... | Dec. 15..... | Jan. 7..... | Dec. 20. |
| Berkeley..... | Feb. 19..... | Dec. 14..... | Jan. 28..... | Dec. 15. |
| Napa..... | Mar. 30..... | Nov. 7..... | Mar. 20..... | Nov. 15. |
| Santa Rosa..... | May 10..... | Oct. 29..... | Apr. 24..... | Dec. 10. |

HUMIDITY.

The relative humidity is high near the coast and bay, but decreases eastward, and is much lower in the valleys separated from the ocean by prominent mountains. The variation in relative humidity in summer and winter is not nearly so marked here as in the interior valleys, owing to the occurrence of fog at both seasons of the year. Fog occurs frequently along the coast, over the north end of the San Francisco peninsula and in the region of Oakland and Berkeley throughout all parts of the year. In the valleys and other places which are protected from the ocean by mountain barriers it is less frequent and occurs mainly during the winter months. In summer, fog generally enters the Golden Gate early in the afternoon and frequently covers the region the rest of the day and most of the night. Along the coast the mountains usually are too high for the fog to pass over readily, and it is generally confined to a belt a few miles in width. In winter, fog frequently occurs in the morning, but usually disappears before noon. Periods of foggy weather lasting for several consecutive days sometimes occur. More elevated areas are freer from fog than the valleys. At times the fog consists of a fine mist which causes trees and other vegetation to drip with water. Fog during winter and spring nights is usually helpful in the fruit-producing valleys in reducing danger from frost.

WINDS.

The average wind velocity at San Francisco is 10 miles per hour. The velocity is higher at points along the coast and on mountain tops, but is less in the valleys. In summer 75 per cent and in winter 30 per cent of the prevailing winds at San Francisco are from the west to northwest, the remainder coming mainly from the northeast and south to southwest. Wind currents entering the Golden Gate from the west split, part entering the Santa Clara Valley as a northwest wind and part deflecting north and northeast into the Sonoma and Napa regions. In the Livermore Valley the prevailing direction is west to northwest. In the valleys near the coast the winds are cool, but they become warmer and contain less moisture as they move eastward.

Along the coast and on exposed slopes and hilltops wind movement is an important factor in tree-fruit culture and should be carefully considered before sites are selected for this purpose. Where the native trees have not all been removed high wind movement may be noted by the generally flattened tops of the trees. Very little injury is done in this area by the hot, dry winds common in the interior valleys. The extreme eastern part of the area enters the Great Interior Valley, and this part has mainly the interior climate.

Generally the region under discussion is very favorable climatically for a wide range of deciduous fruits, and in certain well-protected locations citrus fruits have been grown in a small way.

AGRICULTURE.

Agriculture in the area dates back to the time when California belonged to Mexico. During the early period of agricultural development the markets were distant and transportation was very poor. As a result there was little inducement to extend agriculture, and stock raising was the principal industry until after the discovery of gold. This brought many settlers to the State and offered an outlet for agricultural products, which somewhat stimulated farming.

Grape growing for the manufacture of wine began at Sonoma in 1856 and slowly developed, until it is now one of the leading industries of the region north of the bay. Figs were among the earliest plantings of fruit, but they were grown in a small way only.

Wheat, barley, corn, hay, and vegetables were the leading crops for many years. The virgin soils gave heavy yields, but continuous cropping to grain for many years with crude and inefficient methods of tillage and lack of rotations reduced the returns greatly. From 1890 to the present time the acreages of general farm crops, except hay, have decreased.¹ It is reported that in 1880 there were in the counties included wholly or in part within the survey 554,000 acres in wheat and 195,000 acres in barley. The grain was produced cheaply and was used for flour making, as feed or shipped to outside markets. While land values were low, this industry was quite profitable, but as land values increased it became necessary to take up a more highly specialized agriculture. In 1910 the acreage in wheat is reported as 54,000, and there were about 212,000 acres in barley. During this year only 57 acres of wheat were grown in Marin County, about the same acreage in Sonoma and San Mateo Counties, none in San Francisco County, and about a section or less in that part of each of the other counties covered by the survey, except Napa and Contra Costa Counties.

The production of hay has steadily increased over nearly all the area and is still a very important crop. Much of the hay is fed locally to cattle and dairy cows, but a large amount is baled and shipped to the near-by cities. Grain cut green constitutes about five-sixths of the hay produced (see Pl. I and Pl. II, fig. 2). The remainder consists about equally of alfalfa, cultivated grasses, salt grasses, and prairie grasses.

¹ Statistics and estimates quoted herein are taken from reports of the census, of the State commissioner of horticulture, and in part are based upon interviews and field observations. In most cases statistics of acreage and production are for the counties as a whole, though nearly half of their combined area lies outside the area surveyed.



VIEW ON MOUNT HAMILTON ROAD EAST OF SAN JOSE, SHOWING TOPOGRAPHY OF ALTAMONT ADOBE SOILS, WITH AREAS DEVOTED TO GRAIN HAY.



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FIG. 1.—SHOWING CHARACTERISTIC TOPOGRAPHY OF SOILS OF ALTAMONT SERIES, NEAR ALTAMONT.

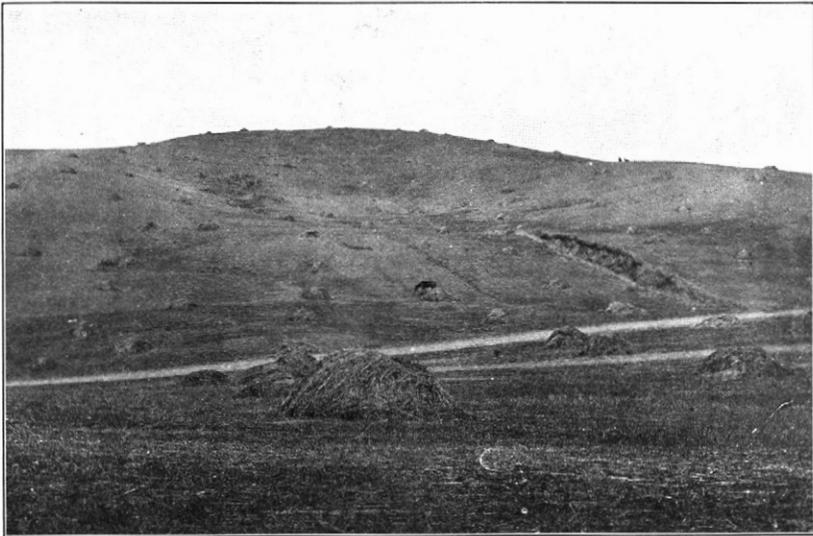


FIG. 2.—GRAIN HAY GROWN ON DIABLO CLAY ADOBE.

Oat production varies considerably in the area. The crop is grown in the valleys mainly as a step in the rotations. Almost three-fourths of the total production is confined to San Mateo County. Good yields are obtained and most of the crop commands ready sale in the near-by cities.

Corn is produced to some extent in the valleys north of the bay. Napa and Sonoma Valleys lead. The rainfall in these valleys is greater than farther south and yields are more certain. Corn is grown in rotation with other crops in the valleys and to a considerable extent in connection with the hog and cattle industries.

The intensive agriculture of the area is confined principally to well-defined valleys, chief among which are the Santa Clara, Livermore, Napa, Sonoma, Vaca, Ignacio, and San Ramon Valleys. Many other smaller valleys, from one to several square miles in extent, lie among the mountains, some of which are highly developed and others used mainly for general farming. Some are centers of large areas of mountain grazing land. They are usually well protected and some afford opportunities for a highly specialized agriculture.

Many of the hills, low ridges, and mountain foot slopes surrounding the larger valleys are used for growing fruits and other intensive crops. Most of the higher mountains and hills are suited only for grazing and forestry. Considerable mountain and hilly areas are segregated as sources of water supply for the larger cities. Where vegetation is scant in such places, extensive plantings of cedar, pine, and eucalyptus have been made to help retard erosion and lessen run-off.

SPECIAL CROPS.

Numerous highly specialized crops are grown in the area where climatic and soil conditions are favorable. The most important will be discussed in some detail.

Grapes.—Grape growing is one of the leading industries. In the warmer valleys and on suitable hillsides table varieties are grown, but varieties for wine making occupy by far the larger acreage. There are about 54,000,000 grapevines in the counties included in whole or in part in the survey. The valleys of Sonoma, San Joaquin, Napa, and Santa Clara, and the Livermore Valley with their surrounding foothills are the main centers for this industry. Many are grown elsewhere, and many highly productive vineyards are located well up in the mountains.

The climate of the area is favorable to the production of those qualities in grapes which are requisite to the making of superior dry wines. Little or no irrigation is practiced for grape culture, the rainfall being usually sufficient to mature paying crops.

The grape grows moderately well on a wide range of soils, but usually attains its finest qualities when produced on well-drained loams, silt loams, gravelly loams, and sandy loams containing a moderate supply of organic matter and lime. The grapes grown on hills and slopes are generally considered to produce wines of better flavor and bouquet than those grown on the deep, fertile river-bottom soils. The yields, however, on the latter are noticeably heavier. Yields and prices vary greatly with location and soil, and care given the vines.

Many of the poorer and less desirable soils for other intensive crops give satisfactory returns when utilized for grape culture, and much of the development in hilly areas is due to this fact.

The area is unsuited, climatically, for raisin production. Tokay, Black Cornichon, Sultanina (Thompson Seedless), Emperor, Black Morocco, and some others are the main table varieties grown. Petite Sirah, Zinfandel, Carignane, Burger, Columbus, and a number of others lead for wine production.

The vines begin bearing at about 3 years and produce well for 10 to 15 years. The cost of bringing a vineyard into bearing varies greatly, depending largely upon soil and situation.

The United States Department of Agriculture has a substation at Oakville, where about 300 vinifera varieties are being tested on different stocks. This work is yielding valuable information for the wine-producing sections.

Plums and prunes.—According to the 1910 census and the records of the various county horticultural commissioners, there are about 5,000,000 plum and prune trees in the counties covered in whole or in part by the survey, about nine-tenths of which trees are in the area surveyed. There are considerably more prune trees than plum trees.

This industry is developed more or less over the entire area, but the most extensive plantings have been made in Santa Clara, Sonoma, Napa, and Vaca Valleys, and two-thirds of the prune production of the area is confined to the Santa Clara Valley.

The prune is characterized by its sweet, firm flesh and its ability to cure without the removal of the seed. Plums will not cure in this manner and must be canned or used as fresh fruit.

Cultural methods and soils are nearly the same for both fruits. The great variety of root stocks upon which these fruits are grafted gives a wide range of soils upon which they will thrive. The peach, bitter almond, and apricot roots are used with great success for loams or lighter types, and the myrobolan stock when the trees are grown on clay loams and clays. The productive period of the trees depends almost entirely upon the kind of soil, root stock used, and care given. Very light soils produce short-lived trees and light yields, and low,

flat, heavy clays, and clay adobe, especially where the subsoil is a heavy clay, give irregular, short-lived trees and uncertain returns. Loams, silt loams, silty clay loams, and light clay loams approach most nearly the ideal soil environment for these fruits. Soils used for the production of plums and prunes must be well drained and free from alkali.

For prune production, the French, Sugar, and Imperial varieties are almost exclusively used. For plums the Burbank, Climax, Wickson, Diamond, Grand Duke, Tragedy, and others are important.

Planting is usually done late in December, January or February, and vigorous 1-year-old trees are generally considered best to set out. Moderate to low heading is the rule.

Plum trees begin to bear when about 3 years of age, and when 5 years old good vigorous trees produce from one-half to 1 ton of fresh fruit per acre. The yield increases with age, reaching its maximum at about 10 years, under favorable conditions. The average yield of mature trees is from 3 to 8 tons of fresh fruit per acre.¹ The yields on the foothills are lighter than in the valleys, but the orchards in the foothills are subject to less damage from freezes.

Plums and prunes bloom late in March and early in April, and harvest begins late in August. Under normal conditions it requires from 10 to 15 days to dry the fruit.

North of the bay most of the plums and prunes are grown without irrigation. This is the practice generally in other parts of the area also, but the use of water for prune culture in the Santa Clara Valley is becoming quite general. An irrigation given immediately after the crop is harvested is thought by some to insure a crop the following year.

Apples.—Apple culture in the area is controlled principally by climate. The valleys and protected mountain slopes near the coast appear to give best results with this fruit, and apple plantings decrease as the interior valley is approached. Western exposures near the ocean are undesirable on account of wind and fog. Well-protected areas of sufficient elevation in all parts of the area where soils and moisture conditions are favorable are utilized with moderate success for apple culture. Western slopes are usually subject to more rapid loss of soil moisture than other exposures.

The acreage planted to this crop was greatest in 1900, and had noticeably declined in 1910. No highly specialized apple centers occur in the area, but Watsonville, a well-developed district for Yellow Bellflower, Red Pearmain, Winter Pearmain, Yellow Newtown, Banana, and a few other varieties of less importance, is situated a few miles outside the area, south of Santa Clara. Another well-

¹ About 2½ pounds of fresh fruit are required to make 1 pound of dry.

developed center in which the Gravenstein is grown is at Sebastopol, just outside the area on the northwest. Most of the apples are produced without irrigation.

The varieties mentioned above also lead in this area. While high-quality fruit is produced the industry does not seem to be increasing rapidly.

Well-drained loams and clay loams, with a moderate supply of organic matter and moisture, give the best results with apples in the area covered by this survey.

Peaches.—Definite centers of peach production are situated in the valleys and on the foot slopes north of Cordelia, in the Vaca Valley, west and southwest of Winters, around Santa Rosa, in the Santa Clara Valley, and lesser plantings occur at many other places in the area. According to the horticultural commissioners of the various counties, there are more than 1,300,000 peach trees in the counties wholly or partly included in this area.

Peach growing is still very important, though it has declined materially since 1900, largely on account of the competition of regions better situated with reference to the large markets in the East, and because other fruits well adapted to the soils on which peaches are grown are more profitable. The fruit is sold fresh and used in large quantities by canneries and for drying.

The peach begins bearing at 3 years and produces well for 12 to 15 years. The quality of the fruit is very good, especially where grown on the more suitable soils. Elberta, Early and Late Crawford, Early Imperial, Georges Late Cling, Phillips Cling, Tuscan Cling, McKeivitts Cling, Orange Cling, Alexander, Hale, Muir, White Heath Cling, and Lovell are the leading varieties grown. Muir and Lovell are very popular for drying. McKeivitts and White Heath Cling are grown largely for canning. Many new strains and varieties, ranking among the best for the soils and climate of the area, have been developed. Cannerymen sometimes contract with growers for their fruit at a fixed price for one or more years in advance.

Most of the peaches are grown without irrigation, and where the soils are deep and retentive of moisture, good yields are obtained. In places where the rainfall is insufficient, or where the orchard is on shallow or droughty soil, irrigation has proved successful.

The cost of bringing an acre of peaches into bearing varies considerably, depending on whether it is hillside land, covered with brush or level valley land. In favorable locations, where the soils are deep and fertile and irrigation is possible, much of the expense is met by growing hoed crops among the trees until they come into bearing.

Very early varieties and fruit of unusually fine quality frequently bring high prices when shipped green to outside markets.

Well-drained sandy loams, loams, and light clay loams containing a moderate supply of organic matter and lime, give the best results with peaches in this area.

Cherries.—There are more than 400,000 cherry trees in the eleven counties, practically all of which are sweet varieties. The blooming period is quite early, and some injury occasionally occurs from spring frosts, especially where the trees are planted in nearly flat or slightly depressed areas of poor air drainage.

Favorite soils for this crop are well-drained fine sandy loams, so located as to be free from severe winds and freezing weather. Purple Guigne, Chapman, Bing, Napoleon, Tartarian, Burbank, Rockport, Republican, May Duke, Advance, Morello, and a few others are the leading varieties. The cost of bringing an orchard into bearing is about the same as for peaches. In many places on the deep, fertile soils hoed crops are very successfully grown until the orchard comes into bearing.

The industry is well distributed over the area, but is most highly developed in the Santa Clara Valley, in the foothills and small valleys from Cordelia to Winters, and in the upper parts of the Napa and Sonoma Valleys. The earliness of the fruit, its choice quality, and the few competing regions generally result in fair to good prices to the grower.

Some irrigating is done with success in the Santa Clara Valley and a few other places. Elsewhere growers depend upon the rainfall.

Apricots.—The growing of apricots is one of the most extensive industries in the area (see Pl. III, figs. 1 and 2). There are about 1,500,000 trees in the counties wholly or partly included in the survey, and about nine-tenths of these trees are in the Santa Clara Valley and in the foothills and small valleys from Cordelia to Winters. The remaining orchards are distributed over the area where soil and climatic conditions are favorable.

Apricots do well on a wide range of soils and closely follow prunes in their requirement. The range of soils is widened by the use of proper root stocks. The climate and soils of the area, except in certain places near the bay and on exposed western slopes along the ocean, are very well adapted to this fruit.

Wherever grown, the trees are usually vigorous, very productive, and long-lived. The early blooming of this fruit makse it necessary to avoid low, flat or depressed locations on account of the danger of damage from frost. The orchards are productive, and there is usually a good demand for the fruit in eastern markets and local canneries, and for drying. Blenheim is the favorite variety, but

considerable plantings of Moorpark, Royal, and Hemskirke have been made.

In favorable soils apricot roots go down 10 feet or more, hence the necessity of giving careful attention to depth of soil before planting. Most of the fruit is produced without irrigation, and in normal years on favorable soils good crops are obtained. Irrigation, however, is growing in favor. It insures returns on shallow soils and in years of low rainfall. One application of water is usually ample for a crop, but occasionally an irrigation is given after harvest to promote tree vigor and the setting of fruit buds for the following year.

The more elevated places with light soils which warm up quickly mature the fruit first, but the yields are usually lighter than on the deeper and more fertile soils.

Pears.—Pears are not so extensively grown as apricots, but their production is important, there being about 666,000 trees in the eleven counties. The Santa Clara Valley and the region from Winters south to Cordelia are the most highly developed centers for this fruit. The fruit is shipped east fresh, and large quantities are canned and dried. Blight, a menace in many places, is not yet serious in the coast valleys and mountains.

Bartlett, Winter Nelis, Comice, and a number of other varieties are grown. The Bartlett and some other varieties that meet no important competition usually command a ready market. Some of the fruit is shipped to European markets, where it brings fancy prices.

Pears generally do best on the heavy soil types, such as the heavy loams, clay loams, and well-drained clays (see Pl. IV, fig. 1). They will grow in wetter soils than most other fruits, but for the best returns and for the longest period of production, the soils should be well drained and open to 4 or 5 feet in depth. If clays are used, those having subsoils lighter than the surface are preferred. In favorable locations trees are long-lived and productive.

Little irrigating is done in producing pears in the area, as the heavier soils are generally sufficiently retentive of moisture, when carefully tilled, to carry the crop to maturity. Some water is given to young trees and is provided for older ones where needed. The industry is increasing somewhat and is considered profitable where well handled and when the fruit is well graded and packed for market.

Figs.—That part of Solano County included in this survey—Sonoma, Napa, and Santa Clara Valleys—leads in fig culture. Most of the figs grown are border trees and little attention has been given to the commercial production of this fruit. Scattering trees occur over all parts of the area, except on rough mountain areas and in areas of unfavorable exposure along the coast.

Most of the trees are of the Mission varieties, but White Adriatic and Smyrna have been planted in a small way where conditions are most favorable. The trees are thrifty and bear heavily. The fruit is used for drying, canning, preserving, and as fresh fruit, and for home use. Little attention has been given to methods of good handling and marketing, and much of the fruit not locally consumed is allowed to fall to the ground and spoil. With improvement in packing, curing, and marketing it would seem that the production of figs might be made a commercial success, as most of the figs consumed in the United States at present are imported.

The trees are long-lived, some of the old Mission varieties producing well for a hundred years or more. Bearing begins at about 4 years of age and little trouble from pests occurs.

Moist, well-drained fine sandy loams, loams, and light clay loams approach most nearly the ideal soil requirements of the fig in this area. It does well on lighter and heavier soils than these, but the bearing is not so regular nor tree growth so uniform.

Little or no attention is given to irrigation for this fruit, and it appears to thrive with moderate care.

Citrus fruits.—The citrus industry has received little attention. There are about 20,000 trees located in small plantings throughout nearly all parts of the counties included wholly or in part in this survey. Some success has been attained with lemons and oranges in a small way where conditions are particularly favorable, but most of the plantings are for noncommercial purposes. The foothills surrounding certain valleys where soil, moisture, and temperature conditions are most favorable may prove of some value for these fruits.

Melons and small fruits.—Cantaloupes, casabas, watermelons, and strawberries thrive in all parts of the area on the loamy sands, sandy loams, and loams. Loganberries, raspberries, blackberries, dewberries, gooseberries, and currants do well on the sandy loams, loams, and clay loams. Most of the fruits, excepting currants, are disposed of in the local markets. Where irrigation is possible these fruits are grown very successfully on shallow soils entirely unsuited to tree fruits and many other crops. Strawberries are so handled that fresh fruit is available for nine months of the year. Currants are grown in great quantities in the Santa Clara and surrounding valleys.

Small fruits yield heavily when well cared for, but the market is too limited and there are too many better located competing regions to warrant extensive commercial plantings here.

Japanese persimmons, loquats, pomegranates, and a number of other new introductions give promise in those parts of the area hav-

ing favorable climatic conditions. Further tests should be made with them, however, before extensive commercial plantings are made.

Olives.—The olive industry is not so highly developed in the area as in the Sacramento Valley and other warm interior regions. Much of the area is too cool for the development of this fruit, but those parts of the area near the interior valley and other places with warm and protected exposures have proved well adapted to it. There are about 95,000 trees in the area, mainly of the Mission and Manzanillo varieties.

The industry has not been especially successful in the past on account of fluctuating markets and inferiority of the fruit. Poor methods of growing and handling are in part responsible for this.

The trees are hardy and will endure considerable mistreatment, and this has led growers in many places to expect big crops with little care. As a result the industry has suffered greatly, and low, uncertain yields of inferior fruit have been the rule. In recent years the demand for olives has increased greatly. The fruit is used both for pickling and for the manufacture of oil.

Trees come into bearing at four or five years. The yields are small at first, but gradually increase, and with good care the orchards when in full bearing produce from 1 to 3 tons per acre. The tree is an evergreen and thrives on well-drained sandy loams, loams, gravelly loams, and light clay loams. Very fertile soils, high in organic matter, produce a great amount of wood at the expense of fruit. The olive does best on soils of moderate fertility and lime content and sufficient moisture to insure a healthy growth and proper maturity of the fruit. Trees appear to suffer in cold weather if the soil is dry. For this reason a fall irrigation is sometimes given. Areas affected by standing water or overflow, low level areas or depressions, and cold, windy exposures are unfavorable.

The trees are long-lived and often produce well for a century or more where properly cared for. The demand for olives in the United States is large, and the imports in 1914 amounted to more than 5,000,000 gallons of a value of more than \$2,000,000.

Nuts.—The nut industry is confined chiefly to the growing of almonds and walnuts. There are over 500,000 nut trees in the eleven counties included wholly or in part in this survey, and about 90 per cent of these are almond trees. The industry, while of growing importance, is only about one-seventh as extensive as that in the Sacramento Valley.

The almond is best suited to the warmer parts of the area, and it is in such places that the industry is most highly developed. The foothills and small valleys from Winters to Cordelia, Santa Clara, Sonoma, Napa, Ignacio, and San Ramon Valleys rank first in the production of both kinds of nuts. Other well-located areas are also developing these industries successfully.

Very little irrigation is practiced in the area for nut culture, rainfall and good tillage being relied upon for returns. Where water is available irrigation is increasing, with good results.

Almonds begin bearing at about 3 years and under favorable soil and climatic conditions continue to be profitable for 20 to 35 years. The productive period of the trees depends largely upon the kind of soil and root stock used.

Both walnuts and almonds give best returns on deep loams and light clay loams. They also do well on the sandy loams, but may need more frequent applications of fertilizers and better care, and the lighter the type of soil generally the shorter the life of the tree. Yields of these nuts from mature trees in this area vary from one-third ton to 1½ tons per acre. The trees are very early bloomers and are therefore subject to injury from frosts when planted in low places. Locations subject to standing water, overflow or alkali are avoided. The foothills and steeper valley slopes with protection from heavy winds, where moisture is ample, are the most satisfactory sites for nut orchards.

Ne Plus Ultra, IXL, Nonpareil, and Texas Prolific are the leading varieties of almonds.

Sugar beets.—Sugar-beet culture in this area is confined almost entirely to the Santa Clara Valley. While good yields have been obtained, the income from the industry has not been as great as from some of the more highly specialized crops, and the tendency in recent years has been slowly to displace this crop with others. Sugar beets have been successfully grown in all parts of the area, except where the soils are shallow, high in alkali, droughty, and subject to extremes of weather.

Hops.—Hop growing is confined mainly to the Napa, Sonoma, and Santa Clara Valleys. The acreage planted to hops is increasing. In favorable years yields of one-half to 1½ tons are obtained.

Hops are produced mainly on the deep, fertile, well-drained alluvial soils along the streams. Overhead trellising is used, the system costing from \$50 to \$100 an acre.

Rice.—No rice is grown in the area, but it is produced successfully in the Sacramento Valley on soils similar to some of the types found in this area.

Truck crops.—The trucking industry is very highly developed just south of San Francisco, in the region between San Jose and Oakland, and to a less degree around nearly all the large towns in the area.

Soils ranging in texture from loamy sands and sandy loams to clay loams and clay are used for this purpose. The light types produce the earliest products. The heavier types mature their crops later and frequently give heavier yields.

A local strain of sweet corn has been developed on the Altamont soils in the foothills of the Santa Clara Valley, which produces its ears in most cases a few inches above the ground. In the foothills the corn matures from 2 to 4 weeks earlier than varieties grown on the valley floor a few hundred feet below. Yields of 50 to 200 sacks per acre are obtained, a sack holding 7 dozen ears.

Rhubarb is grown on a commercial scale south of Oakland. It is produced in individual fields and is quite extensively grown in young orchards. Harvesting begins the second year and good yields are obtained until the fields are 6 to 8 years old. It is now produced principally on loams and clay loams, and good results have been obtained in places on well-drained clay adobe.

Cutting is done from February to April. The crop is grown without irrigation, and good care, with application of manure, greatly increases the yield and quality.

The growing of artichokes is a prominent industry along the coast from Santa Cruz to San Francisco. Harvesting is done as soon as the heads develop to the proper degree of naturity and continues for several months or into early summer. The heads are crated and sent to the city markets. Good yields are obtained and the product sells readily at good prices. With an extended system of distribution and a wider market, this industry should remain very profitable because of the small extent of country in which the plants appear to thrive.

