Series 1938, No. 5 Issued December, 1943

Soil Survey

The Tracy Area California

By

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and
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United States Department of Agriculture

UNITED STATES DEPARTMENT OF AGRICULTURE
Bureau of Plant Industry, Soils, and
Agricultural Engineering
and
Soil Conservation Service
In cooperation with the
University of California Agricultural Experiment Station

For sale by the SUPERINTENDENT OF DOCUMENTS, WASHINGTON, D. C. Price 60 cents

This publication is a contribution from

BUREAU OF PLANT INDUSTRY, SOILS, AND AGRICULTURAL ENGINEERING

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SOIL SURVEY OF THE TRACY AREA, CALIFORNIA

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United States Department of Agriculture in cooperation with the University of California Agricultural Experiment Station

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[1] The field work for this survey was done while the Division of Soil Survey was a part of the Bureau of Chemistry and Soils.

THE REPORT AND HOW TO USE IT

The soil survey map and report of the Tracy area, California, contain information—both general and specific—about the soils, crops, and agriculture of the area. They are prepared for the general public and are designed to meet the needs of numerous readers having varied interests. The individual reader may be interested in some particular part of the report or in all of it. Ordinarily he will not have to read the whole report to gain the information he needs.

Readers of soil survey reports may be considered as belonging to three general groups: (1) Those interested in limited areas, such as communities, farms, and fields; (2) those interested in the area as a whole; and (3) students and teachers of soil science and related agricultural sciences. An attempt has been made to satisfy the needs of these three groups by making the report a comprehensive reference work on the soils and their relation to crops and agriculture.

The readers whose chief interest is in limited areas, such as some particular locality, farm, or field, include the farmers, agricultural technicians interested in planning operations in communities or on individual farms, and real-estate agents, land appraisers, prospective purchasers and tenants, and farm loan agencies. The first step of a reader in this group is to locate on the map the tract with which he is concerned. The second step is to identify the soils on the tract. This is done by locating in the legend on the margin of the map the symbols and colors that represent the soils in the area. The third is to locate the name of each soil in the table of contents, which refers the reader to the page or pages in the section on Soils and Crops where each soil is discussed in detail. Under the soil type heading he will find a description of the soil and information as to its suitability for use and its relations to crops and agriculture. He will also find useful information in the section on Index Ratings of Soils.

The second group of readers includes persons who are interested in the area as a whole, such as those concerned with land-use planning—the placement and development of highways, power lines, docks, urban sites, industries, community cooperatives, resettlement projects, private or public forest areas, recreational areas, and wildlife projects. The following sections of the report are intended for such readers: (1) Description of the Area Surveyed, in which such topics as physiography, vegetation, water supply, population, and cultural developments are discussed; (2) Agricultural History and Statistics, in which a brief history of the agriculture of the area is given and the present agriculture is described; and (3) Index Ratings of Soils, in which a rating of soils according to their relative physical suitability for agricultural use is presented.

The third group of readers includes students and teachers of soil science and allied subjects, such as crop production, forestry, animal husbandry, economics, rural sociology, geography, and geology. The teacher or student will find special interest in the section on Morphology and Genesis of Soils. He will also find useful information in the section on Soils and Crops, the first part of which presents the general scheme of classification and a discussion of the soils with regard to the area as a whole, and the second part of which presents a detailed discussion of each soil. If he is not already familiar with the classification and mapping of soils he will find those subjects discussed in the section on Soil Survey Methods and Definitions. The teachers of other subjects will find the sections on Description of the Area Surveyed, Agricultural History and Statistics, Index Ratings of Soils, and Soils and Crops of particular value in determining the relations between their special subjects and the soils in the area.

DESCRIPTION OF THE AREA SURVEYED

LOCATION AND EXTENT

The Tracy area is in the northwestern part of the San Joaquin Valley of California (fig. 1). It includes the eastern part of Alameda County and the southwestern part of San Joaquin County and

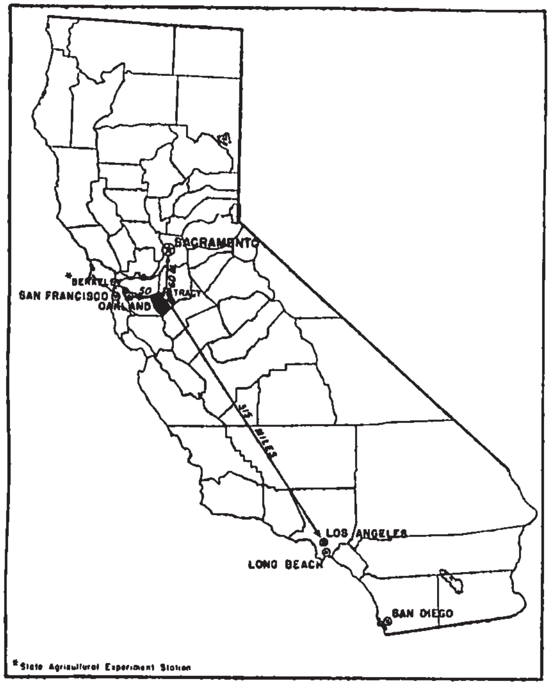

FIGURE 1.—Sketch map showing location of the Tracy area, California.

comprises an area of approximately 385 square miles. It joins with the soil survey of Contra Costa County (*2*)[2] and that of the Sacramento-San Joaquin Delta area (*3*) on the north. It covers a small part of the area included in the old soil survey of the Livermore area (*8*) on the west; and all the valley and basin lands were covered by the reconnaissance soil survey of the lower San Joaquin Valley (*5*).[3]

[2] Italic numbers in parentheses refer to Literature Cited, p. 95.

[3] Since the earlier soil survey of the Livermore area and the reconnaissance soil survey of the lower San Joaquin Valley, subsequent soil surveys have resulted in the recognition of a number of new soil series, some of which were formerly included in the more inclusive surveys of previous date. Comparison of the soil map of the Tracy area with the earlier surveys may therefore indicate apparent conflict in soil classification and mapping. These differences are explainable as the result of field studies and development in the science of soil classification and mapping during the intervening periods.

PHYSIOGRAPHY, RELIEF, DRAINAGE, AND VEGETATION

This area consists of three major physiographic divisions—the western mountainous region, the valley plains, and the river basin. The western part, comprising somewhat less than half of the area, is composed of the hilly and mountainous areas forming the eastern slopes of the Coast Ranges.

The southwestern part of the first division is composed of fairly high mountainous country covered by a more or less open woodland, with considerable brush and grass. In the lower part the trees are mainly oak and in some of the higher areas mainly pine and juniper. The elevation along Crane Ridge is about 2,500 feet, with a few high points reaching approximately 3,000 feet above sea level. The southeastern part of this physiographic division comprises a series of grass- and brush-covered hills that have been eroded considerably. To the eastward this division includes an area of rolling terraces that are deeply dissected by parallel drainageways. The tops of the ridges, when viewed from a distance, clearly indicate the former flat-topped terrace relief. Both areas are penetrated by Hospital, Lonetree, and Corral Hollow Creeks. The terrace areas grade into the broad eastward sloping valley plains. The northern part of the hilly and mountainous belt is composed of less steep grass-covered hills. These are used primarily for grazing sheep, but in the vicinity of Altamont and Patterson Pass they are cropped to dry-farmed grain and grain hay, which has long been known for its high quality.

The second division, comprising the valley plain, is composed of broad, smoothly sloping, confluent alluvial fans, which to a large extent are still more frequently subject to aggradation than to erosion. The streams issuing from the mountainous areas dissipate on this plain, with none of the channels extending to the San Joaquin River. The valley plain was originally grassland, but within the last few years much of the more recent alluvial fans has been brought under irrigation and much of the runoff water from the hills has been distributed over the area through the irrigation systems.

The northern part of the valley plain and a narrow strip along the eastern part bordering the basin and valley trough are occupied by older alluvial fans through which the streamways are somewhat entrenched, and no new depositions of fresh alluvial materials are being made at this time. Because of the fairly flat relief, erosion is very slight. Because of the greater age of these fans, the soils have heavy subsoils or claypans that somewhat lower their suitability for agricultural use.

The basin and flood-plain division occupies the eastern part of the area. The soils occupy low-lying basin and flood-plain areas at elevations ranging from about 10 feet above to slightly below sea level. The northern part comprises the upper part of the San Joaquin delta. This narrows rapidly in the southern part to a strip forming a flood plain along the river. This flood plain is about 3 miles wide where United States Highway No. 50 crosses the area east of Tracy. It narrows rapidly and is less than half a mile wide in the extreme southeastern part of the area.

Before levees were built, all the land within this division was subject to overflow and water stood on the surface from a few weeks to several months each year. Most of these areas have been reclaimed by artificial levees, protecting them from overflow, and by the installation of drainage systems, and they are now intensively farmed.

TRANSPORTATION FACILITIES

The Tracy area is very favorably located so far as transportation facilities are concerned. United States Highway No. 50, an excellent hard-surfaced road, crosses the north-central part from east to west. Much trucking of produce from this area to both Stockton and the San Francisco Bay district is done over this highway. All parts of the area are within easy reach of hard-surfaced roads leading to outside markets. The main valley line of the Southern Pacific Co. between San Francisco and Los Angeles and the main line of the Western Pacific Railroad between San Francisco and Salt Lake City, together with other lines of the Southern Pacific through Livermore and Stockton, pass through the area and serve it adequately with rail transportation.

Stockton, which is only 4 miles from the northeastern corner of this area, is reached by seagoing vessels, and terminal freight rates to eastern shipping centers are available. Terminal shipping rates for produce from this area are also obtained in any of the San Francisco Bay ports, which are easily reached by rail and highway.

Passenger transportation service also is excellent. In addition to railway passenger service, the area is served by a number of stage (bus) lines, both transcontinental and local, and airplane passenger service up and down the Pacific coast or to the East may be had in the San Francisco Bay district or at Sacramento.

SCHOOLS

County- and State-supported district primary schools adequately serve the area. Free bus transportation for students to and from school is provided. A union high school at Tracy with free bus transportation for students outside the town offers rural residents the same educational advantages of those enjoyed by residents of Tracy.

POPULATION

At present (1942) the population of the area is about 10,500. All the San Joaquin County part is included in Tulare Township. The part in Alameda County is very thinly populated, and it is estimated that it contains not more than 300 inhabitants. The population of Tulare Township, practically all of which is within this area, was 1,401 in 1890, 2,797 in 1900, 3,321 in 1910, 4,847 in 1920, 8,053 in 1930, and 11,846 in 1940. These figures show a steady growth in population during this period. Tracy is the only incorporated town in the area, with a population of 4,056 in 1940. Some small communities within this area are Banta, Bethany, Carbona, Midway, and Vernalis. The population of Tulare Township, San Joaquin County, consists mainly of white people.

INDUSTRIES

Agriculture and agricultural enterprises support a very large part of the population. In addition to the actual production of farm products, the area has several large canneries, an alfalfa-meal mill, a beet-sugar factory, bean and grain elevators, and a number of asparagus-packing plants, which furnish considerable employment to the inhabitants. During the late winter and early spring hundreds of migratory workers enter this area to pick peas. This is the only crop furnishing employment for large numbers of workers, who leave the area as soon as all the peas have been picked.

Tracy is an important railroad division point of the Southern Pacific Co., which maintains a large pay roll there. Other industries include the pumping plants of the oil pipe lines and five producing gas wells.

CLIMATE

This area has a climate characterized by hot, rainless summers and cool, moist winters. Approximately 80 percent of the season's rainfall comes between November 1 and March 31. The summer temperatures are high, with maximums between 110° and 115° F. Mild frosts occur during the winter, but temperatures are never sufficiently low to freeze the soil to a depth of more than a fraction of an inch. The average length of the frost-free period at Stockton is 287 days and at Newman 270 days. The frost-free period at Tracy is probably between 275 and 300 days. Over most of the area frosts do little or no damage. The normal crops of grain, alfalfa, and beans are not affected by frost. Grain and alfalfa withstand freezing weather, and beans, although very sensitive to frost, are not planted until May, when all danger of frost has passed.

In the vicinity of Tracy some winter peas are grown for marketing fresh. Heavy frosts cause some injury to the peas, but light frosts seldom do much damage. In the delta frosts are more frequent, and, although they do not permanently injure the asparagus, cold spring weather may delay the crop. The best prices are obtained on the early shipments of asparagus; so delay by frosty or very cool weather greatly reduces the income from this crop.

Fruit is not grown extensively in this area, but a few apricots are grown. Normally, frosts are not sufficiently heavy to injure the blossoms, but occasionally it is necessary to use orchard heaters for a brief period to protect against frost injury.

During the winter and spring strong winds blow along the west side of the San Joaquin Valley in a southeasterly direction. Because of these winds, fruit has not been grown very extensively, and wind injury to fruit is more common than frost injury. Grain is not grown very extensively along the eastern slopes of the hilly area bordering the valley, but it is grown extensively on the western slopes in the vicinity of Altamont and Patterson Pass. This condition is probably due to greater effective moisture in the latter locality, higher rainfall, less wind, and consequent less rapid evaporation.

The rainfall along the valley plain at Tracy and continuing south to Westley and Newman, which are both outside of the area surveyed, is about 10 inches a year. Rainfall is somewhat higher at Stockton to the northeast and Livermore to the west, which have nearly 14 inches of rainfall a year. Rainfall and temperature data available for Tracy in this area and for a few stations nearby are given in table 1.

TABLE 1.—*Precipitation and temperature records for a few locations within and near the Tracy area, Calif.*

Month	Tracy, San Joaquin County		Stockton, San Joaquin County		Livermore, Alameda County		Westley, Stanislaus County		Newman, Stanislaus County	
	Mean temperature	Mean precipitation	Mean temperature	Mean precipitation	Mean temperature	Mean precipitation	Mean temperature	Mean precipitation	Mean temperature	Mean precipitation
	°F.	*Inches*	*°F.*	*Inches*	*°F.*	*Inches*	*°F.*	*Inches*	*°F.*	*Inches*
December	47.6	1.88	44.7	2.31	48.8	2.37	48.5	1.79	46 7	1.75
January	46 8	1.96	44.4	2.04	48.0	3 09	48.0	2.43	46.4	2 15
February	50.6	1.39	50.2	2.29	51.3	2 29	52.1	1 52	51.3	1.66
Winter	48 3	5.23	46 4	7 54	49.4	7.75	49.5	5 74	48.1	5.56
March	54.4	1.71	55 3	2 18	53.7	2 20	56 7	1.93	55 5	1.80
April	60 6	.85	59.5	.91	57.0	.81	63 9	.69	60.9	.66
May	68.8	.58	64.8	.62	61 2	54	70 2	61	67.5	.44
Spring	61.3	3.14	59.9	3.71	57.3	3.55	63 6	3.23	61.3	2.90
June	75 6	.15	71 2	.12	66.8	.11	77 6	.09	74.7	.05
July	79.9	.01	75.4	.01	70 4	.01	82 4	.02	79 8	.01
August	77.5	01	73 6	01	69.9	.01	79 3	(1)	77 9	.01
Summer	77.7	.17	73 4	14	69.0	13	79 8	.11	77 5	.07
September	72.4	.19	68 8	.31	68.1	.36	74 1	.17	72.2	.22
October	64.3	.47	62 9	.62	62 6	.57	67.0	.47	64 4	43
November	54 6	1.06	53.1	1 46	54.7	1.34	56 3	1,03	53 5	1 06
Fall	63.8	1.72	61 6	2 39	61.8	2 27	65 8	1 67	63 4	1 71
Year	62.8	10.26	60 3	13.78	59 4	13 70	64.7	10 75	62 6	10.24

[1] Trace.

AGRICULTURAL HISTORY AND STATISTICS

The history of settlement of the lower San Joaquin Valley dates back to the middle forties. At this time the area was inhabited by Indians who migrated from the mountains to the valley during various seasons of the year. The Indians did no tilling of the soil but lived on acorns, wild berries, game, and fish. A few Mexican land grants had been made in this area, and the owners used their land for raising cattle, principally for the hides and tallow.

According to records, the first grain grown in this part of the San Joaquin Valley was planted in 1846 near French Camp but was not harvested. The following year grain from about 30 acres was harvested, and from then on more and more grain was planted. With the discovery of gold near Coloma and the gold rush of 1849, many gold seekers passed through this area. From this date until 1869 was mainly a period of mining excitement. Stockton became an important trading post, as it was reached from San Francisco by boat and overland. Overland parties traveled south from San Francisco to San Jose, then up what is now Niles Canyon to the Livermore Valley, thence eastward across the San Joaquin Valley, skirting the swampy delta to Stockton.

In 1861 the only two communities on the west side of the San Joaquin River were San Joaquin City (established in 1849) in the southern part of this area, and Wickland on the Old River north of the present town of Bethany. In 1860 coal was discovered in Corral Hollow Canyon, and Wickland was located as a shipping point for coal. In 1869, with the completion of the Central Pacific Railroad from Oakland through Livermore to Stockton, Wickland was moved to Ellis on the railroad. The town grew rapidly and in 1870 contained about 45 buildings. In 1878, when the Southern Pacific Co. completed its line from Oakland to Tracy, many railroad workers came to Tracy, and it was established as a railroad center. This brought about the removal of practically every building from Ellis to Tracy.

From 1847 to 1869 was a period of very little agricultural activity. The area was devoted to livestock raising, mostly cattle. From 1869 to 1898, grain growing increased rapidly. The coming of the railroad brought about good transportation facilities for grain and grain hay that could be grown easily.

By 1900, prices of grain declined and markets were not so good. This condition brought about a breaking up of large landholdings and a more intensive type of farming. Irrigation was practiced on a small scale, and in 1911 the Nagle-Burk irrigation district started serving water, although the district was not officially organized until 1919. In 1914 the Byron-Bethany and in 1915 the West Side irrigation districts were organized. Alfalfa was the principal crop grown. Orchards were planted, but wind injury was severe and most of the plantings were removed.

Reclamation of the swampy or marshlands started early in the sixties. Small tracts of sandy ridges, many of which were not flooded, were first cleared, and small levees, 2 or 3 feet high, were built by scraper and wheelbarrow. The first reclaimed areas were on what is now Roberts Island. Good crops of grain grown without irrigation were obtained on these clearings, so more and more small areas were cleared. Occasionally excessively high water flooded such areas, and the levees had to be rebuilt. It was not until the late eighties, when large dredging machinery became available, that large-scale reclamation of these lands was practicable. This was especially true of the peaty areas on the western half of Union Island and on the lower delta to the north of this area. The cost of building large protective levees ranged from $5,000 to $18,000 a mile, making it possible only for people or organizations with a large amount of capital to undertake such work. At present all marsh areas have been reclaimed and are producing high yields of field and vegetable crops.

Asparagus growing has become very extensive. The growing of asparagus requires much hand labor, and many orientals, mostly Filipinos and Japanese, have settled in this part of the area, to work in the asparagus and vegetable fields.

A brief discussion of the principal crops and some of the problems pertaining to their management are given.

GRAIN

Barley is the most important grain crop grown in this area. Other grain or seed crops are wheat, oats, grain sorghums, and sunflowers. Barley, wheat, and oats are usually grown as dry-farmed crops, but grain sorghums and sunflowers are irrigated. From 75 to 85 percent of the dry-farmed grain is grown on summer-fallowed land. In the valley and on the smoother rolling land the plowing of the stubble is done during the summer or fall while the field is dry. The land is allowed to remain throughout an entire season without any crop. In the hilly areas along the eastern slope a 3-year crop rotation is practiced in which after a crop of grain is allowed to grow up to weeds and grass the field is pastured for a season and then summer-fallowed the third season. In the vicinity of Altamont and Patterson Pass the slopes are steeper and the rainfall is a little higher than in the valley part of this area. Here the practice is to pasture the stubble in the fall and winter, following a crop of grain. The field is plowed as soon as sufficiently dry in the spring and is left fallow only during the summer. As previously mentioned, rainfall is a little heavier in the section where this type of fallowing is practiced, which furnishes sufficient moisture to mature a crop. This practice maintains a crop of either sowed or volunteer grain and grass during each rainy season and is effective in checking erosion. In fact, cultivated fields in this district appear to be no more eroded than pastures on similar slopes. Another factor in the success of this system of cropping is that much of the grain is cut for grain hay, which requires a little less moisture than when the crop is allowed to continue growing until the grain is fully ripened. Yields of grain in normal seasons range from 8 to 15 sacks[4] and of grain hay from 1 to 2 tons an acre. These yields are extremely variable and depend to a large extent on the amount and distribution of the seasonal rainfall.

About 50 percent of the barley seed is treated with copper carbonate and organic mercury dusts before seeding, to control rust and smut.

Grain and grain hay produced in this area are marketed in San Francisco and Stockton for California and national markets.

ALFALFA

All alfalfa is grown under irrigation. Most of the hay is baled and sold, but in the Banta district much of it is fed directly to dairy cattle. This crop is planted on many different soils, but it does better on soils that are open, friable, and fairly deep. Plantings on such soils produce well for five or six seasons before yields begin to decline. On the older alluvial fans, where the subsoils are heavy clays, and in the delta district, where the water table is fairly high, yields decrease rapidly after the third or fourth season, and the crop should then be replanted. Yields are extremely variable, ranging from 2 to 6 tons an acre annually. According to farmers' estimates, some of the better soils occasionally produce as high as 1½ or 2 tons an acre at each early season cutting. Usually from 4 to 6 cuttings are obtained each season. Most of the baled hay is sold outside the area on the Stockton, San Francisco, and Los Angeles markets. It is used mostly for feed for dairy cattle.

BEANS

Since about 1920 the bean acreage in this area has been increasing. At present approximately 80 percent of the bean acreage is planted to baby limas. There are some pinto, black-eyed, and kidney beans.

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[4] The capacity of grain sacks on the different California markets ranges from 100 to 125 pounds of grain, and the average is about 2 bushels.

Beans are planted between May 1 and June 15. Most of the kidney beans are planted in June. Some beanfields are planted following a crop of peas or some other early maturing crop, but less than one-fourth of the beans are double cropped.

In this area beans are not planted until the rainy season is over, so the fields are preirrigated. This irrigation furnishes sufficient moisture to supply the young plants until they are of sufficient size to allow rowing the fields for furrow irrigation. With this practice a large number of weed seeds germinate, and the weeds are killed in working up the field for seeding after the irrigation.

Beans are subject to a number of diseases and pests. Nematodes cause considerable damage, and about the only control is through resistant varieties, which are available for baby limas and blackeyed beans. Worms are a pest in some fields, and no effective control has been discovered, but cultural practices may help. Thrips and red spider do considerable damage. The infestation can be controlled by keeping the district free from weeds and host plants, which grow mostly along fences, ditches, and roadways. If checked in the early stages, red spider can be effectively controlled by sulfur dust.

Most of the beans are marketed in midwestern and eastern markets.

FLAX

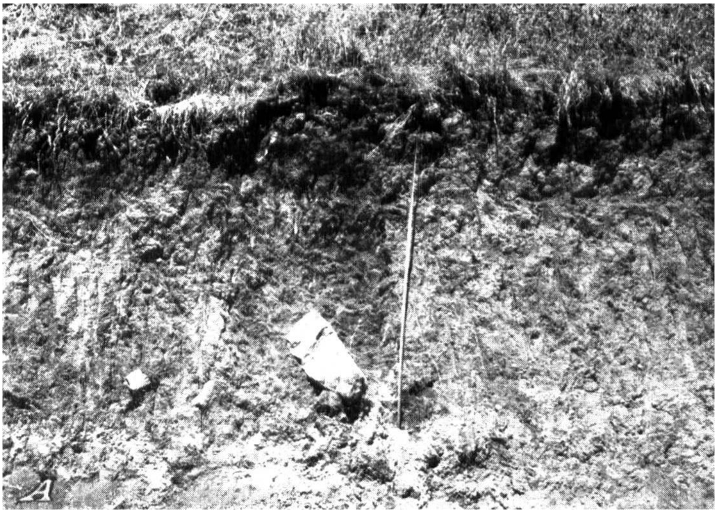
Flax has not been grown very extensively in this area until the last 8 or 10 years, but the acreage is increasing rapidly. It is grown mostly on soils of the older alluvial fans, which are not so suitable for beans and alfalfa. Flax is a rather shallow rooted crop and does well on these less productive soils. Acre yields range from 12 to 24 bushels. The duty of water for this crop is much lower than that for beans and alfalfa. Flax requires only one-third or one-half as much water as the latter crops. Prices for flaxseed have been good, and this product has found a ready market in the San Francisco Bay district, where it is processed for the oil and a wide variety of byproducts.

TRUCK CROPS

The principal truck crop is asparagus, which is grown entirely in the delta district. Plantings are made mainly by root separations and last from 10 to 12 years. All the asparagus is grown in areas having a high water table, and the crop is irrigated by subirrigation. Asparagus is harvested by hand and either canned or packed fresh for the market. The season lasts from February or March to sometime in May. Prices are extremely variable and fluctuate greatly during the season. The first cuttings sell for a very high price, but the price drops rapidly as the yield increases. During the period of most rapid growth the crop is harvested daily.