The moist, cool ocean climate and the dark-colored Dublin loams and clay loams high in organic matter appear to be especially favorable for this crop. While the bushy growth is developing, truck crops, such as peas and beans, are grown between the rows. The artichoke requires a relatively large supply of moisture, and irrigation is practiced wherever possible.

Most of the potatoes produced on the San Francisco peninsula, in the Santa Clara Valley, and in a few other well-located valleys are early varieties. The light types of the Yolo, Dublin, and Antioch series of soils are mainly chosen for this crop. The acreage, price, and yields fluctuate considerably, depending upon the season and demand. The potatoes are of good quality and are disposed of mainly in the local markets.

Horse beans, kale, cabbage, beans, peas, celery, lettuce, onions, tomatoes, and many other kinds of truck crops are produced in large quantities, principally on the light types of the Antioch and Yolo series of soils. Several thousand acres of beans are matured along the coast from Santa Cruz northward.

Heretofore nearly all the products of this industry have been consumed locally on account of prohibitive freight charges, long hauls, and competing areas nearer outside markets.

Wherever water is available for irrigation it is used for these crops, but a large part of the produce is grown without irrigation.

Vegetables come into the market throughout the entire year from local gardens, and in many instances three or more crops are grown in the same field in one year. In such cases fertilizing becomes necessary and organic matter is one of the chief constituents added.

Seed crops.—The production of vegetable seeds, flower bulbs, and flower seeds has developed into an industry of importance in the Santa Clara Valley, and is followed in a smaller way at a few other places in the area. The climate appears to be very favorable for seed production and good yields of high quality are obtained. The product is sold to seed dealers in all parts of the country.

The loams and clay loams of the Yolo and Dublin series are the soils most generally used for seed production.

ANIMAL HUSBANDRY.

Dairying.—Dairying is one of the most important industries of the area. It has proved profitable where well handled. From 1900 to 1910 the capital invested nearly doubled, though dairying in San Francisco County declined in this period, owing largely to expansion of the city. About \$4,000,000 are annually received by the dairymen. Marin County is the most important dairy section, and many other parts of the area are developing rapidly. Butter and milk are disposed of mainly in the Bay Region cities.

Farms generally have a prosperous appearance where dairying is carried on, except in the more hilly or mountainous sections, where there is little irrigation and where the cows graze on the hills almost the entire year. Great outlay for housing is unnecessary because of the mild climate. The excellent markets near-by, the growing demand for dairy products, and the available supplies of feed and pasturage give this industry a bright outlook.

Poultry.—Sonoma County produces more than half the poultry products, and an area with a radius of about 5 miles, with Petaluma as the center, produces nearly half the total product of the area.

The flocks are almost entirely White Leghorn. Hilly areas with good drainage and light soil types are preferred for chicken raising. The production is confined to eggs and meat mainly, although many chicks and eggs for breeding purposes find outside markets. According to the census the industry in this area increased nearly 800 per cent from 1900 to 1910.

There is a big demand for poultry products in the bay cities at good prices, and the industry is still rapidly increasing.

Hogs and sheep.—The hog industry is closely associated with dairying and has an important place in the area.

Sheep raising is confined mainly to the mountains, although many flocks are brought into the valleys for fall and winter grazing. The industry has about the same importance as hog raising. The meat products supply part of the demand of the large cities.

VALUE OF FARM PRODUCTS.

In 1880, in the counties wholly or partly included in the survey, the value of all farm products was about \$21,000,000, as compared with \$35,000,000 in 1900 and \$38,000,000 in 1910.

AGRICULTURAL METHODS.

In cultivating the land traction engines of large size were in more common use before the present intensive cropping systems developed. Smaller tractors, caterpillar engines, and horse power have displaced many of the larger machines. The smaller tractors, as well as horse power, are now used both in orchard culture and general farming. Moderate to good tillage is the rule for general farm lands. In hilly areas contour plowing and cultivation are usual. Many of the hills are too steep for the use of wagons, and in such places the grain hay is raked in windrows and dragged to the bottom of the hills with implements made for the purpose.

Little attention has been given to rotations in the dry-farmed areas, on account of the limited range of crops which can be grown under such conditions. When lands begin to decline in productivity they are summer fallowed every two or three years. This tends to deplete the soil humus, but a period of fallow and cultivation helps yields very materially. On some of the gentler, well-located slopes sweet and field corn and some other crops are grown in rotation, but this practice is not common.

One or two plowings and good cultivation are the rule in orchards and where other intensive crops are grown. In the region from San Leandro southward nearly to Niles rhubarb is profitably grown among both young and mature fruit trees. Certain truck crops are grown elsewhere among the young trees, but clean cultivation, with cover crops at certain times of the year, is the prevailing system in orchards of bearing trees.

Deep plowing has been found to give best results on the heavy loams, clay loams, clays, and clay adobes. Occasional subsoiling and even blasting for heavy, compact subsoils has proved beneficial, especially for tree fruits. On the loose open sands or light sandy loams deep tillage has not proved so beneficial, especially where the subsoils and substratum are porous. Organic matter appears to be the most needed essential for the soils of the area, and it is added

in the form of either manure or cover crops plowed down. Very little commercial fertilizer is used.

NUMBER AND SIZE OF FARMS.

From 1880 to 1900 there was quite a marked increase in the number of farms in the area. From 1900 to 1910 the increase was not nearly so great, and in four counties the number of farms decreased. The greatest increase in number of farms occurred in Santa Clara and Sonoma Counties. This appears to be due to a greater development of highly specialized crops in those counties.

During this period the general tendency has been to reduce the size of farms. This is noticeably so in the counties where intensive farming prevails. In Solano County the average size of farms has increased 13 acres in this period.

LAND VALUES.

Land values have doubled several times in most of the valleys and lower, well-situated foothill areas in the last 25 years. These lands range in price from \$75 to \$300 an acre in valleys where general farm crops are the main products, and from \$200 to \$600 an acre for unimproved areas in districts of highly specialized crop production and where the soils are well suited to fruits. The hill and mountain lands are cheaper and range from about \$20 to \$200 an acre, depending upon the location and whether the soils and climate are favorable for grazing, general farm crops or fruits. Location, type of soil, drainage, exposure, rainfall, water requirements, possibility of irrigation, and improvements constitute the main factors controlling land values in the area.

LABOR.

The cost of farm labor varies considerably, depending upon the skill and type of labor required. It ranges from about \$30 per month, with board, for general farm work, to about \$2.50 a day in highly specialized farming, in which greater skill is required. Many female laborers are employed in canneries and packing houses. These are frequently paid on the basis of work done. Many races, both foreign and native, form the laboring classes of the area. Very little negro labor is employed.

FARM TENURE.

The average percentage of farms in the counties included wholly or in part in the areas, operated by owners and tenants in 1910, was 65 and 31 per cent, respectively. The highest percentage of owner-

operated farms were for Sonoma, Santa Clara, and Napa Counties, and the lowest for Marin and San Mateo Counties.

SOILS.

The reconnoissance soil survey of the San Francisco Bay region includes the areas covered by the Santa Cruz and San Francisco geologic folios of the United States Geological Survey. An inspection of the maps accompanying these folios will reveal the great complexity and detail in which the various geological formations and rock masses occur. It is impossible in this discussion to outline the geological history of the portions covered by these folios, but reference is made to them as containing a great deal of interest. The following from the Santa Cruz folio gives an idea of the mixed occurrence and intricate history of the rocks connected with that part of the area. The same or even greater complexity is true of the region covered by the San Francisco folio:

The California Coast Ranges are young, geologically speaking, yet their history is complex. In other portions of California and Nevada there are Cambrian, Silurian, Carboniferous, Triassic, and Jurassic rocks; the oldest rocks in the Coast Ranges of which the age is definitely known are Lower Cretaceous. Above the basement complex of acidic plutonic rocks and metamorphic schists and limestones, the age of which is uncertain, there are represented within the Santa Cruz quadrangle alone 14 recognizable formations. Nine distinct and far-reaching disturbances, as recorded by profound unconformities, not to mention many local readjustments, took place in the region during the deposition of these formations. Volcanism was active during several epochs, and in at least one of these lasted for a considerable time. Between different areas within the Coast Ranges the correlation of the geologic events, as recorded in the rocks, is made possible by the widespread distribution of certain geologic bench marks, such as characteristic faunas and formations. Correlations between the Coast Ranges and other geologic provinces, the Sierra Nevada, for instance, are extremely difficult and hazardous because the history of each province is more or less distinct, though obviously related in regions of juncture.

The Santa Cruz quadrangle is characteristic of the Coast Ranges in general as regards geologic formations, and in a measure, topography as well, but in respect to vegetation and certain features of topography dependent on the humidity of the region it is quite different from many of the ranges farther south or farther inland. The broader features of the history are the same throughout the coastal belt, however, so that the descriptions following may be applied in general to the whole region from San Francisco south to the region of northern Santa Barbara County.

The soils of this area, as regards their mode of origin, are mainly comprised within three principal divisions or provinces of soil-forming material. The first of these, and by far the most extensive, includes those soils which are derived in place through the disintegration and weathering of consolidated rocks. The soils of this group are generally designated residual soils. The next most extensive division consists of recent alluvial soils, which represent ma-

terial largely derived from the residual soils, transported by water and laid down in their present positions over valley floors or alluvial slopes. Intermediate in character between the residual soils and recent alluvial soils is another less extensive province of soil-forming material which is derived through the weathering and erosion of old unconsolidated water-laid deposits. They resemble the recent alluvial soils in that they are typically not associated with consolidated rocks, and on the other hand resemble the residual soils in that the material has undergone chemical and physical changes through weathering in place and has assumed characteristics indicative of a certain degree of age of material. This is usually accompanied by subsoils heavier in character than the surface soils, and by diversified surfaces which lie above the soils of recent alluvial origin and which are being degraded by erosion. In addition to the three divisions of soil-forming material enumerated, there are minor areas of soils which have originated as wind-laid material, and certain others of miscellaneous character or mixed origin.

In the scheme of classification used by the Bureau of Soils, the soil type is the unit. A type consists of material having definite characteristics of color, texture, and structure in both surface and subsoil or subsurface material, and in origin and mode of formation. Related types, i. e., those having the same characteristics of color, subsoil, origin, mode of formation, etc., are grouped in series.

Owing to the character of this survey, which is general or in the nature of a reconnoissance, and because of the great number of soils encountered and their complexity of arrangement, it was not possible to cover the ground in sufficient detail to differentiate between individual types or even soil series in all cases. In certain cases individual soil types are mapped, but usually two or more associated types, more or less similar physically and in their relation to agriculture are combined and shown on the map by one color as type groups. The different groups are not uniform as regards the number of types included or the range of textures embraced, and members of different series have sometimes been combined and mapped as undifferentiated series. In certain cases soils of rather different characteristics were of necessity grouped together because of their complex and intimate association.

This survey includes the area covered by the earlier detailed soil surveys of the Livermore and San Jose areas.¹ In the soil descriptions in this report reference is made to the earlier mapping, so that the present map may be used in connection with those already pub-

¹ See Soil Surveys of the San Jose and Livermore areas. Field Operations of the Bureau of Soils, 1903 and 1910, respectively.

lished. The San Francisco Bay area, along a portion of its eastern margin, adjoins the area covered by the reconnaissance soil survey of the Sacramento Valley.¹

The following table shows the main divisions of the soils of this survey, with the soil series and types which they embrace and also the areas covered by the various soils as recognized and indicated on the accompanying soil map:

Classification and area of soils.

| Soil groups and types. | Acres. | Per cent. | Soil groups and types. | Acres. | Per cent. |
|---|---------|-----------|---|----------------------------------|-----------|
| Residual material: | | | Residual material—Continued. | | |
| Red soils— | | | Miscellaneous— | | |
| Aiken series— | | | Climax and Olympic clay adobes, undifferentiated.. | 25,088 | 1.0 |
| Aiken loam and clay loam. | 12,288 | 0.5 | Butte and Olympic loams and clay loams, undifferentiated..... | 35,392 | 1.4 |
| Sites series— | | | Altamont, Mariposa, and Sites loams and clay loams, undifferentiated... | 150,400 | 20.1 |
| Sites loam and clay loam.. | 2,368 | .2 | Altamont, Mariposa, and Sites loams and clay loams, undifferentiated, rough broken phase..... | 356,480 | |
| Sites loam and clay loam, rough broken phase..... | 1,984 | | | Stony soils, undifferentiated. | 123,264 |
| Brown soils— | | | Rough stony land..... | 28,928 | 1.1 |
| Holland series— | | | Coastal-plain and old valley-filling material: | | |
| Holland loam and sandy loams..... | 16,896 | 1.8 | Red soils— | | |
| Holland loam and sandy loams, rough broken phase..... | 28,480 | | | Corning series— | |
| Olympic series— | | | Corning loams..... | 6,464 | .3 |
| Olympic loam and clay loam..... | 7,040 | .9 | Reddish-brown soils— | | |
| Olympic loam and clay loam, rough broken phase..... | 16,192 | | | Tuscan series— | |
| Altamont series— | | | Tuscan stony loams..... | 4,416 | .2 |
| Altamont sands and sandy loams..... | 26,880 | 1.0 | Brown soils— | | |
| Altamont loam and clay loam..... | 317,504 | 20.9 | Pleasanton series— | | |
| Altamont loam and clay loam, rough broken phase..... | 209,536 | | | Pleasanton sandy loams.. | 11,392 |
| Altamont adobe soils..... | 133,952 | 5.3 | Pleasanton loams..... | 45,760 | 1.8 |
| Yellow soils— | | | Pleasanton gravelly clay loam..... | 832 | .1 |
| Mariposa series— | | | Pleasanton adobe soils.... | 13,696 | .5 |
| Mariposa loams..... | 3,712 | .1 | Antioch series— | | |
| Black soils— | | | Antioch sands and sandy loams..... | 13,632 | .5 |
| Diablo series— | | | Antioch loam and clay loam..... | 26,432 | 1.0 |
| Diablo soils, undifferentiated..... | 194,944 | 8.1 | Madera series: | | |
| Diablo soils, undifferentiated, rough broken phase | 10,176 | | | Madera loams and clay loams..... | 15,488 |

¹ Reconnaissance Soil Survey of the Sacramento Valley, California. Field Operations of the Bureau of Soils, 1913.

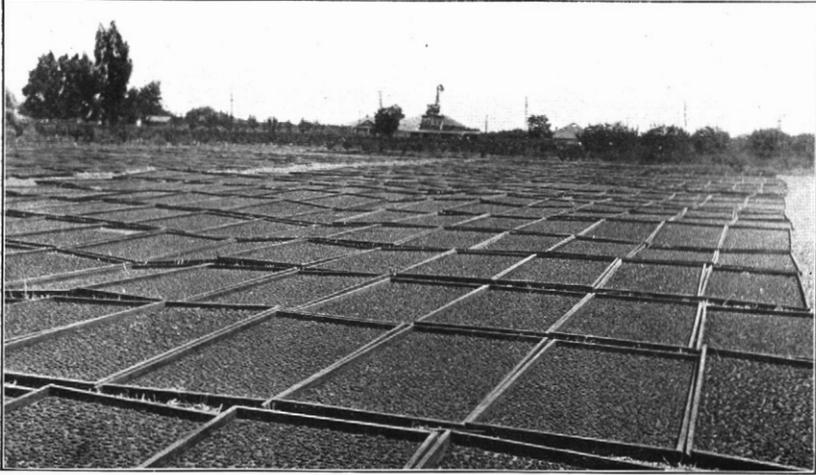


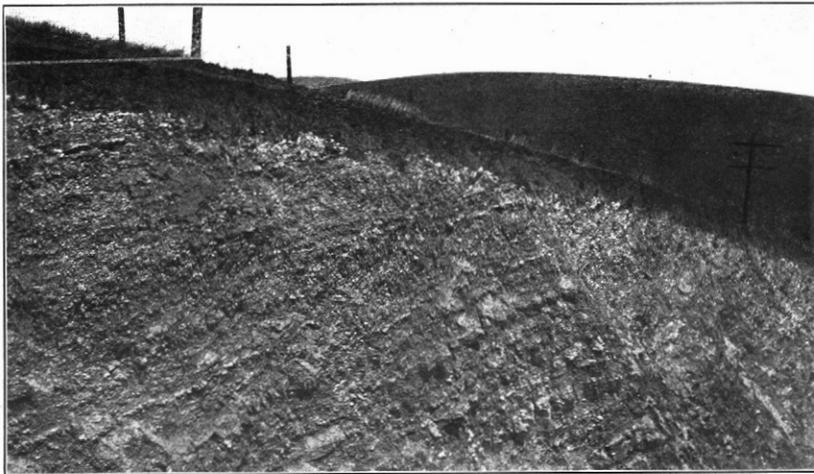
FIG. 1.—DRYING APRICOTS NEAR SAN JOSE.



FIG. 2.—APRICOT ORCHARD ON SOILS OF YOLO SERIES, NEAR DECOTO.



FIG. 1.—PEAR ORCHARD ON YOLO CLAY LOAM ON WEST SIDE OF SANTA CLARA VALLEY.



57664

FIG. 2.—SECTION IN SOILS OF ALTAMONT SERIES NEAR ALTAMONT, SHOWING WEATHERING IN PLACE FROM CALCAREOUS SHALES AND IMPURE LIMESTONES.

Classification and area of soils—Continued.

| Soil groups and types. | Acres. | Per cent. | Soil groups and types. | Acres. | Per cent. |
|---|---------|-----------|----------------------------------|-----------|-----------|
| Costal-plain and old valley-filling material—Continued. | | | Recent alluvial material—Con. | | |
| Black soils— | | | Gray soils— | | |
| Montezuma series— | | | Laguna series— | | |
| Montezuma loams and clay loams..... | 17,024 | 0.7 | Laguna loams and clay loams..... | 5,440 | 0.2 |
| Montezuma adobe soils... | 7,296 | .3 | Dark-gray to black soils— | | |
| Miscellaneous— | | | Dublin series— | | |
| Antioch and Corning loams, undifferentiated..... | 1,152 | .1 | Dublin sandy loams..... | 896 | .1 |
| Recent alluvial material: | | | Dublin loams and clay loams..... | 61,632 | 2.4 |
| Brown soils— | | | Dublin adobe soils..... | 112,192 | 4.5 |
| Yolo series— | | | Wind-laid material: | | |
| Yolo gravelly sandy loams. | 5,696 | .2 | Brown soils— | | |
| Yolo loams..... | 191,712 | 3.6 | Oakley series— | | |
| Yolo clay loams..... | 163,584 | 6.5 | Oakley sands..... | 576 | .1 |
| Yolo clays..... | 17,792 | .7 | Miscellaneous material: | | |
| Yolo clay adobe..... | 10,304 | .4 | Dunesand..... | 13,888 | .5 |
| Willows series— | | | Tidal marsh..... | 141,120 | 5.6 |
| Willows clay loams..... | 1,728 | .1 | Riverwash..... | 576 | .1 |
| Yellow soils— | | | Muck and Peat..... | 23,296 | .9 |
| Tehama series— | | | | | |
| Tehama loams..... | 1,024 | .1 | Total..... | 2,517,120 | |
| Solano series— | | | | | |
| Solano loam and clay loam. | 576 | .1 | | | |

¹ Including Yolo gravelly loams.

RESIDUAL MATERIAL.

As already stated, the soils which comprise this division consist of those derived from the disintegration and weathering of rock in place. They are usually identified with the mountainous or hilly regions of the area and occupy the larger part of it (see Pl. I and Pl. II, fig. 1). They result from the weathering of a wide variety of rocks, the characteristics of which are reflected rather uniformly in the resultant soils, but there are also other factors which bear upon the formation of the soil, and the same character of rock is sometimes noted as yielding different soils under different conditions. On the other hand rather different rocks sometimes yield soils possessing the same general features in so far as they can be observed in the field.

The sedimentary rocks, such as shales and sandstones, are the most widely distributed in the area. They give rise to several series of soils. Of these the Altamont series is the most extensive (See Pl. IV, fig. 2), but the Diablo, Sites, and Mariposa series are also encountered. Their relative importance is indicated in the preceding table where the extent of each is shown. The rocks, yielding these soils

are for the most part rather soft or are feebly consolidated, and a great part of even the rougher mountainous region has a rather deep soil covering. Exception is made of some of the areas where the rock is more resistant than typical.

Minor bodies of igneous rocks of more or less altered character are scattered through the area, especially in the northern part. They have given materials forming a number of series among which are the Aiken, Holland, Olympic, Climax, and Butte series. As with the soils derived from sedimentary rocks, these series are sometimes rather closely identified with certain classes of rock material, but such is not always the case, since, for instance, basalt and diabase in certain parts yield both red and brown soils. As far as possible the character of the rock giving individual bodies of soil is stated in the various soil descriptions.

The residual soils vary greatly in depth within short distances, owing to differences in the durability of the rock, the effect of local erosion or colluvial accumulations of weathered or fragmental material about the base of slopes. The character of the underlying material is usually shown by the rock outcrop. Drainage is usually sufficient and, in this locality of moderate rainfall, often excessive, making intensive agriculture impossible except in the areas of deeper, moister soils. As the residual soils usually lie in elevated or mountainous country, large areas are too steep and broken for agriculture. They are largely utilized for hay and grain (see Pl. I and Pl. II, fig. 2), and intensive agricultural industries locally developed occupy but a small percentage of their total extent. As mapped they may include some undifferentiated coastal-plain and old valley-filling material of sedimentary origin. Recent alluvial soils may also occur on local alluvial fans.

COASTAL-PLAIN AND OLD VALLEY-FILLING MATERIAL.

The soils derived from this class of material are represented in this area by the Pleasanton, Montezuma, Antioch, Corning, Madera, and Tuscan series. They consist of soils which occupy the weathered, eroded, and otherwise modified remnants of old water-laid deposits of alluvial, lacustrine or marine origin. They usually occupy elevations intermediate between the alluvial soils of present stream bottoms and the higher residual soils previously discussed. They differ from the alluvial soils in several features, among which is their general tendency to have developed distinct, heavy-textured subsoils by infiltration of finer material, and the presence in many cases of hardpan. They also typically differ in topography through having lost their original uniform surface by the erosion which succeeded upon drainage or the elevation of the deposits to their present position. The surface is usually rolling or gently uneven and the extreme

ranges in elevation characteristic of the residual soils are rarely developed. In places sharp differences in topography of these soils and the recent alluvial soils occur. Surface drainage is fairly well developed, but the soils at times become water-logged during periods of heavy rainfall. They are in part used for intensive agriculture, but with the scant rainfall of the region are usually too droughty during the dry period for best results without irrigation. Soils with better than average capacity to retain water may be excepted, but on the whole irrigation is desirable.

RECENT ALLUVIAL MATERIAL.

These soils are stream-laid deposits of relatively recent deposition as compared with the soils previously described. They are derived from material washed from the complex soils of the various watersheds of the streams along which they lie. Sedimentary rocks and their derivative soils occupying the higher parts of the area are the source of the greater proportion of the alluvium. The recent alluvial soils in this area are largely the product of small intermittent streams. They occupy broad alluvial fans of gentle slope, and stream flood plains. They comprehend types of widely varying character, differing as regards color, texture, and general worth. They have been grouped in the Yolo, Dublin, Tehama, Willows, Solano, and Laguna series.

The alluvial soils are the principal intensive-crop and fruit soils of the area (see Pl. III, fig. 2, and Pl. IV, fig. 1). Although much development of intensive agriculture has taken place, there is a large proportion of the alluvial area that for reason of poor drainage, large holdings or other adverse conditions is still used principally in the extensive production of grain and hay. These soils are often 6 feet or more deep, but the subsoil usually lacks uniformity. The general tendency is toward lighter colored subsoils, the result largely of difference in organic-matter content and toward a variable texture, owing to the deposition of successive layers of soil-forming material which may or may not be similar in physical character.

WIND-LAID MATERIAL.

The soils of wind-laid origin are not very extensive in this area, and only those of the Oakley series, included in one soil group, and a miscellaneous type, known as Dunesand, were encountered in this survey. The latter, however, is described under Miscellaneous material. The Oakley series consists of brown soils, the parent material of which has been laid down in its present position largely by wind action. The topography is characteristically hummocky and undulating.

MISCELLANEOUS MATERIAL.

Besides the soils previously discussed, there are several other types or groups shown upon the map. Tidal marsh is one of the most extensive of these. It is composed of silt and clay deposited along the margins of the shallow bay, where it forms flats. Another type, Riverwash, is strictly alluvial in character, is predominantly of coarse texture, subject to overflow, and nonagricultural. Muck and Peat are less important in this area than in the adjoining Sacramento Valley area, yet some rather extensive bodies are mapped. The material is the decomposed remains of vegetation, intermingled with variable though small proportions of mineral matter. Dunesand is a miscellaneous type, although closely related to the Oakley series in some of its characteristics. It consists of very sandy dunes, which are little formed at this time.

SOILS FROM RESIDUAL MATERIAL.

AIKEN SERIES.

The soils of the Aiken series are usually shades of red, and in places brownish red or reddish brown. The subsoils, when different from the surface, are either a lighter or darker red. The Aiken soils are residual and are derived mainly from basic rocks, among which diabase, basalt, andesite, and amphibolite are important. The bedrock is reached at various depths ranging from a few inches to 6 feet. Usually it lies much nearer the surface than 6 feet. The topography varies from rolling to hilly or mountainous, and owing to the rough, rocky surface much of the area is nonagricultural. Drainage is always good to excessive.

The Aiken series is shown on the soil map as one group of types, but there are extensive stony areas of Aiken material included in a group with other stony soils.

AIKEN LOAM AND CLAY LOAM.

Description.—In the Aiken loam and clay loam group the clay loam probably predominates. This soil typically consists of a red to deep-red clay loam of rather friable texture. It is often slightly gravelly owing to the presence of angular fragments of the parent rock. There is a considerable range in color of the surface soil which in some places is pale red or brownish red to reddish brown. The surface soil is variable in depth, and may change to a heavier textured subsoil within a few inches of the surface or may continue to the bedrock with little change. Very rarely is the soil and subsoil section six feet deep; more often the parent rock is reached at depths between 18 and 48 inches. The transition from soil to rock material is

usually sharper than in the Holland series, although the lower part of the subsoil may at times consist largely of partially disintegrated rock fragments.

The Aiken loam occurs in areas associated with the clay loam and resembles it in nearly all features, except texture.

Location.—Most of the Aiken material in this area is stony and has been included with "Stony soils, undifferentiated." A number of small bodies of the Aiken loam and clay loam are mapped. Most of these lie in the northern part of the area, in the general region lying east and southeast of Santa Rosa and extending to the area covered by the reconnaissance survey of the Sacramento Valley. A small area is located on the north flank of Mount Zion, one of the Mount Diablo group of elevations. Another important area is that in the vicinity of Sausalito. There are also several minor areas located in the range of low hills between Oakland and the Haywards region. While some of the small bodies in the southern part of the area are typical, portions of them are not as red as usual and the best examples of the types are found farther north.

Topography and drainage.—The rolling to steep topography of this group of soils gives rapid run-off and good drainage, and those parts with steep or broken surface are excessively drained. Although erosion is quite active, the greater part of the group is tillable.

Origin.—Most of these soils in the northern part of the area are derived through the disintegration of volcanic tuffs and breccias occurring in extensive bodies throughout that region. The area near Sausalito is derived from basalt and diabase. The group in the Haywards locality is derived in part from rhyolite.

Utilization and adaptation.—Most of the areas of Aiken clay loam and loam are cultivated, being used for the production of dry-farmed grain and hay. Some orchards and vineyards have been set out, but they occupy a very small part of the area. Some of the larger bodies, such as those east of Napa, contain a great deal of steep land which can be tilled only with great difficulty. A growth of brush and scattered trees covers much of its surface.

SITES SERIES.

The soils of the Sites series are red, brownish red or reddish brown. The subsoil where present is brown or reddish brown from about 18 inches downward to bedrock, which ordinarily lies at less than 72 inches. Angular gravel, loose rock, and rock outcrop sometimes occur in the rolling, hilly or mountainous areas. Drainage is excessive. The soils are residual and are derived largely from sedimentary rocks, often metamorphosed, and from chert.

The series is represented in this area by the Sites loam and clay loam, and a few minor occurrences of Sites gravelly loam and gravelly clay loam. Some areas are grouped with soils of other series. Most of its extent is rough and broken.

SITES LOAM AND CLAY LOAM.

Description.—The Sites loam consists of a red, light-red or brownish-red rather friable loam, grading at an average depth of about 18 inches into a reddish-brown or brown subsoil of about the same texture as or a little heavier than the surface. Occasionally the subsoil differs little from the surface in either color or texture. The parent rock often lies within a few inches of the surface and is nearly always encountered within a depth of 6 feet.

The Sites clay loam is very much like the loam except in texture, although usually a little darker.

The soils of the group are sometimes quite gravelly, in which case they include material of the Sites gravelly loam or gravelly clay loam. The rock fragments are usually angular and consist of chert. Small areas of the Aiken soils are included.

Location.—The Sites loam and clay loam group is of small extent and is represented only by small scattered areas. One lies just west of San Rafael, another a few miles south of Petaluma, one southwest of Palo Alto, several west of Centerville, and one northwest of Napa.

Topography and drainage.—The group is thoroughly to excessively drained. The topography is rolling to hilly, with loose rock and rock outcrop in some places. Those portions too rough for agricultural use were separated and mapped as a rough broken phase, wherever possible, but boundaries between this phase and the typical group were often arbitrarily placed.

Origin.—These soils are derived largely from sedimentary or metamorphosed sedimentary rocks. They also seem to be associated with various cherts. The area northwest of Napa may be more largely derived from igneous than from sedimentary rocks, and consequently should probably be considered as including more or less undifferentiated material of the Aiken series.

Utilization and adaptation.—Most of the Sites loam and clay loam group is not utilized except for pastures, and nearly all the remainder is used for the production of grain or hay. There are a few small orchards, but the soils as a rule are not farmed intensively.

Sites loam and clay loam, rough broken phase.—The rough broken phase of the Sites loam and clay loam group represents the portions of the areas of such unbroken topography as to preclude tillage. The soils, while typical in color, are shallow and are filled with chert fragments.

This phase is mapped in two areas—one several miles south of Petaluma and another on the south slope of Mount Diablo. It covers much of the north headlands flanking the Golden Gate, but is not extensive. Smaller bodies, not shown on the map, are scattered through the area, being most often included within the group of Altamont loam and clay loam, rough broken phase. The surface is steep, rough or even precipitous, and the drainage consequently excessive. The material is, for the most part, derived through the weathering of chert and highly metamorphosed shales. It is untilled, being fit only for grazing. A sparse grass growth with local brushy areas form the native vegetation.

HOLLAND SERIES.

The soils of the Holland series are brown and the subsoils brown or yellowish brown. The series is residual from quartz-bearing rocks, of which quartz diorite is the most prominent in this area. The surface is rolling, hilly or mountainous. Drainage is excessive in the steeper broken areas. These soils are included in one group of types, with the rough broken portions separated as a phase of the group.

HOLLAND LOAM AND SANDY LOAMS.

Description.—The Holland loam and sandy loam group comprises the loam, sandy loam, and fine sandy loam of the Holland series. Of these the loam seems to predominate.

The Holland loam consists of a brown, rather friable loam, usually containing some mica. The greater part of it is relatively light in texture and in many places it is gritty, owing to the presence of sharp particles of the parent rock. It often contains small angular rock fragments. At a depth ranging from 12 to 36 inches the soil grades into a lighter textured subsoil, lighter or more yellowish brown in color than the surface. The parent rock weathers to greater depths than most of the rocks of the area yielding residual soils, and the soil and subsoil together are often 72 inches or more in depth. The material is permeable to water and plant roots.

The Holland sandy loam and fine sandy loam, like the loam, are friable, usually have light-colored subsoils, and pass in their lower depths through partially disintegrated rock before the bedrock is reached.

There are some undifferentiated areas included with this group which are gray to dark gray in color, but are like the typical Holland types in other features. These gray bodies probably represent material of the Siskiyou series. This does not occur extensively enough to warrant mapping. A few red or light-red bodies were also noted, which in a detailed survey would be mapped as Sierra series.

Location.—These soils do not cover as extensive areas as the rough, broken phase of the group, being confined to several irregular bodies lying several miles southwest of San Mateo and northwest of Santa Cruz. In each case they occupy the smoother parts of the Holland area, lying on the broader ridge crests, the gentler slopes or forming clusters of more gently rounding hills. The separation of the arable portions from the rough broken phase was rather difficult, and it is recognized that each group as mapped includes minor areas properly belonging in the other.

Topography and drainage.—The surface is rolling to hilly, and is usually marked by a great many stream ways. Drainage in some places is more rapid and thorough than it should be for best crop growth. There are, however, areas, especially of deep, heavier textured soils, which retain moisture very well.

Origin.—The Holland loam and sandy loam group is derived largely from quartz diorite and to a less extent from quartz-mica schist. The schist yields a soil rather heavier in texture than does the quartz diorite. The former has given some of the medium to heavy textured loam northwest of Santa Cruz.

Utilization and adaptation.—Much of this group is covered with a dense brush and tree growth, and little of it is cultivated. The more accessible portions have been cleared, where necessary and used principally in the production of grain and hay. Wherever sufficiently protected from the ocean winds, and where the depth of soil and the power to hold water are sufficient, the soils have been found well adapted to several kinds of tree fruits and to grapes. Prunes, apples, and peaches are grown in a small way.

Holland loam and sandy loams, rough broken phase.—The rough broken phase of the Holland loam and sandy loams group represents areas too rough for cultivation. It was necessary in the mapping to include small undifferentiated areas capable of cultivation or perhaps even cultivated at the time, but by far the greater area of this phase is nonagricultural. Owing to the tendency of the parent rock to weather deeply, the rough broken phase of the Holland soils usually has greater depth of soil and subsoil than the steep and broken areas of the other residual soils. In color, texture, and in character of subsoil it does not vary essentially from the typical Holland loam and sandy loams.

Several areas of this phase are mapped northwest of Santa Cruz, on the steep sides of ravines and the abrupt slopes in the Ben Lomond Mountain region. An extensive body, including the higher and more rugged portions of Montara Mountain, lies southwest of San Mateo.

As the name indicates, the surface is steep and broken. Much of the area is covered with a growth of brush and trees, while other

parts support no vegetation except grass. Most of the land is used only for grazing.

OLYMPIC SERIES.

The soils of the Olympic series are brown and the subsoils a lighter brown. The surface soil in places extends to the bedrock with little change in color. The series is residual, the soil material being derived principally from basic igneous rocks in which basalt and diabase are prominent, but in part from volcanic tuffs, breccias, and serpentine. The surface is rolling, hilly or mountainous, and drainage excessive, except on the smoother areas.

OLYMPIC LOAM AND CLAY LOAM.

Description.—The Olympic loam and clay loam group is composed about equally of the two types. The loam typically consists of a brown or slightly reddish brown friable loam, rather free from coarse material and gravel. It is usually not deep, even considering both the soil and subsoil, and the soil may extend without change to bedrock or may be underlain by a lighter colored subsoil of the same or a little heavier texture. The depth to rock varies greatly; sometimes it is not more than 12 inches, and it is usually less than 4 feet.

The Olympic clay loam consists of a friable clay loam having about the same range in depth as the loam. Both types are quite similar to the Altamont loam and clay loam in organic-matter content.

Location.—Many areas of these soils are shown on the map, but their total extent is not great. The San Francisco peninsula and southward to a point southwest of San Mateo has this soil group scattered through the hilly sections. The region east and north of the Berkeley-Oakland section also contains a number of areas.

Topography and drainage.—The rougher, more broken areas of the Olympic series are shown as a phase of this group; the typical loam and clay loam form the tillable portion. The latter occur on slopes and in the more gently rolling areas. The drainage is excessive, especially where the soil material is shallow, as it is generally. Rock outcrop and scattered loose stones occur, but are not abundant.

Origin.—The materials forming the soils of this group are derived in nearly all cases from basalt and diabase, but materials have also come from serpentine and some other kinds of metamorphic rocks.

Utilization and adaptation.—The group is relatively unimportant agriculturally. Some of the more important areas are too thickly settled for farming, and much of the remainder lies on ridge crests or in isolated positions. A part is dry farmed to grain or grain

hay, of which good yields are obtained. Brush and a scattering tree growth constitute the principal vegetation.

Olympic loam and clay loam, rough broken phase.—The rough broken phase of the Olympic loam and clay loam group includes the nonarable portion of the types. The soil material is not essentially different from that of the smoother areas, but because of its steep topography it is usually shallower. As with the other groups of rough broken character, its entire extent is not rough, and some areas along more gentle slopes or on the broader ridge crests where farming is not only possible but is actually carried on are included.

Several bodies of this phase are found west of San Rafael, west and northwest of San Mateo, southwest of Palo Alto, and east of the Berkeley and Oakland sections. In a few instances the rough broken phase of the Altamont loam and clay loam includes minor areas which belong to the Olympic group. The surface is composed almost entirely of steep slopes and ravines, which result in excessive run-off and drainage. It is not likely that very much of the group will be cleared of its brush and timber growth.

ALTAMONT SERIES.

The Altamont series includes types with light-brown to dark-brown soils, and light-brown or yellowish-brown, or, where highly calcareous, gray subsoils. Usually bedrock lies within 6 feet of the surface (see Pl. IV, fig. 2), although in some areas it has weathered to greater depths. These soils occupy rolling, hilly or mountainous country. (See Pl. I and Pl. II, fig. 1.) In places on the steeper slopes they are badly eroded and rock outcrop is abundant. More or less fragmental rock also occurs in the soil. The soils are well drained, but retentive of moisture. They are residual in origin, and are derived largely from interbedded sandstones and shales. The areas are partly wooded or in some places practically treeless. As compared with the Diablo series these soils are lower in lime and organic matter, but the subsoils are occasionally rather calcareous.

The series is extensive. It has been mapped in four groups; some undifferentiated material of other series is included.

ALTAMONT SANDS AND SANDY LOAMS.

Description.—The Altamont sands and sandy loams group comprises the sand, loamy sand, fine sandy loam, and sandy loam types of the series.

The Altamont sand consists of a brown, light-brown or grayish-brown, medium-textured sand of loose, porous structure. Local patches approach a gray in color. At a depth ranging from 12 to 30 inches the soil grades into yellowish-brown material, usually a

little heavier in texture than the soil, but in this type, as in others of the same group, the difference in color between the soil and subsoil is not so pronounced as in the heavier textured soils of the series.

The Altamont loamy sand is not essentially different from the sand member, except that it carries appreciable quantities of particles finer than the sands, which give it a greater water-holding capacity and render it a little less subject to drifting.

The Altamont fine sandy loam consists of a light-brown, friable fine sandy loam which grades at about 20 or 30 inches into a yellowish-brown subsoil in many places, but not everywhere heavier textured than the soil.

The Altamont sandy loam is usually light brown, but, like the other members of the group, may have a grayish cast. Usually it is a medium-textured sandy loam, retentive of moisture and well adapted, especially in the northern part of the area, to dry farming. The subsoil is in most respects characteristic of the series, being usually lighter colored than the soil and often showing a yellow tint.

The Altamont sands and sandy loams group includes the soil mapped as Contra Costa sandy loam in the earlier detailed survey of the Livermore area. The type is described as a loamy sand or sandy loam, carrying rounded gravel. It is characteristically brown, sometimes with a reddish tinge when wet. The dry surface has a grayish or yellowish cast. The subsoil is usually heavier than the surface, but is similar to it in color variations.

A notable feature of the Altamont group of sands and sandy loams in the region north of Petaluma is the presence of rather large quantities of fine, waterworn quartz gravel. The largest pebbles have the size of small marbles, and the quantity is hardly large enough to influence tillage. The areas of the soils of this group south of San Francisco contain some patches of dark-colored soils, which might better be considered as Diablo types. The lime and organic matter content of the soils in this locality seem to be higher than normal for the group, which characteristically is lower in these constituents than the Diablo series.

It is noted that the average color of the soils of this group is not as brown as that of the other soils of the series. The color does not differ as greatly in the soil and subsoil as in the other Altamont groups. The average depth of soil material likewise is a little greater than in the heavier textured Altamont soils, but the parent rock nearly always lies within 6 feet of the surface.

Location.—An irregular body of this group of soils of considerable extent lies just north of Santa Cruz. It contains many small areas of other light-textured soils. Those areas in the Livermore Valley, previously mentioned, lie northwest of Livermore, and are of small

extent. A rather important area is found on the peninsula southwest of San Francisco, where the soils are associated with the Antioch sands and sandy loams, from which they are separated with difficulty. The town of Benicia is located upon one of the smaller areas of this Altamont group. There are also some small areas of the group several miles northeast of Mount Diablo. One of the most important areas lies northwest of Petaluma.

Topography and drainage.—The group has a rolling topography, but the relief is not as great as is often the case in the other groups of the series. In some instances the soils merge gradually into the recent-alluvial soils of the valleys. Drainage is well developed. Owing to the light texture of the soils and their consequent high absorptive power, erosion has not cut ravines and caused abrupt changes in the surfaces, except to a small extent near Livermore and in local patches elsewhere. Drainage is excessive in the lighter areas and on some of the more pronounced ridges, such as some of those in the Petaluma section.

Origin.—This group of soils is derived from the disintegration of what are, in most cases, feebly cemented sandstones, sometimes carrying fine, waterworn gravel. There is great variation in this rock from place to place, and south of San Francisco the underlying material is in places practically unconsolidated, so that some of the soils with equal propriety could have been called the Antioch sands and sandy loams. The area near Santa Cruz is largely derived from weakly cemented sands, known geologically as the Santa Margarita formation.¹ Areas are encountered in this locality, where the light-colored sands of this formation are little weathered or altered in color, giving light-gray to white soils.

Utilization and adaptation.—South of San Francisco much of the group is intensively utilized for vegetable production. It is important for this purpose and the land has a relatively high value. Other portions of the soils of the group, because of excessive drainage and other unfavorable features, are less well adapted for cultivation and are largely untilled. The poultry industry which has developed around Petaluma is to a great extent located upon these soils, their good drainage among other things being an advantage. The group in the Livermore Valley is dry farmed to grain and hay, but gives rather light yields. Parts of the area near Santa Cruz are farmed, but much of the soil of this body is light and incoherent and some of it is hilly, and the untilled area is greater than the tilled. The light texture of much of the soil included within this group makes some of it rather droughty for dry farming, but in those parts of the area having the greatest rainfall fruit growing without irrigation is now developed to a small extent.

¹ Santa Cruz Folio, U. S. Geological Survey.

Near Santa Cruz the native vegetation on this group of soils consists of a moderately thick to dense brushy growth, with some trees. Elsewhere grass and scattering trees constitute the principal growth.

ALTAMONT LOAM AND CLAY LOAM.

Description.—The Altamont loam and clay loam group covers wide areas in this survey.

The Altamont loam, owing to its wide distribution, is subject to considerable variation, both as regards its topographic position and in the rocks from which it has been derived. In most places it consists of a light-brown or brown rather friable loam, free from gravel or rock fragments, though the latter may be present. At depths below 10 inches the soils may grade into a lighter brown or more yellowish brown subsoil, although over considerable areas the difference in color between soil and subsoil may not be very marked. Material of heavier texture is often encountered with increase in depth. Bedrock may be encountered at any depth below a few inches, and rarely does it lie at depths greater than 6 feet. The soil is usually deepest where the topography is least steep. In rolling or broken areas the lower slopes, more rounding hills, and flatter ridge crests have a greater depth of soil than elsewhere. The average depth to the rock is about 30 or 40 inches. The soil has some slightly reddish brown variations and some rather red areas resembling the Sites soils are included. In the region northwest of Santa Cruz a tendency toward yellowish brown or brownish yellow is often noted, the soil in some extreme cases being undifferentiated Mariposa material. Wherever associated with the Diablo series, dark-gray patches, becoming almost black when wet, are found.

The Altamont clay loam is a light-brown, brown or dark-brown, relatively friable clay loam. It presents the same variations of color and gradations toward the other series of soils as does the loam. It is often underlain at variable depths below a few inches by lighter colored subsoils of the same or slightly different texture. Like the loam it does not normally contain a sufficient quantity of gravel or rock fragments materially to influence its agricultural value, although some gravelly and stony areas are found. This type averages a little greater in depth of soil and subsoil than the Altamont loam, although it has similar extreme ranges in depth within short distances. The area of Altamont clay loam mapped in the earlier Livermore survey is included and on the whole is fairly typical. Some of it is slightly reddish in color where its lower slopes pass into soils of the Pleasanton series and tendencies toward an adobe structure are noted. The latter feature is true of the heavier textures and flatter portions throughout the soil group and represents a gradation in this respect toward the Altamont clay adobe.

Owing to the rather soft nature of most of the rock yielding these soils, rock outcrop, stony slopes, and loose rocks are not abundant, although small areas of stony soil and of outcropping ledges or exposures, the latter in ravines, are seen locally. Shallowness of soil or steepness of topography usually account for untilled areas. A great deal of the type northwest of Santa Cruz is shallow and droughty.

Location.—This is one of the most extensive soil groups of the area, and together with its rough broken phase it constitutes the principal soils over certain extensive regions. The group is important in the Santa Cruz Mountains and areas of it are scattered through the country lying between Santa Cruz and San Francisco. The Santa Clara Valley is flanked on its eastern side by a hilly region which for several miles back from the valley's edge is largely occupied by these soils. The system of parallel ridges which extends northwestward from the vicinity of Niles and Sunol to Carquinez Strait is largely covered with these soils. They were also encountered north of the bay region, but here are less important. A body near Bolinas Bay, a number of others between San Rafael and Petaluma, and some along the eastern edge of the area from Fairfield northward comprise the greater part of the remaining area of the group.

Topography and drainage.—The topography ranges from gently or sharply rolling to hilly or mountainous. The rough broken phase of this group includes those portions of the Altamont series not capable of cultivation because of topography, but the group under discussion contains many minor undifferentiated areas of steep, broken character, which could not well be separated on the map. In the more mountainous parts the Altamont loam and clay loam comprise only the less broken parts, such as the ridge crests, groups of gently rounding hills, and the less abrupt slopes, being in such places of less extent than the rough, broken phase. In other places, as between Sunol and Mission San Jose, practically all of it is tillable. Drainage is always good and over areas of steep topography usually excessive, but on the more gentle slopes and where the soils are deep the moisture content is usually equal to that of most other soils similarly situated.

Landslides have considerably modified the surface in places, and wherever they occur tillage operations are much more difficult. Some of these slides have an area of several acres. The land in such places can only be used for pasture.

Origin.—These soils are residual from sandstones and shales and to a less extent from conglomerates. Weathering is usually complete to some depth, and this, together with a rather uniform erosion, tends to give nearly all the surface a smooth, uniform covering.

The Santa Cruz and San Francisco geologic folios published by the United States Geological Survey cover a portion of the area included in this survey and describe a great number of sedimentary rocks giving rise to these soils. One of these, the Monterey shale, in some of its extent, yields a shallow phase of the soils in question. The areas northwest of Santa Cruz are largely from this formation.

Utilization and adaptation.—A large percentage of the Altamont loam and clay loam is now under cultivation, mainly in the production of hay and grain. Uncultivated areas support a growth of grass, and a little scattered timber and brush are found. At higher elevations and in ravines the tree and brush growth is usually more extensive than elsewhere.

East of Haywards some good orchards and truck gardens are developed over an area of 2 or 3 square miles. Prunes, apricots, grapes, some vegetables, and sweet corn are produced.

Individual orchards and vineyards are scattered through the mountains where soils, climate, and situation are favorable. Irrigation is possible on only a very small part of the group. Where it can be employed the crop range is considerably wider.

For hay and grain contour plowing is the rule. The products are often dragged downhill in places where the use of wagons is impossible. Yields are greatly influenced by local or annual variations in rainfall.

Altamont loam and clay loam, rough broken phase.—Those portions of the Altamont series, irrespective of texture, which have a topography making tillage impossible, were placed in this group, but separation of the arable and nonarable area was in many instances difficult or even impracticable where the two classes of topography were mixed. The material is predominantly of loam and clay loam texture, but the groups, Altamont adobe soils and Altamont loam and clay loam, contain a great many small undifferentiated bodies which belong to this rough broken phase, and the Altamont loam and clay loam, rough broken phase, on the other hand, includes locally numerous slopes and hills of less abrupt surface than typical, which are possible of cultivation or may be under cultivation at present.

The total extent of this rough broken phase is large, forming 8.3 per cent of the area surveyed. It is usually found in association with the smoother bodies of the Altamont series, its relative extent being governed somewhat by the elevation. In the higher part of the Santa Cruz Mountains it predominates over considerable areas, and the same is true over large areas at some distance east of Oakland. Other bodies of varying importance, too numerous to mention, are mapped. These occur in the rougher portions of the area occupied by the other soils of the Altamont series.

The character of the soil is usually that of the soil group with which it is associated. For instance, in the region east of Mount Diablo it has a shallow soil material like the Altamont adobe soils of that section. The phase is irregularly wooded, some important areas being bare of tree or shrub growth, except along ravines, while other areas are covered with a comparatively dense growth of trees and brush. The north and east slopes are usually more heavily covered with brush and trees than the other portions.

As the demand for agricultural land becomes more intense some parts of this phase will probably be tilled, but such can not be the case with any very large part of it. Its principal value lies in its use for pasture and forestry.

ALTAMONT ADOBE SOILS.

Description.—The Altamont adobe soils group includes the clay loam adobe and clay adobe of the series. These two types have about equal extent and occur in close association in intermingled areas. The soil consists of a brown, light-brown or slightly reddish brown friable clay loam or clay, having the true adobe structure, except in a few places where the texture is lighter than typical, approaching a loam or clay loam. A few cobbles, shale fragments or angular pieces of other rocks are sometimes found on the surface or scattered through the soil, but these are of restricted distribution and are usually confined to the ridge crests or to the areas of steeper topography or shallower soil. The soil is exceedingly sticky when wet, but upon drying checks and has a fine granulated structure, rarely becoming compact or difficult to cultivate. Not all the soils included in this group have the colors mentioned above, as it was necessary on account of their small extent to include some areas of Diablo material, which is dark grayish brown to black. Some areas east and north-east of Vallejo have a more pronounced reddish-brown color, and a somewhat similar color is developed on isolated hills or slopes throughout the area.

The depth of the soil varies widely within short distances, depending upon the character of the parent rock and the topographic position. In most cases rock is encountered at depths of less than 6 feet, although the adobe soils as a whole are deeper than the soils of the Altamont loam and clay loam group. At a depth ranging from 12 to 36 inches the soil often grades into a lighter brown or more yellowish brown clay or clay loam, although the difference in color of the soil and subsoil is in places not very marked. The soil and subsoil are capable of storing considerable quantities of soil moisture, which is an important feature to be considered.

Location.—This group of soils includes some areas extending for many miles north of Benicia and Vallejo. Numerous irregular areas

cover much of the region eastward from Clayton and Mount Diablo to the limits of the survey. The adobes are also prominently developed southwest of Walnut Creek, east and northeast of Livermore, and scattering along the lower foothills southeastward from Haywards to the vicinity of Evergreen. Many other bodies not enumerated were mapped and still others of lesser importance were of necessity disregarded, being most often included with the Altamont loam and clay loam.

Topography and drainage.—The Altamont adobe soils are characterized by rolling to very hilly topography, with some steep slopes that become precipitous along the deeper stream courses and ravines (see Pl. I). They reach a considerable elevation and in some of the steeper portions landslides are numerous. Drainage is everywhere good and even excessive in areas of shallow soil on the steeper slopes. Alkali is found in some of the swales or local valleys, although it is confined largely to the narrow alluvial strips in their bottoms.

Origin.—The soils are derived through the weathering of sandstones and shales, and seem to be more often associated with the latter than with the former. In some of the more important areas, such as that northeast of Livermore, weathering has extended to considerable depths, and rock outcrops are rare. In other areas more resistant knobs and points remain as rock outcrop, though these are less conspicuous than in the other groups of the series.

Utilization and adaptation.—By far the greater part of these soils is now under cultivation, with dry-farmed grain and grain-hay as the principal crops (see Pl. I). Along the east side of the Santa Clara Valley a relatively small area is used in the production of early vegetables, which constitutes an important local industry.

Formerly the group was continuously dry farmed to grain and hay, but a system of summer fallowing was introduced later, and some of the land is used as pasture every third or fourth year. The areas of shallow soil are too droughty for intensive farming without irrigation.

ALTAMONT, MARIPOSA,¹ AND SITES LOAMS AND CLAY LOAMS, UNDIFFERENTIATED.