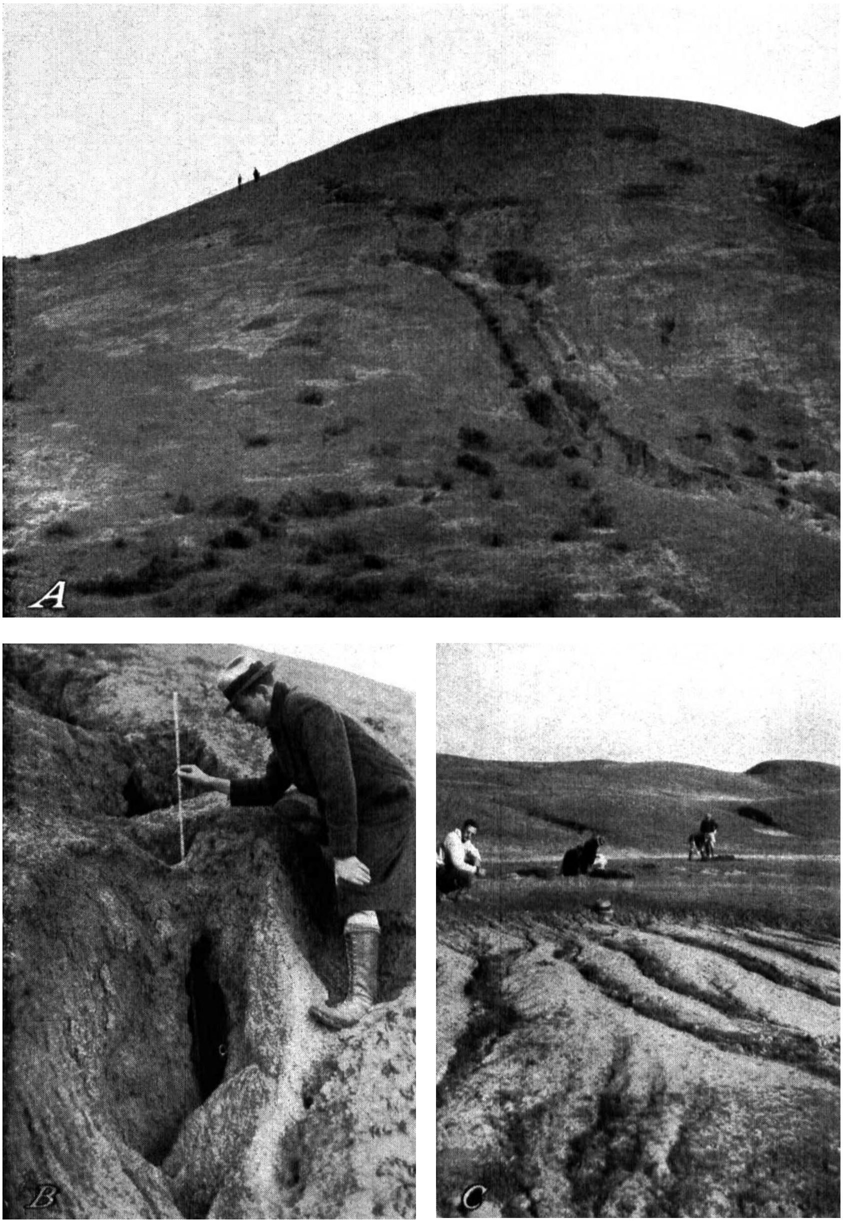
Green peas, mostly for sale as fresh vegetables, are grown on the alluvial-fan areas from Tracy southward. This crop has been grown here since 1930 and now covers 1,500 to 2,000 acres. Plantings are made from November 15 to about January 15. In normal seasons peas are grown without irrigation. The principal cost is that of picking, which is done by hand, mostly by itinerant labor. Markets and prices are uncertain. Peas are shipped both to San Francisco and to eastern markets. The principal disease is mildew, which is fairly well controlled by sulfur dust spray.

A, Sheep grazing in January on elevated terrace at foot of hilly and mountainous district in the western part of the area. *B*, View from high ridge occupied by Vallecitos soils along the western boundary of the area San Joaquin Valley filled with fog in distance Note fog streaming over distant lower ridges. This land is used for grazing in connection with extensive livestock raising.



A, Exposed profile of Altamont adobe clay. *B*, Soil profile of Linne adobe clay.

A, Grain hay on Linne adobe clay. Grain cut green and cured for hay is of high quality and an important crop in this area B, Farmstead on dry-farmed grain area of Contra Costa soils. Note smooth gently rolling relief. Local outcrop of sandstone bedrock in foreground.



A, Severely eroded southwestern slope of Kettleman fine sandy loam; *B*, close-up view of pot-hole gully on hillside in 4 *A*, *C*, collecting samples of Antone clay.

Some tomatoes are grown for canning. Yields are satisfactory, but the crop is susceptible to disease and insect pests. Bacterial canker is controlled by seed selection and by treating seed with mercuric chloride. Various worm pests are successfully controlled by dusting with calcium arsenate and fluosilicate. Crops have to be rotated with tomatoes planted on the same field not oftener than once in 3 or 4 years.

ORCHARDS AND VINEYARDS

There are a few plantings of almonds and apricots and a very small acreage of walnuts in the Tracy area. The apricots and walnuts are more subject to wind injury than the almonds. Almonds and apricots are subject to a little frost injury, but this is not very common. Yields are not exceptional, yet the acreage in orchards is increasing somewhat. Grapes are not grown to a great extent. The few small plantings are comparatively unimportant.

GRAZING AND LIVESTOCK

Hardly any land in this area is idle, as practically all of the uncultivated land is used for pasture (pl. 1, *A*). Pasture lands are rented at rates ranging from 10 cents to about $2 an acre. Practically all of the grassy hill land is pastured to sheep, but in the wooded district cattle are raised more extensively than sheep. The common practice is to pasture sheep in the hills from late fall until early summer, then pasture them in the valley and delta districts during the summer on stubble or straw from grainfields or beanfields.

The mild winters allow lambing in the open. The lambing season is from early December through March. The sheep are transferred from the valley and delta areas to the hills just before lambing season and are kept there until after grain has been harvested in the summer or until the feed in the hills is completely gone. This practice is rather hard on range land, for practically every season the grass is eaten very close to the ground. In years when sufficient light early showers in the fall give the grass a good start before the heavier winter rains, erosion is slight; but in seasons with no early showers and with heavy winter rains before the grass has had a chance to grow, erosion is likely to be rather severe. As most of the land used for pasture in the hills is rented by the season or leased for only a few seasons at a time, overgrazing is common.

Cattle raised in the more wooded hill land are usually ranged there the year round. Water is usually available and summer pasturage is fair in the part of the range land that occupies the southwestern part of this area. These wooded areas are used to only a small extent for sheep, as many predatory animals, such as coyotes, foxes, and wildcats, prey more heavily on sheep than they do on cattle. These areas are not grazed so heavily, and the protective cover of the trees, together with the stony nature of the soils, prevents erosion to a marked extent.

With the exception of the area in the vicinity of Patterson Pass and Altamont and a few small areas along the eastern foothills from Midway northward, all the hilly, mountainous, and high terrace lands are used for range land (pl. 1, *B*). Some of the valley lands close to the hills just north of where Corral Hollow Creek enters the valley are not cultivated. These areas, although suitable for dry farming, are used as range pasture.

The acreage and distribution of the various crops are shown in figures 2 to 7, inclusive. These graphs are from 1936 crop statistics from the county commissioners' offices.

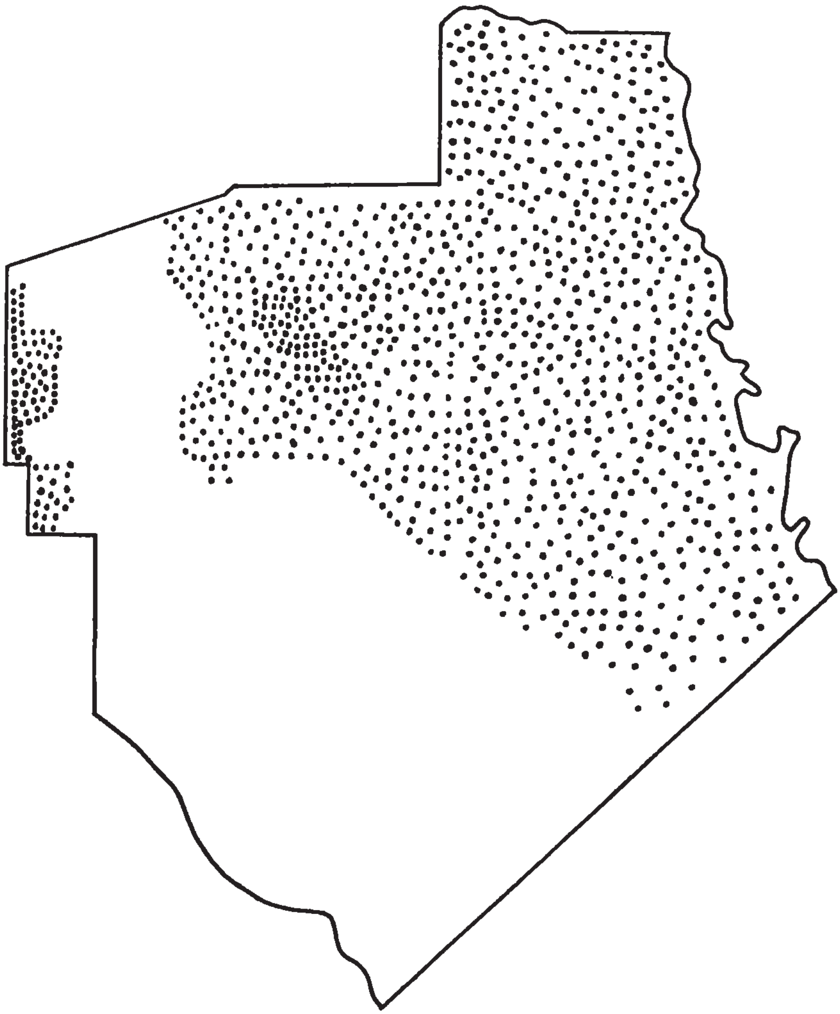


FIGURE 2.—Distribution of grain, grain hay, and summer fallow in the Tracy area, Calif., in 1936 (56,615 acres). (Each dot represents 50 acres.)

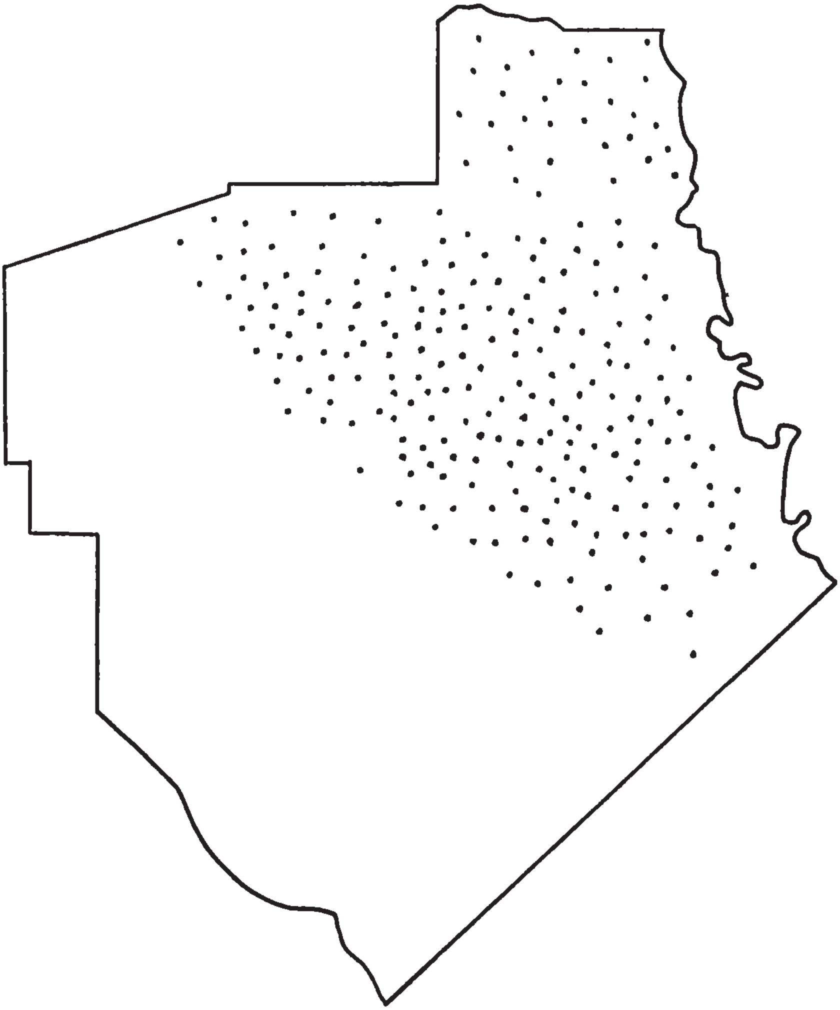


FIGURE 3.—Distribution of alfalfa in the Tracy area, Calif., in 1936 (12,492 acres). (Each dot represents 50 acres.)

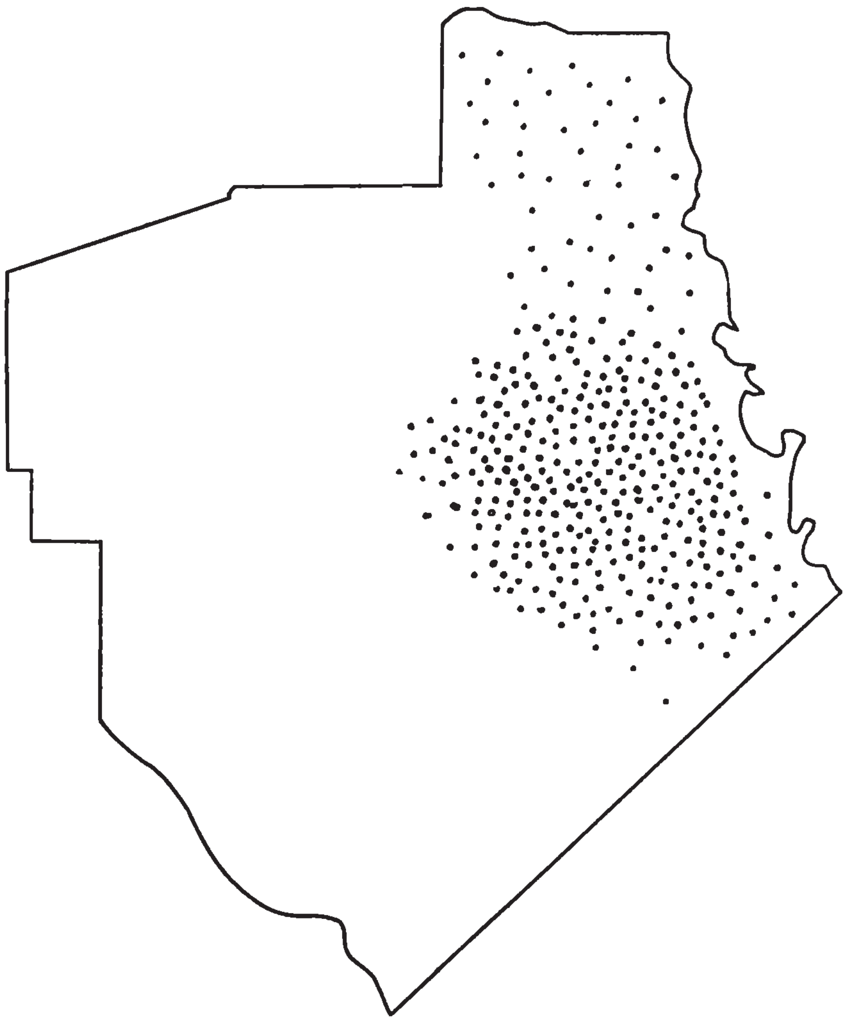


FIGURE 4.—Distribution of beans in the Tracy area, Calif., in 1936 (18,936 acres). (Each dot represents 50 acres.)

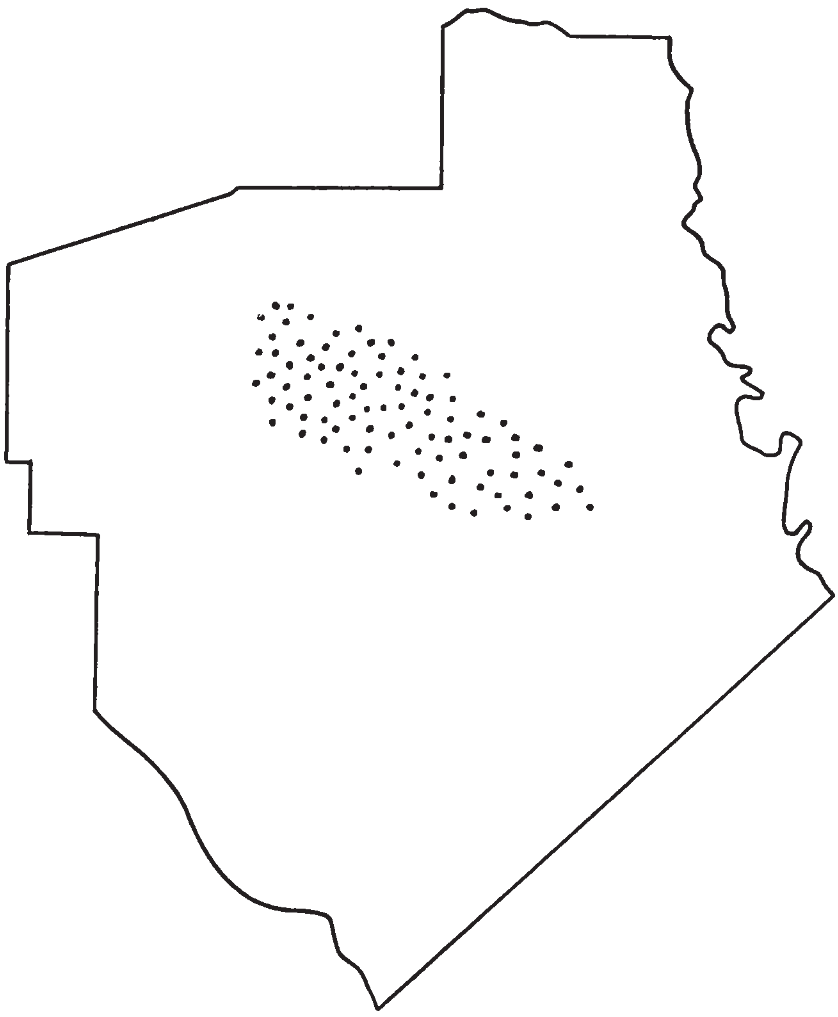


FIGURE 5.—Distribution of flax in the Tracy area, Calif., in 1936 (4,500 acres). (Each dot represents 50 acres.)

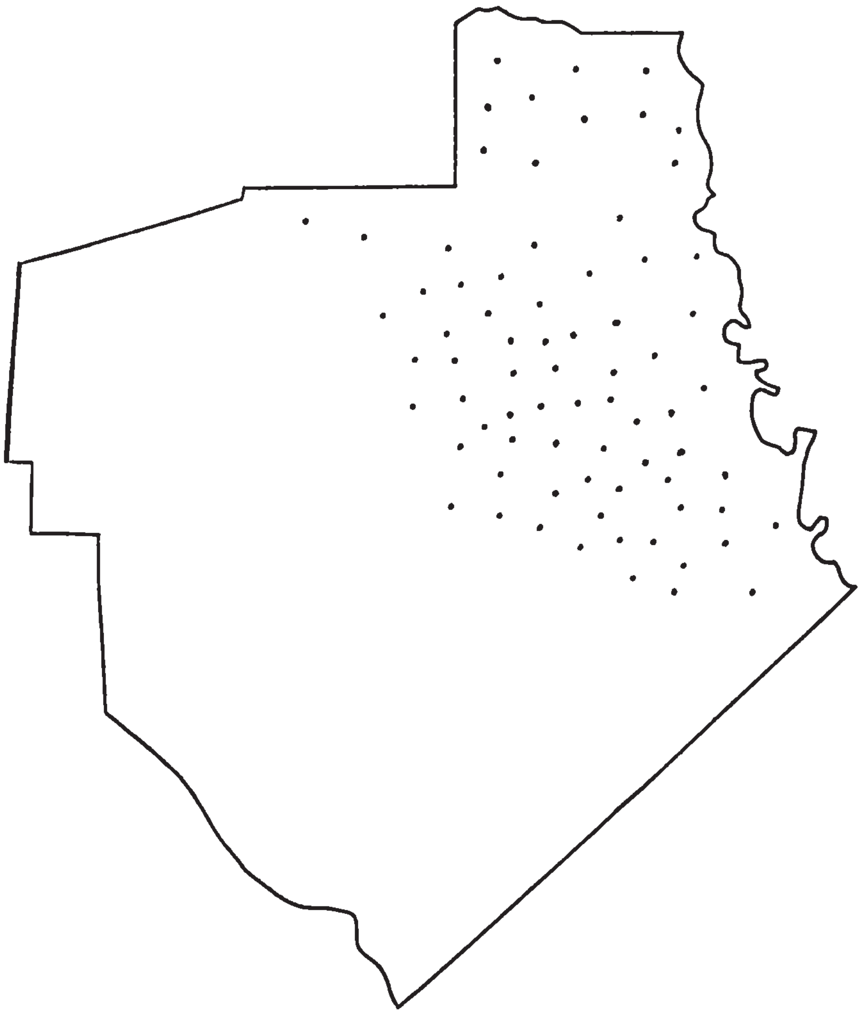


FIGURE 6.—Distribution of truck crops other than asparagus in the Tracy area, Calif., in 1936 (3,923 acres). (Each dot represents 50 acres.)

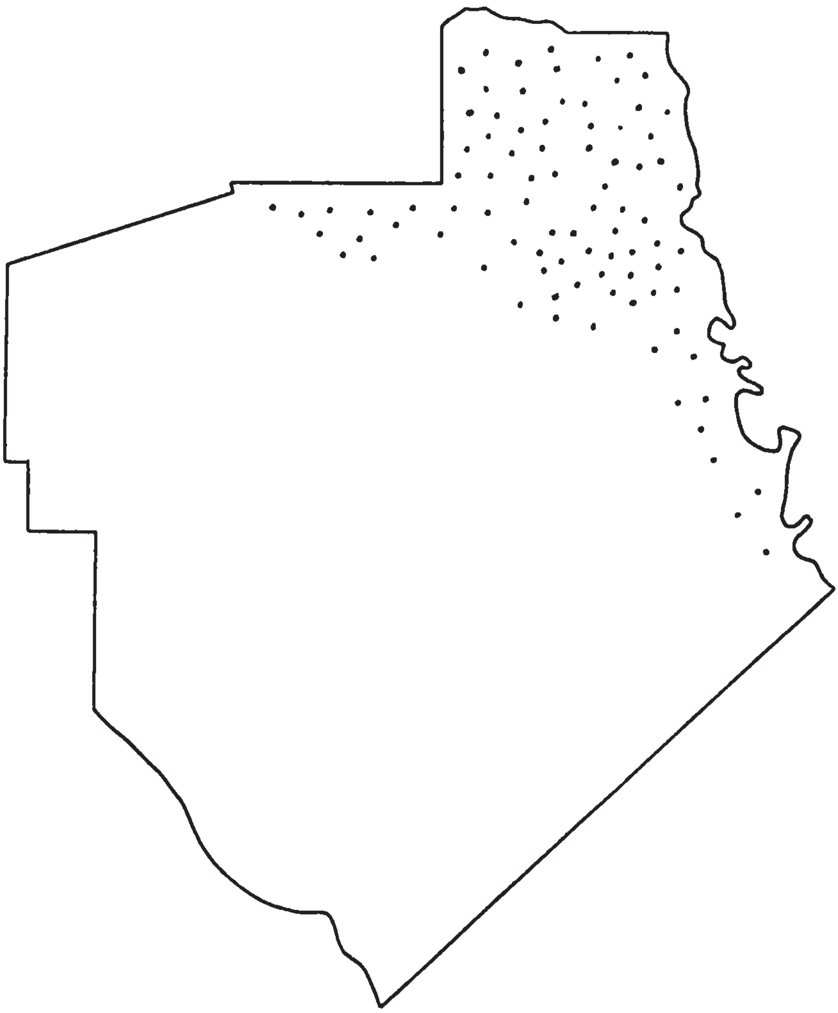


FIGURE 7.—Distribution of asparagus in the Tracy area, Calif., in 1936 (4,348 acres). (Each dot represents 50 acres.)

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SOIL SURVEY METHODS AND DEFINITIONS

Soil surveying consists of the examination, classification, and mapping of soils in the field and the recording of their characteristics, particularly in reference to the growth of various crops, grasses, and trees.

The soils are examined systematically in many locations. Test pits are dug, borings are made, and exposures, such as those in road or railroad cuts, are studied. Each excavation exposes a series of soil layers or horizons, called collectively the soil profile. Each horizon of the soil, as well as the parent material beneath the soil, is studied in detail, and the color, structure, porosity, consistence, texture, and content of organic matter, roots, gravel, and stone are noted. The reaction of the soil [5] and its content of lime and salts are determined by simple tests.[6] The drainage, both internal and external, and other external features, such as stoniness and the relief or lay of the land, are taken into consideration, and the interrelation of the soil and vegetation is studied.

The soils are classified according to their characteristics, both internal and external, with special emphasis upon the features that influence the adaptation of the land for the growing of crop plants, grasses, and trees. On the basis of these characteristics the soils are grouped into classification units, the three principal of which are (1) series, (2) type, and (3) phase. Areas of land—such as riverwash and made land—that have no true soil are called (4) miscellaneous land types.

The series is a group that includes soils having the same genetic horizons, similar in their important characteristics and arrangement in the soil profile, and having similar parent material. Thus, the series comprises soils having essentially the same color, structure, natural drainage conditions, and other important internal characteristics, and the same range in relief. The texture of the upper part of the soil, including that commonly plowed, may vary within a series. The series are given geographic names taken from localities near which they were first identified. Altamont, Zamora, and Sorrento are names of soil series in this area.

Within a soil series are one or more types, defined according to the texture of the upper part of the soil. Thus, the class name of this texture, such as sand, loamy sand, sandy loam, loam, silt loam, clay loam, silty clay loam, or clay, is added to the series name to give the complete name of the soil type. For example, Altamont clay loam and Altamont adobe clay are soil types within the Altamont series. Except for the texture of the surface soil, these types have approximately the same internal and external characteristics. The soil type is the principal unit of mapping, and because of its specific character it is generally the soil unit to which agronomic data are definitely related.

A phase of a soil type is a variation within the type, differing from the type in some minor feature, generally external that may be of special practical significance. Differences in relief, stoniness, and the

[5] The reaction of the soil is its degree of acidity or alkalinity expressed mathematically as the pH value. A pH value of 7 indicates precise neutrality; higher values, alkalinity; and lower values, acidity.

[6] The total content of readily soluble salts is determined by the use of the electrolytic bridge. Phenolphthalein solution is used to detect a strong alkaline reaction.

degree of accelerated erosion may be shown as phases. For example, within the normal range of relief for a soil type some parts may be adapted to the use of machinery and the growth of cultivated crops and others may not. Even though no important differences may be apparent in the soil itself or in its capability for the growth of native vegetation throughout the range in relief, there may be important differences in the growth of cultivated crops. In such an instance the more sloping parts of the soil type may be segregated on the map as a sloping or a hilly phase. Similarly, soils having differences in stoniness may be mapped as phases, even though these differences are not reflected in the character of the soil or in the growth of native plants.

The soil surveyor makes a map of the area, showing the location of each of the soil types, phases, and miscellaneous land types, in relation to roads, houses, streams, lakes, section and township lines, and other local cultural and natural features of the landscape.