Description.—The Altamont, Mariposa, and Sites loams and clay loams group includes the loam and clay loam of the Altamont series, the loam and clay loam of the Mariposa series, the loam and clay loam of the Sites series, and certain other minor types and variations mentioned below.

The Altamont loam and clay loam as included in this group do not vary essentially from the description of these types already given, but the areas are so intermingled with the types of the other series,

¹ For description of Mariposa series, see p. 51; for Sites series, see p. 37.

and have so many gradational variations that it was not feasible to differentiate them. They are represented in almost all the important areas of the group. They are usually shallower, contain less organic matter, and are less retentive of moisture than normal. There are included also some gravelly Altamont types, as in the areas lying in the region southeast of Livermore.

The Mariposa loam and clay loam form an important part of the area mapped in this group. They are yellow or brownish-yellow loams or clay loams, and, like the Altamont types, are in places distinctly gravelly. The average soil depth is usually less than in the areas mapped as Mariposa loams, and this makes them more droughty.

The Sites loam and clay loam comprise the red or reddish-brown areas in the group. They are also gravelly in places. They do not differ greatly from the descriptions already given, but are often very shallow.

Small areas of heavy clay adobe material of each of the three series are included, although less of the Mariposa than of the others is found. The group also includes the types designated as the Vallecitos loam, stony clay loam, and clay adobe in the detailed survey of the Livermore area made in 1910. The group as a whole is one of rather shallow droughty soils. A great deal of the group lying south of Petaluma and from Sausalito to Novato, where some areas of considerable extent are found, has a deeper soil and is comparatively free from gravel.

Location.—These soils occupy the smoother parts of the general regions described below under the rough broken phase of the group. A great deal of their area in the southeastern part of the survey was placed in the typical soils of this group rather than in the rough broken phase, on a basis of its topography and not because it was tilled. Its remoteness and shallow character make it capable of utilization only with great difficulty. The group is also mapped in numerous areas south of Petaluma and extending to the Golden Gate and west of this line to the limits of the survey. It is also encountered in the northeastern part of the area between Napa and the Vaca Valley and also northwest of Napa.

Topography and drainage.—These soils form the smoother parts of mountainous regions or occur as less abrupt lower slopes and ridges along the valley margins. Typically the surface is not so steep as to prohibit tillage, but it varies in steepness and includes areas upon which the use of machinery would not be practicable. Some of it occupies lofty ridge crests which are inaccessible, except by steep roads. Drainage is usually excessive.

Origin.—These soils are residual in origin and are derived mainly from altered sedimentary rocks. Local areas derived from igneous

rocks are included, but these constitute a small percentage of the total area in the group. The soils are often closely associated with the sedimentary rocks of the Franciscan group.¹ These rocks are among the oldest of the area and are often highly altered and leached of their more soluble materials.

Utilization and adaptation.—The greater proportion of these soils is treeless, but some of the protected slopes and ravines support live oak, buckeye, and a variety of other trees and shrubs. In most instances the soils are utilized in connection with the adjoining rough broken phase as grazing land. Some of the better areas in which the soil is deeper than the average are used for grain and grain-hay production, but the area devoted to intensive agriculture, such as fruit or truck growing, is small.

Altamont, Mariposa, and Sites loams and clay loams, undifferentiated, rough broken phase.—The rough broken phase of the Altamont, Mariposa, and Sites loams and clay loams does not differ essentially from the typical group, except in topography and depth of soil material. The phase occupies surfaces too rough, steep, and dissected for cultivation, and the soils are usually quite shallow and droughty.

Owing to the nonagricultural character of the land it is not considered necessary to discuss this group of soils in detail. They are used only for grazing, and their value for this purpose varies greatly.

MARIPOSA SERIES.

The soils of the Mariposa series are some shade of yellow. The surface soil often rests upon the bedrock without an intervening distinct subsoil, but when present it is usually a little heavier textured and browner in color than the surface soil. The Mariposa soils are residual from sedimentary or metamorphosed sedimentary rocks, which underlie the soil at depths varying from a few inches to several feet. The topography is rolling, ridged or mountainous. Drainage is adequate at all times, and there are many droughty areas where the soil is shallow and the surface steep.

This series is represented by the Mariposa loams group. The soils are not largely used at this time except for pasture.

MARIPOSA LOAMS.

Description.—The Mariposa loams group includes the Mariposa loam and the Mariposa silt loam, with minor areas of clay loam and fine sandy loam. The Mariposa loam typically consists of a yellow or light brownish yellow loam of rather silty texture, which may

¹ See Santa Cruz and San Francisco Geologic Folios, U. S. Geological Survey.

extend with little variation to the parent rock found at depths varying from a few inches to several feet. The Mariposa silt loam is similar to the loam, except in texture. Where the soil does not extend to the bedrock a subsoil of heavier texture and more compact structure of slightly browner color occurs. The soil is rather friable when the moisture condition is favorable, but it has the same tendency to compact noted of the Tehama loams.

Location.—A single body of the Mariposa loams is mapped in this area. It lies in the Isabel Valley several miles east of the Mount Hamilton region.

Topography and drainage.—The Mariposa loams occupy a basin-like irregular valley flanked by rather rugged country. Drainage is locally restricted, but in the main is adequate. The area is broken here and there by minor hills and ridges.

Origin.—The Mariposa loams are derived from the disintegration of soft, light-colored shales. The weathering has been deep in many places, and erosion has been rapid and portions of the group resemble alluvial fans or slightly eroded unconsolidated deposits rather than typical residual soils from consolidated rock. Local areas of true alluvial-fan material belonging to the Tehama series are included.

Utilization and adaptation.—The areas of these soils are practically free from trees and shrub growth. They were formerly largely farmed to grain. At this time they are devoted almost entirely to stock raising, being used as grazing land in conjunction with the rougher bordering areas. The soils are remote from transportation facilities, which must be supplied before intensive forms of farming can be developed. Under irrigation the production of a number of valuable crops is possible, but a supply of water for this purpose has not yet been developed.

DIABLO SERIES.

The soils of the Diablo series are typically dark gray or black. The subsoil is often lighter than the surface and ranges through various shades of gray or brown. At times the black soil rests directly upon the parent rock, but it is usually underlain by a heavy calcareous subsoil, resting upon the underlying rock usually at a depth of less than 6 feet. These soils are residual from calcareous shales, sandstones or impure limestones, and are usually identified with the more calcareous rocks, which is one feature distinguishing them from the soils of the Altamont series. They are well drained but are retentive of moisture. The topography is rolling to hilly.

The various soils of this series are mapped in one group, with a separation so far as practicable into arable and nonarable areas,

the latter being shown as a rough broken phase, by means of the phase ruling.

DIABLO SOILS, UNDIFFERENTIATED.

Description.—The Diablo soils, undifferentiated, include types having a rather wide range in texture, but probably more than 80 per cent of their area consists of a clay adobe or a clay loam adobe, of which the former is by far the more extensive. Besides the two types mentioned, the Diablo loam and clay loam are also represented. The extent of these soils, however, is small.

The Diablo clay adobe consists of a black, dark-gray or slate-colored, sticky clay of pronounced adobe structure, which as a rule is darker in color and heavier in texture on the lower slopes or in places where the soil is deepest. Not all the areas mapped in this group have the typical dark-gray or black color, owing to the inclusion of areas representing a gradation of Diablo into Altamont material. Local patches of brown soils occur. The type is rather easy to cultivate, considering its texture, granulation no doubt being aided by a high organic-matter content and by lime from the parent rock. The type is sticky when wet, but when dry it checks and rapidly forms a mellow surface layer. This material may extend to a depth of 6 feet or to the bedrock, usually found at less depths, or it may be underlain at any depth below 12 inches by a lighter colored subsoil of clayey texture and grayish-brown or yellowish-gray color. The subsoil in many places is calcareous. In shallow phases of the type a distinct subsoil may be absent.

The Diablo clay loam adobe differs little from the clay adobe and cracks and checks when dry to about the same extent. Only the closest inspection shows the presence of the sand and gritty material distinguishing the type from the clay adobe.

The Diablo loam and clay loam are usually not so dark colored as the types already described, the range being from dark gray to slate, though they appear black when wet. The material of either type may, as in case of the adobe types, extend to bedrock without change, or the soils may be underlain by lighter colored subsoils. The structure is friable and the soils are retentive of moisture where of good depth. Conditions of moisture are less favorable in some shallow areas occupying denuded slopes.

Location.—The Diablo soils are quite generally distributed in this survey, except in some of the higher regions, such as those in the section around Mount Hamilton. One of the most important developments of this group occurs north of the Livermore Valley, where there is an area many square miles in extent, broken only by minor strips of alluvial soils. Some important areas lie along the east side of the Santa Clara Valley. In this locality, where the soils consist

of much mixed black and brown material in individual areas of small size, separation from the Altamont series was rather arbitrary. The coast region from Santa Cruz to the vicinity of Halfmoon Bay contains some broad areas of these soils, particularly just south of the latter. A great deal of this region consists of the lighter textured types of the group, although the adobe soils are also prominent. Here, as elsewhere, it was difficult to make close separations between the Diablo and Altamont series, and certain shallow gray or light-gray patches were also observed, possibly not belonging to either of the series mentioned. A comparatively wide range in color is found in the body lying several miles east of Livermore, at the margin of the area. This area also contains some very sandy material. Much of these soils in the general region south of Rodeo is lighter colored than typical of the Diablo series, and yet not so distinctly brown as the Altamont series, and it is possible that some light-gray to gray patches should be considered as occurrences of the Arnold or some other similar series of soils recognized in previous surveys. There are numerous widely scattered bodies north of the bay, some of which contain much Altamont material, but it is believed less than 50 per cent in all instances.

Topography and drainage.—The topography of the Diablo soils, undifferentiated, varies from gently or steeply rolling to mountainous (see Pl. II, fig. 2). High ridges and hills of this group lie north of the Livermore Valley or east of Mission San Jose. Some of the area north of Livermore is steeply rolling, yet the contours are everywhere rounded, with few sharp features of erosion and steep slopes to decrease the tillable area. In other parts steep-sided ravines, precipitous hills, and here and there landslides reduce the possibilities of tillage. Most of the area with this unfavorable topography was mapped as the rough broken phase of the Diablo group. Surface drainage is always sufficient, but the remarkable capacity of the soil and subsoil for holding moisture and the ease with which the mellow surface absorbs it prevent crops from suffering during the dry season as quickly as on many of the other hill soils.

Origin.—These soils are residual in origin and are usually derived from more calcareous shales and sandstones than the Altamont series. As with all the residual groups, it contains small areas of colluvial soil.

Utilization and adaptation.—These soils were for the most part treeless in their original state. They furnish good grazing. Unusually heavy growths of bur clover occur on this land. The greater part of the group is probably farmed at this time, and in some localities like that north of the Livermore Valley there is very little waste land. Grain and grain hay are by far the most important

crops (see Pl. II, fig. 2), although in a few places, as northeast of San Jose, more intensive crops, such as apricots and prunes, are grown without irrigation. Special utilization such as this is rare, and the intensively cultivated crops cover a relatively small acreage. Some extension is possible in favorable places, but fruit growing will probably not supplant the extensive farming or grazing now largely identified with the group. Land values range a little higher than for similar soils of the Altamont series.

Diablo soils, undifferentiated, rough broken phase.—The rough broken phase of the Diablo soils includes those portions of the Diablo series which in general have a surface too steep, broken or dissected to allow cultivation. The soil material of the group is of variable texture, probably representing all the types of the series included under the preceding groups but conforming in general to the description of the series as regards color, origin, organic content, and general subsoil features. The soil material in the rough broken areas, however, is generally shallower than in the arable Diablo area. It is prevailingly a dark-gray to black clay adobe, but shallow areas, the result of rather active erosion, have a lighter, oftentimes grayish color. Rock outcrop is frequent and landslides are common over parts of the group. A small part of the group is recognized as suitable for tillage, and small areas are cultivated at this time. On the other hand, some areas of the rough broken phase were of necessity included with the smoother Diablo areas. Separations between the tillable and the rough broken areas is frequently difficult, and in places where the topography is rolling or broken, with smooth slopes or rounded ridges and crests intimately associated with steep-sided ravines or abrupt slopes, the separation is especially difficult, and certain rather extensive areas could, with equal propriety, be placed in either group. Such an area occurs in the region several miles east of Livermore.

Location.—This phase, which is not very extensive, is usually associated with the smoother Diablo soils. A considerable area was mapped east of Irvington and Warm Springs and another east of Livermore. These, with several small areas scattered through the southeastern part of the area, constitute the main part of the group.

Topography and drainage.—While the surface of the phase is too rough and broken for tillage, ordinarily rock outcrop or scattered stones are not present in sufficient amounts to form Rough stony land. Run-off is excessive, but the prevailingly heavy texture of the soil and its location in shaded ravines in places enables the storage of a relatively large supply of moisture, with a consequent good grass growth. The bold exposed slopes of the group are relatively barren.

Origin.—The materials forming the soils grouped in this phase are derived from rocks not essentially different from those yielding the typical Diablo soils, undifferentiated.

Utilization and adaptation.—With the exception of the small included areas of smooth land, previously mentioned, the soils of the rough broken phase are suited only to grazing. A moderate to good grass growth is usually found on them.

CLIMAX SERIES.

The soils included in the Climax series are dark gray to black, rather high in organic matter, and usually friable, even when of heavy texture. Distinct subsoils are not always found, but where they occur they are light brown, yellowish brown or grayish brown. The soils of this series are residual in origin from basic igneous rocks, which lie relatively near the surface, usually within 6 feet.

In this survey the soils are mapped in two groups. In one, the description of which follows, areas of Climax and Olympic material are shown together. In the other the Climax soils of stony character have been mapped with the stony types of a number of other series.

CLIMAX AND OLYMPIC¹ CLAY ADOBES, UNDIFFERENTIATED.

Description.—The Climax and Olympic clay adobes, undifferentiated, group includes the Climax clay adobe and Olympic clay adobe, which are mapped together, owing to the complexity of their occurrence. Besides these types a few areas of clay loam adobe texture belonging to each series are included, though owing to their small extent and similarity of texture they are disregarded in this description.

The Olympic clay adobe consists of brown to slightly reddish brown clay, showing rather strongly the adobe tendency to crack and granulate upon drying. It is fairly friable in structure, with moderate amounts of organic matter, and is rather easily cultivated when the moisture condition is favorable, though difficult to handle at other times. It is subject to great variations in depth. Over much of its area there is no well-defined subsoil, the soil resting at depths ranging from 8 to 20 inches or more upon the parent rock. Shallow areas of this kind are very common in the northern part of the area surveyed, where the soils of the group often occupy high positions. Most of the bodies lying southwest of Palo Alto, west of San Mateo, and elsewhere on the higher slopes and ridges subject to rather active erosion are also shallow. Deeper soils are encountered northwest and southeast of Haywards, where, over large areas, the average depth is 36 inches or more. Even here the soil may continue to the bedrock with little change in color, though in some places a change to lighter brown occurs.

¹ For description of the Olympic series, see p. 41.

The Climax clay adobe constitutes a small proportion of the group, being inextensive, except in the areas near Haywards and southeast of San Jose. It consists of a dark-gray to black clay of pronounced adobe structure. This material may extend to the bedrock, found at depths varying from 12 to 48 inches, or a light-brown, yellowish-brown or grayish-brown subsoil may occasionally be present.

Location.—Besides the areas of this group mentioned as lying southeast of San Jose and those near Haywards and San Mateo, there are numerous others, ranging in size up to several square miles, scattered through that part of the area lying north of San Francisco Bay. The soils of the group here are associated with the soil groups designated as Stony soils, undifferentiated, and Butte and Olympic loams and clay loams, undifferentiated, and some of the separations had to be made in a general way. Areas of Climax and Olympic clay adobes also occur north and east of Oakland and in other parts of the survey.

Topography and drainage.—The topography of this group ranges from undulating to steeply rolling and is typical of the hilly and mountainous sections of the area. Rock outcrop is locally abundant, and much of the group can be tilled only with extreme difficulty, owing to the steepness of the slopes and shallow depth of soil. Much of that near San Leandro or Haywards or southeast of San Jose, however, and a somewhat smaller proportion elsewhere, is under cultivation. Nearly all these soils are well drained.

Origin.—These soils are derived from quite a wide range of rocks, but mainly from igneous or highly metamorphosed igneous rocks. In the northern part of the area andesitic tuffs and breccias give rise to these soils. In a considerable area they come from diabase and basalt, and over a smaller area from serpentine. Rhyolite and silica-carbonate rocks also yield soils of this group, but are less important than the ones previously mentioned.

Utilization and adaptation.—The greater part of the soil of this group is used for grazing. Some of it is not forested in the native state; some of it bears a scrubby growth of brush and a few large trees. Nearly all that is under cultivation is used in the production of grain or hay. The few orchards on it are of little commercial importance. Before the crop range of these soils can be greatly increased it will be necessary to develop irrigation, and this seems impossible except over small areas on the lower slopes.

BUTTE SERIES.

The soils of the Butte series are gray or brownish gray and may extend to bedrock with little change. In cases where a distinct subsoil occurs it is usually a little lighter colored than the surface soil.

The series is residual, being derived mainly from andesitic tuffs and breccias. The surface is rolling or hilly to mountainous and rough. Drainage is consequently good to excessive.

In this area these soils are mapped as the Butte and Olympic loams and clay loams, undifferentiated. The total extent is not great.

BUTTE AND OLYMPIC¹ LOAMS AND CLAY LOAMS, UNDIFFERENTIATED.

Description.—The group of Butte and Olympic loams and clay loams, undifferentiated, includes the loam and clay loam of the Butte series and the loam and clay loam of the Olympic series.

The members of the Olympic series, which probably predominate in this group, are described under the group of the Olympic loam and clay loam. The Olympic loam, as included in the present group, does not vary essentially from the description already given, except that it has many grayish-brown variations which, in their most pronounced developments, approach or even merge into the associated gray soils of the Butte series. The soil material varies greatly in depth, ranging from areas too shallow for cultivation to local areas deep enough for general use. There may be little change in the soil before the bedrock is reached or more yellowish brown or slightly lighter colored subsoil may intervene.

The Olympic clay loam has about the same characteristics as the loam, except that it is a friable clay loam in texture.

The Butte loam consists of a gray or brownish-gray loam, of rather friable character, resting on the parent rock at depths ranging from a few inches to several feet. It is usually low in organic matter and somewhat deficient in power to hold water. In case a well-defined subsoil is found, its color is usually a little lighter than the surface. The underlying rock is usually reached through a zone of partially disintegrated rock.

Except in texture the Butte clay loam differs little from the loam.

Location.—These soils are most extensively encountered in the northwestern part of the area. A great number of areas are scattered through the hills bordering the Napa Valley, and between that general region and the western edge of the area several rather important areas are found. The soils of the group are often associated with Stony soils, undifferentiated, occupying the more stone-free portions of the hilly sections and usually having a greater depth of soil.

Topography and drainage.—The surface is rolling to hilly. Most of the area is capable of cultivation, so far as topography is concerned, though much of it is rather steep. A shallow soil in such areas is also an unfavorable condition, and only a small proportion

¹For description of the Olympic series, see p. 41.

of the group has actually been brought under cultivation. Steep-sided ravines, precipitous slopes, and abrupt individual hills are common, and some of the soils reach very high elevations within short distances from the adjacent low-lying recent-alluvial soils. Some of the bodies consist of the lower extensions of rougher mountain masses where they approach the valleys by more gentle slopes. The run-off is rapid and in nearly all instances the store of moisture is insufficient for larger yields.

Origin.—Practically all these soils are derived through the weathering of fragmental igneous material, in most instances andesitic tuffs or breccias. A part, such as portions lying near Petaluma, is derived from massive rocks, but it more often rests upon the agglomerates yielding the Stony soils, undifferentiated, and other residual soils of that locality. The tuffs are often fine-grained and in a few instances are stratified. A more detailed examination may show that a portion of some of the soils of the group are derived from rocks of sedimentary origin.

Utilization and adaptation.—A small part of the area of these soils is farmed, with grain and hay the principal crops, but the group is most extensively utilized for grazing. A few good orchards and vineyards have been developed. This is possible only upon the deeper, moister areas.

The extension of the cultivated area is possible, but shallow soils will probably limit such development to much less than one-half the total area. Scattered oaks and other tree growth, with brush, is the prevailing vegetation.

MISCELLANEOUS.

STONY SOILS, UNDIFFERENTIATED.

Description.—The group of Stony soils, undifferentiated, is quite similar in general topography, nonagricultural character, and large stone content to the Aiken stony soils, shallow phase, of the adjacent Sacramento Valley area. In the present survey, however, it comprises a rather wider range of soil material, as besides the Aiken, the Butte, Olympic, and Climax series are represented. The most striking features of the group are its typically shallow soil covering and very stony surface. Probably most of the included soil is a loam in texture, but considerable bodies of heavier texture, some of adobe texture, are quite extensively developed. Such variations do not materially affect the value of the areas, owing to the more dominant factors—shallow depth and high stone content. The soil material in most places is not of sufficient depth to have developed distinct subsoils. Aiken material is probably the most extensive although the Olympic is also important, the soils of the Butte and Climax series are of less extent.

That portion of the included undifferentiated soil material recognized as Aiken material usually consists of a red or deep-red loam or clay loam, although light-red or brownish-red areas are probably best considered as belonging to this series. In common with the other soils of this group the soils are shallow and for the most part would be recognized in a detailed survey as shallow, stony phases of the various types. Rock outcrop, loose scattered stones, and slopes almost devoid of soil covering are common features.

The Olympic series of soils is represented by those portions having characteristically brown colors, although color separations are not sharp and the brown soils pass by gradations into the red soils of the Aiken series and the gray soils of the Butte series. The Olympic loam and clay loam probably predominate, but the clay adobe is well developed in certain localities.

The soils of the Butte series are not so extensive as those of the last-mentioned two series. The gray soils scattered throughout the group are shallow and have general features very much like the Butte soils of the Marysville Buttes in the Sacramento Valley area and are correlated with that series. The texture is usually heavier than loam and the material is gritty. The soils are shallow, rocky, and unproductive. They should be considered as shallow phases rather than typical Butte soils. They are usually gray in color, but transitions from this to the colors of associated series are numerous. The Climax series of black soils is less extensively developed than the others. It is represented largely by a shallow stony clay adobe.

The soil material rarely attains a depth of more than 2 or 3 feet, with a probable average of not more than 12 inches, and many slopes and ridges have no soil covering. This unfavorable condition is accentuated by the presence of large quantities of boulders or angular rock fragments, which are generally distributed over the surface, embedded in the soil mass. The areas are also marked by massive rock outcrops. Typically, the group is nonagricultural, the soil being too shallow for cultivation or for sufficient water storage. A low organic-matter content is the rule.

Location.—The most extensive bodies are located in the northern part of the area throughout the broad scope of country extending eastward and southeastward from Santa Rosa to the eastern limits of the survey. The larger unbroken areas are several square miles in extent. The Climax series is poorly represented in this northern region, but the other three series are rather typically developed. In some cases the soils over quite extensive areas belong to a single series, and their separation in a detailed survey would not be especially difficult if it were deemed necessary. Besides these northern areas there are others west and northwest of Palo Alto and southeast of

San Jose. The latter contain well-defined bodies of the Climax series.

Topography and drainage.—The surface is in places uneven, dissected or precipitous, but generally consists of fairly uniform slopes, ridges or plateaulike bodies varied here and there by the more pronounced features. Typically, so far as the general features of topography are concerned, tillage would not ordinarily be impossible. While small areas along ravines and precipitous slopes are similar to Rough broken land, in most instances the nonagricultural character is due to shallow soil and stony nature rather than to topography. In certain localities, as in the extensive bodies lying east and northeast of Santa Rosa, some parts of the group are less stony, but have a rather broken surface, and their classification as the Rough broken phase of the respective series would be proper.

Origin.—Stony soils, undifferentiated, are the shallow, residual product from the disintegration and weathering of andesitic breccias, tuffs, and basalt. In the southern part of the area the group is also derived from serpentine and certain other highly metamorphosed rocks. Most of the soils are from a volcanic breccia which usually consists of fragmental andesite or basalt, wherein the material ranges from fine-grained beds of tuff to massive blocks. Owing to active erosion a deep soil covering does not usually accumulate.

Utilization and adaptation.—Most of the group is covered with a brushy growth, but portions are barren of trees or shrubs. In the deeper ravines and on favorable slopes conifers, oaks, madroña, buckeye, and other trees and shrubs are found. The land affords fair pasturage, which is its sole use. Where the stones are less numerous and small and the soil is deeper than the average, areas can be made productive, but such areas are of minor extent. Certain tilled areas of deeper soil included should be considered undifferentiated areas of agricultural types of the several series. In those parts of the area where the rainfall is greatest, small quantities of fruit have been grown on these shallow soils. Some extension of fruit growing will probably take place, but only a very small proportion of the total extent of the group can ever be developed in this way.

ROUGH STONY LAND.

Description.—Rough stony land is similar to Rough broken land, the only difference being that the former is more rocky. It is non-agricultural both by reason of topography and high stone content, either feature in the absence of the other being sufficient to render the land untillable. As mapped the type includes small areas of tillable soil, but the extent of such soil is less than in the case of the preceding rough broken groups.

Rough stony land consists of shallow patchy soils burdened with an excess of loose rock material and marked by rock outcrop and clifflike escarpments of sheer rock. The character of the soil material varies greatly, with the character of the rock. The small bodies in the eastern part of the Walnut Creek section have soils similar to the Diablo series. Areas in the Mount Hamilton region are excessively steep, almost barren of soil, and consist largely of rock debris derived from metamorphosed sedimentaries of the more rugged parts of the country. The region northeast of Napa included within this type consists largely of rugged, barren rock faces or excessively stony areas with andesite and basalt rocks predominating. The large body in the Mount Diablo region occupies some of the crests and steeper slopes of the main mountain mass and associated ridges, and here also metamorphosed sedimentaries seem to predominate. The crest of Mount Tamalpais could rightly be considered as falling under this type of material, but the main mountain mass, while gravelly or moderately rocky and very steep was not considered sufficiently stony to be classed as Rough stony land. The area lying several miles east of Santa Rosa is similar to the one near Napa. The group of Stony soils, undifferentiated, so widely developed in the northern part of the survey, contains many small areas of steep topography which could have been classed as Rough stony land with equal propriety.

Excessive drainage is a characteristic of Rough stony land. Erosion is exceedingly destructive and soil waste so rapid that little opportunity for accumulation exists. Scattered tree and brush growths are rather common, and a sparse growth of grass affords some grazing.

SOILS FROM COASTAL PLAIN AND OLD VALLEY-FILLING MATERIAL.