SOILS AND CROPS

The soils of this area are placed in five groups, arranged mainly according to physiographic divisions (fig. 8), as follows: 1, Hilly and mountainous areas; 2, recent alluvial fans; 3, older alluvial fans; 4, high terraces; and 5, basin and flood plains.

Group 1 includes soils occupying hilly or mountainous areas. These are soils developed from materials produced by the decay of the underlying bedrock. They are used mainly for range pasture, but some dry-farmed grain and grain hay are grown on some members of the group. Soils of six series—Altamont, Linne, Kettleman, Los Osos, Contra Costa, and Vallecitos—compose this group. The soils of only two of these series—Altamont and Linne—are used for dry-farmed grain or grain hay, whereas all the soils in the group are used for range pasture.

Group 2 includes soils occupying recent alluvial fans and local stream valleys. These soils consist of materials that have been altered very little since deposition and do not have compact subsoil layers. They have smooth gently sloping relief. They are the best agricultural soils of the area, and under irrigation they are suited to a wide variety of field and orchard crops. Where no water is available for irrigation they are used for dry-farmed grain or range pasture. Two series of soils are represented in this group—the Sorrento and the Mocho.

Group 3 includes soils occupying older alluvial fans. Eight soil series are in this group—Zamora, Rincon, Ambrose, Herdlyn, Olcott, Pescadero, Solano, and Antone. All these soils have distinct surface soil and subsoil layers, and there are definite accumulations of clay in the subsoils. Under irrigation the Zamora and Rincon soils have very wide use, but they are not quite so productive as the soils of group 2. To a limited extent, soils of the Ambrose and Herdlyn series are used under irrigation, mainly for grain, flax, and alfalfa. Grain and flax do fairly well on these soils. Stands of alfalfa may be fair on the Ambrose soils, but they do not last very long. Alfalfa on the Herdlyn soils is decidedly inferior to that on the better soils of the area. The Solano and Pescadero soils are saline and have a high water table. Fairly good crops of grain are produced under both dry-farming and irrigation conditions on the Pescadero soils, but the

Solano soils are used only for pasture, and even that is of poor quality. The Antone soils are used only for pasture. They occur in small narrow bodies and are inaccessible to irrigation water, although it is doubtful whether they would be very productive even if water were available. The soils of the Olcott series have very tight claypan sub-

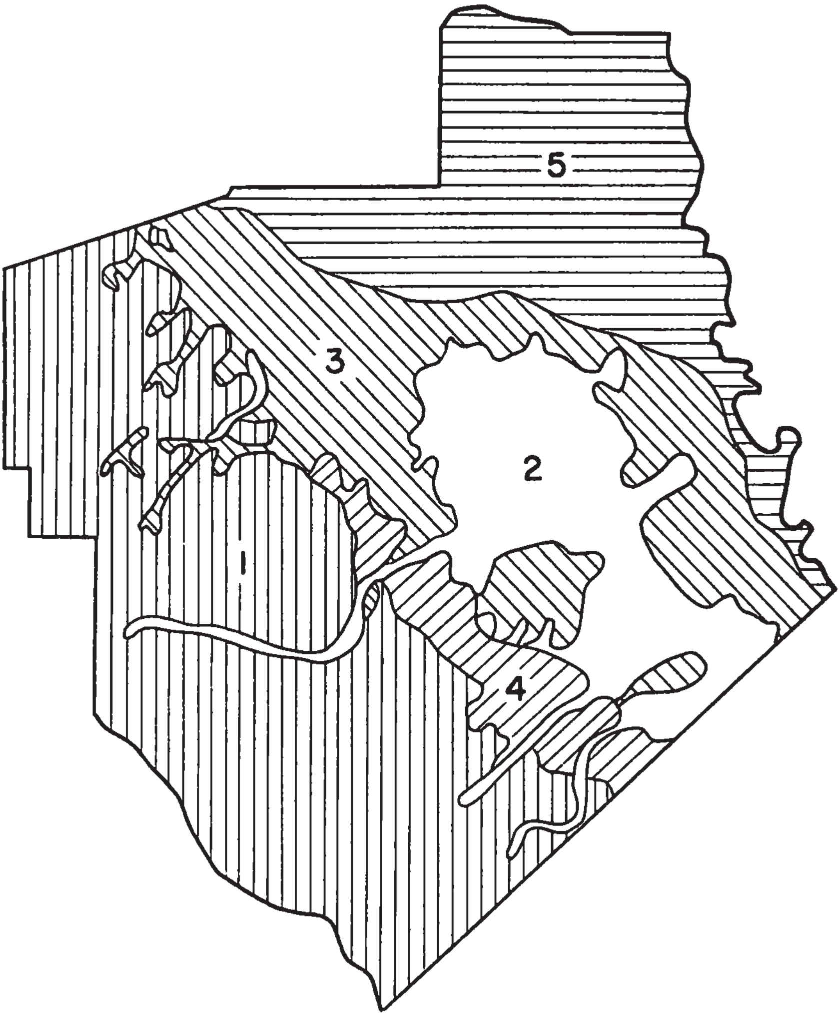

FIGURE 8.—Physiographic divisions of the Tracy area, Calif.: 1, Hilly and mountainous areas; 2, recent alluvial fans; 3, older alluvial fans; 4, high terraces; 5, basin and flood plains.

soils and are unsuited to farming under irrigation, although fair grain yields are obtained under dry farming. Most of these soils, however, are used for range pasture. All the soils of this group have broad gently rolling relief, with the stream channels sufficiently entrenched so that they are not normally subject to overflow.

Group 4 includes soils occupying high terraces and terracelike remnants of old alluvial fans. Streamways are deeply entrenched, and the relief is rolling. The soils have well-defined surface soil and subsoil layers with heavy claypans. Because of their topographic position and relief they are not suited to irrigation farming and are used mainly for range pasture, although some dry-farmed grain and grain hay are grown with fairly satisfactory yields. Three series of soils are represented in the group—Denverton, Montezuma, and Positas.

Group 5 consists of soils on the flood plain and delta of the San Joaquin River. These soils have a high water table and are normally subject to overflow during periods of high water in the river. They all have to be reclaimed by protective levees and drainage before they can be farmed. Where reclaimed these soils are suitable for a wide variety of field and truck crops. Yields are high, and quality is excellent. Drainage and irrigation are normally accomplished by a series of open ditches that serve both purposes. By carefully controlling the water level in the ditches the field may be either drained or irrigated. Irrigation from surface ditches is used only in a few places on soils of this group. These soils lie at elevations ranging from 10 feet above to approximately 10 feet below sea level and from 10 to 30 feet below the high-water level of the river.

Six soil series are in this group, of which four, the Columbia, Ramada, Piper, and Sacramento, are mineral soils. The Burns soils are somewhat intermediate between mineral and organic soils, and the Roberts soils are organic in character.

Grain and alfalfa are the most extensive crops grown on these soils in this area, but asparagus also is grown extensively. A considerable acreage of other truck crops, such as carrots, table beets, and spinach, are grown on these soils, as well as some sugar beets, field corn, and grain sorghums, all with satisfactory yields.

Aside from the soil and moisture conditions, which have the most important bearing on the crops that can be grown in this area, another factor that has a definite influence is wind. The wind during certain seasons is very strong, blowing from the northwest along the western side of the San Joaquin Valley. Much of the area in grain in the hilly areas is in rather sheltered locations, whereas the slopes adjacent to the valley are not used for grain because of the desiccating effect of the winds on the grain and the shattering of the grain as it ripens. In the valley, the soils of group 2 and some of the Zamora and Rincon soils in group 3 are suitable for tree fruits, and they are used for the production of apricots, peaches, almonds, and prunes in the vicinity of Brentwood in Contra Costa County, to the north, and in the vicinities of Westley and Patterson in Stanislaus County, to the south; but in the Tracy area they are not used to a great extent for these crops because of the danger of injury by wind.

As has been stated, the principal field crops of this area are beans, small grains, grain hay, and alfalfa. The beans and alfalfa are grown under irrigation, and most of the grain is grown without irrigation. Practically all of the irrigation water used in the summer is pumped from the San Joaquin River, but during the rainy season floodwaters from the smaller streams are spread over the soils wherever possible. The cost of water for irrigation is rather high. More information regarding duty of water, water supply, and drainage is given in the section on Irrigation and Drainage.

The soil separations in this area are represented by 25 soil series including 43 soil types, 11 phases of types, and 2 miscellaneous land types. The 11 phases are mainly rock-outcrop and steep phases of the soils in group 1. The rock-outcrop phases represent areas where 25 percent or more of the areal extent of the soil bodies consists of outcropping bedrock.

In the following pages the soils of the Tracy area are described in detail, and their agricultural relations are discussed; their location and distribution are shown on the accompanying soil map, and their acreage and proportionate extent are given in table 2.

TABLE 2.—*Acreage and proportionate extent of the soils mapped in the Tracy area, California*

Soil type	Acres	Percent	Soil type	Acres	Percent
Altamont clay loam	3,264	1 3	Herdlyn loam	1,280	0.5
Altamont clay loam, steep phase	2,240	9	Olcott clay loam	1,536	6
Altamont adobe clay	11,776	4 8	Pescadero clay	2,368	1.0
Altamont adobe clay, steep phase	3,072	1 2	Solano loam	192	1
Linne clay loam	1,024	.4	Antone clay	384	2
Linne clay loam, rock-outcrop phase	10,240	4 2	Denverton adobe clay	3,200	1 3
Linne adobe clay	20,736	8.4	Denverton adobe clay, slope phase	1,216	5
Linne adobe clay, steep phase	4,032	1 6	Denverton gravelly clay	320	1
Kettleman fine sandy loam	768	3	Denverton gravelly clay, slope phase	4,928	2.0
Kettleman fine sandy loam, rock-outcrop phase	1,152	5	Denverton gravelly clay, steep phase	1,536	6
Kettleman clay	3,904	1.6	Montezuma adobe clay	1,088	4
Los Osos sandy loam	64	(1)	Positas gravelly clay loam	704	3
Contra Costa sandy loam	384	2	Columbia fine sandy loam	8,448	3.4
Contra Costa loam	192	1	Columbia silty clay loam	3,392	1 4
Vallecitos stony loam	2,816	1 1	Columbia soils, undifferentiated	3,328	1.4
Vallecitos stony clay loam	8,192	3 3	Ramada fine sandy loam, shallow phase (over Sacramento soil material)	448	2
Vallecitos stony clay loam, steep phase	25,920	10 5	Ramada silty clay loam, shallow phase (over Sacramento soil material)	320	.1
Sorrento loam	2,048	.8	Piper fine sandy loam	256	1
Sorrento clay loam	4,288	1 7	Sacramento loam	1,280	.5
Sorrento gravelly loam	2,176	.9	Sacramento clay loam	9,216	3 8
Sorrento silty clay	10,176	4.1	Sacramento clay	17,216	7.0
Sorrento gravelly clay loam	2,432	1.0	Burns clay loam	6,848	2.8
Sorrento clay	11,776	4.8	Roberts muck	576	.2
Sorrento gravelly clay	320	1	Riverwash	960	.4
Mocho loam	448	.2	Made land	192	.1
Zamora gravelly clay loam	384	2			
Rincon clay loam	6,528	2 6			
Rincon gravelly clay loam	1,216	.5			
Rincon clay	7,168	2 9			
Ambrose clay loam	1,664	.7			
Ambrose clay	24,768	10 1	Total	246,400	100 0

[1] Less than 0 1 percent

SOILS OF THE HILLY AND MOUNTAINOUS AREAS

ALTAMONT SERIES

The soils of the Altamont series are mineral pedocalic soils developed on sandstone and shale bedrock, which as a rule is noncalcareous, although considerable lime may be in the cracks in the upper part of the bedrock. These soils occupy rolling or hilly land with rather steep but broad slopes. A few areas have a rather abrupt change in slope and some gullying, but most of the hills have well-rounded tops and rolling contours. The native cover of these soils was mainly native grasses with here and there small areas of brush or scattered oaks. The profiles are youthful or immature in stage of development, with a neutral or very slightly acid reaction in the surface soils and with calcareous subsoils.

The surface soils are brownish gray or olive brown with medium-heavy or heavy texture. When wet the soils seem to have a richer or browner color than when dry. They are extremely variable in depth, ranging from a few inches to approximately 2 feet in the deeper soils. Rather large shrinkage cracks occur in these soils, and the heavy-textured members show typical blocky ("adobe") structure. These soils have rather favorable physical properties, and even the heavy-textured ones are not difficult to work. They are, however, very sticky when wet and can be puddled if worked excessively at unfavorably high moisture content. They break down readily to a fine-blocky or granular structure, and the aggregates are not very hard. Roots and moisture penetrate the soils well. The roots seem to be well distributed throughout the surface soils without concentrating themselves along breakage cracks. The upper part of the surface soils is neutral or slightly acid, but the material becomes more alkaline with depth. There are many small insect and root holes throughout this layer. A few soft rust-brown angular shale or sandstone fragments are found in this layer, and in the lower part some of these may be coated with lime.

The upper subsoil layer is slightly lighter in color and generally slightly heavier in texture than the surface soil, being brown or yellowish brown. It is mildly calcareous in the upper part and strongly so in the lower part. The soil here has some structural development, with the surface cracks extending down through this layer to the lower subsoil layer, giving it a decided vertical breakage. The secondary cracks are not well defined, but the soil breaks into moderately firm irregularly shaped aggregates with some slightly darker colloidal stains occurring on the surface of the aggregates and as linings along root and insect cavities. Many roots are contained in this layer, and here again they seem to be dispersed throughout the layer without concentrating along the breakage cracks. More rock fragments are in this layer than in the surface soil.

The lower subsoil layer is yellowish brown or light yellowish brown and is the zone of heaviest texture and greatest compaction. The surface cracks generally extend down into this layer as the soil dries. When the surface soil crumbles, some of the material falls down the cracks and imparts a dark somewhat streaked appearance to parts of this lower subsoil layer.

The aggregates have a somewhat blocky structure and are coated with slightly darker colloidal stains. They are very firm, yet soften readily when moist. Not so many roots are in this layer as in the layers above, but they are rather evenly distributed throughout. The many rock fragments are coated with lime. The material in this layer is strongly calcareous, and a few thin streaks of segregated lime occur in many places.

The upper part of the bedrock in many places is fairly soft and somewhat shattered. Generally considerable lime coatings are on the fragments and in the cracks in the bedrock, but the bedrock proper in most places is noncalcareous. The average depth of these soils is about 3 feet, but individual profiles range in depth from less than a foot to more than 5 feet.

Drainage is fair to good, but some seepage spring areas occur where the soil is slightly darker and hardly typical in profile. The narrow drainageways also have slightly different soil conditions, and the seepage waters in these drainageways generally have a fairly high content of soluble salts. The drainageways show characteristic salt deposits in the late summer, and saltgrass and salt-tolerant weeds grow in narrow bands along them. These areas, together with the seepage spots, are too small to segregate in mapping and are considered characteristic features of the Altamont series as it occurs in this area.

Erosion is not very severe on the soils of this series. The heavier textured soils are more resistant to erosion than the lighter textured ones. They are used for dry-farmed grain or grain hay and pasture. and under the present method of management they are very stable and seem to be withstanding erosion as well as areas that are pastured, despite the fact that areas with 35 and 40 percent slopes are being cultivated. A few areas along Corral Hollow Creek are badly eroded, but these areas are in a locality of many fault lines, where the underlying bedrock is badly broken up and easily eroded, allowing the cutting of deep gullies.

The soils of this series are extensive in the hilly part of this area, extending from the northern to the southern boundary, but narrowing out rapidly in the southern part. Fairly good yields of high-quality grain and grain hay are obtained on these soils.

Soils of the Altamont series have been extensively mapped in the Coast Ranges of the State. Two types and two phases occur in this area.

Altamont clay loam.—The surface soil of this type is olive-brown or brownish-gray noncalcareous clay loam that breaks up cloddy when dry. The clods crumble readily to a granular condition, and, unless puddled by working at excessive moisture content, the surface soil maintains a favorable tilth. At a depth ranging from a few inches to almost 2 feet, the subsoil, of somewhat lighter color and slightly heavier texture, is reached. The subsoil is generally calcareous and many of the rock fragments within the layer are coated with lime. The material breaks into rather soft clods and is easily penetrated by roots and moisture. This layer is underlain by brown or yellowish-brown sandstone or shale bedrock, which is soft in the upper part and may have a little segregated lime in the cracks, although the bedrock proper in most places is noncalcareous. Bedrock occurs at a depth ranging from a few inches to as much as 5 feet and in a few spots rock outcrops occur.

This soil occupies rolling or hilly land and, although fairly resistant to erosion, it is more erosive than the heavier textured Altamont adobe clay.

Altamont clay loam is not extensive and is used mostly for range pasture. It supports a fairly heavy grass cover that has a very good carrying capacity for livestock. Some small areas are used for dry-farmed grain and grain hay. The yields are extremely variable and depend mainly on the seasonal rainfall. In years of favorable rainfall, yields and quality of grain and grain hay are good.

This type includes a few small bodies in the northwestern part of the area in which many outcrops of bedrock occur. These are indicated on the soil map by rock-outcrop symbols. In these areas the soil is normally more variable in depth and in texture of the surface soil. The surface soil in most places is clay loam, but in some areas small spots having lighter or heavier textures occur. The surface soil generally is shallower, and the somewhat heavier subsoil is not so pronounced where the soil is thin. Most of the rock outcrops are sandstone and are fairly hard. The relief is more rugged and steeper than that of the typical soil. These areas are used only for range pasture.

Altamont clay loam, steep phase.—The surface soil and subsoil of this phase are similar in color and other characteristics to those of typical Altamont clay loam. Owing to the steeper slopes (in excess of 40 percent except in included small areas), which are more favorable to local landslips and erosion and to movement and creep of soil material under gravity, the soil profile is less consistent, the depth to the parent bedrock is more variable, and rock outcrops are somewhat more numerous.

Conditions of relief favor more rapid runoff and sheet erosion. The slopes are too steep to allow effective use of farm machinery and cultivation, and soil of this phase is used for pasture, which has fair carrying capacity in favorable seasons. Care should be exercised to avoid overgrazing.

Altamont adobe clay.—The surface soil of this type is olive-brown or brownish-gray noncalcareous clay, which, when dry, has a typical blocky structure, with large massive blocks that become further divided by a series of smaller cracks, thereby forming fine blocks. These are firm when dry, but the soil is friable when moist, though plastic and sticky when wet (pl. 2, *A*). At a depth ranging from 8 to 24 inches is the upper subsoil layer of slightly heavier texture. It is similar to the surface soil in color and in many places is calcareous in the lower part. The large vertical cracks of the surface soil extend through this layer, giving it a distinct prismatic structure. This layer, although very heavy in texture, is easily penetrated by roots and water. The lower subsoil layer is compact yellowish-brown calcareous clay with a somewhat cubical structure. The aggregates and root and insect holes are lined with darker colored colloidal stains. At a depth ranging from 15 to 60 inches this layer rests on bedrock of shale that is shattered and has considerable segregated lime in the cracks in the upper part, although the bedrock proper is noncalcareous.

Despite the heavy texture, drainage is good throughout the entire soil mass. The moisture-holding capacity is high, although the content of organic matter is not great. This soil is resistant to erosion even on fairly steep slopes.

This soil is used for dry-farmed grain and grain hay and for range pasture. In favorable seasons yields and quality are high. Slopes with a gradient of 35 percent can be cultivated for grain under the system used in this area without any more erosion than occurs on adjacent areas used for range pasture. Even areas of as much as 45-percent slope are being successfully farmed under careful management. In the vicinity of Altamont and northward this soil has been farmed since the late fifties, and at present it does not appear to be any more eroded than adjacent areas that have been pastured during the same period.

Along the boundary of Contra Costa County (2) the texture becomes lighter and the slopes steeper and this soil merges with areas of Altamont clay loam, steep phase, as mapped in that county.

Altamont adobe clay, steep phase.—This soil is represented by areas of Altamont adobe clay in which the slope exceeds 40 percent. Like the steep phase of Altamont clay loam, the soil materials are similar to those of typical Altamont adobe clay, but the profile is of more heterogeneous and less consistent character.

Although this soil is resistant to erosion, and the steep slopes are successfully cultivated to grain and grain hay in this area, it is not recommended for cultivation and is more safely used for pasture.

LINNE SERIES

The soils of the Linne series are mineral pedocalic soils developed in place on sandstone, shales, and conglomerates. These soils occupy rolling or hilly land and are naturally covered with grass and a few scattered oak trees. The soils are immaturely developed; that is, they do not have clearly defined developed layers.

The surface soils are brownish-gray, dark brownish-gray, or dusky-brown calcareous material of medium-heavy or heavy texture and rather characteristic blocky structure. The soils are very dark when wet and dry out considerably lighter, yet they are characteristically dark-colored soils. The surface material cracks into large blocks on drying, but with many secondary cracks it breaks down to a friable granular condition. The texture is clay loam or clay, and the material is sticky and plastic when wet. It is well permeated by roots. Drainage is good, and the presence of cracks causes the soil to absorb water readily and somewhat checks the runoff of rain water. The soils range from mildly to strongly calcareous. The areas of deeper soils near the base of the slopes in many places are only mildly calcareous, whereas on the upper parts of the slopes and tops of the ridges they are strongly calcareous. A few rock fragments, coated with lime, are in the surface layer.

The upper subsoil layers are brownish-gray calcareous material of possibly slightly heavier texture than the surface soils. They are well permeated by roots in no definite pattern. The root holes and faintly developed structural aggregates have a little colloidal staining on them, and in a few places a little segregated lime occurs. The clods are soft and easily crumbled to a soft granular structure. The quantity of rock fragments increases with depth.

The lower parts of the subsoils are light brownish-gray or light yellowish-brown calcareous material of slightly heavier texture and some structural development. The material in these layers breaks into irregular-shaped clods that have definite darker colored colloidal coatings and are not very firm but can be crushed with moderate pressure. Roots penetrate the material freely. Some segregated lime occurs along the root channels and worm holes and on the surfaces of some of the aggregates.

The upper part of the bedrock of sandstone, shale, or conglomerate generally is well decomposed and soft to a depth of a foot or more. The rock fragments are coated with lime, and some of the soil material has worked down into the cracks. The sandstone and shale are light-colored, generally light gray or yellowish gray, and the conglomerate consists of fine-grained sandstone or shale with rounded gravel of harder sandstone or basic igneous rocks. Only a small proportion of the Linne soils of this area are derived from conglomerate.

The depth of the soil mantle over bedrock is extremely variable, ranging from less than a foot to more than 5 feet, with an average depth between 2½ and 3 feet.

These soils, like those of the Altamont series, are fairly resistant to erosion. They are used for grain, grain hay, and pasture, and produce favorable yields of high-quality products. The Altamont soils are slightly more resistant to erosion than those of the Linne series, but both are fairly resistant, except where they occur in faulted areas where the bedrock is shattered to a great extent. In some places these soils are severely gullied along the contact with the soils of the Vallecitos series south of Corral Hollow Creek, where the southwestern slopes are deeply gullied. The bedrock here is greatly shattered, and the dip to the eastward causes the gullies to cut deeply on the western slopes.

Very narrow areas of included alluvial soil in drainageways, too small for mappable units, show the effect of soluble salts in the drainage waters.

This is a well-established series of soils, having been mapped extensively along the eastern slopes of the Coast Ranges. Two soil types and two phases of this series occur in this area.

Some of the bodies have somewhat darker colored surface soils than are typical of the Linne soils, and represent material transitional to the related soils of the Zaca series.

Linne clay loam.—The surface soil of this type is brownish-gray or dark brownish-gray calcareous soft cloddy clay loam, becoming distinctly darker when wet. On drying it checks and cracks into blocks that break down rather readily to a granular mass, but it is very sticky and plastic when wet.

At a depth ranging from 8 to 24 inches the surface soil grades into a subsoil of heavy clay loam or clay that is but little more compacted than the layer above. It breaks into clods that are irregular in shape and are readily broken down to a friable granular structure. This subsoil becomes lighter in color, and it may have considerable segregated lime in the lower part.

The bedrock of sandstone or shale is reached at depths ranging from 12 to 60 inches. The upper part is rather soft and has some segregated lime in the cracks. Rock fragments, most of which are coated with lime, occur in most places throughout the soil mass, and the quantity increases with depth. Normally, in this area the bedrock proper is not calcareous.

Linne clay loam is not extensive and is somewhat more erosive than Linne adobe clay. This soil is used for dry-farmed grain, grain hay, and pasture. Yields and quality of crops are fairly good in favorable seasons, although the yields are not so high as on Linne adobe clay.

Linne clay loam, rock-outcrop phase.—This phase is similar in internal soil characteristics to typical Linne clay loam, but it is more variable in depth and may be slightly lighter or heavier in texture. Although all soil types of this series include some rock outcrops, the rock-outcrop phase is mapped only where 25 percent or more of the area is made up of rock outcrops.

The soil is calcareous throughout. It is brownish gray or dark brownish gray and has physical properties similar to those of the typical soil. The subsoil is less compact and heavy in many places, and the relief is more rugged. The greater part of the outcropping rocks in this phase are sandstone. None of this soil is under cultivation, the soil being used entirely for range pasture.

Linne adobe clay.—The surface soil of this type is dark brownish-gray calcareous clay with a characteristic blocky structure. It is very dark when wet but dries to a distinctly lighter gray color. It cracks into large adobe blocks that develop numerous secondary cracks breaking the material down to a fine-granular structure (pl. 2, *B*).

The subsoil lies at a depth ranging from 8 to 26 inches below the surface. It is lighter colored and is slightly more compact than the surface soil. It is strongly calcareous, in many places containing considerable segregated lime. The material in this layer is also very friable and breaks into clods that are easily crumbled.

The upper part of the bedrock lies at a depth ranging from 12 to 60 inches, is generally soft, and has considerable segregated lime along the seams and cracks, although the bedrock proper is noncalcareous. Just west of Patterson Pass in a small body of this soil many large oystershells are found on the surface and throughout the soil.

This soil contains a fair or moderate amount of organic matter and has a high water-holding capacity. Drainage is good, and, although the soil is resistant to erosion, it seems to erode a little more readily than Altamont adobe clay under similar conditions.

Linne adobe clay is used for range pasture and dry-farmed grain and grain hay (pl. 3, *A*). The yields and quality of the crops are fairly high. Slopes of 35 percent or slightly more are being cultivated with fair success without excessive erosion, although in a few areas slopes of 35 to 40 percent are eroding rather badly. Some areas along the contact between this soil and the soils of the Vallecitos series south of Corral Hollow Creek are severely gullied. The gullies have been developed in localities where the bedrock has been shattered and weakened as a result of faulting.

Linne adobe clay, steep phase.—This phase is represented by areas of Linne adobe clay in which the average slope exceeds 40 percent. The surface soil and subsoil materials have been somewhat more mixed and the soil profile is less definite and uniform than in typical Linne adobe clay, but otherwise this soil differs only in the steeper slope.

This soil is resistant to erosion, owing to its favorable texture, structure, and grass cover. The slopes are so steep that they are unfavorble to or prohibit effective use of farm machinery and of necessity limit the use of the soil to grazing.

KETTLEMAN SERIES

The soils of the Kettleman series are mineral pedocalic soils developed on sandstone and shale bedrock. The soils are youthful or immature; that is, they do not have very distinct surface soil and subsoil layers. They occur on gently rolling or hilly relief and are shallow, in few places having a greater depth to the crumbling bedrock than 30 inches. Normally the soils are covered with native grasses or low brush and grass. These soils are light colored and calcareous throughout. Drainage is free, and on steep hillsides erosion is excessive.

The surface soils, to a depth of not more than 15 inches, are very light brownish-gray, very pale brownish-gray, or light yellowish-brown calcareous friable material. They contain many grass roots throughout and have no definite structure. The material is soft and friable, and the soft clods of even the heavier textured members are easily crumbled to a granular condition. Angular rock fragments occur throughout the entire soil mass and increase in quantity with depth.

The subsoils are very light brownish gray or, in many places, very light yellowish brown. The subsoils are highly calcareous, and they may show incipient development of a profile. Where any cloddy structure is developed the clods are very soft and friable because of the presence of so much disseminated lime. The texture of the subsoils may be slightly heavier than that of the surface soils, but this difference is not very apparent. Some segregated lime occurs in the subsoils, and the rock fragments are heavily coated with lime.

The upper part of the bedrock is very soft and crumbly and very calcareous, with lime segregations extending down the cracks and seams to the more firmly consolidated bedrock, which in general is noncalcareous. Many gypsum crystals are found in the cracks in the bedrock in some areas of the soils of this series.

The Tracy area represents the northern limit of the occurrence of the soils of the Kettleman series, which border the San Joaquin Valley from here southward. As mapped in this area, in a few locations these soils are only faintly calcareous in the topmost few inches. Two small bodies of soils of this series occur just south of Mountain House, and the remainder extends from Corral Hollow Creek southward, with by far the largest acreage occurring in the extreme southern part of the area.

The seepage waters from these soils are somewhat saline, and salt incrustations occur along the narrow drainage channels.

These soils are very erodible and gully badly, and a fairly delicate balance seems to exist between the amount of vegetal cover and the degree of erosion. On areas where these soils occur on both northern and southern exposures, erosion on the southern exposure is much greater than that on the northern. Most of the perpendicular-sided gullies cut deep into the soft bedrock. Where fault lines occur in the parent rocks these soils are badly gullied, in many places to the point of almost complete removal of the soil mantle and upper part of the soft bedrock. These severely eroded areas are generally under a grass cover. The brushy cover grows on areas of shallower soil with somewhat harder bedrock, and the gullies are less numerous and less deep. A few small areas are included with the Kettleman soils, in which the surface soils are somewhat darker and browner and have been leached of lime. They occur mainly on the northern and eastern slopes, which are to some extent protected from the more severe conditions of evaporation and drought. The soil materials tend to be somewhat thicker, and they support a vegetation in which shrubs and scattered scrub oaks are more numerous. These areas represent a soil development transitional between the Kettleman soils and the Altamont soils, but they are inextensive, are subject to erosion if overgrazed, and have the same limitations in use as the typical soils of the Kettleman series.

Two types and one phase of the Kettleman series are represented in this area.

Kettleman fine sandy loam.—The 10- to 12-inch surface soil of this type is very light brownish-gray or light yellowish-brown fine sandy loam that is calcareous, soft, and friable. Below this the color becomes still lighter brownish gray, in many places with a yellow cast. The texture may or may not change with depth. Very little evidence of a distinct subsoil is apparent, except for an increase in the content of lime with depth. In many places in the subsoil both segregated lime and gypsum are present. This soil in most places is rather shallow, in few places exceeding a depth of 30 inches to the soft light-gray sandstone bedrock. The upper part of the bedrock is generally crumbly and contains considerable segregated lime in the cracks. The bedrock proper, however, is generally noncalcareous.

This soil occupies fairly steep hilly land and in many places is subject to severe gully erosion. The normal cover is grass and low-growing brushy shrubs, and in this area the soil is only used for range pasture. The forage produced is not so heavy as that on the soils of the Altamont and Linne series. This soil is not quite so extensive as Kettleman clay in this area.

Included with Kettleman fine sandy loam is a small body of soil that, although definitely derived from Kettleman fine sandy loam, appears to occupy a truncated fan that is so severely gullied as to have very uneven relief. This small body occurs at the mouth of Corral Hollow Creek and joins the larger body of Kettleman fine sandy loam that lies immediately to the south. If it were more extensive this small inclusion would probably be separated as a soil of a different series. As it is badly dissected by erosion and indefinite in profile characteristics, yet definitely of the same character of material and has the same use, it is included in mapping with Kettleman fine sandy loam.

A few small areas occupying northern slopes bordering Lonetree Creek in the southern part of the area, in which the surface soil is of slightly darker and browner color, are also included. In these the surface soil has a somewhat higher organic-matter content, and in most places is leached of lime to a depth of a few inches. The native vegetative cover is somewhat heavier than in the areas of typical Kettleman fine sandy loam, and shrubs and scattered oaks are more abundant.

Kettleman fine sandy loam, rock-outcrop phase.—This soil is generally considerably shallower than typical Kettleman fine sandy loam, and it varies considerably in texture, some areas having a clay loam texture. Rock outcrops are numerous, and the soil between the outcrops is very shallow. Nearly all of this soil is covered with low brushy shrubs, and it affords only fair pasture at best. It occupies rough hilly land and has no possibilities for improvement by controlled grazing.

In a few small bodies between Hospital and Lonetree Creeks in the southern part of the area the surface soil is slightly darker.

Kettleman clay.—The 12- to 14-inch surface soil of this type is light brownish-gray or very light yellowish-brown calcareous very friable clay. In general the subsoil is slightly lighter in color, in many places having a distinct yellow cast. It may be slightly heavier in texture, and it shows a slight tendency to break into clods. With depth the quantity of lime increases and the color becomes slightly lighter, and in a few places at a depth greater than 2 feet bedrock of fairly soft crumbly shale is reached. The lower part of the subsoil and the upper part of the crumbling bedrock contain much segregated lime and some crystalline gypsum, although in most places the solid bedrock below is noncalcareous.

This soil occupies steep or hilly land and is used only for range pasture. The natural cover is grass or low brushy shrubs and grass. Erosion is severe in places, gully erosion being more pronounced than sheet erosion.

This soil is normally deficient in organic matter and seems to have a fairly low water-holding capacity. It does not support a very luxuriant growth of grass, but the grass growth appears to be a little earlier on this soil than on the associated soils, and it tends to dry first in the late spring. The amount of forage produced is slightly more than on Kettleman fine sandy loam but is less than on the soils of the Altamont and Linne series.

Small included areas on the northern and eastern slopes, with shrub and scrub oak vegetation, have a slightly darker surface soil than the typical Kettleman soils.

LOS OSOS SERIES

The soils of the Los Osos series are pedalferic soils developed on materials left by the decay of sedimentary rocks—in this area mostly from sandstone conglomerate. The sandstone material is medium to strongly acid in the weathered part, and the embedded rounded gravel consists of harder sandstones together with some basic igneous rocks. The basic igneous rocks are very hard, and it is doubtful whether any appreciable quantities of them have disintegrated and contributed to the soil mass.

These soils occur only in a few scattered bodies south of Patterson Pass and are surrounded by soils of the Altamont and Linne series. Like those soils, they are grass-covered and have rolling to hilly relief. The soils are immature and are not typical of the Los Osos soils in areas where they occur more extensively. They are somewhat grayer and possibly a little darker. In fact, they are intermediate between the Los Osos and Cayucos soils but are more closely related to the former.

The surface soils are medium-gray, dark brownish-gray, or brown noncalcareous rather coarse textured materials that bake somewhat on the surface when dry but are easily broken down to a fine-granular condition when disturbed. A few rounded pieces of gravel are found on the surface and throughout the soil mass. Roots and moisture penetrate the soil readily. These soils are rather shallow, in few places exceeding 3 feet in thickness. The surface layers are moderately acid, having pH values of about 6.0. The subsoils are brown soft cloddy moderately acid materials (pH value 5.5 or less) having a slightly heavier texture than the surface soils. The sandstone conglomerate bedrock is light grayish yellow with embedded dark gravel. The sandstone material has a pH value ranging from 5.5 to 6.5. It has a few cracks, into which some of the soil material has worked down.

These soils are used entirely for range pasture but do not support such a luxuriant grass cover as the Altamont and Linne soils. Erosion is moderate—mainly sheet erosion with very little gullying.

Only one type in this series, Los Osos sandy loam, is mapped.

Los Osos sandy loam.—The surface soil of this type to a depth ranging from 6 to 18 inches is dark-gray or dark brownish-gray noncalcareous rather coarse textured sandy loam. It crusts over somewhat on the surface when dry, but the material breaks down readily to a fine-granular structure. The reaction is slightly or moderately acid, the pH value ranging from 5.8 to 6.5.

The subsoil, to a depth of 15 to 40 inches, is brown friable sandy loam with possibly a very slightly heavier texture than the surface soil. A few colloidal stains line some of the root or worm holes. This layer is moderately acid, with a pH value ranging from 5.0 to 5.6.

The upper part of the sandstone conglomerate bedrock is soft and crumbly. It is penetrated to some extent by roots, but not nearly so much so as the soil material in the layers above. This crumbling bedrock is generally very acid, with a pH value ranging from 5.5 to 6.5.

Some well-rounded gravel is on the surface and throughout the soil mass. This gravel consists mainly of hard sandstone, quartzitic, or crystalline rocks.

This soil occurs only in a few small bodies, surrounded by areas of the Linne and Altamont soils, in the western part of the area just south of Patterson Pass. The native vegetation is grass, but the stand is not so good as on the Linne and Altamont soils.

As mapped in this area this soil is a little darker than is typical of the soils of this series. Its only use is for range pasture. The relief is rolling or hilly, and erosion is slight or moderate—mostly sheet erosion.

CONTRA COSTA SERIES

The soils of the Contra Costa series are shallow pedalferic soils overlying light-colored sandstones and sandstone conglomerates in rolling to hilly areas. The soils are moderately or strongly acid and do not have well-defined heavier subsoils. Rock outcrops occur in places (pl. 3, *B*). The cover is native grasses. These soils occur as small scattered bodies surrounded by Altamont and Linne soils. The depth of the soils in few places exceeds 30 inches. Where the underlying bedrock is sandstone conglomerate, rounded gravel is present on the surface and throughout the soil mass. This gravel consists of pebbles of hard sandstone, quartzitic, and basic igneous rocks. The latter two are very hard, and it is doubtful whether they have weathered sufficiently to contribute any fine material to the soil mass.

The 6- to 12-inch surface soils are light brown or light reddish brown, and the structure is indefinite. The material bakes rather hard on drying but is easily crushed to a granular or single-grain condition. The reaction is acid but is rather variable, the pH value ranging from less than 5.0 to about 6.0. These soils are well penetrated by roots and have good drainage. The subsoils are strong brown or light reddish brown and have a soft friable consistence. They show very little evidence of concentration of clay and colloids, although a few colloidal stains are present in places. The subsoils are slightly more acid than the surface soils, and they contain many fine plant roots throughout. The bedrock of yellow sandstone or light-colored sandstone conglomerate is fairly soft in the upper few inches and in many places is streaked with shinv dark-colored manganese stains. Some of the soil material and plant roots extend down into the cracks in the bedrock.

The grass cover on these soils is not so heavy as on the Altamont and Linne soils. The Contra Costa soils are more subject to sheet erosion, but they do not gully very badly. These soils are not extensive. Besides the areas mapped, a few small spots, too small to be differentiated on the scale of mapping used, occur throughout the Altamont soils in the northern part of the area.

Two types of this series, Contra Costa sandy loam and Contra Costa loam, are mapped in this area.

Contra Costa sandy loam.—The surface soil of this type, to a depth ranging from 5 to 15 inches, is light-brown or light reddish-brown moderately or strongly acid sandy loam that crusts on the surface but breaks to a granular or single-grained structure with slight pressure. The subsoil is strong brown or light reddish-brown of slightly redder or richer color than the surface soil. It has about the same texture as the surface soil and is loose or friable and rather strongly acid, with a pH value ranging from 5.0 to 5.5. The bedrock of light-colored sandstone or sandstone conglomerate occurs at a depth ranging from only a few inches to more than 30 inches below the surface in a few places. The upper part is soft and crumbly and in many places is streaked with dark-colored shiny manganese stains. The crumbly bedrock is generally strongly acid. It is either sandstone or sandstone conglomerate. Where it is conglomerate some rounded fragments of gravel of hard sandstone and crystalline rocks are scattered over the surface and throughout the soil mass.

Contra Costa sandy loam occupies rolling hilly land surrounded by soils of the Altamont or Linne series. It occurs in small bodies scattered throughout the western and northwestern parts of the area. It supports a growth of native grasses about equal to that on the Los Osos soils but inferior to that on the Altamont and Linne soils. The land is used only for range pasture.

Erosion, particularly sheet erosion, is more active on Contra Costa sandy loam than on the soils of the Altamont and Linne series.

Included with this soil are a few small areas in which the soil material is shallow and 25 percent or more of the surface consists of outcrops of massive sandstone, in many places occurring as ledges. Therefore the relief is somewhat more irregular than that of the typical soil.

Contra Costa loam.—The surface soil of this type is light brown or light reddish-brown moderately acid loam or heavy loam that crusts over to a rather great extent on drying and breaks into moderately firm clods or lumps of irregular shape. At a depth ranging from 6 to 16 inches is a slightly richer colored subsoil of similar or slightly heavier texture. This layer generally shows slight evidence of profile development, with some colloidal stains lining the root and worm cavities. The reaction is acid, the pH value ranging from 5.0 to 6.0. The bedrock of rather fine grained light-colored sandstone or sandy shale occurs at a depth ranging from 12 to 36 inches below the surface. The upper part is soft and is somewhat penetrated by roots, although they are not so numerous as in the soil material above. The reaction is acid, the pH value ranging from 5.0 to 6.0.

This soil occupies rolling or hilly land surrounded by soils of the Altamont and Linne series. It occurs in small bodies, few of which exceed 40 acres in extent. It supports a native vegetation of grasses. The cover is heavier than on Contra Costa sandy loam but not so heavy as on the Altamont and Linne soils.

This soil is not so resistant to erosion as the Altamont and Linne soils. It is subject to both gully and sheet erosion. It is used only for range pasture.

VALLECITOS SERIES

The soils of the Vallecitos series are developed in place on a complex of sedimentary and metamorphic rocks with some included igneous materials. These rocks, according to Anderson and Pack (*1*), make up the Franciscan formation and are probably of Jurassic age. This is the oldest formation in the Diablo Range. The rocks consist of sandstones and shales that have undergone some metamorphism, cherts, schists, and some igneous material that is mostly basic.

These soils occupy hilly or mountainous land with sharp narrow ridges and steep sloping sides. The crests and southern and western slopes of the ridges are covered with grass and scattered oaks, with here and there an area of brush (pl. 1, *B*). The northern and eastern slopes are fairly well wooded with oaks, pines, and junipers with a grass undercover. These soils are very shallow and many angular hard rock fragments of flat metamorphosed shale and irregular-shaped cherty material occur on the surface and throughout the soil. In most places the depth of the soil ranges from 10 to 20 inches but a few areas on the northern slopes are considerably deeper and have heavier subsoils. The latter areas may be as much as 5 feet deep.

The surface soils are pale brown or light brownish gray when dry, but when moist they are somewhat darker and browner. The structure is rather indefinite, and the material breaks into soft irregular-shaped clods. These soils have many roots throughout the entire soil mass.

The subsoils are slightly richer or browner in color than the surface soils, especially when wet, although they are generally just a trifle lighter in color. Some evidence of concentration of clay and colloids is present in the subsoils. The aggregates are a little firmer and have some faint colloidal coatings, and the root holes are lined with colloidal stains. The entire soil mass is mildly acid, with slightly greater acidity in the surface soils.

In a few scattered spots the soil material is deeper. Here the subsoil is considerably redder than the surface soil, and definite colloidal stainings occur on the well-defined irregular-shaped angular clods, which are firm when dry but soften readily when moist. These spots do not have so many rock fragments throughout the soil, and their difference is probably due to differences in the characteristics of the bedrock, which is considerably softer under these areas. These bodies are not numerous and are very small, few exceeding 3 acres in extent in any one body. Hence they are too small to map separately. The bedrock is badly shattered, and soil material and plant roots extend down into the upper part of it. Although the bedrock is generally noncalcareous, in places a little lime occurs along the cracks in this part of it.

Despite the steep slopes, these soils are not very erodible. The flat shale rocks and other rock fragments seem to be effective means of preventing erosion.

Because of their mountainous relief, shallowness, and stoniness, these soils cannot be used for cultivated crops, but they afford rather favorable range pasture for cattle. Some of the more grassy and brushy slopes are pastured to sheep, but the wooded areas are not so much used for sheep pasture, because they are badly infested with predatory animals, such as coyotes, foxes, wildcats, and even mountain lions.

Two types and one phase of this series are mapped.

Vallecitos stony loam.—The 4- to 8-inch surface soil of this type is pale-brown or light brownish-gray noncalcareous stony loam. The stones are angular fragments of somewhat metamorphosed sandstone and shale in addition to some crystalline rocks. The fine soil material is friable, but its structure is masked by the rock fragments. The reaction is slightly acid, from pH 5.8 to 6.5. The subsoil is somewhat lighter and very slightly richer in color, being pale-brown or light yellowish-brown clay loam. Many rock fragments occur, and the material is slightly compact. Many roots penetrate this layer, and many of the root and worm cavities are lined with colloidal stains. The material in this layer is generally about neutral in reaction. The parent bedrock of shattered angular rock fragments is reached at a depth ranging from 10 to 24 inches and in most places extends to a depth of several feet. Some of the soil material from the layer above has worked down into the cracks to a considerable depth. A few roots work their way down into these cracks, but they are not nearly so numerous as in the layers above.

In a few places along the slopes the soil is much deeper. In such places the subsoil is fairly heavy and is brownish red.

This soil is distinctly brownish gray or pale brown when dry, but during the rainy season it is distinctly brown.

This soil occupies steep hilly land. The northern and eastern slopes are well wooded with oak, pine, and juniper, with a grass undercover, whereas the southern and western slopes support a scattered growth of oak with some brush and grass. The large quantity of rock fragments and the grass cover seem to protect the soil fairly well against erosion, which is only slight, in spite of the steep slopes that average 40 percent or more.

This soil is extensive in the southwestern part of the area but is not so extensive as Vallecitos stony clay loam. It is used only for range pasture, mainly for cattle. In the wooded areas numerous coyotes, foxes, wildcats, and some mountain lions take a heavy toll of sheep when they are pastured on these areas.

Vallecitos stony clay loam.—The 4- to 10-inch surface soil of this type is pale-brown or light brownish-gray stony clay loam containing many angular fragments of metamorphosed sandstones and shales and some crystalline rocks. It breaks into irregular clods. The entire soil material is slightly acid, the higher acidity being in the surface soil. This layer is well penetrated by roots and water. The subsoil, to a depth ranging from 12 to 24 inches, is somewhat heavier in texture and is pale brown, light yellowish brown, or in a few places, rich brown or reddish brown. It consists of heavy clay loam or clay and is somewhat more compact than the surface soil. It breaks into irregular-shaped units or clods that are coated with thin colloidal stains, and root channels and worm casts are lined with colloidal stains. The quantity of rock fragments increases with depth. The bedrock is shattered to a depth of several feet, and some soil material and plant roots occur in the cracks.

On most of the narrow ridge crests this soil is very shallow, but it is somewhat deeper along the slopes, in a few areas as much as 5 feet deep. In such places the subsoil is considerably heavier in texture and much redder than the typical soil.

Vallecitos stony clay loam is distinctly brown when wet but generally pale brown or brownish gray when dry. It occupies steep hilly areas and supports a fairly heavy vegetative cover. The northern and eastern slopes are wooded with small oaks, pines, and junipers, together with a good grass undercover, and the ridge tops and southern and western exposures support grass, brush, and some scattered oaks. The soil is extensive in the southwestern part of the area.

Some of the more open areas are pastured by sheep, but the more wooded areas are pastured almost entirely by cattle. The wooded areas are heavily infested with predatory animals that take too heavy toll of sheep.

Erosion is very slight despite the very steep slopes.

Vallecitos stony clay loam includes areas in which the soil is very stony and includes many outcrops of hard metamorphosed rocks, mostly sandstones and shales. These areas are indicated on the soil map by rock-outcrop symbols. The soils are very shallow. The soil is covered with brush and grass, but the cover is not very heavy.

Erosion is slight, although the slopes are moderately steep. The areas of rock outcrop are not very extensive.

Vallecitos stony clay loam, steep phase.—This phase conforms closely in characteristics with typical Vallecitos stony clay loam except that the soil profile is somewhat less uniform and the depth of the soil material is somewhat shallower. The slopes are steep, dominantly more than 40 percent. The areas are somewhat more susceptible to erosion than the typical soil, but most of them are protected by vegetation. This soil has nearly the same use and value as typical Vallecitos stony clay loam.

SOILS OF THE RECENT ALLUVIAL FANS

SORRENTO SERIES

The soils of the Sorrento series occur extensively on the alluvial fans of Corral Hollow, Lonetree, and Hospital Creeks and a number of smaller creeks. They are recent or young; that is, the soil material has been deposited in comparatively recent times and has been modified comparatively little since deposition. Considerable variation, however, occurs within very short distances. In some places the very recent deposits have little or no evidence of soil development, although the surface soils and the subsoils contain no lime. In other locations the subsoil material is slightly compact, with some evidence of development of structural units having colloidal stains along root channels. These units are very unstable, however, and are of soft consistence. The building up of the fans by intermittent streams, which change their courses from time to time, leaves parts of the fans without deposition of fresh material for some time and gives an opportunity for slight profile development, whereas other parts of the fans are subject to more frequent deposition of sediments. The recurrent flow of the stream courses back and forth across the fans accounts for the minor differences in profile development in soils of this series.

The surface soils are pale brown or medium to light brownish-gray noncalcareous soils of indefinite structure. Under proper management they retain excellent physical properties, but they are easily puddled if poorly managed. Plow soles, which greatly inhibit the penetration of roots and water, are formed if the soil is too wet when cultivated. These soils are normally low in organic matter and about neutral in reaction.

The subsoils are slightly lighter in color, generally brown or light brown, with little consistent relation in texture to that of the surface soils. They are stratified in many places and are freely penetrated by roots and water. They are calcareous at a depth of 20 to 40 inches and may show slight colloidal staining. In many places a little segregated lime lining the root holes shows a mycelial pattern.

The underlying substrata, to a depth of many feet, consist of light-brown calcareous stratified alluvial deposits of variable texture, ranging from gravelly to clayey deposits, with the medium or medium-heavy textures predominating in this area.

These soils are subject to deposition rather than erosion. Even at present, the waters of such streams as Corral Hollow, Hospital, and Lonetree Creeks are spreading over these soils during the rainy periods, so that they are being slowly built up even under cultivation.

The fans have very gentle slopes—from 1 to 5 percent. Drainage is excellent throughout, and rain and irrigation waters readily enter the soils except where they have been puddled or a tight plow sole has developed. Despite their occurrence in a section of low rainfall, these soils are free from injurious quantities of soluble salts, yet they contain sufficient nutritive material, with the possible exception of nitrogen, for vigorous plant growth. Where these soils are intensively farmed, nitrogen fertilizers have given profitable returns.

The soils of this series are the best within this area for general agricultural purposes. They are suitable for a wide range of orchard and field crops. Seven types of this series are mapped in the area.

Sorrento loam.—The surface soil of this type is pale-brown or medium to light grayish-brown noncalcareous friable loam of rather light fine sandy texture. It may have a soft clod structure that breaks down readily, although a plow sole is formed if the soil is cultivated when its moisture content is excessive. At a depth of 15 to 36 inches is the slightly lighter colored subsoil. This layer is of variable but generally of medium or rather coarse texture. It is loose, friable, and calcareous. In places the upper part of this layer is noncalcareous, and where the subsoil is rather coarse textured it may be only mildly calcareous. At a depth ranging from 4 to 6 feet a substratum of calcareous stratified sediments is present, which in most places extends to an undetermined depth. Some rounded gravel may occur in some of the layers of the subsoil and substratum of this soil.

This soil is open throughout, and roots and water penetrate it freely. Most of it occupies fairly narrow ridges bordering stream channels. Although rather low in organic matter, the soil has fair water-holding capacity. It has excellent physical characteristics and is one of the best agricultural soils of the area. Under irrigation it is used for a wide variety of field crops producing excellent yields of high quality. Beans and alfalfa are grown extensively on this soil. Although orchard crops are grown to only a small extent in this area, most of them are grown on this soil and Sorrento clay loam.

Where not irrigated this soil is used mostly for dry-farmed grain. Although very satisfactory yields are obtained, the soil is not considered quite so good for dry farming as some of the heavier textured members of this and of the Rincon series.

This soil occupies smooth gently sloping alluvial fans, but some leveling must be done before it can be successfully farmed under irrigation. It is not so extensive as some of the other soils of the Sorrento series.

Sorrento clay loam.—The surface soil of this type is brownish-gray or pale-brown noncalcareous fairly friable clay loam of rather light texture. It is easily puddled, and a plow sole is formed when the soil is worked too wet. It commonly breaks into rather soft clods and is readily worked to a fine granular condition under cultivation. The subsoil, which occurs at a depth of 1 to 3 feet, is somewhat lighter or paler brown friable calcareous material of variable texture but in most places similar to that of the surface soil. Lime generally occurs in disseminated form and normally is found at a depth of 20 to 30 inches. In a few places thin streaks of segregated lime coat the fine root cavities. The substratum, occurring at a depth of 4 to 6 feet below the surface, is similar to the subsoil in color and is composed of stratified sediments of variable textures. It extends to a depth of 15 feet or more.