CORNING SERIES.

The soils of the Corning series are red in color, with variations of yellowish or light-red color. They are easily puddled, boggy when wet, deficient in organic matter and lime, and hard to handle except under proper moisture conditions. The subsoils are red to deep red, of heavy compact structure, slightly impervious to moisture, and pass into gravelly substrata. These coarse underlying beds are variable, but most often occur within the depth of 6 feet as masses of rounded quartzose gravel mixed with less amounts of clayey material. The soils of this series are derived from old unconsolidated deposits now constituting elevated terraces or remnants of an older sedimentary valley filling, which have, however, been altered and modified by weathering and erosion. The soils usually occupy regions of intermediate elevation along the valley margins, being

flanked on their upper side by the residual soils from consolidated rocks and on the lower by recent alluvium. They occupy sloping to undulating or hilly uplands and valley plains. The surface is frequently marked by "hog wallows," and by numerous small shallow depressions and local poorly drained areas. The members of this Pleasanton series on a basis of color, the soils of that series being brown.

The Corning series is inextensive in this survey, being represented by one soil group and an undifferentiated portion of another.

CORNING LOAMS.

Description.—The Corning loams group includes the Corning gravelly loam and the Corning loam.

The Corning gravelly loam usually consists of a red loam of medium texture, containing gritty material and varying proportions of waterworn and angular gravel. The coarser gravel fragments, usually quartzose, sometimes attain a diameter of 3 or 4 inches, but usually less, and do not seriously interfere with cultivation. The organic content is low. Although the type is considered as a red soil, a great deal of it in this area is light red, yellowish red or brownish red, being in some places rather difficult to separate from the Pleasanton soils. It is boggy when wet and very compact when dry, being somewhat similar to the Pleasanton series in these features. The variation in the character of the deposits yielding this type, the different degrees of erosion and weathering, and other features result in a lack of uniformity in the subsoil. In its average occurrence, however, the surface gravelly loam grades at 12 to 20 inches into a compact clay or clay loam, either similar in color or of lighter or darker shades of red than the surface soil. It is often rather free from gravel and of adobelike structure, cracking upon exposure. This heavier subsoil material usually gives way within a few inches to a very gravelly substratum of fine to coarse waterworn gravel, mixed with clayey materials or interbedded with strata of silt and clay. The type is not characterized by a hardpan layer, but the gravelly substratum, especially its upper part, may sometimes be semicemented and very unfavorable for root and water penetration.

The Corning loam closely resembles the gravelly loam in both soil and subsoil, except that it is relatively free from gravel. The well-defined gravelly substratum at a depth of less than 6 feet is always found where the soil is typically developed.

The greater part of the area of this group, as mapped, possesses the gravelly substrata, but small portions do not. The latter are really considered as undifferentiated bodies of the Kimball series of

soils, recognized in the reconnaissance soil survey of the Sacramento Valley area. Some of the material of the soils of this group in the Livermore Valley has a hardpan almost extensive enough to warrant classification with the Redding series, which is widely developed in the Sacramento Valley. The content of lime and organic matter seems to be low in these soils, and this accounts in part for their compact structure and lack of retentiveness of moisture. The addition of organic matter has been found to be very beneficial to these soils, improving their tilth and increasing their power to retain moisture.

Location.—These soils are inextensive. They are in most cases associated with the Pleasanton series, and an area just south of Livermore contains some undifferentiated Pleasanton types. On the other hand, some Pleasanton areas near by include patches of Corning soils. Some high, eroded terraces near Clayton, north of Mount Diablo, are covered by Corning soils. That body shown southwest of Mountain View is not typical, since the color tends more toward brown or reddish brown. There are several small areas of the group near Saratoga. The northeast corner of the area surveyed contains a small development which is an extension from the Sacramento Valley area. The area northwest of Sonoma includes small undifferentiated bodies of both residual and recent alluvial soils.

Topography and drainage.—The surface is often rolling and is sometimes marked by hummocks. As with the other soils derived from unconsolidated materials, there are not as great ranges in elevation as are found in the residual soils such as the Altamont series. The group is usually quite distinct in topography from the alluvial soils which it sometimes adjoins, but is quite as distinct from the higher residual soils, there being considerable differences in elevation along the line of contact. These soils, because of their relative elevation, are generally well drained, except during the rainy season. At this time the soil becomes saturated and boggy, owing to the lack of underdrainage. Later in the season the supply of moisture is insufficient and the crop range of the soils in dry farming is therefore narrowed.

Origin.—The Corning loams are derived from unconsolidated material that has been subjected to little change, except by weathering, a slight reworking by water, and by erosion of the original water-laid surfaces to produce the present uneven topography. The materials are very much the same as those giving rise to the Pleasanton series.

Utilization and adaptation.—Some dry-farmed orchards are found upon these soils, and a part is devoted to pasture, but the greater part is dry farmed to hay and grain. Lack of irrigation water is the prin-

principal factor limiting the use of the Corning loams under present conditions. If water were supplied, these soils could be made valuable producers of varied products. Some parts of the group in this area can be developed to a greater extent without irrigation water than similar soils in the Sacramento Valley, owing to the less intense heat and in some sections to a greater rainfall than in that locality. The quality of fruit produced on these soils is good, but the yields are lighter than on the lower lying recent-alluvial soils. In use and value per acre this group of soils is similar to the Pleasanton series, but it is not the equal of the various groups of recent-alluvial soils.

TUSCAN SERIES.

The soils of the Tuscan series are reddish brown and, so far as mapped in this survey, carry quantities of andesitic or basaltic gravel or roughly rounded stones scattered through the soil and upon the surface. They are shallow and rest upon massive beds of firmly or partly indurated waterworn gravel and finer interstitial material, sometimes interbedded with deposits of gray sandy material, but nearly all andesitic in origin and existing as a water-laid product from volcanic tuffs and breccias. The materials giving rise to the Tuscan series are the weathered products of old sedimentary valley-filling deposits. The soils occupy extensive, elevated, dissected valley plains, and are excessively drained, arid, and usually treeless. The cemented substrata are relatively impenetrable to roots and impervious to water. These strata occur at shallow depths or are exposed over considerable areas, with but a patchy soil covering. These soils are mapped in one group—the Tuscan stony loams.

TUSCAN STONY LOAMS.

Description.—The fine earth of the Tuscan stony loams group typically consists of a reddish-brown loam and sandy loam, slightly sticky when wet and rather compact when dry. The color in this survey is oftentimes redder than typical of the soils of this series and over considerable areas may be red. Certain other variations are approximately brown. The loam and sandy loam types do not differ materially except in texture. The average depth of soil is about 16 inches. A great part of the area of these soils carries large quantities of cobblestones from a few inches to a foot or more in diameter, either scattered over the surface or embedded in the soil mass. These stones are usually andesite or basalt, and in disintegrating yield quantities of angular fragments which fill the soil. Much of the soil in this area has a deeper soil covering than the average given above and may be rather free from the cobbles. Usually, however, it is underlain at a depth much less than 6 feet by masses of

cemented waterworn gravel and cobbles, irregularly stratified, and sometimes interbedded with sandy or silty layers.

Location.—The Tuscan stony loams occupy several areas in the general region between Santa Rosa and Sonoma, in the northwestern part of the survey. They occupy benches, old terraces or dissected alluvial fans intermediate in elevation between the elevated residual soils and the recent alluvial soils in the present stream bottoms.

Topography and drainage.—The Tuscan stony loams occupy sloping or dissected areas and the drainage is usually excessive. In the more elevated areas the surface is marked by entrenched stream ways, but in the one lying just west of Sonoma the waterways lie in shallow channels and the original water-laid topography of parts of the area have been modified little by erosion. A tendency toward a hog-wallow surface is found in places. Along the contact with the foothill soils the transition in both topography and soil material usually is gradual. Rather well marked terrace lines usually separate it from the recent-alluvial soils of the lower valleys. Much of the group was originally treeless or supported a scattered growth of oaks and shrubs.

Origin.—The Tuscan stony loams are derived from the weathered products of material deposited as coarse-textured alluvium, consisting almost entirely of andesite, basalt or similar igneous rocks. Subsequent to its deposition these waterworn products were cemented into the rather solid mass, as seen at present in the substrata.

Utilization and adaption.—The Tuscan stony loams are not largely utilized except for grazing. The soils have a rather low water-storing capacity, and in the absence of irrigation are subject to drought and are rather poor soils for dry farming. Most of the group will probably remain in an unproductive condition until irrigation is supplied. There are indications, however, that a considerable range of crops would be possible over a good part of the area covered by the group were water available, especially where the substratum is least firmly cemented. The deeper parts may be used even without irrigation for certain crops and are now being cultivated to a small extent. In areas of deeper soil these types are well adapted, under irrigation, to the stone fruits, apples, berries, and certain other crops. Even alfalfa can be grown upon the deepest soils. Irrigation will probably be the main factor in the further development of the Tuscan soils.

PLEASANTON SERIES.

The soils of the Pleasanton series are typically brown or light brown, with variations of grayish-brown or reddish-brown color. They normally pass into heavier textured subsoils, which in turn are

underlain at less than 6 feet by substrata composed of coarse water-worn gravel, mainly quartz, mixed with small proportions of clayey materials. The surface ranges from rather uniform to rolling or uneven, and is well drained, except during the rainy season, at which time the soils are boggy, owing to slow internal drainage due to the compact subsoil and substratum. These soils are derived from old unconsolidated waterlaid deposits, which now lie somewhat above the stream bottoms.

The soils of these series are mapped as the gravelly clay loam and in three groups, the sandy loams, loams, and adobe soils.

PLEASANTON SANDY LOAMS.

Description.—The Pleasanton sandy loams group comprises the Pleasanton sandy loam and gravelly sandy loam. The soils are similar to those mapped in the Livermore area.¹

The Pleasanton sandy loam consists of a light-brown, brown or slightly reddish brown fine to medium sandy loam, 18 to 36 inches deep, often carrying small quantities of fine to coarse angular gravel. Rounded and angular stones are in many places scattered over the surface, especially on the higher ridges. The soil is often underlain by a red or yellowish-red sticky clay loam, comparatively free from gravel, and exhibiting the adobe structure when exposed. The stratum of clay material is sometimes thin or occasionally wanting, but usually varies in thickness from 8 to 14 inches. At 24 to 48 inches below the surface occur compact gravelly strata, composed of waterworn gravel and clayey material, usually of various reddish or brownish colors. These strata, while of irregular occurrence and character, usually extend below 6 feet, but may alternate with other strata of finer textured material. The soil is quite sticky, apt to be boggy when wet, and puddles readily, but is easily tilled when handled under proper moisture conditions.

The Pleasanton gravelly sandy loam consists of a brown or slightly reddish brown loam generally carrying perceptible quantities of medium to coarse sand and large quantities of rounded or angular gravel. The ridge crests carry the most gravel, and are also lightest in texture. The more gentle slopes are often marked by patches of heavier textured soils. Brown is the predominating color, although variations are common, in places approaching the red color of the Corning series. The type is boggy when wet and hard and compact when dry. The soil is underlain at a depth of 18 to 30 inches by a layer of yellowish-brown or reddish-brown clay loam a few inches thick, which in turn is underlain by a gravelly stratum of waterworn material, usually compact and in rare instances semicemented.

¹ Soil survey of the Livermore Valley. Field Operations of the Bureau of Soils, 1910.

Location.—Several areas of this group are mapped in the Livermore Valley, south of Pleasanton and southeast of Livermore. It is recognized that the Pleasanton loams group contains locally small bodies of Pleasanton sandy loam.

Topography and drainage.—The group has a varied topography, ranging from smooth to rather hilly and dissected. Its prevailing elevated position and rolling surface insure good surface drainage, but the compact clay subsoil retards the underdrainage, and during the rainy season the soil is often water-logged. These soils, especially the gravelly sandy loam, are rather poorly adapted to dry farming.

Origin.—The Pleasanton sandy loams are the weathered product of unconsolidated sedimentary deposits, consisting largely of gravelly and clayey materials. These old-alluvial deposits now lie considerably elevated above the recent stream bottoms.

Utilization and adaptation.—The group is practically treeless, except along ravines where live oak and buckeye, with some brush growth, are found. The Pleasanton sandy loam is either dry farmed to grapes, hay, and grain, or used for grazing purposes. At present grapes are the most profitable crop. Where hay and grain are grown it is a common practice to pasture the land every third year, but under most favorable conditions the yield of hay is seldom more than one ton per acre. The type affords good pasturage during a short time after the rainy season, but best results can not be obtained without irrigation.

No attempt has been made to cultivate the greater part of the Pleasanton gravelly sandy loam. It is used almost entirely for grazing and affords good pasturage during the late winter and spring months.

Under the climatic conditions existing in this area the soils of the group will not yield best results without irrigation, but if a supply of water at reasonable cost were available, tree fruits and quite a range of field crops could be grown. The soils are low in organic matter and the yields of crops could probably be increased by supplying this soil constituent.

PLEASANTON LOAMS.

Description.—The Pleasanton loams include the loam and gravelly loam of the Pleasanton series.

The Pleasanton loam as recognized in the earlier detailed survey of the Livermore Valley area is included very much as it is mapped in that area, except that the redder portions have been separated and mapped with the Corning loams. The Pleasanton soils are subject to considerable variation, but most often consist of a brown or light-brown loam or gravelly loam, extending to a depth of 12 to 36 inches.

The loam and gravelly loam are practically identical, except for the presence of gravel in the latter. This gravel is usually waterworn and contains much quartz rock. The two members of the series grade into each other and both types are usually represented in all bodies shown on the map. Though brown is the typical color, variations in this character are common and occur within short distances. Reddish-brown colors approaching those of the Corning series are found, and dark gray, much like the color of the Montezuma series, is also encountered.

The loam or gravelly loam soil material usually grades into a compact light-brown or yellowish-brown clay loam nearly always free from gravel and showing upon exposure an adobe structure. This subsoil is occasionally wanting, but ordinarily ranges in thickness from a few inches to 2 feet or more. In all typical areas it rests upon gravelly beds at less than 6 feet. The character of this coarse stratum varies widely, but in most places it consists of medium-sized, waterworn gravel mixed with smaller amounts of clayey material and often interstratified with layers of silt and clay. On some of the higher ridges the surface loam is very shallow. Another variation has been included, where the clayey subsoil is absent and the soil rests on the gravelly stratum. Some low-lying, poorly drained, darker colored areas, less productive than the typical soil, are also found.

Location.—The Pleasanton loams group is widely distributed in this survey, although its total area is only 71.5 square miles. A number of areas, ranging from a few acres up to 2 or 3 square miles in extent, are found in the southern part of the Livermore Valley, chiefly along the lower slopes of the range of hills lying between Livermore and Sunol. It is represented east of Concord, by many areas around Napa and Sonoma, others between Palo Alto and Saratoga, and also along the eastern side of the Santa Clara Valley. Nearly all parts of the area contain patches of the soils of this group, many of them not large enough to map.

Topography and drainage.—The country occupied by soils of this group ranges from hilly, rolling areas, with elevations of several hundred feet above the recent-alluvial soils, to relatively low, gently undulating areas, which are difficult to distinguish from the more recent soils. In extreme cases the surface is rough, but the greater part of it is tillable. Owing to the rolling surface the drainage is usually well established and sufficient, except for short periods during and immediately following long-continued rains, when the soil becomes thoroughly saturated, the compact subsoil preventing the rapid removal of excess water by subdrainage.

Origin.—The origin of these soils is identical in most features with that of the Corning loams, from which the Pleasanton differs in color, and with the Antioch loam and clay loam, from which it differs

in having a gravelly substratum. The soils have been derived from unconsolidated sediments lying at some elevation above the valley floors, modified by weathering and erosion.

Utilization and adaptation.—Some of these soils in the Livermore Valley are planted to wine grapes, but by far the larger proportion of their area is devoted to hay and grain or used for grazing. The latter uses are the most important throughout the area, but on the deeper, better soils, like much of the areas in the Santa Clara Valley, some very good orchards of prunes, apricots, peaches, and some vineyards have been developed without irrigation. Practically the whole group is suited to a wide range of crops when water is supplied. Applications of organic matter greatly improve these soils.

PLEASANTON GRAVELLY CLAY LOAM.

Description.—The Pleasanton gravelly clay loam consists of 15 to 30 inches of brown, dark-brown or slightly reddish brown clay loam, carrying considerable quantities of angular or waterworn gravel. On the ridges, the soil is somewhat lighter in texture and more gravelly than on the steep slopes, where small bodies of adobe comparatively free from gravel are occasionally found. The gravel, in which quartzite rock predominates, is distributed through the soil and is frequently strewn over the surface. The soil is underlain by a yellowish-red or reddish-brown clay loam which becomes more gravelly and somewhat lighter in texture with increasing depth. It usually extends to a depth of 6 feet or more, but may be interstratified with clayey beds relatively free from gravel.

Location.—The largest area of this type lies several miles southwest of Livermore, and several small bodies northeast of Petaluma.

Topography and drainage.—The area in the Livermore Valley is comparatively rough, with many ridges and deep ravines, the bottoms of which are frequently 300 to 400 feet lower than the crests of surrounding ridges. The areas in the neighborhood of Petaluma are smoother, but rise perceptibly above the Dublin adobe soils in which they occur as remnants of older deposits. The surface drainage of the type is good to excessive, and the type is rather poorly adapted to dry farming.

Utilization and adaptation.—The Pleasanton gravelly clay loam is devoted almost entirely to grazing. A small part is used for grain growing. The topography and the lack of irrigation water render development of most of the type problematical.

PLEASANTON ADOBE SOILS.

Description.—The group of Pleasanton adobe soils comprises the clay loam adobe and clay adobe.

The Pleasanton clay loam adobe constitutes the greater part of the group and typically consists of a brown, grayish-brown or slightly reddish brown clay loam, containing in many places considerable quantities of waterworn or subangular gravel. The ridge crests usually bear more gravel and cobblestones than other portions of the surface; a large proportion of it is gravel free. At depths ranging from 15 to 36 inches a lighter colored layer of yellowish-brown or reddish-brown clay or clay loam is usually encountered. This layer may be absent, but ordinarily is from 4 to 20 inches thick, below which there is normally the compact gravelly stratum characteristic of the series. There is wide variation in the depths at which the different layers lie, and the gravelly stratum may be much nearer the surface than 40 inches or may not be found until a depth of 5 or 6 feet is reached. It is usually composed of waterworn gravel of various sizes mixed with clayey material. While typically it is not cemented or impervious, in places it is very compact.

The Pleasanton clay adobe is similar to the clay loam adobe, except as regards its texture. Local undifferentiated bodies included within the group do not have the gravelly substratum within 6 feet, and where this is the case the soils really belong in the Antioch series. The Pleasanton adobe soils are moderately well supplied with lime and organic matter, being in these respects probably slightly better than the other soils of the same series or of the Corning series, though not so good as the Montezuma soils.

Location.—The group is not extensive. Most of the Pleasanton clay adobe as mapped in the Livermore area is included as previously mapped, except some portions considered too dark in color and included in the present survey with the Montezuma adobe soils. Several areas lie in the Livermore Valley, a small one several miles north of Benicia, another several miles east of San Jose, and one near Clayton, just north of Mount Diablo. In addition, several important areas are mapped along the eastern foot slopes of the mountains between Palo Alto and Saratoga.

Topography and drainage.—The surface is usually rather diversified, being rolling or even hilly, with some rough broken areas, rather high ridges, and deep ravines. Several of the areas occupy elevated, slightly dissected terraces. The surface drainage is usually good to excessive, the run-off being rather rapid; yet the heavy-textured soils favor the retention of water and crops do not suffer during the dry season as much as on the lighter soils of the series.

Origin.—In common with the rest of the soils of the Pleasanton series, the soils of this group are derived from old unconsolidated, gravelly, clayey deposits, lying usually at considerable elevations above the alluvial bottoms of the active streams. These old sedimentary deposits have reached their present form through erosion,

and are now gradually disappearing, to give way to the more recent soils.

Utilization and adaptation.—A great deal of the group is so steep that it can be cultivated only with difficulty, and is devoted to grazing. Upon those parts which are tillable grain and grain hay are the principal crops. In the area just north of Saratoga there are several dry-farmed orchards. Deeper tillage and the addition of organic matter to increase the power of the soil to store and hold water are important where intensive crops are to be grown on these soils.

ANTIOCH SERIES.

The soils of the Antioch series are brown, light brown or grayish brown and usually of rather friable structure. The subsoils are heavier in texture, predominantly light brown or yellowish brown in color and often calcareous. The series occupies sloping, slightly rolling or otherwise modified terraces. It is derived from unconsolidated sedimentary deposits. Drainage is usually good, except in some depressions.

The soils of this series are mapped in three groups, one including soils of another series.

ANTIOCH SANDS AND SANDY LOAMS.

Description.—The Antioch sands and sandy loams group includes the sand, loamy sand, sandy loam, and fine sandy loam of the series, the loamy sand and sandy loam covering the greater area.

The Antioch loamy sand consists of a brown or light-brown to slightly reddish brown medium-textured sand, with enough fine material, silt or clay, to give it a slightly loamy texture. It is friable and much more retentive of moisture than would be expected from its light texture. It grades at 12 to 18 inches into a lighter brown or yellowish-brown subsoil, of somewhat the same texture as the surface. It is in places compact or even slightly cemented, but usually permeable by roots and water. The subsoil is rather uniform to depths of 6 feet or more.

The Antioch sand is of small extent, including those parts of the group of more sandy texture, incoherent structure, and low water-holding capacity. In some places it represents areas where wind action has accumulated a more than average sandy covering, and in some of these places the material is probably the Oakley sand, to be described later.

The Antioch sandy loam is usually a light-textured, friable sandy loam having about the same average depth and character of subsoil as the loamy sand member. It is somewhat more retentive of

moisture, contains more organic matter, and is a slightly better agricultural soil than the lighter types of the series.

The Antioch fine sandy loam is not extensive and differs little from the sandy loam, except in the finer grades of the sand constituents.

Location.—The most important occurrence of this group is on the San Francisco peninsula south of San Francisco. A portion of the city of Oakland and nearly all the city of Alameda are located on these soils. Several other minor bodies occur along the coast north and south of Halfmoon Bay, but are of little relative importance as compared with the bodies previously mentioned, and too small to show on the map.

Topography and drainage.—The group is usually rolling. Some of it, such as that in the city of Alameda, has a relatively flat surface, is less elevated above water level than usual, and has been less modified by erosion. Stream channels in the main body south of San Francisco are at times deeply entrenched, but at other times are bordered by rather uniform surfaces only slightly higher than their channels. Under these conditions the Antioch soils are separated with difficulty from the recent-alluvial soils. The group is well or excessively drained, much of the rainfall percolating into the subsoil.

Origin.—These soils are derived from unconsolidated alluvial or marine deposits, which have been elevated since their deposition. The distinction between consolidated and unconsolidated character of the parent material as maintained between the Altamont and Antioch series of soils is rather arbitrarily made along their contact on the San Francisco peninsula.

Utilization and adaptation.—Nearly all the area of the Antioch sands and sandy loams on the San Francisco peninsula not occupied by various towns and villages, is used for growing vegetables. An important trucking industry has been established, many Italians being engaged in it. Considerable barnyard manure and commercial fertilizers are used and irrigation is practiced where possible. The soils warm quickly and several successive crops are grown each year on the same land. The soils are easily tilled and well suited to truck growing. The areas at Oakland and Alameda have been subdivided into building lots and have been withdrawn from use as farm land.

ANTIOCH LOAM AND CLAY LOAM.

Description.—In the Antioch loam and clay loam group the loam is the more extensive type. It consists of a brown, light-brown or grayish-brown rather sticky loam extending to an average depth of about 18 inches, but varying from less than this to 30 inches or more.

It is usually rather friable when moist, but becomes compact and often refractory when dry or poorly handled. It is normally rather free from gravel, but may contain small quantities, in which case a slightly gravelly subsoil is also usual. It often becomes slightly heavier with increase in depth, becoming a clay loam in texture at about the point where the subsoil begins. The subsoil is light brown or yellowish brown, often mottled in color, and consists of a very compact clay loam with light-colored calcareous seams or incipient hardpan. The deeper stratum consists of clayey beds, relieved at times by pockets or thin strata of coarser material.

The Antioch clay loam consists of a brown or dark-brown sticky clay loam with about the same range in depth as the loam. It usually averages a little darker in color than the latter type and along swales or in areas of stagnated drainage the color may even be as dark as that of the Montezuma series. The subsoil of the Antioch clay loam resembles that of the loam except that it is usually heavier and in places more compact.

Absence of a gravelly substratum distinguishes these soils from the Pleasanton series. They are rather low in organic matter in this area, and the subsoils are often sufficiently compact or cemented to diminish their agricultural value.

Location.—These soils usually occur as small areas, but the one extending northwest from San Mateo and that in the vicinity of Berkeley and Oakland each cover several square miles. The body lying along the northern boundary of the area northeast of Concord is an extension of the same group from the adjoining Sacramento Valley area mapped earlier. Those areas near Santa Cruz are in part of light texture, including in such instances undifferentiated material of the Antioch sands and sandy loams. The group is represented by other smaller areas on the map, and in addition the Pleasanton loams group includes some material without a gravelly substratum, which properly belongs to the Antioch series.

Topography and drainage.—The surface is usually rolling or somewhat dissected, although not presenting the great relief usually found in the soils derived from consolidated rocks. Some of the larger areas of the group have retained in part the uniform surface of the original terraces, but are marked by numerous small valleys at frequent intervals. There is usually a rather marked descent before the flood plains of the streams are reached, although in places where the erosion has proceeded quite evenly or to an advanced stage it is sometimes difficult to distinguish these soils from those of the recent-alluvial group. Local minor depressions are often found which are poorly drained, but on the whole the soils are well drained and are inclined to droughtiness. They have a deep water table and no tendency toward alkali or seepage.

Origin.—These soils are derived from unconsolidated sediments, modified by erosion, weathering, and the development of distinct subsoils. Typically they are old deposits, elevated since deposition, weathered, and now subject to erosion, as distinguished from the recent-alluvial soils now in process of formation.

Utilization and adaptation.—The area on which parts of Oakland and Berkeley are built has largely been withdrawn from cultivation, and the same is becoming true of the long, irregular area northwest of San Mateo, which is being settled rapidly. The remaining area of these soils is used in the production of dry-farmed hay or grain and pasturage. There are a few orchards, but intensive crops are unimportant. Irrigation would widen the range of crops and considerably increase the value of this group of soils.

ANTIOCH AND CORNING LOAMS, UNDIFFERENTIATED.