This soil is rather low in organic matter, but it has about the same agricultural use as other soils of the Sorrento series, and it produces excellent crops under irrigation, or under dry farming in favorable seasons. This soil is somewhat more extensive than Sorrento loam and occurs in larger bodies, hence it is probably a little better all-around soil for agriculture than Sorrento loam and is the best farming soil of this area.

It occupies smooth gently sloping alluvial fans generally favorable for effective irrigation. Despite the smooth slope, however, some leveling must be done before water can be properly distributed for irrigated crops. Although this soil is not so extensive as either the silty clay or clay types of the series, several fairly large bodies occur in the central part of the area.

Sorrento gravelly loam.—The surface soil of this type is grayish-brown soft cloddy noncalcareous gravelly loam to a depth of 1 to 3 feet. The subsoil also is gravelly and in many places is stratified. It is mildly calcareous but fairly loose throughout, although the presence of the gravel gives it the appearance of some compaction. The substratum is composed of brown or grayish-brown calcareous stratified sediments that in most places are gravelly.

This soil differs from Sorrento loam mainly in the gravel occurring throughout the soil material, although as a rule it has less lime in the subsoil. This soil is not extensive and occurs in rather small bodies in the southeastern part of the area. Its agricultural use is similar to that of the other soils of the series. The gravel generally is rather fine, few pebbles exceeding 2 inches in diameter, and its principal hindrance to tillage implements is its dulling effect. This soil is slightly more difficult to work but only slightly less productive than Sorrento loam.

Sorrento silty clay.—The surface soil of this type, to a depth of 10 or 15 inches, is brownish-gray or pale-brown noncalcareous cloddy silty clay. The clods are irregular in shape but are easily broken into a granular tilth under favorable conditions of moisture and cultivation. The soil is fairly easily puddled, however, and forms a plow sole when worked too wet. The lower part of the surface soil, to a depth ranging from 18 to 30 inches, is very similar to the upper part, except that it is lighter in color and is somewhat more friable. The subsoil, to a depth of 4 or 5 feet, is calcareous friable material of variable texture. The lime is generally disseminated, but some thin streaks of lime line the fine root pores, and in places this layer may be slightly compact. The substratum, extending to a depth of many feet, is composed of stratified calcareous sediments that are loose throughout and readily penetrated by roots and water.

This soil is extensive on smooth alluvial fans from Tracy southward and is one of the more important agricultural soils of the area. Most of it is under irrigation, and excellent crops of a wide variety are produced. Beans and alfalfa are the principal crops. Winter peas are often planted and harvested on land planted later in the season to beans. Excellent yields of flax, sugar beets, and grain are also obtained. Yields on this soil are almost as good as those on Sorrento loam and Sorrento clay loam for most crops and may be even slightly higher for dry-farmed grain or winter peas. The somewhat heavier texture, however, makes this soil a little more difficult to manage and a little more expensive to operate.

Sorrento gravelly clay loam.—The surface soil of this type is brownish-gray gravelly clay loam that is easily puddled yet normally fairly friable. The subsoil is somewhat lighter in color, is calcareous, and is without consistent development of a profile. The substratum consists of stratified gravelly layers which are normally calcareous. This soil is highly productive and only slightly inferior to Sorrento silty clay. The gravel is not coarse enough to interfere greatly with tillage operations, yet it dulls implements and makes the soil slightly harder to work. Roots and water penetrate the soil freely.

This soil is not very extensive in the area. It occurs near the streamways on the upper part of the fans. Under irrigation it produces good yields of a wide variety of crops, and where no irrigation water is available it is used for dry-farmed grain and pasture. Satisfactory yields of grain are obtained in favorable seasons, and pasture grasses do as well on this soil as on any soil in the area.

Sorrento clay.—The surface soil of Sorrento clay is brownish-gray or brown noncalcareous clay that appears lighter colored and grayer when dry. It breaks into hard clods when dry, but these soften readily when moistened. The color of this soil is slightly darker and grayer than that of the other soils of this series, especially on the lower part of the alluvial fans. The lower part of the surface soil is somewhat more friable and of slightly lighter color than the upper part. The subsoil, occurring at a depth ranging from 18 to 36 inches, is brown calcareous clay that may have a little lime in fine threadlike streaks and may have very slight compaction. It breaks to irregular-shaped clods that are friable and may be easily broken down to smaller aggregates. The substratum, occurring at a depth ranging from 40 to 60 inches, is stratified heavy-textured calcareous friable material of brown or grayish-brown color.

Roots and water penetrate every part of the soil mass freely, and most field crops do very well. Yields of alfalfa are only slightly less than those on the lighter textured members of the series, and dry-farmed grain appears to do equally as well. The soil contains only small or moderate quantities of organic matter, but it has a fairly high moisture-holding capacity. Because of its heavy texture, it is more difficult to till than the lighter textured members of the series. It breaks into large hard clods when worked dry and puddles easily if worked too wet.

On the lower part of the fans, especially in the district between Banta and Tracy, this soil has a fairly high water table, which lies at a depth of approximately 2½ to 3 feet in the winter and 4 to 5 feet in the summer. Excessive irrigation on such a soil probably will cause a further rise in the water table.

Sorrento gravelly clay.—The surface soil of this type is brownish-gray or brown noncalcareous clay. It bakes and forms a hard surface crust on drying, breaks into hard clods, and easily develops a plow sole if worked too wet. The lower part of this layer is slightly lighter in color and somewhat more friable. The subsoil, occurring at a depth of 20 to 36 inches, is brown calcareous gravelly clay that shows very little if any evidence of development of a profile. The substratum is stratified calcareous gravelly material. Roots and water penetrate this soil a little more freely than they do Sorrento silty clay.

This soil occurs in small bodies in the central part of the area, associated with other members of the Sorrento series. It is slightly harder to work than Sorrento clay but is about as productive. Good yields of field crops are obtained under irrigation, and dry-farmed grain does about as well on this soil as on any soil in the area.

MOCHO SERIES

The soils of the Mocho series are very similar to those of the Sorrento series, except that they are calcareous throughout, whereas those of the Sorrento series are calcareous only in the subsoils. These soils are not very extensive in this area and occur only as narrow flood plains, principally along Patterson Run. The soil material is practically unmodified, with no evidence of development of a horizon of illuviation. The soil materials are stratified throughout with many layers of different-textured materials. These layers are very thin, in few places being more than 6 inches thick.

The surface soils are brownish-gray permeable calcareous materials and are freely penetrated by roots and water. The subsoils, extending to depths of more than 6 feet, are light brownish-gray calcareous materials that are highly stratified. The layers are very thin and are mostly coarse textured, but a number of layers, in few places more than an inch or two thick, of laminated silty material occur. Most of these thin layers are slightly darker colored and may represent old surfaces that have been covered by more recent overflows. There is no distinction between the subsoils and the substrata of these soils as mapped in this area.

Although this soil series was established in 1910 in the Livermore area (*8*), these soils have not been extensively mapped. Only one type, Mocho loam, is mapped here.

Mocho loam.—The 6- to 12-inch surface soil of this type is brownish-gray soft calcareous loam that is easily broken down to an almost single-grain condition. The subsoil and substratum consist of stratified layers of brownish-gray or grayish-brown calcareous sediments that are loose or friable. The texture is variable, and gravelly layers are present in many places.

Drainage is free to excessive, and there is little or no compaction in the subsoil. Roots penetrate freely.

Only a small acreage of this soil is mapped in this area, on a narrow flood plain along Patterson Run. A small part of the land is under irrigation. It is planted to alfalfa, and excellent yields are obtained. Where it is dry farmed to grain, yields are not quite so satisfactory as on the adjacent heavier textured Ambrose soils. The coarse-textured subsoil does not hold sufficient moisture to produce heavy yields under dry-farming conditions. The rest of this soil is in range pasture and supports a good cover of grass.

Mocho loam is subject to overflow, and new material is added almost every year. This would be an excellent soil for diversified crops if it occurred in larger bodies.

Included with this soil are several very small bodies of slightly heavier material of the same character, which has been washed in on older soil materials, possibly of the Rincon series. The surface material in most places is loam, and it overlies the older heavier textured soil at a depth ranging from 1 to 3 feet. These small bodies lie close to the rolling terraces that skirt the western side of the valley south of Corral Hollow Creek. They are used only as dry-farmed grain and range pasture, with satisfactory yields in favorable seasons. They would be fairly satisfactory under irrigation, but they cover only about 200 acres and are above the irrigation canals.

SOILS OF THE OLDER ALLUVIAL FANS

ZAMORA SERIES

The soils of the Zamora series represent mineral soils developed on old valley-filling materials derived from sedimentary rock sources. The parent materials, as they occur in this area, consist principally of outwash from the Altamont and Linne soils with possibly a little material from the Vallecitos soils. The Zamora soils are not extensive in this area, and all are near the mouth of Corral Hollow Creek, except one small body lying in the extreme northern part of the area along the Contra Costa County line. These soils are well drained and under natural conditions support a good growth of native grasses. They appear to represent an immature or intermediate stage of soil development.

The surface soils are brownish-gray or dull brown, with a distinctly richer color when wet. They break into clods that are rather soft and crumble readily to a coarse-granular tilth under cultivation. They are easily puddled, however, if worked or pastured while too wet, and the clods thus formed are firm and are broken down only with difficulty. Most areas of these soils contain considerable rounded gravel throughout the soil mass. They are freely penetrated by roots and water, and many roots and worm casts are found throughout both the surface soils and the subsoils.

The subsoils have a slightly lighter and richer brown color and are a little heavier in texture and more compact than the surface soils. The subsoil materials break into irregular-shaped somewhat angular clods that generally have faint colloidal coatings on their surfaces. Root and worm holes are lined with colloidal stains. Considerable well-rounded gravel occurs in this layer, especially in the lower part, and in many places the pebbles are covered with thin lime coatings, but the soil mass itself is noncalcareous.

For the most part the substratum is made up of stratified gravelly and sandy layers. The gravel may be lime coated. It consists principally of well-rounded hard sandstone and hard basic igneous rocks washed from the sandstone conglomerate rocks along Corral Hollow Creek. These soils are no longer subject to overflow but are entirely free from erosion. They occupy rather smooth fans or flood plains near the mouth of Corral Hollow Creek and have a slope of less than 2 percent.

They are above the main irrigation canals and are used mainly for dry-farmed grain and winter peas, yields of which are very good. The remainder of these soils are in pasture or are in areas where they are being excavated for the gravel in the lower layers.

These soils occupy a position below the terracelike areas of the Denverton and Olcott soils, although they are not outwash from these soils but form the apex of a fan starting at the mouth of Corral Hollow Creek. They lie above the soils of the Sorrento series and more closely resemble them than any other soils with which they are associated.

The quantity of gravel in these soils is greater than is normally expected for soils of this series. One type in this series, Zamora gravelly clay loam, is mapped in this area.

Zamora gravelly clay loam.—The surface soil of this type is dull-brown or dark dull grayish-brown noncalcareous friable gravelly clay loam. This soil has a fairly rich color when wet but dries to a dull rather dark color. When dry it breaks into rather soft clods that may be worked easily to a loose granular condition. It is easily puddled, however, and a plow sole is readily formed. The subsoil, which lies at a depth of 8 to 14 inches below the surface, is brown noncalcareous slightly more compact heavy clay loam. It breaks out rather cloddy, and colloidal stains coat some of the aggregates and line the root and worm holes. Although the soil material itself is noncalcareous, some of the pieces of gravel in the lower part of this layer are coated with lime. The substratum, occurring at a depth of 27 to 42 inches, is composed chiefly of stratified gravelly layers containing very little soil material. These extend to a depth of 40 feet or more.

This soil occupies a smooth gently sloping fan near the mouth of Corral Hollow Creek. No irrigation water is available, as the land is above the irrigation canals. Dry-farmed grain and winter peas are grown on this soil with favorable yields of both. If the land could be irrigated, yields only slightly inferior to those obtained on Sorrento gravelly clay loam might be expected. The quantity of gravel in this soil is more than is normal for soils of this series, and much of the soil is being excavated for the gravel in the lower layers.

Included with this soil in mapping is one small body, joining Contra Costa County to the north, that is not nearly so gravelly and has a slightly more compact subsoil than is characteristic of the gravelly soil just described. In a few places a little lime is present in the subsoil of this body, although for the most part the entire soil mass is noncalcareous.

Areas of this soil join with areas of Zamora clay loam in the Contra Costa area (*2*), in which pieces of gravel are less numerous.

RINCON SERIES

The soils of the Rincon series are developed on old alluvial outwash materials originating from sedimentary rock sources, mainly sandstones and shales. The soils in the southern part of the area are a little lighter colored and show the influence of material from the Vallecitos soils, whereas areas of these soils in the northern part of the area show more clearly the influence of the Altamont and Linne soils. The native cover is grass, which grows luxuriantly during the rainy season.

These soils occupy broad alluvial fans with streamways entrenched so that no new sediments are added. The surface is undulating or gently rolling with a very faint suggestion of hog-wallow microrelief. The slopes are gentle, few exceeding 2 to 3 percent. The banks of the drainageways have gentle slopes, and in dry-farmed areas these slopes and even the bottoms of the drainageways are planted to grain.

The profiles are moderately well developed, with definite horizons of compaction and accumulation of clay and lime. The surface soils are neutral to slightly acid in reaction, and the lower part of the subsoils and the substrata are calcareous.

The surface soils, to a depth in few places exceeding 15 inches, are brown or brownish-gray noncalcareous material, which is easily puddled and dries out to a hard crusted surface layer that breaks into clods. The color of these soils is generally very dull when dry, but during the rainy season they have a rich-brown color. Roots penetrate the soils well, and in an undisturbed condition or under proper management they absorb water readily. This layer, where not puddled, is fairly porous, with many root and worm holes throughout. The soils are naturally deficient in organic matter.

The upper subsoil layers, to a depth ranging from 20 to 30 inches, are brown or dark-brown noncalcareous somewhat compact clay or heavy clay loam with an irregular coarse blocky structure. The blocks are coated with colloidal stains. They are firm yet are easily penetrated by roots, although roots are not so numerous in these layers as in the layer above. The material in these layers softens readily when moist and under normal conditions does not greatly retard the penetration of water. These layers are noncalcareous but are alkaline in reaction where they grade into the layers below. In cultivated areas plow soles form readily in the lower part of the surface soils and upper part of the subsoils if worked at unfavorable moisture contents. These plow soles greatly retard the penetration of water into the soil.

The lower subsoil layers are distinctly lighter in color, being light brown, light grayish brown, or yellowish brown. They are calcareous, with large quantities of disseminated lime and some segregated lime occurring as seams. The soil aggregates here are smaller than those in the upper subsoil layers but are firm and more heavily coated with colloidal stainings. These layers contain fewer roots and root cavities but many small cracks. The aggregates break loose from the mass more easily than those in the upper subsoil layers, but the units are just as compact. The segregated lime is in seams and cracks, and in a few places some gypsum occurs with the calcium carbonate. The lower part of these layers is less compact, and at a depth ranging from 36 to 60 inches the material grades into the substratum, which is approximately the same or of slightly lighter color. This layer is friable, with very little segregated lime, and in most places it is of lighter texture.

Under irrigation these soils are farmed to beans, flax, and alfalfa, with moderate to fair yields, although alfalfa stands do not last so long as on the Sorrento soils. The Rincon soils are more extensively used for dry-farmed grain, and the yields are fair to good.

Because of their gentle slopes and the farming practices in this area, erosion is very slight. Under irrigation the fields are generally in alfalfa or flax, or are plowed rough and left cloddy during the rainy season. Under these conditions there is very little runoff. In dry-farmed areas the seedbeds are not worked down very smooth and the early planted grain soon forms a protective cover against erosion. The summer-fallowed fields are plowed rough and left that way so as to prevent runoff.

These soils in general are practically free from alkaline or saline salts and have adequate but slightly restricted drainage. Three types of this series occur in the Tracy area—Rincon clay loam, Rincon gravelly clay loam, and Rincon clay.

Rincon clay loam.—The surface soil of this type, to a depth of 8 to 14 inches, is grayish-brown or brown noncalcareous cloddy clay loam that normally is fairly friable, yet it bakes rather hard on drying and is easily puddled. When moistened by winter rains this soil has a distinctly richer color than when dry. The upper part of the subsoil, extending to a depth ranging from 20 to 30 inches, is brown noncalcareous rather compact heavy clay loam or clay with a coarse blocky structure. The aggregates are firm, and many of them are thinly coated with slightly darker colloidal stains. The lower part of the surface soil and the upper part of the subsoil in many places develop a rather hard plow sole when worked too wet or plowed too often to the same depth. The lower part of the subsoil, to a depth ranging from 36 to 50 inches, is light-brown calcareous cloddy clay having considerable compaction. The blocks are smaller than in the layer above but are of firm consistence and coated with colloidal stains.

Some segregated lime and in places a little gypsum appear in thin streaks in the cracks between the aggregates. The substratum, extending to a depth of more than 6 feet, is yellowish-brown calcareous stratified material, generally of lighter texture than the subsoil horizons. It is without accumulated clay and in few places contains segregated lime.

Despite the fact that the subsoil layers are hard when dry, they soften somewhat when wet, so that penetration of roots and moisture is fair throughout the soil mass. Although the content of organic matter is low, the moisture-holding capacity is good.

Much of this soil is used for dry-farmed grain. The yields are only slightly inferior to those on Sorrento silty clay. Under irrigation this soil is used mainly for beans, alfalfa, and flax. Yields of beans and alfalfa are not so good as on the Sorrento soils; but flax, which is a more shallow-rooted crop, seems to do about as well on this soil as on Sorrento silty clay. Because of this fact most of the flax is grown on soils of Rincon clay loam and on the Ambrose soils.

The surface of this soil is a little more irregular than that of the Sorrento soils, and more leveling is necessary where crops are to be irrigated. This soil occurs extensively on the broad alluvial fans between Carbona and Vernalis, and it is farmed intensively to both irrigated and dry-farmed crops. Erosion is very slight.

Rincon gravelly clay loam.—The 10- to 16-inch surface soil of this type is dark-brown or dull-brown gravelly clay loam that breaks into clods. The upper part of the subsoil, extending to a depth of 20 to 36 inches, is brown or dark-brown noncalcareous clay that is somewhat more compact than the surface soil and has faint colloidal stains. This material grades into a brown calcareous moderately compact layer of gravelly clay containing some segregated lime and colloidal stains. This layer extends to a depth ranging from 36 to 60 inches below the surface and grades into a yellowish-brown calcareous stratified substratum of lighter texture containing considerable gravel throughout. The compact subsoil softens somewhat on becoming moist, and roots and moisture penetrate it fairly well.

This soil occurs south and west of Carbona. It occupies a sloping alluvial fan surrounded by soils of the Denverton and Ambrose series. It occurs above the irrigation ditches and is used only for range pasture, although it could be used for dry-farmed grain.

The surface is gently sloping but with a few low mounds somewhat suggestive of a hog-wallow microrelief.

Rincon clay.—The surface soil of Rincon clay, to a depth ranging from 7 to 14 inches, is dull-brown or brownish-gray noncalcareous clay with irregular blocky ("adobe") structure. The blocks are large and firm, but they soften to a rather friable consistence when moist. This soil has a distinctly richer color during the rainy season. The upper part of the subsoil, extending to a depth ranging from 18 to 30 inches, is brown or dark-brown somewhat more compact noncalcareous clay with some evidence of vertical breaking. A small amount of colloidal staining is in evidence, and the layer has many roots throughout. The lower part of the subsoil is light-brown compact calcareous clay breaking into smaller blocks of somewhat cubical shape. The aggregates are firm, and colloidal coatings of somewhat darker color are numerous. Not so many roots are in this layer as in the layers above. Some segregated lime and some crystalline gypsum are present. At a depth ranging from 36 to 60 inches below the surface, this layer grades into a yellowish-brown calcareous stratified substratum of somewhat lighter texture containing little or no segregated lime.

Penetration of roots and moisture into the subsoil is somewhat restricted, and therefore this soil is not so well suited to irrigated crops as Rincon clay loam. Some alfalfa and beans are grown but with only moderate success, yet flax and irrigated grain do fairly well, and dry-farmed grain is grown successfully.

This soil occurs mostly along the lower edge of the alluvial fans and has smooth to gently undulating relief. Deposition of fresh alluvial material on this soil is rare, but the slope is very gentle and erosion is slight. Along the lower margin of the valley plain where this soil joins the Pescadero or Sacramento soils the water table may be less than 6 feet below the surface.

AMBROSE SERIES

The soils of the Ambrose series have developed on old alluvial outwash materials from sandstone and shale rocks and associated soils. The Linne soils seem to furnish most of the material from which these soils are derived. The Ambrose soils occupy smooth gently undulating alluvial fans extending from the foothills to where they join with the soils of the valley basin or basin rim. The streams are somewhat entrenched, and little or no fresh alluvial material is being added to the surface soil. Drainage is somewhat restricted, and under present conditions the lower parts of the fans have water tables that in some places are not more than 4 feet below the surface. Under these conditions some accumulation of soluble salts may occur, but normally these soils are free from alkali. These soils have rather strongly developed moderately compact heavy-textured subsoils that definitely restrict the penetration of moisture and roots. The native vegetation is grass, which grows luxuriantly during the rainy season.

The surface soils, to a depth of not more than 24 inches, are dark dull-brown noncalcareous clay loam or clay. When dry the soil material has a dull lifeless color, but when moist it has a more pronounced brown color. These soils naturally break up cloddy. The clods are firm and hard when dry, but where the soil has not been puddled by mismanagement, they are easily crushed when worked at a favorable moisture content. The surface cracks, although not very wide, extend down into the subsoils when the soil dries out. Roots and water penetrate the surface soils readily, and the latter contain numerous root and worm cavities throughout. The immediate surface soils are generally neutral, but the lower part of these layers in many places are basic in reaction, though noncalcareous.

The upper parts of the subsoils are only slightly lighter in color than the surface soils. They are slightly heavier textured and are compact, breaking into irregular-shaped aggregates that have faint colloidal stains on their surfaces. Root and worm holes are lined with colloidal stains, and in places in the lower part of this layer, which extends to a depth ranging from 24 to 40 inches, a little segregated lime is present. The upper part of this layer is only mildly calcareous.

The lower parts of the subsoils, extending to a depth ranging from 36 to 60 inches, comprise the zone of greatest compaction and colloidal clay accumulation. The material is dull grayish-brown calcareous cloddy clay with rather small aggregates strongly coated with colloidal material. The aggregates are irregular in shape but have a suggestion of cubical structure. The surface cracks seem to extend into the upper part of these layers, which are penetrated by thin tongues of darker colored material, undoubtedly some of the surface soil that has fallen down the cracks. Fewer roots are in these layers than in the layers above and they have a tendency to follow the cracks, although some roots penetrate the soil aggregates. Many lime seams and some gypsum crystals are in these layers. The quantity of gypsum is greater in areas on the lower part of the fans. Normally the winter rains are not sufficient to moisten these soils down through these layers, but in years of higher rainfall the material may so retard penetration of water that for short periods the surface soils and upper subsoil layers are saturated with water.

The lower subsoil layers grade into the substrata of lighter colored, lighter textured materials, which in many places are stratified but generally are of medium or fairly heavy texture. These materials are calcareous, friable, and in many places contain a little segregated lime, but in much smaller quantities than the layers above.

These soils have very gentle slopes, in few places exceeding 2 percent. The very gently undulating relief is such that surface runoff is slow and erosion almost negligible.

Under irrigation these soils are planted mainly to flax and alfalfa, although some beans and truck crops, such as tomatoes, are grown, all with fair yields, although here again alfalfa stands die out after only a few seasons. Dry-farmed grain produces very well, and pastured areas furnish a good growth of grasses.

Two types of this series occur in this area—Ambrose clay loam and Ambrose clay.

Ambrose clay loam.—The surface soil of this type, to a depth of 10 to 24 inches, is a dark dull-brown or dark grayish-brown noncalcareous clay loam. The soil is plastic and easily puddled when wet, and it breaks into rather hard clods when dry, yet when worked at a suitable moisture content it is very friable. The upper part of the subsoil, to a depth ranging from 30 to 60 inches, is dark brownish-gray calcareous clay that is somewhat more compact. The material breaks into hard irregular angular lumps or blocks coated with colloidal stains, and some segregated lime occurs along the cracks and within the aggregates. In many places gypsum crystals are associated with the segregated lime in this layer. The material becomes lighter in color and grades rather gradually into a substratum of light-brown or yellowish-brown calcareous sediments that have very little if any compaction and no segregated lime.

The subsoil in most places is sufficiently compact to retard somewhat the penetration of moisture. Internal drainage is rather sluggish, but roots have little difficulty in penetrating the subsoil.

This soil is not so extensive as Ambrose clay, and it occurs nearer to old streamways. Under irrigation it is used for the production of alfalfa, flax, beans, and grain. Grain and flax do fairly well, but alfalfa and beans, although they can be grown, do not do so well as on soils with less dense subsoils.

Streamways are sufficiently entrenched so that no new material is being deposited on this soil. The slope is very gentle, in most places not more than 1 percent, and erosion is very slight.

Ambrose clay.—The surface soil of Ambrose clay is dark-brown or dark brownish-gray noncalcareous clay having in many places a blocky structure. The soil breaks into large blocks or lumps that are very hard when dry but soften to a readily workable condition when moist. At a depth ranging from 15 to 30 inches this layer grades into a dark-brown or brownish-gray clay calcareous subsoil. This layer becomes somewhat lighter in color with depth, but at a depth ranging from 24 to 42 inches it is penetrated by tongues or streaks of darker colored soil material from the surface that has fallen into the vertical cracks that are formed as the soil dries. The vertical cracks through this layer give it a semblance of prismatic structure. The surfaces of the rather hard angular clods or blocks are heavily coated with colloidal stains, and the aggregates are very firm. Considerable segregated lime and some gypsum appear in streaks throughout this layer. The substratum, occurring at a depth ranging from 30 to 60 inches below the surface, is composed of light-brown or yellowish-brown calcareous stratified sediments generally of somewhat lighter texture.

The heavy texture and the dense subsoil offer considerable resistance to the penetration of roots and water. Some areas of this soil occur on the lower part of the fans and have a high water table that somewhat restricts the number of crops that can be grown.

In the vicinity of Lammersville School and extending southwestward, lenses of hardpanlike material are present in the substratum of this soil in places. This material occurs intermittently, generally at a depth of 4 to 6 feet. It seems to be unrelated to the soil material above, and it does not appear to affect in any way use of the soil. Only in this locality was any hardpanlike material found.

This soil produces satisfactory yields of dry-farmed grain and grain hay, and of flax under irrigation. Some alfalfa and grain are grown under irrigation. Good stands of alfalfa are obtained, but visible yields fall off rapidly after the second or third season. Because of its heavy texture, this soil is difficult to work and is more suitable for dry farming than for irrigation farming, except for flax, which appears to do fairly well.

This soil is normally free from harmful accumulations of soluble salts except on the lower edges of the alluvial fans, where a high water table and a few salty spots occur.

In most places the slope of this soil is 1 percent or less and erosion is very slight. The soil seldom receives deposition of fresh alluvial materials.

HERDLYN SERIES

The soils of the Herdlyn series have developed on old alluvial outwash materials mainly from soils of the Altamont and Contra Costa series. These soils occupy gently sloping old alluvial fans, with well-entrenched drainageways and mild hog-wallow microrelief. These soils have definite compact claypans. Although the relation is not very clear, these soils might be considered as an older stage of development of the Rincon soils. Where the Rincon soils occur adjacent to soils of this series in the northwestern part of this area, fairly close relation is apparent; but this relation is not so pronounced in the vicinity of Vernalis, where the larger bodies of Rincon soils occur. The Herdlyn soils under virgin conditions are grass-covered, and they support a fairly good growth of native grasses.

The surface soils, to a depth ranging from 8 to 12 inches, are pale brown when dry but have a very slight red tinge when wet. They are very soft and sticky when wet, bake hard with very few cracks when dry and break into firm, angular blocks or clods. The layer is well penetrated by roots and contains many fine root and insect pores. The soil material is slightly acid in the topmost part of the surface soil and nearly neutral in the lower part. The pH value ranges from about 6.3 to about 7.0.

The upper subsoil layers are moderate-brown, dark-brown, or chocolate-brown noncalcareous heavy clay that is massive when moist but dries to a somewhat prismatic structure with definite vertical breakage planes. The aggregates are large dense prisms about 4 to 6 inches in diameter across the base and 6 to 8 or more inches in vertical dimension. These aggregates are covered with colloidal coatings. Roots do not seem to be appreciably concentrated along the breakage planes and are numerous throughout these layers, which extend to a depth of 15 to 24 inches, where they change abruptly to the lower subsoil layers.

The lower subsoil layers, to a depth ranging from 24 to 40 inches, are brown calcareous heavy clay with a slight red tinge. The structure is blocky, and the materials are not so tough or dense as the layers above, but the aggregates are more heavily coated with colloidal stains and are very firm. These aggregates break into smaller blocks, which also are coated with colloidal stains. Fewer roots are in these layers, and they have a tendency to concentrate in the cracks. There are some streaks of shiny manganese stains, and some streaks of segregated lime along the cracks and some of the larger root channels. The lower parts of these layers are less compact, and the structure is not so pronounced, but they have a greater content of accumulated lime and considerable segregated gypsum.

The substratum is a little lighter in color and texture than the lower subsoil layers. It is calcareous, and light brown or yellowish brown, and may contain a little segregated lime and faint colloidal staining; but for the most part it is friable with no definite structure and some stratification.

Drainage, although somewhat slow, is moderately good. Normally these soils are free from salts. The seepage waters, however, are saline, and some salts are accumulated along the drainageways and at the lower edge of the fans where these soils join the soils of the Solano series.

The Herdlyn soils are used for pasture and for dry-farmed grain, with only fair to moderate yields of grain. Owing to their very gentle slope and the method of management practiced, very little erosion occurs on these soils.

Only one type of the Herdlyn series, Herdlyn loam, is in this area.

Herdlyn loam.—The surface soil of Herdlyn loam, to a depth ranging from 8 to 12 inches, is pale-brown or light yellowish-brown noncalcareous cloddy loam with a slight red tinge on the surface of moist

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fields. It bakes on drying, and the surface crust becomes very hard. The upper part of the subsoil, to a depth ranging from 15 to 24 inches, is medium-brown, dark-brown, or chocolate-brown noncalcareous cloddy clay with a fairly well defined prismatic structure. The prism-shaped clods are 4 to 6 inches in diameter at the base and 6 to 8 inches in length. They are very hard when dry and are tough and plastic when moist. Some colloidal stains coat the faces of the aggregates. Fine grass roots are numerous and do not have a tendency to concentrate along the breakage planes but are about evenly distributed throughout. This layer rests rather abruptly on a light-brown compact calcareous clay layer with a somewhat blocky structure. The aggregates here are much smaller but are more compact and more heavily coated with colloidal stains. Some segregated lime is present in this layer, the lower part of which does not have quite so well defined structural units but has more segregated lime and gypsum and a few dark shiny streaks of manganese. At a depth ranging from 36 to 60 inches this layer grades into the substratum of lighter colored and somewhat lighter textured material composed of rather stratified calcareous sediments.

This soil occupies old alluvial fans with well-entrenched drainageways. The slope in few places is more than 2 percent, but small mounds and depressions give the land a mild hog-wallow microrelief. No new alluvial material is being deposited on this soil, and erosion is very slight.

Drainage through this soil is somewhat retarded, yet it is not so poor as to have caused mottling in the soil mass. The soil is normally free from salts. Because of its heavy claypan subsoil, this soil is not very well suited to irrigation, but it may be used with fair success for dry-farmed grain. It supports a good stand of native grasses and can well be used for range pasture.

OLCOTT SERIES

As occurring in this area the Olcott series is represented by a single type, the clay loam. This soil occupies an old alluvial fan, in which the parent material is derived from a variety of rocks coming from the sandstone, conglomerates, and Franciscan rocks along Corral Hollow Creek. The gravel throughout the soil and in the subsoil are well rounded and consist of hard partly metamorphosed sandstones, shales, cherts, schists, and quartzite rocks, as well as some hard basic igneous material. The surface soil is very slightly acid, and the subsoil, which is heavy and compact, is neutral to slightly basic in reaction. This soil occurs just below the terrace soils of the Denverton series and above the soils of the Zamora series. It occupies gently sloping alluvial fans with entrenched drainageways. The areas are no longer subject to deposition of sediments, and erosion is slight. Drainage is fair, and the soil is entirely free from alkali. The native cover is grass.

In typical areas, the surface soil, to a depth ranging from 8 to 12 inches, is medium- to dark-brown noncalcareous material of fairly heavy texture. It breaks into clods but is moderately friable, and where it has not been puddled the clods are easily broken down to a somewhat granular condition. Roots and water readily penetrate this layer, and it contains many insect and root holes. The content of organic matter is low. When moist this soil has a rich dark-brown color.

The upper part of the subsoil, to a depth in few places exceeding 25 inches, is of similar color and possibly slightly heavier texture. It is a little more compact and breaks into irregular-shaped angular clods or blocks that have some colloidal coatings, as have the worm and root holes.

This layer rests rather abruptly on a strong-brown or reddish-brown layer of very dense heavy clay. The clay material has definite vertical cracks, and the soil breaks into small prisms not more than 2 inches in diameter at the base and from 3 to 5 inches in length. These prisms have angular sides, are very firm, and are heavily coated with reddish-brown colloidal stains. The roots in this layer are not so numerous as in the layer above, and they are concentrated along the breakage planes.

At a depth ranging from 30 to 45 inches this layer grades into material containing considerable rounded gravel. The soil material is of similar color and texture as the layer above, but it is not so compact and has numerous colloidal stains. Some of the pebbles are coated with lime.

The substratum consists of stratified layers of soil and gravel, most of the gravel being coated with lime.

Olcott clay loam.—In this area the surface soil of Olcott clay loam, to a depth ranging from 6 to 12 inches, is brown or dark-brown noncalcareous heavy clay loam, which is of richer brown color when wet. The soil breaks into clods when plowed. A plowed field when wet appears to have a slightly red cast. Roots and water penetrate the soil well. The upper part of the subsoil, to a depth ranging from 15 to 24 inches, is noncalcareous brown or dark-brown clay loam or clay. There is very little difference between this layer and the surface soil, except that the texture is a trifle heavier and a few colloidal stains coat the aggregates and line the root and worm cavities. Roots and water pass through this layer fairly well.

The lower part of the subsoil, extending to a depth ranging from 30 to 42 inches, is light-brown or light reddish-brown noncalcareous heavy clay with a well-defined prismatic structure. The soil breaks into slender prism-shaped aggregates with sharp angular corners. The aggregates are from 1 to 2 inches in diameter at the base and two to four times as long. They are very compact and hard when dry and heavily coated with colloidal material. The roots in this layer are not so numerous as in the layers above and generally are concentrated along the cracks between the aggregates.

The substratum consists of stratified layers of gravelly material. The upper part of this layer has considerable clay that has worked down into the spaces between the pebbles, causing the upper part to appear partly cemented. The quantity of clay in the gravel decreases with depth. Much of the gravel of this layer is coated with lime, but the soil material itself is noncalcareous. Some well-rounded gravel occurs throughout the soil mass, but not nearly so much as in the substratum.

This soil has gently undulating relief with very gentle slopes, few exceeding 2 percent. No fresh alluvial material is being deposited, and erosion is only slight. The soil is used either for dry-farmed grain or for range pasture, and occasionally some winter peas are grown. Grain yields are fair but not so good as on the Rincon and Sorrento soils of similar texture.

One fairly large body of this soil occurs below the high terrace north of Corral Hollow Creek.

PESCADERO SERIES

The soils of the Pescadero series are pedocalic soils developed on old alluvial parent material mainly from sandstone and shales. These soils occupy the flat lower part of the alluvial fans bordering the soils of the valley trough or basin. Natural drainageways are only slightly entrenched, and occasionally, during or after very heavy rains, the soils receive a little fresh sediment. Erosion is very slight, and drainage is restricted. Under natural conditions these soils have a cover of grass, and some water-loving plants grow along the drainageways.

The surface soils are dark gray or dark dull brownish gray, heavy in texture, and when dry they break into large blocks that are dense and do not develop a great deal of secondary cracking. Many roots penetrate this layer but do not follow the lines of breakage. The supply of organic matter is moderate, and the soil is neutral to slightly alkaline. The lower part of this layer contains a few gypsum crystals and in some places a little segregated lime.

The upper subsoil layers are dark, in many places slightly darker than the surface soils. They are heavy in texture and dense, and the surface cracks extend down into these layers, giving definite vertical breakage. The clods or blocks are large and irregular shaped and have faint colloidal coatings. Many light streaks of segregated lime and gypsum are scattered through this layer, the gypsum being more abundant. Roots are well distributed through this layer and do not follow breakage lines.

The middle subsoil layers are gray or brownish-gray clay with a cloddy structure and considerable colloidal staining. Much more segregated lime and gypsum are in this layer, and in places some hard lime silica pellets; and a few light-gray mottlings are present throughout the material, which is usually saturated by the ground water during part of the season and is nearly always so moist that the natural structure is not clearly expressed.

The lower subsoil layers are lighter colored and less compact than the layers above. They are high in segregated lime and gypsum. The presence of so much crystallized gypsum gives these layers a distinctly mottled appearance. The texture is lighter, and the material contains a few hard lime silica pellets throughout.

The deeper substratum is very pale brown or light yellowish-brown calcareous friable stratified materials with some segregated gypsum and hard lime silica pellets.

These soils are somewhat saline throughout their occurrence in this area, and in a number of places moderate and high quantities of soluble salts occur, but no black alkali.

Pescadero clay.—The 8- to 16-inch surface soil of this type is dark-gray noncalcareous heavy clay of adobelike structure. Wide cracks cause the clay to form large hard blocks of irregular shape when dry. Although penetration of water is somewhat retarded, the soil contains many fine grass roots throughout. The lower part of this layer in places is slightly calcareous and contains a few gypsum crystals.

The upper subsoil layer is dark-gray or nearly black calcareous heavy dense clay with a blocky structure. The blocks are large and dense, but roots penetrate them rather freely. The large vertical cracks extend through this layer. Some segregated lime and gypsum occur in thin streaks, mostly within the aggregates. The color becomes a little lighter in the lower part, and at a depth ranging from 18 to 30 inches this layer grades into a lower horizon that is of heavy texture, gray or brownish-gray in color, and somewhat mottled with brown iron stains. The material breaks into angular irregular-shaped clods that are coated with thin colloidal stains. Few roots are in this layer, but considerable segregated lime and gysum, together with some hard lime silica pellets, are present.

The lower subsoil layer, reached at a depth of 30 to 42 inches, is light brownish-gray clay without visible structural arrangement of aggregates. This layer is less compact than the layer above and shows less colloidal stains but possibly more segregated lime and gypsum. Very few roots reach this layer.

The substratum, which is reached at a depth ranging from 36 to 66 inches, is light yellowish-brown or pale-brown mottled calcareous stratified material generally of lighter texture than that in the layer above. It is calcareous and has some lime silica pellets in the upper part.

Internal drainage through this soil is definitely restricted, and the ground water level is generally within 5 feet of the surface. In most places this soil contains some soluble salts throughout, and small areas have fairly strong accumulations. This soil is developed on the lower part of the alluvial fans of the northern part of this area and occasionally receives a very light deposit of alluvial material eroded from the higher parts of the fans.

Pescadero clay, because of its very heavy texture, high water table, and saline condition, is suitable only for grain or pasture. Alfalfa does very poorly on this soil, as do most other irrigated crops, although irrigated grain produces fair yields.

SOLANO SERIES

The soils of the Solano series are pedocalic soils developed on old valley-filling sediments of sandstone and shale origin. These soils have heavy compact subsoils with a rather poorly defined solonetz-like structure. They are closely related to the soils of the Herdlyn series and have been formed from the same parent material but have developed under conditions of poor drainage and a high water table. The soils contain considerable quantities of neutral and alkaline salts. They are normally covered with salt-tolerant grasses and shrubs, such as saltgrass and greasewood. These soils occupy rather flat lower parts of the alluvial fans, yet the drainageways are entrenched and no new alluvial material is being deposited. A rather definite hog-wallow microrelief is characteristic of these soils, with some local areas of sheet erosion around the edges of the mounds.

The surface soils are pale-brown or light brownish-gray noncalcareous medium-textured material. In most places they are very shallow, extending to a depth ranging from 6 to 18 inches but generally less than 10 inches. The material is very friable and has a distinctly brown color when moist, but it bakes very hard on drying and has a decided gray color. Roots penetrate the surface soils fairly well.

The upper subsoil layers are slightly darker brownish gray and have a faintly developed solonetzlike structure, with columns that are slightly rounded on the top. Roots are fairly well concentrated along the surface of the aggregates, which are strongly coated with colloidal stains. The subsoil layers are noncalcareous in the upper part but calcareous below. The texture here is very heavy—generally clay.

This material passes into light yellowish-brown or light grayish-brown calcareous very compact clay. When moist the clay is massive and has colloidal stains coating the few root holes. This material probably would have a somewhat blocky structure if allowed to dry in place. Many streaks of segregated lime and gypsum occur throughout, and a few thin lenses of calcareous hardpanlike material occur in this layer and the one below. These lenses of accumulated lime appear to have been caused by the evaporation of lime-charged water from a water table that was probably maintained at a high level for a considerable time.

The lower part of the subsoil is less compact but of similar color and texture. It is somewhat mottled with dull-brown stains and has many colloidal stains throughout. Very few roots are found in this layer. The structure here is rather indefinite, as the soil material is generally moist. If dry it would undoubtedly break into irregular-shaped angular clods.

The substratum consists of light-brown or light brownish-gray calcareous stratified materials of medium texture with some gypsum crystals and a few hard calcareous pellets. It is somewhat mottled with brown iron stains, and a very few roots extend into this layer, which generally is below the water table.

Only two small bodies of Solano soil are mapped in this area, and both are used solely for pasture. Most of the grasses are salt-tolerant and afford only fair pasture at best.

During the rainy period the Solano soils are very wet, water often standing in pools in the lower places. As the water table is high and internal drainage poor, the pools often remain for some time after a period of rainy weather.

Only one type of this series, Solano loam, occurs in this area.

Solano loam.—The surface soil is pale brown or light brownish-gray noncalcareous loam. It breaks into clods that may be worked down rather readily. The upper subsoil layer, occurring at a depth ranging from 6 to 18 inches, is grayish-brown heavy clay loam or clay with a faintly developed columnar structure. The columns are short and slightly rounded on the top. Roots are strongly concentrated along the cracks between the soil aggregates, which are coated with colloidal stains. The lower part of this layer does not have so definite a structure and is slightly calcareous. This passes, at a depth ranging from 18 to 30 inches, into yellowish-brown somewhat compact calcareous clay. Wherever this soil was observed this layer was moist and the structural units were very indefinite, although colloidal stains were numerous. If allowed to dry out, the material in this layer would probably break into a block structure. Segregated lime and gypsum occur throughout this layer, also a few lenses of calcareous hardpan. Very few roots extend down into this layer. The lower subsoil layer, at a depth ranging from 26 to 48 inches, is calcareous light grayish-brown or yellowish-brown clay or clay loam that is less compact than the material in the layer above and appears to be structureless. Segregated lime and some gypsum occur throughout, and a few hardpan-like lenses similar to those in the layer above are present. This layer grades into a light yellowish-brown calcareous layer of stratified variably textured sediments generally of lighter texture than those in the layers above.

Solano loam occurs on the lower parts of alluvial fans, but the streamways are sufficiently entrenched so that no fresh alluvial material is being deposited. The surface generally is comparatively flat, with hog-wallow microrelief. Both sheet and gully erosion are evident, and in most places this soil is high in accumulated salts. The land is used only for pasture, and its principal cover is saltgrass together with some greasewood and other salt-tolerant plants. Drainage is very poor, and the water table is high.

A very small area of this soil joins with an area of Solano silty clay in Contra Costa County (*2*). The soil in this area is of heavier texture than typical Solano loam and represents a transition to the heavier textured soil in Contra Costa County.

ANTONE SERIES

The soils of the Antone series are developed on alluvial parent materials originating principally from sandstones and shales. They have slight or moderately well-defined differences between surface soil and subsoil layers and vary considerably within rather short distances. These soils occur on narrow bottom lands along intermittent streams that traverse areas of the Kettleman, Altamont, and associated soils, and in most places they are cut into by fairly deep vertical-walled drainage channels of the narrow valleys. In a few areas new soil material is being deposited on the surface, but for the most part the drainageways are well entrenched and no fresh alluvial material is being deposited.

Seepage waters from these soils contain some salts, and some small areas are bare, because of alkali. The vegetation is mainly native grasses, which do not make a very luxuriant growth. Few of the slopes exceed 5 or 6 percent, but sheet erosion is very severe in small spots where the entire surface soil appears to have been removed, thereby exposing the subsoil. Such spots are not easily penetrated by rain water and are wet to a depth of only a very few inches when adjacent areas are moist to a depth of several feet.

The surface soils are dark-gray or dark brownish-gray noncalcareous heavy-textured materials with vertical cracks. These cracks give the soil a prismatic structure, although the aggregates break very readily into irregular-shaped clods. Plant roots may concentrate somewhat along the cracks, although many roots penetrate the clods. The soil material is nearly neutral, and the content of organic matter is moderate.

The upper subsoil layers are dark dull brownish-gray noncalcareous compact clay. The vertical cracks continue from the surface into these layers, and the roots are more definitely concentrated along the breakage planes. The aggregates have colloidal coating and are very firm when dry and highly plastic when wet.

This material passes into a lighter gray or brownish-gray material which becomes a little lighter in texture with depth. This material is moderately compact and breaks into rather small firm blocky aggregates. Many light-colored streaks of segregated lime and gypsum, mostly the latter, appear in these layers, especially in the lower part. The blocks are firm and are coated with darker colored colloidal stains. Roots are not so numerous here as in the layers above. The structure becomes less definite with depth, and the amount of compaction decreases until this layer grades into the substratum of stratified heavy-textured sediments with some lime and gypsum segregations.

Considerable variation occurs in the profiles of these soils in different localities. In some places the subsoil has a feebly developed solonetz-like structure, and in others the soil aggregates are very indefinite in size and shape. Some gravel and stones occur in certain areas. They are angular and have been transported only a short distance. In a few areas these soils have been covered with an overwash of calcareous recent alluvial deposits.

The substratum is friable and contains some crystallized gypsum in some areas. Where erosion extends through to these materials, which are highly erosive, deep gullies result.

Only one type of this series, Antone clay, is mapped in the area.

Antone clay.—The 6- to 18-inch surface soil is noncalcareous very dark gray or dark brownish-gray clay with a cloddy structure. The clods are angular and firm but are freely penetrated by roots. The upper part of the subsoil, extending to a depth ranging from 20 to 30 inches, is slightly more compact dark-gray or dark brownish-gray noncalcareous blocky clay. The blocks are almost cubical and are heavily coated with colloidal material. Grass roots have a tendency to follow the cracks and concentrate along the faces of the blocks.

The lower part of the subsoil is gray or brownish-gray calcareous clay or sandy clay. It is very plastic when wet, but the material is moderately friable and less compact than that in the layer above. In most places this layer contains considerable gypsum and some segregated lime. The color becomes lighter with depth until, at a depth ranging from 36 to 48 inches, it grades into a light olive-gray or light brownish-gray substratum of various-textured materials. Many fairly large pieces of crystalline gypsum are present in this layer. Roots are very few in the lower subsoil layer and substratum, and in many places gravel from nearby sources is included.

This soil occupies terraces or bottom lands along Corral Hollow Creek and other narrow drainageways. Most of the drainageways are well entrenched, and the soils are free from overflow or deposition of fresh alluvial material, but a few small areas are included where some deposition is apparent.

This soil gullies badly and contains some saline salts in a few areas, although the native grasses are not salt-tolerant species.

The acreage of this soil is small, and it is all used for range pasture. The grass cover is not so heavy as on the hilly Linne or Altamont soils adjoining areas of this soil.

SOILS OF THE HIGH TERRACES

DENVERTON SERIES

Soils of the Denverton series are formed on high terraces and terracelike remnants of old alluvial fans from materials having their source principally in sedimentary or metamorphosed sedimentary rocks. Some gravel of basic igneous rocks is contained in the soil, but this is very hard, and it is doubtful whether any appreciable quantity of it has disintegrated and contributed to the soil mass. These soils occupy rolling old alluvial-fan areas with well-entrenched drainageways. On some of the higher fan remnants deep channels have been cut, giving the area a definite hilly relief with fairly steep slopes and flat tops, which comprise from 15 to 40 percent of the total area. The soils on the flat tops of these areas are typical Denverton soils, but the soils on the slopes are varied and indefinite. Sheet erosion is slight on these soils, but in some places gullies have been cut deep into the substrata. On the lower more gently rolling areas, where the typical soils occur, both sheet and gully erosion are slight. The native cover is grass, which grows luxuriantly during the rainy season.

The surface soils are brownish-gray or brown heavy-textured material with definite blocky structure. During the dry period the cracks extend well into the subsoils. The surface soils are generally 12 to 18 inches thick but in a few places are more than 24 inches thick. The topmost part of the surface soil in most places is noncalcareous, but at a depth of 6 inches and downward these soils are increasingly calcareous. Although of very heavy texture, plastic when wet, and low in organic matter, these soils are very friable under favorable conditions of moisture and break out naturally into small irregular-shaped clods or blocks, which crumble readily to a granular condition. Drainage is good, and many roots are distributed throughout this layer.

The upper part of the subsoils is similar to the surface soils in color and structure. It is slightly more compact, and the aggregates are firmer and are coated with colloidal stains. The surface cracks extend down through the lower part of the subsoils. The roots are well dispersed throughout, and a little lime in threadlike streaks may have accumulated in the lower part. Many insect and root cavities throughout this layer increase its porosity. This layer in few places is more than 15 inches thick.

This layer is underlain to a depth ranging from 30 to 48 inches by brown or rich-brown materials somewhat streaked with the darker surface soil that has fallen down the cracks. This is the zone of greatest compaction and clay accumulation, and the materials are very dense, breaking into large irregular-shaped angular blocks coated with colloidal stains. Considerable segregated lime is present mainly as seams in the breakage planes and as soft lime nodules, and a few manganese stains appear in this layer and the layer below; but roots are less numerous here than in the upper part of the soils.

The lower part of the subsoils, between depths of 40 and 60 inches, is brown or reddish-brown calcareous clay that breaks into small angular clods that have firm consistence and are coated with colloidal stains. Very little segregated lime and very few roots are in this layer, as it is below the normal depth of penetration of the rains.

The underlying substratum consists of a mixture of clay and well-rounded gravel. This material is highly calcareous, and the gravel is coated with lime.

These soils are used almost entirely for pasture and produce excellent stands of grass. A few well-rounded pebbles are present on the surface and throughout the soil mass. Two types and three phases of this series occur in this area.

Denverton adobe clay.—The surface soil of this type is medium-gray, dark brownish-gray, or weak-brown adobe clay with large and many secondary structural cracks when dry. When in favorably moist condition the soil breaks into small irregular-shaped blocks or clods that are easily crumbled, and, considering its heavy texture, the surface soil is surprisingly friable. When moist this soil has a darker and distinctly browner color than when dry. The material in the upper few inches of this layer, which extends to a depth ranging from 10 to 20 inches, is noncalcareous, but the lower part is mildly calcareous. Many fine roots occur throughout this layer and the one below.

The upper subsoil layer, to a depth ranging from 18 to 30 inches, is calcareous clay of about the same color as the surface soil. The cracks beginning in the surface soil extend through this layer. The aggregates are irregular-shaped angular blocks or clods with slightly longer vertical than horizontal axes, are very firm, and are coated with colloidal material of slightly redder color. A small quantity of segregated lime occurs in the lower part of this layer as the color becomes a little lighter and grades into the layer below. This upper subsoil layer is underlain, to a depth ranging from 36 to 60 inches, by brown or rich-brown calcareous clay with colloidal stains on the surfaces of the aggregates. It is penetrated by tongues or streaks of darker soil material that has fallen down the cracks from the surface. Segregated lime and in places some gypsum occur in this layer. Roots are not so numerous but are fairly well distributed throughout the layer. The lower subsoil layer, to a depth ranging from 48 to 72 inches, is rich-brown or reddish-brown calcareous clay. It breaks into angular clods that are firm but rather small, few being more than 2 inches in diameter. The faces are coated with colloidal stains, and a few dark manganese stains appear in the lower part of the layer above and throughout this layer.