Description.—The group Antioch and Corning loams, undifferentiated, includes the Antioch loam and clay loam and the Corning loam and gravelly loam. As descriptions of these soils have already been given in connection with other groups (see pp. 63 and 73) it will not be necessary to describe them again here.

Location.—A single area of this group of soils was mapped, occurring in the extreme northeastern portion of the survey, along its contact with the previously surveyed Sacramento Valley area. The area is an extension into the present survey of the soil group mapped in the Sacramento Valley survey as Antioch and Montezuma soils, undifferentiated. At the junction of the two areas, however, the Montezuma soils seem to be absent, and within the present survey the Corning loams take their place.

Topography and drainage.—The surface of these soils is not essentially different from that of the two series described elsewhere in this report. The area covered is flanked on the west by a higher region, occupied largely by the Altamont series, from which it is rather indefinitely distinguished by topography. The drainage is good, except that the Corning loams become water-logged in the rainy season.

The Corning loams are derived through weathering from old coarse alluvial deposits. The Antioch loams have much the same origin but differ from the Corning soils in being brown and in lacking the gravelly substratum typically developed in the latter. The land in this group is largely used for the production of dry-farmed grain and fruits.

MADERA SERIES.

The soils of the Madera series are brown and have heavier textured, compact, lighter colored subsoils, in turn underlain typically by brown

¹ For description of Corning series, see p. 62.

or yellowish-brown hardpan, but which in this area may be of gray or brownish-gray color. The arrangement and thickness of these strata are subject to considerable variations, but the soil and subsoil together average about 36 inches in depth. The subsoil may constitute but a thin layer resting on the hardpan. The latter varies in thickness and character from a few inches of distinctly cemented impenetrable hardpan to thicker layers of less thoroughly cemented material. A deeper substratum of more friable character usually extends to 72 inches. The surface is uneven, owing to hummocks and small depressions, but in general it is sloping or gently rolling and slightly elevated above the recent-alluvial soils. Drainage is restricted during the rainy season, owing both to the depressions and to the retardation of underdrainage by the hardpan. The soils are derived from the weathered products of old alluvial fans.

The series is represented in this area by one inextensive group of soils including several types. While these soils in this survey have been correlated with the Madera series, it is possible that in future more detailed studies they may, owing to certain features in which they depart from the typical Madera soils, be recognized as a distinct series.

MADERA LOAMS AND CLAY LOAMS.

Description.—The Madera loams and clay loams group for the greater part consists of loam or clay loam, but it also includes a smaller area of silt loam and silty clay loam.

The Madera loam is a brown, light-brown or grayish-brown loam, usually free from gravel and about 14 inches deep. It is only fairly friable, often compact, and in some areas poorly drained. A reddish-brown variation is occasionally found. While the soil is typically brown, a rather mottled appearance is given the surface by the presence of numerous darker colored patches in the poorly drained depressions. A gray or brownish-gray variation is also included. The soil grades at about 14 inches into a lighter brown, heavier textured subsoil, which is locally very compact and hard when exposed and dried. This heavy layer of subsoil varies from a thin seam to 18 inches or more in thickness. In most places it rests upon a rather well defined layer of hardpan, although only a semicemented stratum may occur. These relatively impervious layers have an important influence on root and water penetration. The hardpan is usually gray or brownish-gray in color, and a distinctive feature is the common occurrence of black or dark bluish seams and coatings in the frequent checks or joints. Below this relatively impervious layer, which may be from 1 to several inches thick, material more friable than either the overlying subsoil or hardpan is encountered in many places.

The Madera clay loam, silt loam, and silty clay loam have about the same variations in subsoil and substrata features as the loam and have the textures indicated by their names.

The types mapped in the earlier survey of the Livermore area as the Ulmar fine sandy loam and Ulmar loam are included in this group. The former is a light-textured sandy loam varying in depth from 30 to 72 inches, but typically is underlain by lighter colored, heavier textured subsoils which usually have a rather well developed hardpan within 72 inches. The Ulmar loam is a light-brown to dark-brown loam extending to a depth of 15 to 24 inches, where it is underlain by sticky, more clayey subsoils. At about 36 inches a hardpan is found, varying in thickness from a few inches to 2 or 3 feet. The hardpan is sometimes absent and the soil here rests upon compact or semicemented clayey beds, which have somewhat the same effect on drainage as hardpan layers.

These soils contain a moderate to small amount of organic matter and are difficult to till on account of unfavorable conditions of drainage and structure.

Location.—Several areas of the Madera loams and clay loams were mapped from the vicinity of Santa Rosa southward for several miles. Another area lies southwest of Sonoma and Shellville, and it is possible that some of the Pleasanton loams near the latter places contain other undifferentiated soils. More detailed examinations may also show that some of the soil mapped as Antioch loam and clay loam south of San Pablo should be included in the Madera series. The Livermore Valley, as previously noted, contains several small areas of the Madera soils.

Topography and drainage.—The surface is usually quite uneven, owing to the presence of numerous small mounds and intervening depressions, sometimes known as hog wallows. These depressions retain water during the rainy season. The broader features of the topography are those of a gentle plain, lying slightly above the recent-alluvial soils. In some instances isolated areas of this group remain as slightly elevated remnants within areas of the more recent soils of the Dublin and Yolo series. Most of the Madera soils are free from alkali, but a part in the Livermore Valley contains injurious quantities.

Origin.—The Madera soils occupy the remnants of old alluvial deposits. Their greater age as compared with the recent-alluvial groups is indicated by the hog-wallow surface and the presence of heavier subsoils and hardpan.

Utilization and adaptation.—A large proportion of the group in the Santa Rosa locality has been subdivided into small tracts, and some intensive agriculture is yielding very good results. Considerable leveling must be done to fit the land for irrigation, which is

necessary for best results on much of it, owing to the shallow depth of soil available for water storage. Prunes, peaches, and some apples, together with grapes, small fruits, and truck, are grown in small amounts. On much of the group near Sonoma and Shellville attempts at farming have been attended with little success.

Most of the group is not yet farmed to intensive crops, and the production of grain, grain hay, and pasturage are its main uses.

MONTEZUMA SERIES.

The soils of the Montezuma series are typically dark gray to black and sometimes of slightly brownish tint. They are usually friable and retentive of moisture, with rather high contents of organic matter and lime. The subsoils are lighter colored than the soils, being grayish brown, yellowish brown or gray. They contain little gravel. Seams or nodules of calcareous nature often occur, very rarely amounting to an intermittent hardpan. The surface is rolling to hilly, being usually of rounding outline, with few dissected drainage ways. The soils are derived from old water-laid deposits of alluvial, lacustrine or marine origin, and now elevated above their former position. The original forms of these deposits have usually been modified by erosion, but certain smooth portions are separated with difficulty from the recent-alluvial soils.

The Montezuma soils are of great local importance in this area, though of small extent. Two groups are shown, one including the soils of lighter texture and the other those of heavier texture and adobe structure. As mapped, some brown areas, in reality Antioch soils, have been included.

MONTEZUMA LOAMS AND CLAY LOAMS.

Description.—The Montezuma loams and clay loams group comprises the sandy loam, loam, clay loam, and silty clay loam. Of these the loam and clay loam probably predominate.

The Montezuma clay loam consists of a dark-gray or black, rather friable clay loam normally free from gravel. It extends to an average depth of about 18 inches, where it grades into a light-brown or grayish-brown subsoil, often of rather mottled appearance and bearing calcareous concretions or seams of similar material along cracks and fissures. The subsoil is usually rather compact in places, even approaching a joint clay structure, but is nevertheless permeable to roots and water. Typically the soil, subsoil, and substratum are free from gravelly beds, but occasional seams occur.

The Montezuma loam consists of a dark-gray to black friable loam with about the same range in soil and subsoil features as the clay loam.

Small bodies of the sandy loam are found associated with the loam, but they are relatively unimportant. The texture is that of a friable sandy loam, the depth about that of the Montezuma soils, and the subsoil is somewhat lighter textured than in the heavier types.

The Montezuma silty clay loam is the counterpart of the clay loam, except that it contains more silt.

The soils of the group as a whole are rather easily tilled and are retentive of moisture. A rather high lime and organic content no doubt increases the productiveness of the soils. While the color typically ranges from dark gray to black, many of the areas contain bodies of brown soil which in a detailed survey would be recognized as of the Antioch series. Developments of Antioch soil are especially prominent in the areas near Walnut Creek and in some of those lying along the coast near Santa Cruz.

Location.—The Montezuma loams and clay loams group occupies areas along the coast from Santa Cruz to a point north of Halfmoon Bay. A part of Castro Valley near Haywards is included in this group, although much of the soil here is brownish and approaches the Antioch series in color characteristics. A small area was mapped in the region between Berkeley and Oakland, and many other areas in this locality are more or less like this series. Their separation, however, would be difficult, as the Antioch and Montezuma series grade into each other and alternate within short distances. The group was not very well defined in the Walnut Creek section and areas not shown in the group may occur. An important area lies near Mission San Jose and Irvington.

Topography and drainage.—Typically the Montezuma loams and clay loams have a gently undulating or rolling topography, erosion having considerably modified the original smooth surface. Most of the areas are somewhat above the recent-alluvial soils, bordering the courses of present streams. In some places the surface has not been dissected or modified greatly. This is true of some of the sloping marine terraces up the coast from Santa Cruz. Parts of some of these bodies with rather smooth surfaces and with minor streams discharging across them from the hilly areas to the east are better considered as areas of recent-alluvial soils of the Dublin series. The group, as a whole, is well drained, and there are but few places where the run-off is insufficient or the underdrainage sluggish. No accumulations of alkali were seen.

Origin.—These soils are derived from alluvial, lacustrine or marine sediments now occupying higher relative positions than at the time of their deposition and consequently modified more or less by erosion. The sediments are typically unconsolidated, but vary somewhat in composition and compactness, giving rise to variations in the soil and subsoil within short distances.

Utilization and adaptation.—Practically all these soils are tilled. They are used for a variety of purposes, depending largely on the variations in climate. Some of the areas near Walnut Creek support unirrigated orchards and the remainder is used in growing grain or grain hay. The same use is made of areas in the Castro Valley. Some good orchards and vineyards have been developed near Irvington and Mission San Jose. These soils along the coast from Halfmoon Bay to Santa Cruz lie in a position rather bleak and exposed for fruit growing and have been developed but little to orchard industries, although the intensive production of vegetables has been successful. Irrigation is supplied wherever possible, and heavy yields of artichokes, beans, potatoes, and various other vegetables are grown. Excepting the recent-alluvial soils, this is one of the best groups in the area for intensive cultivation, although irrigation is desirable on most of it.

MONTEZUMA ADOBE SOILS.

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

The Montezuma clay adobe, which probably predominates, is typically a very dark gray or black clay of pronounced adobe structure. It is sticky when wet, yet friable and moderately easily tilled when moist. Although the color is prevailingly as stated, patches, streaks, and poorly defined areas have a distinct brownish or dark-brown color, which when prominently developed constitute undifferentiated bodies of the Antioch series. The area lying several miles southeast of Pleasanton contains much of this brownish variation. Gravel and other coarse materials do not usually occur in the surface soil. At depths ranging from 15 to 36 inches the soil grades rather sharply into a yellowish-brown, light-brown or gray, rather compact subsoil of clay loam, silty clay loam or clay texture. Occasionally layers of more sandy and gravelly material displace this subsoil, but ordinarily they do not amount to a gravelly substratum. Nodules and seams of calcareous material in places are common in the subsoil. True hardpan is normally absent. The organic-matter and lime content of the type is apparently high.

The Montezuma clay loam adobe is very similar to the clay adobe in all its essential features, except texture, and in most instances exhibits the adobe structure in a degree almost as marked as the clay adobe.

Location.—A few small bodies of this group are mapped. One lies south of Mission San Jose, two or three north of Concord, others several miles east of Concord, near the margin of the area, and some southeast of Pleasanton.

Topography and drainage.—The surface of the group is rolling and the run-off rapid, yet the absorption and retentive powers of the soil are quite high, and it stores much moisture. No alkali is present. The surface relief is greater than that of the Montezuma loams and clay loams, but only small areas are too steep for tillage.

Origin.—These soils are typically derived from unconsolidated deposits very much like those giving rise to the Pleasanton soils, except that in case of the Montezuma the materials are finer and more calcareous and yield soils of darker color. It is possible that some material which has been included with the group will on more detailed inspection be found derived from consolidated rocks, in which case it should be classed as material of the Diablo series. On the other hand, some of the lower slopes mapped as the Diablo soils may be from unconsolidated deposits and so belong to the Montezuma series.

Utilization and adaptation.—Practically all this group is dry-farmed to grain and grain hay, with very little attempt at more intensive use except on small parts of the area lying south of Mission San Jose, where there are some successful orchards and vineyards. Irrigation would add to the possibilities of crop production and should be provided wherever a water supply can be developed.

SOILS FROM RECENT-ALLUVIAL MATERIAL.

YOLO SERIES.

The Yolo series includes soils of brown, light-brown or dark grayish brown color. The subsoils are predominantly lighter colored, ranging from light brown to yellowish brown. They are alluvial in origin and occur typically as recent alluvial-fan deposits. As mapped in this area, however, areas of smaller extent, occupying more or less well defined stream flood plains and alluvial terraces are included. The material is derived from a rather wide range of rocks, in which the sedimentaries or metamorphosed sedimentaries greatly predominate. The surface is level or gently uneven and the drainage good (see Pl. III, fig. 2, and Pl. IV, fig. 1). The soils are free from alkali and highly productive.

The series is mapped in this survey in five groups and one type and is the most important alluvial series in the area.

YOLO GRAVELLY SANDY LOAMS.

Description.—The Yolo gravelly sandy loams group includes the gravelly sandy loam, the gravelly fine sandy loam, and small areas of gravelly sand of the series. The soil mapped in the survey of the Livermore area as the Mocho gravelly fine sandy loam is mapped as

Yolo in the present survey. The group, for the most part, consists of very light textured gravelly material closely associated with some of the intermittent streams and rather closely confined to their overflowed bottoms or to areas but little above them. Some areas resemble Riverwash in their main features.

The Yolo gravelly fine sandy loam consists of 10 inches to 3 feet of a brown, light-brown or grayish-brown fine sandy loam or loamy fine sand, carrying varying quantities of rounded, waterworn gravel. Some of the areas occurring in the Livermore Valley have a grayer or yellower color than typical. Where the type closely borders the streams it is usually underlain by a bed of coarse gravel with little fine earth many feet thick. The loose friable character of the soil makes it easy to till, except where the gravelly subsoil approaches too near the surface.

The Yolo gravelly sandy loam does not differ essentially from the gravelly fine sandy loam except in texture.

It is recognized that the texture of the soils in this group varies widely within short distances and that all the types include several phases. The presence or absence of the gravelly substratum has a marked influence on the agricultural value of the different areas.

Location.—The principal part of the group occurs in the Livermore Valley region, where it occurs as elongated areas bordering Arroyo Mocho, Arroyo del Valle, and Alameda Creek. Several small strips lie along some of the intermittent streams east of Mount Hamilton, another borders Los Gatos Creek southwest of San Jose, and a small area lies east of St. Helena in the northern part of the area.

Topography and drainage.—The group is usually confined to the vicinity of intermittent stream ways. It is most often found where streams emerge from the hills and spread over the adjacent valley floor, or in local flat-bottomed valleys of intermittent streams. The surface of the group, as a whole, is comparatively level, although it may be marked by numerous abandoned stream channels. Drainage is usually excessive, except in flood times, when the soils are often overflowed. The areas lie but little above the streams and are sometimes badly eroded during floods.

Origin.—This group includes some of the most recently deposited soils of the area, and over a considerable part of its extent is now subject to addition or change by annual floods. The soils represent the coarser textured alluvial material, closely associated with the main-stream channels.

Utilization and adaptation.—Owing to the porous, sandy nature of the soil and in many places the gravelly subsoil, the group is poorly adapted to dry farming. The better portions are dry-farmed to hay and grain, of which moderate yields are obtained. Much of the group, which has a shallow soil and is subject to annual overflow,

is used for grazing. With an abundant water supply the soils could be developed into very good truck and fruit types, but heavy applications of water would be necessary.

YOLO LOAMS.

Description.—The Yolo loams group includes the loamy sand, sandy loam, fine sandy loam, loam, and silt loam, the last two forming the principal part of the group area.

The Yolo loam consists of a brown, light-brown or grayish-brown, medium-textured friable loam, sometimes containing small quantities of gravel. There is not always a sharp demarcation between the soil and subsoil within a depth of 6 feet, but below a depth ranging from 16 to 40 inches the subsoil is usually a lighter brown than the surface soil. There is no consistent difference in texture between the soil and subsoil. The latter may be either heavier or lighter than the surface or consist of alternating layers of different textures, and even gravelly beds may occur within 6 feet near the site of present or abandoned stream channels. The Mocho loam recognized in the earlier survey of the Livermore area was included in this group. It is somewhat darker colored than the typical Yolo and is underlain by alternating layers of silty or sandy texture to a depth of several feet. It is usually underlain by a heavier substratum, which retains moisture well.

The Livermore loam of the Livermore survey was also included, a large part of which does not seem to differ essentially from the Yolo loam. It is brown or grayish brown, sometimes with a reddish-brown tinge when wet, and often carries small quantities of water-worn gravel. It has the lighter colored subsoils of variable textures common to the Yolo loam. The Sunol loam of the Livermore area, which was likewise included, is very similar to the average occurrence of the Yolo loam, except that some of its variations approach a light clay loam in texture and possess subsoils rather uniformly heavier than the surface.

The Yolo silt loam is a brown, light-brown or grayish-brown friable silt loam, sometimes extending to more than 72 inches, but usually with a tendency to grade into a light-brown or yellowish-brown subsoil at a depth of about 36 inches.

The Yolo fine sandy loam consists of 15 inches or more of fine sandy loam of light-brown or grayish-brown color. The subsoil is subject to considerable variation in texture, but distinct changes in color between soil and subsoil are not so marked as in the heavier types of the series. The Mocho fine sandy loam of the Livermore area, included with the Yolo loams in the present survey, is practically identical with the soil just described. Like the Yolo fine sandy loam

of other portions of the area, it is underlain by alternating strata of fine sandy loam, fine sand, silt loam, and even more clayey layers, while pockets of sand are likely to occur. The position and texture of the several strata are subject to a variation too wide for accurate description. The Livermore fine sandy loam is another type of the Livermore Valley survey which approaches the general character of the Yolo fine sandy loam, and is included with it in the present survey. Like the other soils included, it is brown and friable, and is underlain by lighter colored subsoils of variable character. The Livermore silty fine sandy loam of the Livermore area contains a little more silty material.

The Yolo sandy loam is a light-brown or grayish-brown friable sandy loam subject to considerable variation in depth. Sometimes it continues with only slight changes to a depth of 6 feet, but more often it grades into a slightly lighter colored subsoil before that depth is reached. Alternating strata of various textures may begin a few inches below the surface and continue throughout the soil column. The Mocho sandy loam of the Livermore area, while subject to many variations, was included in this soil group in the present survey very much as mapped at the earlier date. It does not differ much in its average constitution from the Yolo sandy loam, but is often underlain by the dark-colored material of the Dublin series, which it sometimes adjoins.

A few bodies of very sandy character were encountered closely associated with the heavier textures of the Yolo series and properly considered as belonging to that series, although the color is much lighter than typical. An incoherent sand or fine sand occupies some very recently deposited bodies in areas swept by flood waters. A light-brown loamy sand often underlain by heavier textured material was found, but these soils of extremely sandy nature are of minor extent as compared with the types previously described.

These soils include some variations which are dark in color and approach the Dublin series and other variations of yellowish and light-gray color which approach the Tehama and Laguna series, respectively, but it seemed inadvisable to make more detailed separations in this survey. The soils of the group as a whole are among the most easily tilled in the area and their retentiveness and great depth available for plant roots make them well adapted for either dry-farmed or irrigated crops.

Location.—Some of the most important areas of this group, both as regards extent and agricultural development, occur in the Santa Clara Valley. Most of the group in that region is of loam or silt loam texture, although more sandy strips are found at those points where overflow deposits the heaviest loads of material. Gravelly

streaks are also found and should be considered as the Yolo gravelly loam. The Livermore Valley contains many important areas of this group of soils. The distribution of the types of the various textures in that locality is indicated in detail in the earlier survey of the Livermore area. A body of several square miles in extent is mapped in the Alameda Creek fan around Niles and extending westward. Every texture in the group is represented in this area, with some of the more sandy soils prominently developed. The area shown around Pacheco near Concord is in places a recent overwash of incoherent sandy material rather grayish to be typical of the Yolo series. Other areas are mapped south of the bay, many of great fertility and local importance, though not forming a great part of the total area. The group is also encountered north of the bay in numerous small areas scattered through the alluvial deposits. Some of the areas northwest of Petaluma are very sandy.

Topography and drainage.—These soils have the general slope of the alluvial fans, of which they are a part, which is usually sufficient to give good drainage. Drainage is favored by the free and open character of the subsoil. Some of the more sandy areas or those having gravelly substrata are excessively drained, and certain other portions are periodically flood swept, but the soils as a whole are well drained, without being droughty. The surface is often marked by old stream channels, which sometimes occupy slight ridges. Although most of these soils lie on alluvial fans, some portions occur either on terraces or in stream bottoms.

Origin.—The Yolo loams are alluvial soils, derived largely from materials washed from sedimentary rocks. Igneous rock material or that from unconsolidated deposits has also influenced it in certain localities, so that as mapped in this area the material of the group is in part of mixed origin.

Utilization and adaptation.—About all the area of these soils is farmed, and their average use is perhaps as intensive as that of any other considerable group of soils in the area. They are highly prized in the Santa Clara Valley for various orchard crops and all the other crops of that intensively farmed region. Nearly all the area between Niles and Alvarado is intensively cultivated to both truck crops and fruits. Among the principal fruits grown on this group are prunes, plums, apricots, cherries, peaches, pears, and grapes (see Pl. III, fig. 2, and Pl. IV, fig. 1). Small fruits, olives, nuts, and rhubarb also thrive. Truck crops and flower and vegetable seeds also occupy an important place. The soil is well adapted to alfalfa and other field crops, but is often more profitably utilized for the special crops mentioned.

In the Livermore Valley some of these soils are intensively cultivated, with fruit growing successfully followed on portions, but hay

and grain farming still cover most of the group. Hops, sugar beets, many truck crops, vegetables, and alfalfa are grown there on the moister areas, as in the absence of irrigation it is rather difficult to conserve enough soil moisture to make a varied intensive agriculture possible.

Although a great deal has been accomplished upon this group and it is one of the heaviest producers of fruit and truck crops in the area under dry-farming methods, practically all of it would give an increased yield under irrigation, justifying considerable expense in the development of water supplies. Irrigation is being practiced over a great proportion of these soils in the Santa Clara Valley, and will no doubt be extended there and developed elsewhere. The present system of irrigation, whereby the entire surface is flooded, has a tendency to puddle and compact the soil, doing much to destroy its natural friable condition.

YOLO GRAVELLY LOAMS.

Description.—The Yolo gravelly loams most often consist of a brown or light-brown, medium-textured loam carrying variable amounts of medium-sized gravel. In common with the rest of the series this group is typically brown, but its wide distribution and gradation into associated soils cause a rather wide color range. Southwest of San Jose and in other places along the west side of the Santa Clara Valley the soil is sometimes yellowish brown and even approaches in color material of the Tehama series. Some of it on the east side of the Santa Clara Valley has a dark grayish brown color, the type here representing a gradation into the dark-gray soils of the Dublin series. The soil is rather friable, and while the gravel content is often large it rarely affects cultivation seriously.

This group has been made to include the Livermore gravelly sandy loam recognized in the survey of the Livermore area. Usually the soil consists of 2 or 3 feet of a brown, dark grayish brown or slightly reddish brown loam, sometimes carrying as much as 60 per cent of gravel. This coarse material consists chiefly of flattened or angular rock fragments. The interstitial material in this soil contains enough clay particles to make it sticky when wet.

The subsoil of the Yolo gravelly loams is variable and subject to abrupt changes within short distances. In places in the surface gravelly loam extends to 6 feet without marked change in any feature, except that below 2 or 3 feet the color is a little lighter or a redder or more yellowish brown than the surface. In other places the gravelly loam surface may be underlain by heavier textured subsoils of a pronounced yellowish brown color and in still others by gravelly beds. Strata of various textures may alternate in irregular

order from a few inches below the surface downward, and the substratum may consist of beds of either gravel or clay.

Some of the group is a gravelly sandy loam rather than a gravelly loam, and a small area is probably a gravelly clay loam in texture. The close association of this phase with stream channels or as the upper parts of alluvial fans where the streams enter upon the valley slopes, accounts for its rather coarse character and the great variation of the material forming it.

Location.—Some of the most important areas of the Yolo gravelly loams occur in the Santa Clara Valley, where the group most often occupies the upper portions of alluvial fans near the points where the streams emerge from the hills. Calaveras and San Felipe Valleys, which are minor inclosed valleys in the mountains east of the Santa Clara Valley, are largely covered by this phase. There are numerous areas in the Livermore region and others farther north near Concord, and a few small areas are scattered through the valleys north of San Francisco Bay. The Yolo loams group throughout the area, but particularly in the Santa Clara Valley, contains meandering gravelly streaks or patches of the gravelly loams. It is impossible to separate all these minor bodies and it would be difficult even in a detailed survey.

Topography and drainage.—The gravelly loams group has a typical alluvial-fan topography, except where it occurs on benches or more or less well defined terraces. It is usually sloping and is marked by winding depressions representing abandoned stream channels or the channels of modern streams. In areas on terraces in some instances there is a marked drop of several feet between terraces of different age. This condition of surface is found over much of the phase in the Livermore Valley. Where the hillward margin of some of the type is flanked by the Pleasanton series, the surface is sometimes rather uneven, marked by only partially reworked small knobs or slight ridges of the latter series, rendering the placing of boundary lines between the types rather arbitrary. Owing to the gravelly nature of the soil and to its usual position on elevated slopes the drainage is often excessive. In practically all cases irrigation is beneficial. No tendency to the accumulation of alkali is noted.