The underlying material consists of stratified gravelly and calcareous clayey deposits. The gravel is well rounded, and the upper part of this layer is held firmly together by infiltration of clay from the layer above. This soil is well drained throughout. It occupies high alluvial fans or valley terraces with well-entrenched drainageways. The relief is smooth and undulating, with slopes of less than 10 percent, and erosion is very slight.

Because of its position, this soil lies above the sources of gravity water for irrigation. It is used to some extent for dry-farmed grain, with favorable results, but is used more extensively for range pasture, having excellent stands of range grasses in years of favorable rainfall. This soil occurs along the western side of the valley bordering the hills from Patterson Run southward beyond the confines of this area.

Denverton adobe clay, slope phase.—This phase is similar in occurrence, color, and other essential characteristics to typical Denverton adobe clay, but is of more sloping relief and has less uniform soil characteristics. The slopes are broad, generally smooth, and dominantly in excess of 10 percent. The soil is somewhat more susceptible to erosion, and small areas occur on the more steeply sloping terrace escarpments, in which gullying is rather severe. The land is used for range pasture.

Denverton gravelly clay.—The surface soil of this type, to a depth ranging from 10 to 18 inches, is dark brownish-gray generally calcareous gravelly clay that breaks into rather soft clods. The upper subsoil layer is brown calcareous gravelly clay that breaks into irregular clods coated with colloidal material. Roots are numerous through these upper two layers. At a depth ranging from 20 to 30 inches the upper subsoil layer grades into a rich-brown calcareous gravelly clay layer that is rather compact. Colloidal stains are more numerous, and there is much segregated lime, in many places occurring in large soft nodules. The gravel in this layer is coated with lime. Grass roots are not so numerous but are fairly well distributed throughout the layer. The material becomes less compact with depth and grades into a more friable substratum of stratified gravelly deposits.

This soil occupies higher fan and terrace remnants than Denverton adobe clay. The drainageways have cut deeply into the old fans, giving a very hilly relief characterized by rather flat ridge tops and steep sides. The ridge tops comprise about 15 to 40 percent of the extent of the areas of Denverton gravelly clay and its phases, and typical Denverton gravelly clay is developed only in the flatter areas. The soil is not greatly unlike Denverton adobe clay, but it is somewhat more variable and much more gravelly. Erosion on the flat and more gently sloping areas is slight or moderate.

This soil is used only for range pasture. It produces fairly heavy stands of good-quality grass in seasons of favorable moisture supply.

Denverton gravelly clay, slope phase.—This phase includes areas of Denverton gravelly clay of moderate to steep slope, dominantly ranging from 10 to as much as 40 percent. Soil of this phase and of the steep phase covers more extensive areas than typical Denverton gravelly clay, which occupies the flatter land. It is deeply dissected by streams and has developed a strongly rolling to hilly landscape in the southeastern part of this area.

The soil on the steeper slopes is variable and in many places lacks definite surface soil and subsoil layers. In some places a part of the soil material has been removed by erosion, whereas in others soil material has been accumulated on the concave slopes by erosion and gravity. The soil on the steeper slopes differs widely from typical Denverton gravelly clay and may in future surveys be recognized under a distinct series of soils.

This soil is subject to both sheet and gully erosion. Like typical Denverton gravelly clay, it is used for range pasture.

Denverton gravelly clay, steep phase.—This phase is similar in character of soil material to the slope phase, with which it is associated. Depth of soil material, however, is somewhat more varied, the soil is more heterogeneous in character, the slopes are steeper, dominantly more than 40 percent, and gullying and sheet erosion are somewhat more severe.

The soil is used for range pasture. Grazing should be carefully controlled in order to reduce danger of further serious erosion.

MONTEZUMA SERIES

The soils of the Montezuma series are pedocalic soils developed on materials having their source in sedimentary and metamorphosed sedimentary rocks. These soils occur on old terrace and alluvial fan remnants along the west side of the San Joaquin Valley north of Corral Hollow Creek. They are closely related to the soils of the Denverton series, from which they differ mainly in darker color of the surface soil, although free lime lies at a somewhat greater depth in the Montezuma soils than in the Denverton soils.

The surface soil, which in few places is more than 18 or 20 inches thick, is dark brownish-gray or brownish-black noncalcareous material of heavy texture. It is dense and plastic when wet but when dry shrinks and forms large blocks that break further into small blocks. Vertical cracks extend into the subsoil. Grass roots are well distributed throughout the layer, and there are many root and worm casts.

The upper part of the subsoil, to a depth ranging from 15 to 30 inches, is very dark grayish brown, noncalcareous, and of heavy texture. The surface cracks extending into this layer cause a somewhat prismatic structure. The aggregates are coated with colloidal stains and are hard when dry. They break into secondary small irregular clods, which also are coated with colloidal material. Roots and root cavities are numerous and well distributed throughout. The lower part of this layer in many places is calcareous.

The lower part of the subsoil, to a depth ranging from 24 to 48 inches, is brownish-gray calcareous clay. The aggregates are irregular shaped, angular, and hard when dry. There is more or less segregated lime in this layer, varying from only occasional thin streaks to large amounts of nodular accumulation. The aggregates are coated with colloidal stains, but the roots are well distributed throughout the layer, although they are not so numerous as in the two layers above. The density and amount of colloidal matter decreases in the lower part of this layer, where it grades into the substratum, which is composed of clay and rounded gravel together with much segregated lime. The gravel is well rounded and includes hard sandstone, partly metamorphosed sandstone and shale rocks, quartzite, chert, and a small quantity of very hard basic igneous rocks.

Erosion is slight on these soils except on the steeper breaks, where a little gullying takes place. These soils are used exclusively for pasture and produce an excellent growth of grasses in seasons of favorable moisture supply.

Only one type of the series is recognized in this area.

Montezuma adobe clay.—The surface soil is dark brownish-gray noncalcareous clay with pronounced blocky structure when dry. It is characterized by deep cracks forming large irregular blocks, in which numerous secondary cracks develop, giving rise to small angular blocks, clods, and fragments. The upper part of the subsoil begins at a depth ranging from 8 to 14 inches. It is noncalcareous dark brownish-gray clay only slightly lighter in color than the surface soil. This layer is of irregular blocky structure. Some colloidal coatings are on the faces of the aggregates, which are hard when dry, and they also occur as linings in the root channels. Many roots occur throughout this and the surface layer.

The lower part of the subsoil is brown or brownish-gray calcareous clay with irregular blocky aggregates that are more heavily coated with colloidal material. Segregated lime in varying quantities occurs in this layer. The cracks extend from the surface into this layer, and the darker colored surface soil has fallen into them, forming dark tongues and streaks extending throughout the upper part of the layer. The lower part of the layer is less compact but has more segregated lime. This grades into a substratum of stratified gravelly deposits high in accumulated lime and in many places rather firmly cemented.

The soil occupies high alluvial fans and valley terraces, similar to those occupied by Denverton adobe clay. The relief is rolling, and erosion is slight except on the steep breaks where gullying is very bad.

This soil is used only for range pasture, but it could be used for dry-farmed grain in favorable seasons. Only a few areas are mapped. They occur near the mouths of Corral Hollow and Mountain House Creeks.

POSITAS SERIES

The soils of the Positas series have developed on gravelly old stream terraces, the parent material being derived chiefly from sedimentary and metamorphosed sedimentary rocks. The native cover is grass. The relief is gently rolling with drainageways well entrenched, so that no deposition of fresh alluvial materials is being made on these soils. Erosion normally is only slight, but where these soils occur at the base of the hills some of the drainageways have cut deep vertical-sided gullies through the soil. The surface is generally smooth and gently rolling, with faint suggestions of hog-wallow microrelief on the flatter areas.

The surface soils are brown or rich brown when dry and dark brown when wet. The soil bakes somewhat on the surface and breaks into rather soft irregular-shaped clods when disturbed. The surface soils and the upper subsoil layers are very slightly acid or neutral, and the lower subsoil layers are slightly alkaline, although noncalcareous. Roots and rain water penetrate the surface soils well. There are numerous worm and root holes through these layers that increase the porosity.

The upper subsoil layers are rich brown, slightly heavier than the surface soils, and have a distinct red tinge when wet. They are slightly more compact and break into irregular-shaped angular clods. Some colloidal stains are on the faces of the clods and embedded gravel, and they also line the root and worm cavities, which are fairly numerous throughout.

The lower part of the subsoils is strong-brown noncalcareous heavy-textured material containing embedded gravel. The material is dense and massive in place but breaks into irregular-shaped angular aggregates that are hard when dry and are well coated with darker colloidal stains. The number of grass roots in this layer decreases rapidly with depth. The lower part of the layer is a little lighter in texture and less compact as it grades into the substratum.

The substratum is less compact and somewhat lighter in color and texture. The gravel is coated with lime, and occasional small streaks of segregated lime are present, although there is only a small amount of disseminated lime in the soil mass.

As a rule this soil is very gravelly throughout, and in many places stratified gravel layers are reached at a depth of 2 to 3 feet.

These soils are used primarily for pasture, although a little dry-farmed grain is grown on the lower lying areas. Yields are fair, and the quality of the grain is good. Only one type of this series is mapped.

Positas gravelly clay loam.—The surface soil, to a depth ranging from 12 to 20 inches, is brown or rich-brown noncalcareous cloddy gravelly clay loam. The soil puddles easily and under such conditions is hard when dry, but otherwise it is fairly friable, has good drainage, and is well penetrated by roots.

The upper part of the subsoil is rich-brown noncalcareous gravelly clay to a depth ranging from 24 to 40 inches. It is slightly richer in color than the surface soil and has a distinct red cast when wet. It breaks into irregular-shaped angular clods with faint colloidal stains on their surfaces. Root and worm holes also are lined with colloidal stains.

The lower part of the subsoil, extending to a depth ranging from 42 to 72 inches, is noncalcareous light-brown or light reddish-brown gravelly clay. The layer is dense, and the irregular-shaped clods are tough when moist and very hard when dry. Heavy colloidal stains coat the outside of the soil aggregates. Plant roots are fewer in this layer. Drainage appears to be adequate, as there are no evidences of sluggish drainage.

The soil material becomes lighter in color, lighter in texture, and less compact with increasing depth until it grades into the substratum of stratified gravelly deposits with some clayey material intermixed. In some places some of the pebbles are coated with lime and a little segregated lime occurs.

The soil occupies stream terraces below those of the Denverton soils along Lonetree and Hospital Creeks. They have gentle slopes of 2 to 4 percent with a microrelief of small mounds. Abrupt embankments next to the streams show some gullying, but otherwise this soil is only slightly eroded. It is used for dry-farmed grain and range pasture. Yields of grain are moderate or good in favorable seasons, and the grass cover is fairly heavy. Because of the upland position of this soil, no gravity water is available for irrigation.

SOILS OF THE BASIN AND FLOOD PLAINS

COLUMBIA SERIES

The soils of the Columbia series are mineral recent alluvial soils derived from mixed rock sources. These soils occupy overflow flood plains of major streams and basinlike areas of the valley trough, cut with many narrow distributaries and waterways. They support a growth of trees and willows with an undercover of grass and some herbaceous and aquatic plants. The soils are noncalcareous but only mildly acid or neutral throughout. They do not have distinct surface soils and subsoils but consist of stratified layers of various-textured micaceous sediments, with considerable mottling with iron stains. They occupy low flat areas, yet their microrelief is irregular and the land requires leveling before it can be cultivated. As a rule the water table is fairly high, and areas of this soil require some drainage before they can be used for a wide variety of crops.

The surface soils are brown or yellowish-brown noncalcareous friable materials containing considerable mica.

The subsoils are brown or grayish-brown mottled friable loosely stratified micaceous sediments. The mottlings are rust-brown stains in the upper part, but they become duller and less oxidized with depth. The heavier textured members of this series in this area rest on soils of the Sacramento, Roberts, or Burns series at a depth ranging from 18 inches to 4 feet.

Outside of areas protected by artificial levees, these soils are subject to overflow and deposition. They are not subject to sheet erosion, although there may be a slight amount of shifting of the soils by wind in the lighter textured members. Under the present farming practices, the soils are fairly well covered with vegetation during periods when wind damage is most likely, so that there is very little evidence of any modification by wind.

These soils are used for a large variety of truck and field crops, including alfalfa, all of which do very well. Because of their high water table, they are for the most part not satisfactory for orchards or vineyards, although in the Sacramento-San Joaquin Delta area to the north they are used for the production of pears.

Three types of this series are recognized in this area.

Columbia fine sandy loam.—The surface soil of this type, to a depth ranging from 6 to 24 inches, is light yellowish-brown or pale-brown noncalcareous loose or friable micaceous fine sandy loam. The subsoil consists of stratified light- or medium-textured micaceous noncalcareous sediments mottled with rust-brown iron stains. Many root channels are lined with these iron mottlings. The color is brown or light brown but is rather dull because of the high water table. The subsoil extends to a depth ranging from 3½ to more than 6 feet. In the island district, in the northwest part of this area, darker, heavier textured soil material, similar to that of the Sacramento soils, underlies this soil. In many places along the stream ridges and close to the banks of sloughs and river channels this underlying material lies at a great depth or is absent.

Under natural conditions this soil was flooded annually during periods of high water. The vegetation is dominantly willows, grasses, and some aquatic plants. All the soil of this type that is now being farmed is protected by levees and drainage ditches, which have been installed to control the water table. This control of the water table functions both for drainage during periods of high water and for irrigation during the summer. Although the land in most places is almost flat, it is cut by sloughs and drainageways and must be leveled before it can be successfully farmed.

A wide variety of field and truck crops are grown on this soil. Small grains, corn, and alfalfa are the principal field crops, and asparagus, onions, carrots, and tomatoes are the main truck crops grown. All these crops do well under proper management.

Columbia silty clay loam.—The surface soil, to a depth ranging from 8 to 20 inches, is grayish-brown, brown, or yellowish-brown noncalcareous micaceous friable silty clay loam. Despite its medium-heavy texture, this soil maintains a loose or friable consistence and is difficult to puddle.

The subsoil consists of brownish-gray or brown highly mottled micaceous sediments of medium or heavy texture, containing a large quantity of silt. The mottlings in the upper part of this layer are rust-brown iron stains, but they become a little duller with depth. Many root channels lined with rust-brown mottlings occur throughout the layer.

At a depth ranging from 3 to 5 feet this soil is underlain by darker somewhat heavier textured soil materials similar to those of the Sacramento series, over which the Columbia soil has been washed or superimposed.

Before this soil can be farmed it must be reclaimed, since it has a high water table and is subject to overflow during periods of high water in the San Joaquin River. In this area almost all of this soil is reclaimed by protecting levees and suitable drainage ditches.

The soil is suitable to a wide variety of field and truck crops and is used in the same manner as the Columbia fine sandy loam, with about equally good results.

As mapped, the texture is somewhat variable, ranging from silt loam to silty clay loam. Because of its very friable character, the soil has the physical properties comparable to medium-textured loams or fine sandy loams of many other soils. It is very easily worked and maintains excellent structure when tilled.

Columbia soils, undifferentiated.—These soils consist of various-textured types of Columbia soils occurring along streamways and in areas outside of protecting levees where they are subject to overflow. The textures are extremely variable within short distances and impracticable of differentiation on a small-scale map. The surface soil is yellowish-brown or brown friable noncalcareous material of variable texture, underlain by noncalcareous brown stratified micaceous sediments highly mottled with iron stains.

These soils are rarely farmed because of the risk of loss of crops by flooding. Most of the areas support a growth of willows and tall grasses. In dry periods when there is no overflow, they are used for pasture.

These soils occupy small areas, mainly along Paradise Cut and the main channel of the San Joaquin River and outside of the levees.

RAMADA SERIES

The soils of the Ramada series are mineral alluvial soils derived from mixed igneous and sedimentary rock sources. In physical properties, development, and morphological features they are very much like the soils of the Columbia series. They differ from the Columbia soils mainly in having a stronger brown or reddish-brown color, especially in the subsoils, and in having more highly mottled subsoils.

The surface soils consist of rich-brown noncalcareous friable micaceous materials. They are slightly acid to neutral in reaction.

The subsoils consist of yellowish-brown or reddish-brown noncalcareous highly mottled micaceous stratified sediments without indication of profile development. The mottlings in this layer are rich rust brown in the upper part but become duller with depth. There are a few streaks of dark-colored partly decomposed organic matter that add to the mottled appearance. These soils occur in rather small bodies throughout the areas of the Sacramento and Columbia soils and may represent localized areas where the deposits were derived mainly from basic igneous rocks.

Like the soils of the Columbia series, these soils are highly productive for a variety of field and truck crops but are not very suitable for orchards or vineyards.

Where soils of this series join the Sacramento-San Joaquin Delta area (*3*) to the north, they were included with the Columbia soils. Two shallow phases of the Ramada series are mapped in the Tracy area.

Ramada fine sandy loam, shallow phase (over Sacramento soil material).—The surface soil of this phase is rich-brown or yellowish-brown noncalcareous friable micaceous fine sandy loam extending to a depth ranging from 10 to 20 inches. The subsoil is stratified rich-brown highly mottled light- or medium-textured material showing no compaction or accumulation of clay and colloids. Many roots occur throughout the surface soil and the subsoil and in many places root cavities are lined with rust-brown iron stains. The mottlings are rust-brown in the upper part of the subsoil, but the color becomes duller with depth. In most places considerable partly decomposed organic matter occurs in streaks through this layer, and this adds to the mottled appearance.

Underlying this soil, at a depth ranging from 3 to 6 feet is a dark-colored heavier textured soil material, like that of the Sacramento soil, that is typically present under the Columbia and Piper soils of this part of the delta region.

This soil is suitable for a wide variety of field and truck crops and produces excellent yields of good quality. Like the Columbia soils, this soil has to be protected from overflow before it can be farmed, and in some places drainage ditches must be installed.

This is not an extensive soil. It occurs in small bodies in the delta district closely associated with soils of the Columbia and Sacramento series.

Ramada silty clay loam, shallow phase (over Sacramento soil material).—The surface soil of this phase is rich-brown or yellowish-brown noncalcareous friable micaceous silty clay loam to a depth ranging from 8 to 18 inches. It has excellent tilth and permeability and is not readily puddled. The texture is very smooth, and there is no coarse gritty material.

The subsoil consists of stratified, fine-textured, highly mottled, rich-brown micaceous sediments. The mottlings are bright orange in the upper part and become duller with depth. Considerable quantities of organic matter occurring in dark streaks through this layer add to its mottled appearance. There are many roots through this and the surface layer.

The substratum of darker heavy textured Sacramento soil material occurs at a depth of 2½ to 4 feet.

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This soil must be protected from overflow by levees before it can be farmed. It is suitable for a wide variety of field and truck crops and produces high yields of excellent quality. The water table is high, and both irrigation and drainage are accomplished by control of the height of the water table, which, in turn, is achieved by means of open ditches, with pumps in some places.

The soil occurs in small bodies associated with soils of the Columbia and Sacramento series in the upper delta of the San Joaquin River.

PIPER SERIES

The soils of the Piper series are mineral pedocalic soils developed on alluvial materials from both igneous and sedimentary rocks. The parent materials have been transported by major streams, and the soils occur as low stream-built ridges over soil materials of the Sacra mento, Burns, or Roberts series. They have been slightly modified since deposition and generally contain some lime-cemented pellets and soft lime concretions.

These soils normally have fairly high water tables, and some areas are affected with soluble salts. The native vegetation is saltgrass. These soils occur as low sandy ridges bordering the major streams, especially the Old River. Where the land is farmed, considerable leveling has been done and much of the soil material from the surface has been spread out over the associated darker Sacramento, Burns, or Robert soils.

The surface soils are brownish-gray, calcareous, and friable or loose. Some hard lime-silica pellets are contained in this layer.

The subsoil is slightly lighter and grayer and is strongly mottled with lime and iron stains. There is a slight compaction in this layer on drying, but this is not apparent when the soil is moist. The root holes are lined with rust-brown iron stains.

Like the soils of the Columbia and Ramada series, these soils are underlain by the typical basin soils of the Sacramento, Roberts, or Burns series at a depth ranging from 2 to 6 feet.

These soils occupy narrow, inextensive stream-built ridges and are slightly less productive than the surrounding better soils. The saline areas are especially unproductive. The Piper soils occur in very small bodies in the western part of the delta region. Only one type of this series—Piper fine sandy loam—is mapped.

Piper fine sandy loam.—The surface soil, to a depth ranging from 18 to 24 inches, is brownish-gray friable micaceous fine sandy loam. It is highly calcareous and may contain a few hard lime-cemented pellets.

The subsoil is light brownish-gray or light olive-gray calcareous material that is somewhat stratified. When moist it appears to be as soft and friable as the surface soil, but on drying it is somewhat more compact. It is highly mottled with rust-brown mottlings, which become much duller in color with depth, and it contains some lime pellets. Less lime is present in the lower part of this layer. The compaction is not sufficient to interfere with root penetration.

At a depth ranging from 3 to 6 feet a substratum of dark heavy-textured noncalcareous material similar to that of the Sacramento soils is reached.

This soil occurs along narrow ridges extending like fingers into the soils of the Sacramento, Burns, and Roberts series. In many places it is very salty. In farming, these ridges are leveled and worked with the other soils. They are not so productive as the surrounding soils, and the alkali spots produce very little. Only a very small acreage of this soil occurs in the area, and it is relatively unimportant. Many of these sandy ridges, where favorably located, are used as sites for farmsteads and corrals because they are higher and better drained than the surrounding soils.

SACRAMENTO SERIES

The soils of the Sacramento series are mineral pedocalic soils of the flat valley trough or shallow basinlike areas. The parent material sediments came originally from mixed igneous and sedimentary rocks and have been deposited by major streams. The soils have relatively indistinct surface soil and subsoil layers. They are high in organic matter, which promotes a fairly friable condition and masks the heavy texture and any concentration of clay in the subsoil. The vegetative cover is normally grasses and aquatic plants such as tules, reeds, and similar plants. Where unprotected by levees the soils are subject to slow deposition of sediments from muddy waters that settle in the basins. Considerable evidence of old buried surfaces is found, and here and there a thin buff-colored ashy layer, denoting burning of organic matter, is present. The sediments are somewhat micaceous. The surface soils are slightly acid, but in many places the subsoils are calcareous in the deeper part. In some places in this area, however, they do not contain enough lime to cause effervescence when tested with dilute acid.

The surface soils consist of gray or brownish-gray noncalcareous material of low density and soft friable consistence. Even when thoroughly dry this material crumbles very readily. It is very smooth and contains a fairly high percentage of organic matter. It is well penetrated by roots and water.

The upper part of the subsoils is slightly heavier than the surface soils, is usually a little darker, and is highly mottled with rust-brown iron stains. The soil aggregates are coated with dark colloidal stains, and the root channels are lined with rust-brown iron and dark colloidal films. Despite a definite accumulation of clay and a compact consistence, the material is permeable and friable and breaks into soft clods. The organic-matter content is fairly high. The material contains a great many fine pores, and it has a fairly low volume weight.

With increasing depth, the subsoils are somewhat stratified, the color is lighter, and the numerous mottlings are less conspicuous and indicate less oxidation. At a depth ranging from 2½ to 7 feet these soils are underlain by a sandy substratum. This sandy material is light gray, mottled, noncalcareous for the most part, and somewhat micaceous. In places the subsoils are calcareous, and hard lime-silica pellets are commonly found.

These soils have developed under a high water table. Protection from overflow and artificial drainage have to be provided before they can be farmed. Under adequate drainage, vegetables and field crops, including alfalfa, do very well on these soils, although alfalfa stands do not last more than three or four seasons.

Three types of this series are mapped.

Sacramento loam.—The 12- to 24-inch surface soil of Sacramento loam is dark-gray or brownish-gray noncalcareous friable fine loam. The upper part of the subsoil, to a depth ranging from 30 to 48 inches, consists of dark brownish-gray noncalcareous loam or clay loam that breaks into clods yet is fairly porous. This layer has some accumulation of clay and colloids, but this is somewhat masked by the large quantity of organic matter. It is mottled in the upper part with rust-brown iron stains, but the mottling becomes less conspicuous with increasing depth.

The lower part of the subsoil consists of stratified gray or brownish-gray medium or heavy-textured sediments, which are variable and mildly calcareous. In most places this layer is below the water table and has numerous gray or bluish-gray mottlings.

Underlying the entire profile, at a depth ranging from 4 to 8 feet, is the light-gray sandy substratum typical of this part of the San Joaquin delta.

This soil is very inextensive and occurs principally as low broad ridges extending across bodies of the heavier textured soils of this series. It is farmed in conjunction with the heavier soils and produces satisfactory yields of crops of excellent quality. Field crops, such as grain, milo, and alfalfa, and truck crops, such as asparagus, tomatoes, and carrots, are the principal crops produced on this soil. Alfalfa yields are high for the first three seasons, after which there is a rapid dropping off unless the fields are reseeded.

Sacramento clay loam.—The surface soil of this type is dark brownish-gray noncalcareous somewhat micaceous friable clay loam of high silt content, extending to a depth ranging from 10 to 20 inches. The soil is high in organic matter and has very low density.

The subsoil, to a depth ranging from 30 to 60 inches, is dark-gray or bluish-gray clay with considerable silt. It is mottled with rust-brown and dull-gray iron stains and shows some evidence of an accumulation of colloidal clay. Many root channels and worm casts occur throughout, and the high content of organic matter promotes a friable condition. The mottlings in the lower part of the subsoil are more numerous but are of a much duller color than those in the upper part. Occasional streaks of buff-colored ashy material in this layer denote remains of old burned organic matter that have long since been buried.

A substratum of light-gray sandy material underlies this soil. This material is stratified and generally single grained.

The soil is easily penetrable by roots and water, and nearly all areas have a high water table. Where reclaimed by artificial drainage and protected from floodings by levees, this soil produces excellent yields of alfalfa, small grains, corn, asparagus, tomatoes, and other truck and field crops. Control of the water table through open ditches serves as a means of both irrigation and drainage in the island district, whereas some surface irrigation is practiced on areas south of the Old River and Paradise Cut.

This soil is extensive and is an excellent soil where drained and properly managed, although it is best suited to the more shallow-rooted crops. Deep-rooted crops, such as tree fruits and grapes, are not successfully grown.

Sacramento clay.—The 8- to 15-inch surface soil of Sacramento clay is gray or brownish-gray noncalcareous clay of silty texture.

When wet it appears brownish black. It breaks into clods that are somewhat rounded and of low volume weight. They are friable and are easily broken to a granular condition. The high content of organic matter effectively masks the heavy texture and promotes excellent tilth and permeability.