Origin.—The Yolo gravelly loams are alluvial in origin. The materials have been derived from a wide variety of rocks. The greater part of it has come from the rocks and soils of the Altamont and Mariposa series, with lesser amounts from the rocks and soils of the Pleasanton, Corning, and Diablo series. Some of the phase along the east side of Napa Valley is derived from the soils and rocks in which igneous material predominates. In this respect it does not conform to the typical Yolo series description and probably should be recognized as included material of a distinct series of soils. A

large part of the body lying east of Oakville is much like the Vina gravelly loams, shallow phase, as mapped in the reconnoissance survey of the Sacramento Valley area. It there has a coarse gravelly substratum with many large cobbles of almost wholly andesitic or basaltic character, and the soil often has a faint reddish brown cast. The same is true of some of the type lying several miles south and a little east of Santa Rosa.

Utilization and adaptation.—A great deal of the Yolo gravelly loams in the Santa Clara Valley is used for fruit growing, with and without irrigation. Prunes, apricots, peaches, cherries, walnuts, and almonds are the principal varieties grown here and the output is sufficient to rank this type as one of the intensively farmed soils of the area.

In the Livermore Valley much of it is dry farmed to grain and hay, but with a low average yield. It produces a large part of the wine grapes of that region, and while the yields of grapes are small, the quality of the wine produced is said to be excellent. Some attempt has been made there to grow tree fruits, but owing to the lack of an adequate water supply the attempt has been practically abandoned. Here as elsewhere the indications are that alfalfa, fruit, and general farm crops would do well under irrigation.

Some of the areas of more gravelly, coarser textured soils are much less valuable than the remainder of the type, and it will require heavy irrigation to make them productive.

YOLO CLAY LOAMS.

Description.—The Yolo clay loams group includes the clay loam and silty clay loam of the series, the silty clay loam probably being the more extensive.

The Yolo silty clay loam usually consists of a friable, silty clay loam of brown, light-brown or grayish-brown color. The surface of cultivated fields often appears grayish, but the brown color is accentuated upon wetting, and some areas may even appear slightly reddish brown. Gravel is seldom present in sufficient quantities to affect the character of the soil. There are local areas of relatively compact nature, but most of the type is easy to till. At a depth of 2 or 3 feet the surface soil is underlain quite uniformly by a lighter brown or yellowish-brown subsoil, of about the same texture as the soil, which extends to a depth of 6 feet or more. As in most recent-alluvial soils, the subsoil is not uniform, and may be either lighter or heavier than the surface over considerable area. Both soil and subsoil are rather absorptive and retentive of moisture, but conditions in this respect are less favorable in some areas in which a dense clay loam or clay is found in the subsoil. This type merges by slight transitions of texture and color into the associated soils, so that some boundaries as placed upon the soil map are rather arbitrary. There

are occasional variations which are a dark brownish gray or grayish brown, which could be grouped with the Dublin series.

The Yolo clay loam is closely associated with the silty clay loam member, and gradations from type to type within short distances are common. Its color range is the same as described above, and it is subject to the same variations in other respects. It is a friable clay loam, and aside from this feature of texture has no uniform feature separating it from the silty clay loam. The Livermore clay loam mapped in the earlier survey of the Livermore area, is included with this group. Some of it seems to have a color slightly darker than typical of the Yolo series, but the subsoils are similar. The Tassajero clay loam of the same areas was likewise combined with the Yolo clay loams. Though portions have a dark-brown or brownish-gray soil, in the main the soil is brown, with a lighter brown subsoil.

Location.—The Yolo clay loams group is one of the more extensive alluvial groups and forms a part of nearly every large alluvial fan or valley. It is predominantly developed in the Santa Clara Valley, where it is important by reason of both its extent and its agricultural value. It forms large areas on the slopes along the east side of San Francisco Bay, and occurs less extensively on the west side. A few small but important areas are found in the Livermore Valley. East and north of Oakland to Carquinez Strait and Suisun Bay there are many other lesser valleys and alluvial fans which contain soils of this group. Some of these areas south of Concord and between Walnut Creek and Danville contain Dublin soils. North of the bay the Yolo clay loams group is locally extensive and important. Much of Vaca Valley and its small tributary valleys and the general region lying northeast of Cordelia are occupied by rather continuous areas. In the floor of Napa Valley, for many miles northwest of Napa, areas of these soils, with numerous areas of associated soils, occur. The regions about Sonoma and Santa Rosa, together with minor valleys farther south, such as Novato Valley, Ross Valley, and numerous others of more or less importance, are mainly occupied by these soils.

Topography and drainage.—The Yolo clay loams group occupies sloping, gently undulating, or level areas forming alluvial fans, slight terraces or stream bottoms. There are usually few irregularities of surface to interfere with tillage. Some of the group forms low stream-built ridges, with the shallow remnants of the original channels still visible. Most of the group has been deposited by minor streams. The soils are well drained, but not so droughty in the dry season as many of the other soils. The water table is usually deep. Practically no damage is done by seepage or alkali.

Origin.—The origin of these soils, both as regards method of formation and source of material, is in the main typical of the series, i. e., alluvial largely derived from sedimentary rocks and their derivative

soils, but in certain places as mapped in this survey igneous rocks and soil material from such series as the Pleasanton, Antioch, and Tuscan have contributed to their formation.

Utilization and adaptation.—A part of the Yolo clay loams group is still devoted to such extensive crops as hay and grain, but it is more largely used both with and without irrigation, for the production of the more intensively cultivated crops. Many of the best orchards in the Santa Clara Valley, the Santa Rosa region, the Napa Valley, and of many other fruit centers are located upon these soils. This group is the largest producer of fruits in the area. Irrigation has been supplied in some places and is being extended. The fruits and other crops grown on the Yolo loams are also grown very extensively on the present group. Apples and pears seem to do better on the Yolo clay loams than on the Yolo loams.

Excepting the poorly drained areas and some other unfavorable areas, this is one of the best groups of soils for intensive agriculture in the area.

YOLO CLAYS.

Description.—The Yolo clays group includes types having clay textures, but without pronounced adobe structure. A clay, silty clay, and heavy clay would no doubt be mapped in a detail survey. Differences in drainage and alkali content cause a wide variation in the agricultural value of the included areas.

The Livermore clay, mapped in the earlier survey of the Livermore area, is included. That part lying in the Livermore Valley is a brown or dark grayish brown clay. Sometimes a thin covering of lighter textured material is found. The soil is compact and is inclined to crack upon drying. Local gravelly areas also occur. At depths of 30 to 40 inches the soil grades into a lighter colored and lighter textured subsoil, usually a grayish-brown or light-brown clay loam or silty clay. Many variations exist in both the soil and subsoil, the type ranging locally from a light clay loam to a very heavy clay. The soil is difficult to cultivate when either wet or dry.

Outside the Livermore Valley the group is represented by areas scattered from Newark southeastward to the southern edge of the survey. In the vicinity of Newark the poorly drained areas of this group occupy the lower slopes of alluvial fans where they gradually descend into the Tidal marsh. The soil, for the most part, is a slightly grayish brown or light-brown clay, and the subsoil a light-brown clay loam or silty clay loam. A great part of these areas has a hog-wallow surface, carries much alkali, and is of little agricultural value. Patches of dark-colored soils are scattered throughout this locality, some of which are distinctly Dublin soils, while others represent gradations in color between the Yolo and Dublin series.

The Yolo clays northwest and southeast of San Jose lie usually in the lowest parts of the alluvial fans or valley floor, in many places in slight basinlike areas between stream-built ridges. The soil is usually a dark grayish brown clay, but frequently contains considerable sand. The soils are here difficult to till and contain in places excessive quantities of alkali. The intensive agricultural development on some of the lighter textured Yolo soils has extended onto this group only here and there. The subsoil is lighter colored than the surface and sometimes a little more silty and permeable in the lower depths and occasionally presents a mottled appearance.

The small area mapped as the Yolo clay at Eldridge has a surface soil ranging from a silty clay loam to a silty clay, and is underlain at about 24 inches by a heavy clay subsoil. It is poorly drained during the rainy season. A long, narrow area is found just north of Benicia, and another southwest of Suisun. In each of these some Dublin soils are included.

Topography and drainage.—These soils occupy the flatter parts of alluvial fans and valley bottoms, and except in the case of the areas with a hog-wallow surface near Newark, they are comparatively smooth. The surface is usually rather flat. In some places it is marked by abandoned stream channels, which act as drainage ways during the rainy season. These drain the surface rather slowly. The dense structure of the soil and subsoil retards the downward movement of water, and in places the surface is covered with water for short periods.

Origin.—The Yolo clays are alluvial in origin, with some areas formed of material deposited under conditions of restricted drainage in basinlike areas.

Utilization and adaptation.—This group is practically treeless. In the Livermore Valley it is largely used in the production of hay and grain, of which good yields are obtained. The rainfall is hardly sufficient to insure success with other farm crops. Under irrigation much more could be accomplished. In the Santa Clara Valley there are a few orchards on these soils, but these are in most instances situated on areas having lighter textured and more permeable subsoil. A much larger area of the group could be used for intensive cultivation by careful methods, but the texture and drainage are unfavorable and the soils require much more effort to obtain good results than the lighter types of the series.

YOLO CLAY ADOBE.

Description.—The Yolo clay adobe consists of a light-brown, brown or dark grayish brown clay adobe 15 to 30 inches deep, resting on yellowish-brown or light-brown clayey material, in many places of lighter texture than the surface soil. While fairly compact,

the subsoil is not usually difficult to penetrate with the soil auger. The substratum usually continues as fine-textured material and both soil and subsoil are well adapted to store and retain moisture. Like most of the other soils of this series, it apparently contains moderate amounts of organic matter. Under proper moisture conditions the type is relatively friable, but when wet it is sticky and plastic. In places there is enough sand in the soil to give it the texture of a clay loam adobe.

Location.—The Yolo clay adobe is inextensive, being confined to the eastern margin of the survey. One of the larger areas lies north-east of the Livermore Valley, where this survey extends for a short distance over the marginal slopes of the San Joaquin Valley. Another area is found in Lone Tree Valley east of Mount Diablo, and some smaller areas lie farther south. All these lie in the drainage basin of the San Joaquin Valley. Another area occurs in the vicinity of Fairfield.

The Yolo clay loams contain some areas of the clay adobe and some of the browner soils included in the Dublin adobe soils resemble them.

Topography and drainage.—The type usually occupies nearly level alluvial fans or minor flat-bottomed valleys. It is usually fairly well drained, but where the fall is slight the drainage may be inadequate. Overflows of short duration affect parts of the areas along intermittent streams. The surface is traversed by the channels of small streams. In a few places the type occupies low terraces.

Origin.—Most of the Yolo clay adobe is derived from materials washed from the Altamont soils.

Utilization and adaptation.—Nearly all the type is dry-farmed to grain and grain hay, of which good yields are obtained. Very little attempt has been made to grow the more intensively cultivated crops, such as fruits and grapes. Irrigation, deep tillage, and the incorporation of organic matter will widen the crop range.

WILLOWS SERIES.

The soils of the Willows series range in color from a reddish brown to dark chocolate brown. The subsoils are light brown, reddish brown or brownish yellow, occasionally mottled with gray, may carry lime and gypsum, and are more compact and impervious than the subsoils of the Yolo series. The Willows soils are alluvial in origin and are derived mainly from materials washed from calcareous shales and sandstones. In places materials from unconsolidated old valley-filling deposits and from igneous rocks have also entered into their composition. In places the soils have been modified by deposits from the water of overflow basins. The series occurs along the stream courses and on the broad alluvial fans of minor intermittent foothill streams. The surface ranges from gently sloping

to flat, and the heavier members are often poorly drained, subject to overflow, and impregnated with alkali.

One group of this series, of small extent, is mapped in the present survey.

WILLOWS CLAY LOAMS.

Description.—The Willows clay loams group includes the loam, clay loam, and the silty clay loam of the series, the first named being very inextensive.

The Willows clay loam consists of a reddish-brown to chocolate-brown clay loam, 20 to 36 inches deep, grading into a yellowish-brown clay loam or clay. It is usually retentive of moisture when well tilled, though less so than the Yolo clay loams. It has a fairly friable structure, but compacts if carelessly handled.

The Willows silty clay loam differs from the clay loam in having a more silty texture, but is much like it in other features.

Location.—This group occurs in a few small areas. One area lies several miles northwest of Fairfield and another small one in Deer Valley east of Mount Diablo. The soils of the latter were mixed and not all typical of the Willows. Two other small bodies were mapped at Kenwood. Some of the redder soils mapped with the Yolo are recognized as probably belonging in the Willows series.

Topography and drainage.—The Willows clay loams group is usually well drained, free from alkali, and comparatively smooth, the surface having the characteristics of alluvial fan or stream bottom topography.

Origin.—The group is of mixed origin. All except that at Kenwood is derived as wash from soils derived from sedimentary rocks, usually of the Altamont series. In other areas the materials have come almost entirely from igneous rocks and represent the wash from the Aiken loam and clay loam and associated series. If of greater extent such soils would probably be recognized as a distinct series.

Utilization and adaptation.—Nearly all this group is used for grain production. The soils are productive and capable of much more intensive development were irrigation available.

TEHAMA SERIES.

The soils of the Tehama series are predominantly yellow. The subsoils are usually light brown or yellowish brown in color. Both soil and subsoil often appear light brown when wet. The types, though often compact and puddled, are typically free from hardpan or cemented layers. Quartz gravel is abundant in certain places, giving rise to gravelly soils. The surface is level, slightly uneven, or sloping. These soils are typically of alluvial-fan formation, but may include minor areas of flood-plain and alluvial-terrace material

along intermittent streams. Some of the bodies are now elevated somewhat above existing waterways. The parent material of the series is in places derived from erosion of old valley-filling material giving rise to the Corning and Redding series and from the massive beds of yellow silty material by which they are sometimes underlain. At other times they are derived from materials washed from a variety of rocks and soils.

TEHAMA LOAMS.

Description.—The Tehama loams group is composed mainly of the silt loam and loam of the series with smaller areas of the gravelly loam member. These soils are yellow and light brownish yellow in color and along the contact with the associated Yolo series become yellowish brown. Under moist field conditions the soils often have a light-brownish color closely resembling the lighter colored phases of the Yolo series, but typically they are predominantly yellow rather than brown. As indicated, the texture has a considerable range.

The Tehama silt loam consists of a smooth-textured silt loam, friable under proper moisture conditions, but somewhat compact when dry. In many places, at depths ranging from 12 to 30 inches, a heavier subsoil is found, similar in color to the surface soil, but more compact. In other places the surface material may extend to a depth of 6 feet with little change, or it may become lighter colored in the deeper subsoil.

The Tehama loam does not differ essentially from the Tehama silt loam except in texture.

The Tehama gravelly loam consists of a rather friable loam bearing considerable quantities of angular or subangular siliceous gravel. This type may be underlain by subsoils similar to the other types of the series or may have a gravelly subsoil similar to the surface.

Location.—The Tehama loams group is confined to several inextensive areas lying several miles southwest of San Jose along the southern margin and a small body in the extreme northeast part of the survey. Small bodies of this group occur in the Yolo soils, but they are not shown because of their small size. It is also possible that a part of the soils of the Isabel Valley in the region east of Mount Hamilton would be considered in a detailed area as belonging to the Tehama series.

Topography and drainage.—The surface of the Tehama loams is in the main typical of alluvial fans. Some of the areas southwest of San Jose, however, occupy areas slightly depressed below the general level of the region and in times of excessive rainfall are not so well drained as the surrounding fan soils. The group, as a whole, has good drainage.

Origin.—The Tehama loams are of alluvial origin and form small parts of extensive alluvial fans. They differ little in process of formation and source of material from the soils of the Yolo series.

Utilization and adaptation.—Soils of this group are generally farmed in conjunction with the Yolo gravelly loam and seem to have about the same crop adaptations and productiveness. Prunes are the principal crop, usually grown without irrigation, and since the areas are usually somewhat more elevated and drier than the moister lower levels of the valley the yields are considerably less. Irrigation of all the areas would greatly increase yields and widen the range of crops that could be grown profitably.

SOLANO SERIES.

The soils of the Solano series are prevailingly yellow, with some areas assuming a brownish or light-brown color when wet. The subsoils are yellow, usually compact, and of heavier texture than the surface, in places becoming more friable and of lighter texture below depths of 3 or 4 feet. The surface is sloping to flat, the latter topography often resulting in imperfect drainage. The series is alluvial in origin, the heavier members being deposited in areas of stagnated drainage, the materials being washed largely from the areas of Altamont soils.

SOLANO LOAM AND CLAY LOAM.

Description.—The Solano loam and clay loam group includes only the loam and clay loam of the series. The Solano loam is a rather sticky loam of silty character and compact structure, with a low organic-matter content. When dry the soil is grayish yellow or brownish yellow, and when wet somewhat browner—a light brown or grayish brown. Usually at a depth of 24 to 36 inches the soil is underlain by a yellowish clay loam or clay, locally very compact. The subsoil in many places becomes lighter with increase in depth, until a rather friable loam is reached at about 60 inches.

The Solano clay loam consists of 20 to 30 inches or more of a grayish-yellow or a brownish-yellow sticky clay loam of compact structure.

Soils of the group grade through slight transitions in color into the Yolo series which lies to the west. The lower parts of the group pass gradually into the darker colored, heavier textured, and flatter Tidal marsh on the south.

Location.—A single area of this soil group occurs in the present survey. It lies along the eastern margin of the area opposite Fairfield and Suisun. It is a westward extension of more important areas of the same group occurring in the Sacramento Valley area.

The soils form a part of the valley slope, and extend from the vicinity of the foothills almost to tide level.

Topography and drainage.—Drainage is better here than farther east and conditions differ little from those on the associated Yolo clay loams. The topography is also similar to that of the Yolo clay loams. In the southern part of the area injurious quantities of alkali are present and the surface is marked by hog wallows.

Origin.—The Solano loam and clay loam are alluvial soils deposited by intermittent streams. The materials forming the soils are largely derived from the soils of the Altamont series and the rocks giving rise to this series.

Utilization and adaptation.—Most of the area of these soils is devoted to the production of dry-farmed grain. The southern part is used for pasture. With irrigation much of the area would be capable of intensive farming.

LAGUNA SERIES.

The Laguna series includes types with gray, light-gray or brownish-gray soils, which may extend to 6 feet, with little or no change in color or texture, or may be underlain at 12 to 36 inches by grayish or occasionally brown subsoils. The subsoils are sometimes compact, but no hardpan is present. The drainage is usually good, though in places seepage and some alkali occur. The soils are usually low in organic matter, but are not very difficult to till. The series usually occupies gentle slopes and alluvial fans. A slight "hog-wallow" topography is developed in places. The series is derived from materials washed from many different kinds of rocks, sedimentaries being important.

One group, consisting mainly of two types of small extent, was recognized in this survey.

LAGUNA LOAMS AND CLAY LOAMS.

Description.—The Laguna loams and clay loams group comprises the loam, silt loam, clay loam, and silty clay loam, the loam and silty clay loam predominating.

The Laguna loam consists of a gray, light-gray or brownish-gray, rather friable loam, in places extending to 72 inches, with little change in color or texture, but occasionally underlain at depths between 12 and 36 inches by a gray clay loam and in other places by brown subsoils resembling those of the Dublin series. The soil is usually free from gravel.

The silt loam is inextensive and is similar to the loam, except in texture.

The Laguna silty clay loam consists of a gray or brownish-gray silty clay loam, usually underlain by a light-brown subsoil, or along

its contact with Tidal marsh by a dark-gray material similar to that forming the subsoil of the latter type.

The Laguna clay loam is in general characteristics similar to the Laguna silty clay loam, but contains somewhat less silt.

Much of the body in the Alvarado locality is rather compact, poorly drained, carries alkali, and merges in its lower portions with Tidal marsh.

These soils seem to be low in organic matter and in places are ir-retentive of moisture. The deeper substratum of the areas near Sonoma and several miles north of Napa may be compact or even semicemented.

Location.—These soils are of small extent, being practically confined to the areas near Alvarado, Sonoma, and Napa. Parts of the area of Yolo loams lying east of Alvarado have a grayish color, and include some soil better considered Laguna than Yolo material.

Topography and drainage.—The Laguna loams and clay loams group occupies sloping alluvial fans. The area near Alvarado occupies the lower margin of the Alameda Creek fan where it approaches Tidal marsh, and here the drainage is poor and the land subject to periodic overflow. North of Napa some of the soils have a slight hog-wallow topography. Here, as at Sonoma, the drainage is adequate.

Origin.—Most of the soils of the group are composed of material washed from the soil group recognized and mapped in this survey as Stony soils, undifferentiated, in which the minor streams depositing the material have their sources. That body along Alameda Creek, however, does not have an origin essentially different from the Yolo and Dublin series with which it is associated.

Utilization and adaptation.—Several vineyards of wine grapes are located on these soils and a few small orchards of various fruits, but the greater part of it is used for grain and grain-hay production. The poorly drained alkali areas are used as pasturage.

DUBLIN SERIES.

The soils of the Dublin series are dark gray to black. The subsoils are grayish brown or brown in the better drained areas and gray or brownish gray where drainage is poor. The series is alluvial in origin and typically occupies alluvial fans with some small areas in stream bottoms or on terraces. The drainage is good over most of the lighter textured types, but the heavy members often occupy flats or depressed areas with stagnated surface drainage during the rainy season. These soils are derived typically from sedimentary rocks, but in this survey it is mixed with material from igneous rocks, with some areas derived entirely from the latter. These bodies would in

a more detailed survey probably be recognized as a distinct series. A rather high organic and lime content characterizes the series.

The series is extensive in this area and is mapped in three groups.

The lower, flatter areas bordering bodies of Tidal marsh may include some undifferentiated marine sediments not properly classed as Dublin material.

DUBLIN SANDY LOAMS.

The Dublin sandy loams group consists mainly of the Dublin sandy loam and Dublin fine sandy loam, with a smaller area of Dublin gravelly sandy loam and Dublin loamy sand.

The Dublin sandy loam consists of a friable, dark-gray or drab sandy loam, from 20 to 36 inches deep, underlain by light-brown or grayish-brown material usually of heavier texture. Gravelly layers are sometimes encountered in the subsoil, but these are of irregular occurrence. The type as a whole readily absorbs the rainfall and, except in the areas underlain by coarse subsoils, is fairly retentive of moisture. It is not usually as dark colored as the heavier members of the series, having when dry a brownish cast in places, approaching in this respect the darker areas of the Yolo soils.

The Dublin fine sandy loam does not differ consistently from the sandy loam in any feature except in texture. It consists of a friable fine sandy loam, underlain by subsoils having the same variations found in the subsoil of the sandy loam.

Dublin gravelly sandy loam is the counterpart of the sandy loam, but with the addition of enough gravel to make a gravelly type.

The Dublin loamy sand consists of a medium-textured sand, bearing appreciable quantities of finer material, but not in sufficient quantity to form a sandy loam. This texture makes the soil more retentive of moisture than an ordinary sand. A part of the small area of the group lying a few miles north of Santa Cruz consists of this loamy sand soil.

The Dublin sandy loams group is distinguished from the similarly textured soils of the Yolo series on a basis of color, the latter series comprising soils of various shades of brown and the Dublin soils being in general dark gray. The color distinctions are sometimes indefinite where the series grade into each other and sharp boundaries do not exist.

Location.—The group is practically confined to two small bodies, one north of Santa Cruz and another 2 miles north of Milpitas, though it is recognized that the Dublin loams and clay loams group include small areas of these lighter textured soils.

Topography and drainage.—The area north of Santa Cruz occupies the bottoms of small streams and the adjacent foot slopes. It is surrounded by the more elevated soils of the Altamont series. The area north of Milpitas occurs as the upper part of an alluvial fan in asso-

ciation with the other groups of the same series and of the Yolo soils. It has a typical alluvial-fan topography, is well drained, free from alkali, and without marked surface inequalities. It is traversed by the channel of the stream which is responsible for its deposition.

The group is alluvial in origin, the areas of higher lying Altamont soils being the principal source of material. The prevailing light texture of the body near Santa Cruz is due to its close association with an area of Altamont sands and sandy loams.

Much of the area of this group is used for the production of fruits and vegetables, for which it seems eminently fitted, though the yields could be materially increased with irrigation.

DUBLIN LOAMS AND CLAY LOAMS.

Description.—The Dublin loams and clay loams group includes the loam, silt loam, silty clay loam, and clay loam of the series, with small gravel to form the gravelly loam type.

The Dublin loam consists of a dark-gray to black friable loam usually underlain at 12 to 30 inches by lighter colored subsoils of variable texture, but consisting over much of the type of a grayish-brown or brown loam or clay loam. In a few cases the surface soil extends to a depth of 6 feet without significant change. Pockets and thin strata of sandy material are frequently encountered in the subsoil, but rarely of sufficient coarseness and thickness to make it leachy. Areas of brownish soil are common along the contact with the Yolo series and spots of similar color within the main areas. The Dublin loam of the Livermore area is included very much as it was mapped in the earlier survey. The Santa Rita loam of the same area, possessing about the same color and textural characteristics as the Dublin, is likewise included. The loam is easily tilled and is retentive of moisture.

The Dublin silt loam is not very extensive, but some areas of dark-gray or black, friable silt loam occur, which are rather typical of the series. It has about the same variations in color and subsoil as the loam. Like the loam, it is easily tilled and is retentive of moisture.

The Dublin silty clay loam is probably the most extensive soil of the group. Typically it consists of a dark-gray to black friable silty clay loam which grades at 12 to 30 inches into grayish-brown, gray or light-brown subsoil of the same or slightly different texture, extending to a depth of 6 feet. Aside from local puddled areas occasioned by stagnated drainage, the soil is easy to till and capable of holding a large store of moisture. Like the other soils of the series, it appears to have a high organic-matter content and to be calcareous, especially in the subsoil. Gravel or coarse layers are rarely found at any point in the soil column, but small strata hav-

ing little influence are locally developed. Both soil and subsoil are in places somewhat heavier in the lower or flatter spots, or where the type borders the group of Dublin adobe soils. This type and the other soils of the group occur in association with the Yolo soils, and transitions in color or even small areas of the latter series are included within the group under discussion. The Santa Rita silty clay loam of the Livermore area is also included.

The Dublin clay loam, an important member of the group, is typically a dark-gray or black clay loam, closely resembling the silty clay loam type, except in texture. The areas mapped in the Livermore area are included. These contain more or less gravelly soil, some of which is a true gravelly clay loam. This is true of other areas of the type, and the separation would be feasible in a detailed survey.

Location.—The Dublin loams and clay loams group is widely distributed, usually in areas of less than a square mile extent. In several localities, as around San Leandro and south of Haywards, it is the principal group, occurring in irregular areas, in all covering several square miles. The main floor of the Santa Clara Valley and the prominent alluvial fans along the bordering mountains contain many areas of the group. North of Halfmoon Bay and southward along the coast toward Santa Cruz the alluvial bottoms and associated foot slopes along several small streams are occupied by these soils. The group also occurs rather extensively north of Walnut Creek. The area shown there includes some soils of the Montezuma and Yolo series. Between Oakland and Walnut Creek and northward to Carquinez Strait some rather typical areas occur. As previously mentioned, numerous areas of these soils are found in the Livermore Valley and associated minor valleys. Besides the occurrences mentioned many other small areas of the group are encountered in various parts of the survey.

Topography and drainage.—The general surface features and drainage conditions of the Dublin loams and clay loams are similar to those of the Yolo clay loams. The group occupies alluvial fans or stream bottoms, usually with sufficient slope to give good surface drainage, although where it grades into the Dublin adobe soils or along swales drainage may be sluggish during the rainy season. The latter condition exists in the Santa Rita silty clay loam of the Livermore area. Alluvial-fan areas are usually traversed by slight ridges or shallow abandoned stream ways and by one or more active channels which now convey surplus waters through the body of the group. Some areas lying along stream ways flanked by hills occur as flat alluvial deposits, with occasional small alluvial fans superimposed upon the hill margin by tributary streams. These soils are seldom droughty, even where their surface is most sloping. Only small

parts of the group are subject to overflows and ordinarily these are neither serious nor prolonged.

Origin.—The soils are alluvial throughout. The materials forming the soils are usually derived from sedimentary rocks, but in some places in this survey a mixture of materials from sedimentary and igneous rocks or from igneous rocks solely have given rise to these soils.

Utilization and adaptation.—This group includes some of the most intensively farmed soils of the area. In the Santa Clara Valley it is important in the production of a variety of fruits, truck crops, seeds, and other crops. In the highly developed fruit sections around San Leandro and Haywards the soils of this group are among the important types. A wide range of fruit and truck crops is grown here.

A great many of the minor valleys occupied by these soils have some fine orchards and afford good opportunities for the extension of the fruit industry. Many of the small areas along the coast between Santa Cruz and San Francisco are used for growing truck crops, among them artichokes, beans, peas, and cabbage.

In the Livermore Valley the greater part of the group is under cultivation, with grain hay and grain the principal crops. Hops, sugar beets, and alfalfa have also been grown successfully where moisture conditions were most favorable. Peaches and other fruits are also produced in a small way.

Although the fruit and other intensive industries are very important on these soils, their original use for hay and grain still continues over important areas.

DUBLIN ADOBE SOILS.

Description.—The Dublin adobe soils group includes the Dublin clay adobe and Dublin clay loam adobe, of which the former is the more extensive.

The clay adobe consists of a dark-gray or black clay, exceedingly sticky when wet and very compact and hard when dry. It has the typical adobe structure, cracking and checking into large blocks, which, in turn, further subdivide into small pellets and irregular granules. The principal cracks sometimes extend to a depth of 2 or 3 feet, but the development of the finer fragments is usually confined to the surface few inches. The cultivation of this type is easier than would be inferred from its texture, owing to this peculiar manner of disintegration. The organic-matter content seems to be high, which no doubt tends to make the heavy clay soils more friable.

At depths ranging from 10 to 36 inches or more the soil grades into a lighter colored subsoil, which shows some variation. Where the type occurs on alluvial fans or slightly sloping surfaces, the sub-

soil usually consists of a light-brown, light grayish brown or yellowish-brown compact clay loam, silty clay or clay, extending to depths greater than 72 inches. In low-lying flat area, such as many of the areas which are but slightly elevated above the Tidal marsh, the subsoil is nearly everywhere a light-gray or light grayish brown clay loam or calcareous clay. Here the type approaches the Stockton adobe soils of the Sacramento Valley area, but it does not have the semicemented or calcareous subsoil or hardpan typically found in the latter series. Small parts of the Dublin clay adobe in this area, which upon detailed inspection are found to possess hardpan should be considered as belonging to the Stockton.

The Dublin clay adobe and the Santa Rita clay adobe of the Livermore area survey are included in this group in the present survey. The subsoil of the Santa Rita is often mottled in color, but its dark-colored surface soil is usually underlain by a rather compact layer of slate-colored or black heavy clay, which continues to a great depth. Some of it may be a clay underlain by alternating layers of silty or sandy material and clay. Portions of the type previously mapped as San Joaquin black adobe in the San Jose area are also included.

The Dublin clay loam adobe is similar to the clay adobe in practically all features, except texture. It is more friable and is more easily tilled than the clay adobe. The soil in areas previously recognized in the Livermore area usually contains small amounts of shale or angular rock fragments and has a less pronounced adobe structure than the clay adobe. Certain bodies are included, which are brown in color and represent soils of the Yolo series.

Location.—The Dublin adobe soils are widely distributed in the present survey. One important development extends irregularly northwestward from San Jose to the Tidal marsh bordering the southern extension of San Francisco Bay, and from this point to the westward in broken areas to San Mateo. It occurs in many small areas elsewhere in the Santa Clara Valley. Areas also are found along the eastern shore of the bay from near Milpitas to the city of Oakland. The group occurs in all parts of the Livermore Valley, but chiefly in its northern half, where it extends as a rather uniform, unbroken body from north of Livermore westward and up the San Ramon Valley to Danville. There are some areas near Concord and other important but irregular areas occupying the flatter, lower portions along the bay shore from Berkeley to Richmond. North of the bay there is a large, rather continuous development of these adobe soils extending from southeast of Petaluma northward almost to Santa Rosa. Napa and Sonoma Valleys also contain them, and a large body extends from Vallejo and north of Napa Junction. Besides these more important areas there are numerous other areas scattered throughout the survey, either in asso-

ciation with other types of the series or as low, poorly drained areas often almost entirely surrounded by the soils of the Yolo series.

Topography and drainage.—These soils have a gently sloping, level or flat surface and are more or less closely associated with sluggish drainage conditions. In places the slope is sufficient to carry off the surplus surface water, but in others it is so flat that water stands over large areas for days during the rainy season. With the exception of a few alluvial fans of considerable slope, the group occupies nearly level positions, as east and north of Petaluma and from Santa Clara to Agnew and west of the latter place. In the latter case the soils merge with decreasing slopes into Tidal marsh, and the general gradient is so slight that artificial drainage will no doubt be necessary to fit them for growing a variety of crops. Injurious quantities of alkali have accumulated in some small areas, its presence being indicated by a lighter color in the surface soil, a growth of salt grass, and the presence of bare spots. A part of the group several miles east of San Jose occupies a swampy basin and it is recognized that the soil here is not typical.

Origin.—The Dublin adobe soils are derived from recent-alluvial material laid down on gently sloping alluvial fans and their flat outer extensions and in flat semibasin depressions, in which the run-off of higher lying areas collects. In places a close association between the residual soils of the Diablo series and the Dublin soils exists, the latter being alluvial products derived from them. In such cases the Dublin adobe soils may occupy rather decided fans or foot slopes. The alluvial soils formed from materials washed from soils less calcareous than the Diablo series, are usually brown in all the better drained situations, with the Dublin series developed only where drainage is more or less imperfect.

Utilization and adaptation.—These soils were almost entirely barren of native tree or shrub growth, except in the better drained parts largely occupied by the clay loam adobe member. At present nearly all these soils are under cultivation, grain and hay being by far their principal utilization. A few orchards are located upon them, but poor results are the rule, except where drainage is better than the average and the subsoil is more friable and permeable than is usually the case. Some trucking is done with fair results, and it could probably be extended, although these soils are difficult to handle. Vegetable and flower seeds, including onions, lettuce, and sweet peas, are produced in the Santa Clara Valley, but the total acreage devoted to this industry is small.

Rice could possibly be grown successfully on the flatter bodies, as the closely related Stockton clay adobe of the Sacramento Valley is now being used for the production of this crop. While the range of crops on this soil will always be somewhat restricted on account

of its coldness and heavy character, improved drainage and deeper tillage will considerably increase the number of crops that may be grown.

WIND-LAID MATERIAL.

OAKLEY SERIES.

The soils of the Oakley series are brown in color, and rest upon subsoil not essentially different in color or texture. The series is derived from wind-laid material consisting largely of river sand. The topography is quite uniformly undulating and some distinct dunes are found.

OAKLEY SANDS.

Description.—The Oakley sands group prevailingly consists of brown, medium-textured sand or loamy sand usually 6 feet or more in depth. It is nonmicaceous, low in organic matter, and of rather loose structure. Where less than 6 feet deep the soil rests upon loamy sand of better water-holding capacity. This condition occurs where the type grades into adjoining soils or where it is spread as a rather thin veneer over the surface. Considerable fine material gives the sand a loamy consistency also in the smoother areas, and over some parts of the type the texture may closely approach light sandy loam. The soil is friable, rather retentive of moisture, and responds readily to applications of organic matter. The deeper underlying material is usually similar to that of the Antioch series.

Location.—The group is confined to one small body in the northeast corner of the survey, where it represents an extension of a more important area lying in the Sacramento Valley area. Some parts of the area mapped as Dunesand, where the topography is rather smooth and the material of sufficient stability to permit cultivation, could have been mapped as Oakley sands in more detailed work. Likewise, some of the group of the Antioch sands and sandy loams, where sufficiently modified by wind action, could be considered as Oakley sands.

Topography and drainage.—The surface of the group is smooth, slightly uneven, and gently rolling, with a few sandy hills. Modification due to drifting is apparent in nearly all places, and some drifting is now taking place, though this usually is not serious. Drainage is good to excessive and is mainly subsurface, as there is rarely any run-off.

Origin.—The group is derived from wind-laid material, which is derived largely from exposed sandy bars or benches in the river-delta region lying a short distance north of the limits of this area.

Utilization and adaptation.—Under natural conditions the type supports a scant vegetation. Most of the group is now used in the production of grain, almonds, grapes, and peaches. With irrigation

even the areas of more porous soil can be successfully developed in the production of these crops and early-maturing truck crops.

MISCELLANEOUS MATERIAL.

DUNESAND.

Description.—Dunesand consists of wind-blown brown or light-brown, medium-textured, incoherent sand, generally unstable and subject to further surface modification. It is many feet in depth and without consistent variation from soil to subsoil. Many of the dunes are barren of vegetation, and the material is here subject to movement by winds at the present time. Others are covered with a scrubby growth of native vegetation which prevents drifting. The type in its natural uneven condition is usually considered nonagricultural. Even if level, both irrigation and protection from the winds would be necessary to make its use practicable. Locally there are areas, however, which are now being tilled. In these the surface is rather more uniform than the average and a little more loamy than usual, or irrigation is practicable. Such areas should probably be considered as belonging to the Oakley series.

The group in this area contains a considerable extent of so-called "Madeland," which, for the most part, consists of originally depressed or submerged areas, filled by artificial means, with transported dunesand or with sandy material dredged from San Francisco Bay. Several sandy bars and beaches are included with the group.

Location.—By far the most important body of the group is that occupying several square miles in the northern part of the San Francisco Peninsula. The city itself is largely built on this material, but leveling and filling have obliterated much of the original topography. In addition to the narrow beaches already mentioned, there are also several clusters of dunes included in areas of the Montezuma loams and clay loams bordering the coast north of Santa Cruz.

Drainage.—Dunesand is excessively drained, except where its surface is low lying and near water level. Lagoons and marshes have been inclosed in some places by the encroachment of dunes.

Origin.—Dunesand has originated through the accumulation of sands blown from the beaches south of the Golden Gate. The material is of recent formation and is being added to at the present time.

TIDAL MARSH.

Description.—Tidal marsh consists of a few inches of gray or brownish-gray clay, silty clay or lighter textured material, underlain to a depth of many feet by bluish, dark-gray or black clay of sticky, plastic character. The lighter colored surface material may extend to a depth of several feet or may be entirely wanting, and the

entire soil column consist of the darker colored clay before mentioned. Content of organic matter is usually high and the type grades in places into Muck and Peat. Owing to water-logged conditions and lack of aeration it is usually in poor physical condition.

Location.—The most extensive development of Tidal marsh is along the southern extension of San Francisco Bay and the northern side of San Pablo Bay. Besides this there are many detached areas along San Francisco Bay and its various estuaries.

Topography and drainage.—Tidal marsh in its general surface and drainage features is remarkably uniform. It is flat and depressed, being, with the exception of Muck and Peat, the lowest lying soil material in the area. Its general level is but a few inches above the water and its surface is marked by many winding tidal sloughs. At ordinary tides these slough ways are filled with water and the slightly more depressed parts of the marsh are submerged and at times of high tide there is very little of the type that is not flooded, and the soil is water-logged almost to the surface at all times.

Origin.—Tidal marsh has been built up of clayey sediments deposited by the waters of streams and tidal sloughs. The material is now in process of deposition about the mouths of all the principal streams entering the bays, and in most instances the stream channels traverse several miles of Tidal marsh before they reach the open water. The formation of Tidal marsh is succeeded by the encroachment of low flat alluvial-fan deposits superimposed upon its surface, and for this reason it is occasionally difficult to determine the exact boundary between Tidal marsh and the heavier, darker colored types of the various alluvial soils. Notable extensions of the Tidal marsh are being built by the Sacramento River in Suisun Bay.

Utilization and adaptation.—By far the greater part of the Tidal marsh is unreclaimed and of no present agricultural value. It supports a fairly heavy growth of pickleweed, salt grass, and kindred vegetation, which yield some pasturage in those parts sufficiently stable to support cattle. Some other extensive areas have been reclaimed, notably on the north side of Suisun Bay and San Pablo Bay, southwest of Warm Springs adjacent to San Francisco Bay, and in other scattered areas. A large tract is occupied by salt works around the southern part of San Francisco Bay, notably in the region west of Alvarado. Salt pans, ranging in size up to a few acres, have been constructed and their total area amounts to many thousand acres. Most of the reclaimed Tidal marsh has been diked and is devoted to the production of grain hay. Wherever possible use has been made of fresh flood waters from year to year for flooding the surface to aid in leaching out the included salts and reclaiming the land. Reference to the reclamation and crop possibilities of this type is made in the discussion of alkali.

RIVERWASH.

Description.—Riverwash typically consists largely of waterworn gravel, cobblestones, and coarse sand, with small quantities of finer sediments. Its prevailing coarse character, low water-holding capacity, and low-lying position for the most part make it nonagricultural. The deposits usually extend with more or less uniformity to a depth of 6 feet, but irregular stratification may exist and thin layers of heavier textured material are found. The surface may be covered with thin layers of fine sandy or silty deposits.

Location.—One body of Riverwash was mapped in this area. It occurs in the region east of the Livermore Valley, extending for several miles along Corral Hollow. Smaller bodies occur along the streams traversing the Livermore Valley and some of the other larger streams of the area, but these are not shown upon the map, owing to their small size.

Topography and drainage.—Riverwash occurs as an elongated area bordering the intermittent wash mentioned. It lies from a few inches to 2 or 3 feet above the gravelly bed of this wash. Much of it is subject to reworking or destructive erosion at times of high water, but during the dry season it is excessively drained and incapable of crop production without irrigation.

Origin.—Riverwash is the coarse-textured debris resulting from the rather rapid erosion of the rolling region bordering the parent stream. The gravel material is not so well rounded in this area as along larger streams in some other parts of the State, nor does it have a permanent water table near enough the surface to support the vegetation as it often does along the Sacramento and San Joaquin Rivers and other important streams of the State.

Utilization and adaptation.—Riverwash under the present conditions is nonagricultural and will probably remain so.

MUCK AND PEAT.

Description.—The areas mapped as Muck and Peat consist of 6 feet or more of more or less decayed vegetable matter intimately mixed with small proportions of alluvial silts or other fine sediments. The surface few inches in most areas consists of a black muck of pasty consistency when wet, and of great water-holding capacity. Below this at shallow depths is a brown, more fibrous peaty material which extends to a depth of several feet. In areas containing relatively large proportions of mineral materials the surface soil when dry is gray. Where the soils adjoin other types they may be underlain at less than 6 feet by alluvial sediments. Small areas of Tidal marsh, especially where Muck and Peat areas are traversed by streams carrying heavy loads of silty material, are included. Great variations in total depth of the material of this group are found, and while much

of it contains clayey or silty layers or is underlain at 10 feet or less by similar or sandy material, other wide areas occur in which the organic deposits extend to great depths. Even where reclaimed the water table usually lies near the surface and the underlying fibrous material is often an unstable, spongy, semifluid mass. Although quite sticky when wet, there is little or no likelihood of puddling, and the surface is friable and is easily cultivated after the first plowing. Some of the Muck and Peat supports a brackish or salt-water vegetation quite similar to that of Tidal marsh, but the typical vegetation is tule.

Location.—The Muck and Peat group is practically confined to the region above Carquinez Strait. Grizzly, Joice, Ryer, and Roe Islands and much of the other low-lying material north and south of Suisun Bay were included in the area covered by this group.

Topography and drainage.—The Muck and Peat areas are flat and slightly above or below mean tide level. Nearly all of them are traversed by the winding sloughs and are tidal estuaries. In the work of reclamation levees are usually placed along the banks of the sloughs and the surface is converted into a system of islands. Those bodies lying below the water level must be drained by pumping the water over the levees, and this entails the maintenance of permanent ditches and pumping plants. A part of the Muck and Peat area is not yet reclaimed, but much progress has been made and eventually the greater part of it will probably produce crops. The cost of reclamation varies considerably, but is ordinarily not out of proportion to profits derived.

Origin.—The soil has originated through the accumulation of the remains of aquatic plants, important among which is the round tule.

The ignition of these soils often proves troublesome. Burning greatly reduces their value, the surface residue being a bed of ash which favors capillary movement of moisture from below, with increased accumulations of alkali salts. Under continued cultivation the material of the Muck and Peat deposit settles and shrinks.

Utilization and adaptation.—When reclaimed, Muck and Peat are poorly adapted to the growing of alfalfa or other deep-rooted crops on account of the shallow water table. They are, however, especially adapted to certain crops, such as asparagus, potatoes, onions, beans, celery, and many other vegetables. Some of the grasses, such as timothy, redtop, and rye grass, do very well. When reclaimed the soil is very productive of many specialized crops, if the alkali content is not too high.

IRRIGATION.

Irrigation in this area is of comparatively recent development. The source of water is confined mainly to underground supplies,

which are tapped by wells bored or sunk either by individual or by several cooperating owners.

Practically none of the streams of the area are perennial and thus can not be relied upon as a constant source of water. Some of them have small flows in their upper courses which continue throughout summer, and in some places this is either diverted to small holdings along the stream or is piped to the lower foothill sections, where it is used to supply the household, or to irrigate gardens or orchards. In years of abundant rainfall the water supply from springs and underground sources is much more plentiful, but in years of scant precipitation many springs dry up and streams disappear which otherwise would supply water through the entire summer.

A great deal of the drainage and water supply of the region south and east of San Francisco Bay, excepting the Santa Clara Valley, is controlled by corporations supplying water for bay cities. This company has constructed many reservoirs in the smaller valleys which receive the drainage from the surrounding region. It also controls much of the underground water supply in certain places, which is pumped into the system. Most of the other cities and towns of the area obtain their city supplies from similar sources in the area, and this greatly lessens the water available for irrigation.

There is also a large amount of water lost during the rainy season as run-off, much of which could be stored and used for irrigation.

Irrigation is most extensive in the Santa Clara, Vaca, and Ignacio Valleys and along the coast from Santa Cruz to near San Francisco. Most of the water used is supplied by pumping.

The northern part of the area receives more rainfall than the southern part and requires less irrigation to mature crops. Provision for the use of water on shallow soils and during dry years, however, has proved very profitable. Irrigation by pumping and the use of small storage reservoirs is increasing in many of the valleys with very satisfactory results. Electricity and gasoline provide the motive power, the former being the more popular.

Alfalfa, fruits, and certain truck crops are the leading irrigated crops. Where soils are deep and retentive of moisture one irrigation is sufficient for the fruits. The first crop of alfalfa matures without water, but one application for each succeeding crop is considered necessary.

The check method is most generally used in the irrigation of fruit, but furrow irrigation is gaining in favor. Long-continued flooding has in many places so affected granulation that the soils behave under field conditions like soils of heavier texture. In places where the surface is irregular movable pipe lines are used to carry the water from one elevation to another. The open ditch is used very little, and most of the water is distributed by pipes laid underground.

The soil is cultivated as soon as possible after each irrigation to conserve moisture and prevent the ground from baking.

No careful tests have been made in the area showing the requirements of various crops for water. The permeability of the different types of soils and subsoils, their lime and organic content, their wide range in topography, and the diversity of crops grown, each with its special demands for water, will need study before information regarding the duty of water is known.

Although much is accomplished in the production of crops without irrigation, there are but few soils in the area which would not yield greater returns if irrigated. The general tendency is to increase the irrigated area, even though the expense incident to the development of water supplies is great.

DRAINAGE AND ALKALI.

In general drainage is not a serious problem in the area covered by this survey. Areas needing drainage comprise the extensive tracts of Tidal marsh, the less extensive developments of Muck and Peat, and local bodies of soils, mainly of the Yolo and Dublin series.

Of the last class examples occur in the Livermore Valley, east of San Jose, in various localities along the Tidal marsh, and in the valley floor south of Santa Rosa. During periods of heavy rainfall these areas are sometimes seriously affected for one or more months by overflow from near-by intermittent streams or by water collecting in depressions. Overflows also cover some areas lying along Walnut Creek in Ignacio Valley and along Napa River in Napa Valley.

The poor drainage of these areas largely prevents the growing of intensive crops. Until protection is afforded by levees or drainage is improved by ditches or tiles they will continue to be of low value, except in the production of general farm crops. Fruit culture has been attempted in a number of places where the soils are waterlogged for several months during the winter, but with little success.

In the case of the Tidal marsh, all of which in its present condition needs drainage, large areas have been reclaimed simply by leveeing to keep out the tide and by exposing the soil to the leaching effects of fresh flood waters. By these means the salts which occur in this material are slowly removed. Good crops of grain hay are often produced, even with moderate to large quantities of alkali in the subsoil. Pumps are sometimes used to lift the surplus drainage water over the levees. Reclamation of these lands is not expensive in most places, and where water is available for flushing the surface moderate to good crops of grain hay are possible the second or third year. After reclamation, thorough tillage, and aeration these lands produce good truck crops and bush and vine fruits, but at present appear to be unsuited to tree fruits, on account of the coldness of the soil, unfavorable subsoil, poor underdrainage, heavy texture of the

soil, and danger of damage from late spring freezes. Alfalfa is grown in a small way, but is short lived. Grain hay yields heavily, 2 or 3 tons per acre per year being common.

Small areas of Muck and Peat occur in the Tidal marsh lands, increasing in extent in the Suisun Bay region. These areas are generally associated with fresh water and support moderate to heavy growths of tule. Where tules occur the soil is nearly free from alkali, but where salt grass and other alkali-resistant plants are present reclamation entails both drainage and the removal of alkali.

The most effective means of reclaiming such lands, where sufficient fall can be obtained, consists in laying tile drains and flooding the surface. In some places open ditches and flooding are used, and elsewhere heavy flooding alone. No definite system can be recommended which will fit all conditions. Each problem will need careful study and fitting of the method to the particular conditions.

Most of the alkali of the area is confined to Tidal marsh, which occupies extensive areas. These clayey flats are naturally highly charged with sodium chloride and other marine salts. An area of about 50 square miles, or 25 per cent of the area of the type, has been reclaimed. Most of this land is in contact with salty or brackish water at each high tide, and is in a perpetually water-logged condition, with the permanent water table at or near the surface.

Besides the Tidal marsh, local poorly drained depressed areas scattered over the survey and usually associated with the heavy members of the Yolo series contain alkali.

Sodium chloride and sodium sulphate are the forms of alkali found in the soils of this area, the former prevailing in the Tidal marsh lands. Affected areas usually carry so much alkali that it is necessary to reclaim them before they can be farmed profitably. At present the alkali areas are used mainly for pasture and the production of hay. Parts of the affected area carrying moderate accumulations are used for the production of grain.

SUMMARY.

The area covered by this survey is 3,933 square miles, or 2,517,120 acres. It includes the Livermore, Sonoma, Vaca, Ignacio, and San Ramon Valleys; parts of the Santa Clara, Napa, and Santa Rosa Valleys; some smaller valleys; and the mountains and hills separating and surrounding them. The area is one of the foremost in the State in agricultural importance, and has a population of nearly 1,000,000.

San Francisco and Oakland are the largest cities and are important shipping points.

The greater part of the area is hilly or mountainous and is not thickly settled or intensely developed, though many of the included valleys have a highly specialized agriculture.

The climate is varied. Near the ocean and the bays the summers are cool, more or less foggy, and nearly rainless. Further east toward the interior the summers are warmer, approaching those of the Great Interior Valley. Winter is mild, and most of the rainfall, which varies from 15 to 30 inches, occurs from November to May, inclusive. Practically no snow falls in any of the valleys, and the growing season is long. Killing frosts occur only in the winter months and ice is rare. Hardy vegetables thrive throughout the winter.

Cattle raising and general farming prevailed during the earlier periods of development, but later many intensively cultivated crops became important. Among these are grapes, prunes, peaches, apricots, cherries, small fruits, and truck crops. Dairying and poultry raising are also important industries.

Irrigation has received little attention in the past, but is being extended. Nearly all the streams cease flowing during the summer, and water for irrigation is mainly obtained by pumping from bored wells.

The soils of the valleys are principally recent-alluvial soils and in most instances are deep and fertile. Those of the hills and mountains are mainly residual, and vary with the character of the underlying rocks. Much of the high mountainous area is too rough and broken for agriculture and is valued mainly for grazing and for its resources. Wherever small tillable areas occur in the mountains successful crops are grown without irrigation.

Remnants of old water-laid deposits occur along the margin of many of the valleys. These occupy a position intermediate between the residual and recent-alluvial soils. The soils are rolling and sometimes have hardpan.

Areas of soils derived from wind-laid material, including bodies of Dunesand, occur inextensively.

More than 200 square miles of Tidal marsh land occurs around the margin of San Francisco, San Pablo, and Suisun Bays. A considerable part of this has been profitably reclaimed. Less extensive areas of soils derived largely from accumulations of decaying vegetable matter are mapped as Muck and Peat. These occupy a position similar to Tidal marsh.

Flood control is a local problem, and valuable land in places awaits the building of levees and drainage to fit it for intensively cultivated crops.

Except in Tidal marsh areas, little alkali land exists. This is confined to small bodies of heavy-textured, poorly drained soils.

[PUBLIC RESOLUTION—No. 9.]

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

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

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

Approved, March 14, 1904.

[On July 1, 1901, the Division of Soils was reorganized as the Bureau of Soils.]

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