The upper part of the subsoil is dark-gray or dark brownish-gray clay or silty clay of somewhat heavier texture and greater density than the surface soil, yet it is porous, with many root channels and worm casts. Some colloidal stains occur, and dark streaks of organic matter are common. This layer is highly mottled with rust-brown mottlings at greater depths. This grades into the lower part of the subsoil, which consists of somewhat lighter gray less compact clay. The mottlings here are dull bluish-gray ferrous stains.

Thin layers of buff-colored ashy materials represent remains of organic material left by surface fires. These remains were buried by later floods.

The substratum of light-gray sandy material is reached at a depth ranging from 2½ to 6 feet below the surface. The subsoil and the substratum are commonly noncalcareous, but in places they contain some lime.

South of the Old River and Paradise Cut, where the influence of material from sedimentary rock sources is more evident, the subsoils in most places are calcareous.

This soil has been formed under poorly drained and marshy conditions and must be protected from floods by levees and have artificial drainage before it can be farmed. Grain, alfalfa, corn, asparagus, tomatoes, and other truck and field crops are grown extensively, and excellent yields of high quality are obtained. Deep-rooted crops, such as tree fruits and grapes, do not do well on this soil because of the high water table.

In this area the soil is almost entirely free from alkali. This is a very extensive soil type in the delta region, and it is an excellent soil for the crops commonly grown.

For the most part irrigation and drainage are accomplished by controlling the height of the water table through the use of open ditches. In the area south of the Old River and Paradise Cut, surface irrigation is practiced more extensively than subirrigation.

This soil joins with Sacramento adobe clay of Contra Costa County (*2*), in which the blocky structure appeared to be more strongly developed.

BURNS SERIES

The soils of the Burns series contain much organic matter. They are formed from mixed sediments in the San Joaquin River delta and organic remains of reeds, sedges, and other aquatic plants. Doubtless some of the original organic matter has been depleted by decomposition, and the soils contain a fairly large quantity of transported fine river sediments justifying their classification as mineral soils. These soils seem to represent a transition between the mineral Sacramento soils and the organic Roberts soils. In physical properties they are much like the Roberts soils. They have low volume weight and very high moisture-holding capacity, but they have higher volume weight and lower moisture-holding capacity than the Roberts soils. Ashy layers, similar to those characteristic of the Roberts soils and present in places in the Sacramento soils, are common in these soils. The soils are normally medium to slightly acid, with pH values ranging from about 5.5 to 6.5, and in a few areas the lower subsoil layers are mildly calcareous.

The surface soils, to a depth ranging from 16 to 24 inches, are dull brownish-gray highly organic material with a pH value of 5.5 to 6.0. They are friable and permeable and are easily worked under a wide variety of moisture conditions. The volume weights are fairly low, and the soils have high moisture-holding capacity.

The upper parts of the subsoils, to a depth of approximately 3 feet, are noncalcareous, of heavy texture, and of rather blocky structure, breaking into angular units. These, however, are high in organic matter, very porous, and easily broken down to a granular condition. Vertical root channels extend downward through this layer and the material below. These channels are similar to those in the Roberts soils and are lined with iron stains and colloidal organic matter. There are some rust-brown iron mottlings in this layer. The pH value ranges from 6.0 to 6.5.

The lower parts of the subsoils are medium gray or dark gray. The material has a blocky structure, is high in organic matter, and is fairly porous. The mottlings are much duller and less conspicuous than those in the layer above and decrease with depth.

The deeper materials may have a few stratified layers of heavy-textured sediments more or less intermixed with sandy material. These layers contain considerable organic matter. In many places the lower part of the subsoil rests directly on the sandy material that underlies this entire area.

Irrigation and drainage practices on these soils are conducted as on the Roberts soils, and in some places as on the Sacramento soils, by control of height of the water table. Only one type of this series is mapped.

Burns clay loam.—The 12- to 24-inch surface soil is gray or brownish-gray friable clay loam that is high in organic matter. It breaks into soft clods that may be crumbled easily even when dry and that have a low density. A few small flat fragments of hard ashy material are common throughout this soil.

The upper subsoil layer is medium-gray or dark-gray blocky clay. The blocks are firm but are not hard, probably because they contain a large quantity of organic matter. There are many fine roots throughout this layer, and vertical root cavities, starting in this layer and extending down through the underlying material, are numerous. The root cavities are well lined with iron stains and seem to have very few laterals branching off from them. The mottlings in this layer are rust brown and are not very numerous.

The lower subsoil layer consists of somewhat stratified slightly lighter colored sediments of moderately heavy texture. There is less organic matter in this layer.

One or more layers of light-buff ashy material somewhere in the subsoil indicate long-buried remains caused by surface fires. The sandy substratum typical of this part of the delta underlies these soils at a depth ranging from 3 to 6 feet.

This soil is very friable and easily worked. It is used primarily for the production of grain and asparagus, both of which do very well.

Some excellent yields of alfalfa have been obtained, and there are some new plantings in the area.

This soil, like all other soils of the delta area, must be protected by levees and drained before it can be farmed. Practically all areas are irrigated by subirrigation. This soil occurs rather extensively on Union Island, and there are a few smaller bodies on Roberts Island.

It is a good soil and is suited to a wide variety of field and truck crops but is not suitable for tree fruits and grapes.

ROBERTS SERIES

The soils of the Roberts series are organic soils composed chiefly of the remains of marsh plants, mostly reeds and sedges. This material is somewhat intermixed with fine mineral sediments similar to those making up the heavier members of the Sacramento series. These soils have reached a stage of decomposition in which the structure of the plant remains is very indistinct and much organic colloidal material is developed. These soils were formed in marshy areas in the San Joaquin River delta and have been reclaimed by building up levees along natural streamways. The elevation ranges from 5 feet below to 10 feet above sea level.

During the process of formation of these soils apparently there have been periods when the land was not completely covered by water, as evidenced by ashy layers throughout the profile, indicating periods of fires. The soils are normally rather acid, with a pH value ranging from 4.5 to 6.0, but they are less acid in areas where there are large quantities of ashy material.

The characteristics of these soils are determined largely by the character of the organic remains and the state of decomposition. In this area the series is represented by a type classed as Roberts muck.

Where the land is reclaimed, the water table is high and is maintained at the desired level by the use of lateral drains and pumps. The drainageways act as both drainage and irrigation ditches. Irrigation is accomplished merely by raising the water table.

The surface soils to depths in few places exceeding 18 inches are brownish black when moist and appear slate gray or brownish gray when dry. They are very light in volume weight and are soft and easily crumbled. They are definitely mucks but include some mineral sediments. The pH values range from 5.5 to 6.0.

The upper subsoil layers are very dark gray or black muck with slight compaction and rather definite platy layers. They break down to rather firm lumps. There are a few rust-colored flakes and streaks of ashy material in these layers, and a layer an inch or two thick of this ashy material is found here and there in the profile. Some vertical root channels start in these layers and extend downward. The root channels are stained with rust-brown iron stains and dark-colored organic matter. Many live roots are found in these layers. The pH values range from 5.5 to 6.0.

The lower subsoil layers, to a depth ranging from 3 to 6 feet, are very dark gray or almost black fairly compact muck with a rather rubbery consistence. This material breaks up in fairly large blocks, but it has a platy structure. These layers are mottled with ashy material and may contain appreciable quantities of mineral sediments. The vertical root channels, which start in the layer above, continue down through this layer. The acidity here is greater. This layer rests upon the mineral substratum, which may have some heavy blue clayey material of variable thickness above the typical sandy material that underlies the soils of this region.

The microrelief of this region is uneven, and a few sandy streaks representing old drainageways are not uncommon throughout these soils.

The Roberts soils are closely associated with soils of the Burns and Sacramento series. They are much like the soils of the Burns series, which have a somewhat higher mineral content.

Roberts muck.—The surface soil of Roberts muck is dark brownish-gray moderately acid muck. It is granular and friable and contains a small quantity of fine-grained mineral sediments that have been washed in.

The upper subsoil layer, at a depth ranging from 6 to 18 inches, is dark fibrous peat with a somewhat platy structure. This material is of variable thickness, ranging from a few inches to a foot or more. It is firm and in many places rather tough.

The lower subsoil layer generally is highly organic clayey material of no definite structure. This layer is somewhat mottled with dull iron stains and has many streaks of organic matter, which add to its mottled appearance.

Both subsoil layers are medium or strongly acid and have vertical root channels lined with iron stains extending down into the substratums.

The buff ashy layer, occurring in a few places in the Sacremento soils and in many places in the Burns soils, is almost everywhere present in the subsoil of Roberts muck, in many places being 6 to 8 inches thick. This layer is generally a little less acid than the rest of the profile except possibly the surface soil.

The sandy substratum occurs at a depth ranging from 3 to 6 feet in this area, becoming somewhat deeper near the Grant Line Canal in the northern part of the area.

This soil is not very extensive and is used primarily for growing asparagus, although it may be adapted to the same crops as the Burns and Sacramento soils. Practically all irrigation is accomplished by subirrigation.

MISCELLANEOUS LAND TYPES

Two miscellaneous nonarable types of land are mapped in this area—riverwash and made land.

Riverwash.—This type comprises coarse sandy, gravelly, and bouldery material along the channels of the streams of intermittent or transitory flow entering the area from the west. These bodies are comparatively barren, with some growth of cottonwoods and a little scattered grass, and they are subject to overflow during periods of heavy rains. They may provide a little pasture, but for the most part they are of little or no present or potential agricultural value.

Made land.—The areas of made land in this survey comprise gravel pits and dumps and areas where materials from excavations have been deposited. These areas occur along Corral Hollow Creek and a few miles south of the mouth of this creek. The land is barren of vegetation and of no agricultural value.

MORPHOLOGY AND GENESIS OF SOILS

Soil is the product of the forces of environment acting on the parent soil materials deposited or accumulated by geologic agencies. The characteristics of the soil at any given point depend on (1) the physical and mineralogical composition of the parent soil material, (2) the climate under which the soil material has accumulated and has existed since accumulation, (3) the plant and animal life in and on the soil, (4) the relief, or lay of the land, and (5) the length of time the forces of development have acted on the material. External climate, although important in its effects on soil development, is less so than internal soil climate, which depends not only on temperature, rainfall, and humidity, but on the physical characteristics of the soil or soil material and on the relief, which in turn, strongly influences drainage, aeration, runoff, erosion, and exposure to sun and wind.

The soils of this area may be considered as belonging to five natural physiographic groups or divisions (fig. 8, p. 20). The first physiographic division (group 1) represents hilly and mountainous areas where the soils have developed in place on bedrock mainly of sedimentary origin, with some metamorphosed and mixed material of rather limited extent.

The second physiographic division (group 2) is represented by soils of the recent alluvial fans, in which the parent soil materials have been transported from the soils and soil-forming materials of the first division. These fans are smooth and gently sloping, and the soils of this group are deep and friable and are the best agricultural soils of the area. They are subject to overflow during the rainy season.

The third physiographic division (group 3) represents soils developed on materials of the older alluvial fans of smooth relief and derived from the same source as the parent materials of group 2. These fans are older and are no longer generally subject to overflow. The stream channels are entrenched, and the soils are now subject to very slight erosion.

The fourth physiographic division (group 4) represents older high alluvial terraces, which have undulating or rolling relief. The erosion cycle is well advanced and entrenched drainageways cut deep into some of the terrace materials, most of which are gravelly and represent old alluvial deposits. Some of the stratified but unconsolidated gravelly layers are somewhat tilted. The soils are characterized by considerable development of claypans.

The fifth physiographic division consists of the lower valley basin and flood plains. The soils of this division are included in group 5. They are derived largely from mixed parent material deposited by the San Joaquin River. These areas are poorly drained and in some parts have a mantle of accumulated organic soils over the mineral sediments.

The climate of the area is semiarid, with an average rainfall between 8 and 13 inches. The summers are dry and hot, and the winters are mild and moist. Practically all of the rainfall comes between December and May. Nearly all of the rain water that falls in this area is dissipated in the area; that is, there is very little runoff into the San Joaquin River.

For the most part the soils are calcareous, mostly with developed lime, although some of the rocks forming the parent material are but slightly calcareous. There are a few noncalcareous soils in groups 1, 3, and 5. The noncalcareous soils in groups 1 and 3 probably owe their lack of lime to some peculiarity in the parent material. Those in group 5, although occurring in an area of fairly low rainfall, have been subject to overflow and in many instances have been under water a good part of the year and have been subjected to prolonged leaching.

In general, in the valley part of the area the amount of rainfall decreases slightly from north to south. There is undoubtedly some variation in the amount of rainfall in the mountainous areas, the amount decreasing from west to east. There are very few stations where rainfall data have been kept in this area, and consequently it is difficult to ascertain just what differences there are in amount of rainfall in the various parts.

Some differences in the soils in group 1 may be attributable to differences in rainfall, but for the most part the differences due to parent material far overshadow those due to differences in rainfall.

For the most part the soils are immaturely developed. The only soils in which distinct development of a profile occurs are in groups 3 and 4, which are no longer subject to overflow and are not sufficiently steep to allow very rapid erosion.

SOILS OF THE HILLY AND MOUNTAINOUS AREAS

Soils of the hilly and mountainous areas are represented by six soil series, all of which have developed in place on parent bedrock. Four of these, the Altamont, Linne, Kettleman, and Vallecitos are Pedocals, and the remaining two, the Los Osos and Contra Costa, are Pedalfers. All the members of this group have youthful to immature profiles with only slight or imperfect development of B horizons.

The soils of the Altamont, Linne, and Kettleman pedocalic series are very closely related to one another, yet they possess individual characteristics by which they can easily be recognized. They occupy gently rolling to fairly steep hilly areas covered mainly by native grasses, or grass and brush, with here and there some scattered oaks. The soils of the Altamont and Linne series are on the gentler slopes, with smooth rolling relief, whereas those of the Kettleman series occupy more steeply sloping areas with rougher relief. The Altamont and Linne soils are generally heavier textured than the Kettleman soils and are darker. The Altamont soils have brownish-gray or olive-brown surface soils, whereas the Linne soils are dark gray or dull dark brownish gray. The Kettleman soils have light brownish-gray surface soils, with a somewhat yellow cast in many places.

The rock formations on which these soils are developed are of variable geologic age, but all are sedimentary rocks. Some of the rounded gravel in the conglomerates is of basic igneous rocks. Some of the sandstone and shale formations are somewhat calcareous, but for the most part the bedrock immediately below the soil is noncalcareous and the lime in the soil profile is developed lime from calcium minerals. Some of the bedrock material contains considerable gypsum.

The Linne and Kettleman soils are calcareous throughout the soil profile, whereas the Altamont soils are calcareous only in the subsoil. The Altamont and Linne soils are more extensive in the northwestern part of the area, although in the southern part, along Lonetree and Hospital Creeks, there are areas where the soils of all three series occur very close together. The Kettleman soils, as they occur in this area, include some areas, on the north and east exposures, of somewhat browner soil than is typical, in which the topmost few inches may be leached of lime. The soils on the south and west exposures are shallower, and the vegetation is not so heavy. This same relationship does not seem to hold for the Altamont and Linne soils, yet the Altamont soils do seem to occur in places where the rainfall is slightly higher. The western part of the extreme northern part of the area close to the Livermore Valley is occupied mainly by the Altamont soils, whereas the lower foothills on the eastern side bordering the San Joaquin Valley are mainly Linne soils. The rainfall in the Livermore Valley is higher than it is immediately to the east in the San Joaquin Valley. Just south of Altamont, however, in the vicinity of Patterson Pass, where the rainfall should be about the same as that just north of Altamont, the soils are principally of the Linne series. In this area, however, there appears to be some difference in the parent material, which is more calcareous, and in many places large fossil oystershells are present in the soil, and these may apply some lime to the parent material.

The Vallecitos soils are considered Pedocals, although few of them contain free lime carbonate in their profiles. The lower subsoil layers are basic, and at times some lime occurs in thin seams in the upper part of the parent material. These soils are similar in mode of formation and development to the Altamont soils, but are derived from harder parent materials. They occupy more rugged and mountainous areas, occur in large bodies, and the profiles in general are shallower even than those of the Kettleman soils. These soils, although they are probably zonal soils, come closer to being Lithosols than any other soils of this area.

No attempt is made in this publication to group the soil series into the great soil groups of the world, because of the great differences in environment and character that occur within very short distances. For example, both pedocalic and pedalferic soils occur in this small area of about 375 square miles.

The two pedalferic members of this group, the Los Osos and Contra Costa, are similar in origin, mode of formation, and parent material. The Los Osos and Contra Costa soils are developed in small scattered bodies in association with the Linne and Altamont soils, although they are distinctly different from them.

The Los Osos and Contra Costa soils differ from each other mainly in their color; the former is brownish gray or dark brown, and the latter is light rich brown or reddish brown. Where they occur near each other south of Patterson Pass the Los Osos soils are not so strongly acid as are those of the Contra Costa series; but north and northeast of Altamont, where the Contra Costa soils occur as small bodies surrounded by soils of the Altamont series, the reaction is very similar to that of the Los Osos soils previously mentioned.

SOILS OF THE RECENT ALLUVIAL FANS

Soils of the recent alluvial fans are pedocalic recent alluvial soils that do not have compact subsoils with distinct accumulation of clay, colloids, and lime. They are derived from outwash materials, mostly from sandstone and shale rocks, and owe their characteristics largely to the character of the stratified parent materials. The parent materials have been transported by minor streams and laid down as smooth gently sloping confluent fans or associated narrow flood plains. The material has been transported only a short distance and was washed from the nearby hills on which are soils of the Altamont, Linne, Kettleman, and Vallecitos series. Soils of the recent alluvial fans are represented by two series, the Sorrento and the Mocho, both of which are somewhat related to the more extensive Yolo series, the soils of which are mapped extensively throughout California but occur in regions of somewhat higher rainfall than the Tracy area. The Yolo soils are noncalcareous, and few areas occur where the average annual rainfall is less than 15 inches; whereas those of the Sorrento series are calcareous in the subsoil, and the Mocho soils are calcareous in both surface soil and subsoil. These soils occur in regions of somewhat lower rainfall.

SOILS OF THE OLDER ALLUVIAL FANS

Eight series of soils occupy the older alluvial fans, and they represent several different conditions with regard to mode of formation. The soils of the Zamora, Rincon, Ambrose, Herdlyn, and Olcott series occur on alluvial fans in which the drainageways have been entrenched so that there is seldom any deposition of new material on the surface. The soil materials have been in their present position long enough for weathering and soil development to have caused the formation of well-defined soil layers. These soils, except in small included local areas, occur under fair drainage. In the northern part of the area they occupy all the alluvial fans from their apex to a place where they border the basin rim soils of the Solano and Pescadero series, which are at the lower margins of the fans where they, in turn, join the basin soils of the San Joaquin River bottoms. In the southern part of this area, extending approximately from Tracy southward and eastward, the soils of the Ambrose and Rincon series border the basin soils and lie below those of the more recent Sorrento soils on the same series of confluent fans. In this position they lie out on the lower slopes of the alluvial fans; but the slope here is slightly greater than on the Solano and Pescadero soils, and the streamways have entrenched themselves, so that no fresh sediments are being deposited.

The first five soils of the group are considered pedocalic, although neither the Zamora nor the Olcott soils have sufficient calcium carbonate in the soil mass proper to effervesce with dilute hydrochloric acid; yet the gravel present in the subsoils is coated with lime and effervesces freely with acid. These soils are normally free from alkali. Their parent material was deposited by small intermittent streams and represents chiefly outwash from the residual soils described in group 1. These soils are somewhat variable in stage of profile development, with the least development in the Zamora soils and the greatest in the Olcott. The Rincon soils are next to the Zamora in stage of development, followed by the Ambrose and Herdlyn, although the difference in age between the Rincon and the Ambrose is not very apparent in many instances. The soils of the Herdlyn series appear definitely to have undergone greater modification by weathering and soil development than those of the Ambrose series.

Four of these soils are brown or have a definitely brown tinge. The Zamora is dark brown or brownish gray, the Rincon is brown or dull brown, the Olcott is about the same color, and the Herdlyn is brown or grayish brown with a very slight red cast when wet. The other member of this subgroup of five soils—the Ambrose—is dark gray or dark brownish gray with a rather dull cast.

There does not seem to be any striking genetic relation between the soils of these five series. That is, there is no apparent evidence that the more strongly developed members have developed through successive stages from the younger members of this group. There is some variation in the stage of development of the profiles in the individual series, and these differences occur within very short distances. The play of the streams over the fans in the process of their formation was so slow that parts of the same fan may have been exposed to soil-forming processes while other parts were receiving deposition. These differences in stage of the development of a profile are minor, and, although recognizable in the field, the changes are so abrupt and in such intricate patterns that no attempt is made to separate these minor distinctions.

Of the remaining members of the group, the soils of the Pescadero and Solano series occur on the lower edge of old alluvial fans, whereas those of the Antone series occur in narrow valleys in the hilly areas.

The Pescadero and Solano soils as mapped in this area are imperfectly or poorly drained intrazonal soils. They border the basin soils. The water table is within 5 feet of the surface during most of the season, and the soils are somewhat affected by salts. These soils have very little mottling in the subsoils, indicating that at least during a part of the season the water table is sufficiently low to allow fair aeration. The Pescadero soils have definite accumulations of clay in the subsoil but no distinct claypan, whereas the Solano soils have a claypan with rather indistinct solonetzlike structure.

SOILS OF THE HIGH TERRACES

Soils of three series comprise the high terraces. They are all Pedocals. Although the soils of the Positas series do not contain free lime, the gravel in the subsoils is coated with lime and the reaction of the soil material is basic. The Montezuma and Denverton soils are very closely related in profile characteristics, age, and mode of formation, differing mainly in color. The Positas soils are very different in profile characteristics and occur on slightly different formations with slightly different relief. All these soils have definite compaction and concentration of clay and colloids in the subsoils.

The Denverton and Montezuma soils in this area are developed on gravelly deposits representing old outwash materials principally from the Franciscan geologic formation. Most of the softer rocks have decomposed, and those remaining are rounded gravel of chert, quartzites, and some of the harder partly metamorphosed sandstones and shales as well as a few hard crystalline rocks, most of which are basic in character. These soils occur on rather high old alluvial fan remnants or old terrace formations bordering the western edge of the valley extending from Patterson Run southward beyond the southern boundary of the area. These old fan remnants have a gentle eastward slope of 2 to 6 percent, but they have been cut deeply by many small drainageways until some of them have rather hilly relief with nearly parallel drainageways running in a northeasterly direction. A view of the San Joaquin Valley from the western hills shows truncated relief of old alluvial fans entrenched by drainageways. For the most part these soils are noncalcareous in the surface soil, but areas are included in the Denverton soils that are somewhat calcareous in the surface soil. There is not sufficient difference in the amount of rainfall to account entirely for the difference in color of the Denverton and Montezuma soils, for they occur very close together and on similar formations.

The Positas soils occupy terracelike remnants along Lonetree and Hospital Creeks. These remnants are at lower elevations than the surrounding soils of the Denverton series, yet they seem to have as much development of a profile. They seem to be developed on more recent outwash from the Franciscan formation and from soil material of the Vallecitos series. They have compact subsoils with heavy colloidal staining on the surfaces of the soil aggregates.

SOILS OF THE BASIN AND FLOOD PLAINS

The group of soils of the basin and flood plains comprises six series—the Roberts, Burns, Columbia, Ramada, Piper, and Sacramento—four of which include definitely mineral soils that do not have very clearly defined surface soil and subsoil layers. The soils of the Roberts series are organic soils, and the soils of the Burns series represent somewhat of a transition between the definitely organic soils of the Roberts series and the truly mineral soils of the Sacramento series.

Of the mineral soils, those of the Columbia and Ramada series appear to consist of the most recently deposited sediments. These soils show no evidence of an accumulation of clay or development of structural forms. The soil materials are highly stratified, and, except where artificial levees have been erected, the land is subject to overflow and deposition of fresh sediments. The soils of these two series are much alike, differing mainly in color. The Columbia soils are pale brown or light yellowish brown, and the Ramada soils are yellowish brown and somewhat more highly mottled with iron stains in the subsoil. The soils of the Piper series are similar to those of the Columbia, but they have somewhat more compact subsoils, are brownish gray, and are calcareous, whereas the Columbia and Ramada soils are noncalcareous throughout. The soils of the Sacramento series are generally of fairly heavy texture and range from dull gray to dark gray. These soils are strictly basin soils and under normal conditions were flooded annually and remained under water from a few months to a considerable part of the year. They are noncalcareous in the surface soils but may or may not be calcareous in the subsoils.

The soils of the Roberts and Burns series are slightly darker than those of the Sacramento series . These soils are high in organic matter and are normally moderately or strongly acid throughout, the Roberts soils generally being the more acid.

Soils of the Roberts and Burns series occur along the upper delta of the San Joaquin River at elevations ranging from about 5 feet below sea level to about 5 feet above. The delta is underlain by sandy material at a depth ranging from 2 to 8 feet in this area. This sandy substratum seems to continue, but at greater depths, farther out on the delta. This material consists of well-rounded sand grains that show considerable variation in texture and contain considerable quantities of mica. The soils of the Roberts, Burns, and Sacramento series seem to be resting on this sandy material, and the soils of the Columbia, Ramada, and Piper series have been washed in on these other soils, especially on those of the Sacramento series. The lighter textured members of the Columbia and Ramada series seem to follow old streamways and less frequently rest on the darker, heavier soils. There are a few areas of Columbia soils along the channels of the major streams, particularly the San Joaquin River and the Old River, that are not underlain by the heavier textured Sacramento soils.

The sediments from which the mineral soils of this group are formed are those carried by the San Joaquin River, and they are derived from both igneous and sedimentary rocks. They are somewhat micaceous and well assorted. The sand grains generally are very fine and smooth, and all the soils contain high quantities of silt.

INDEX RATINGS OF SOILS

The soils of the Tracy area are here rated according to the Storie (*6*) index, which rates the soils on their inherent productive capacity in terms of percent, ranging from 100 percent for the most productive soils to very low values for the very poor soils. The productive capacity of any soil is dependent on the soil itself, and especially on the degree to which the soil presents conditions favorable for the extension and development of plant roots. In this index the soils are grouped in six groups according to their profile characteristics. Group I consists of secondary soils with undeveloped or very slightly developed soil profiles with previous soils and subsoils to depths of 6 feet or more; group II, secondary soils with moderately developed profiles having compact subsoils with moderate accumulations of clay, which somewhat inhibit root penetration; group III, secondary soils with strongly developed profiles having dense clay subsoils with loose unconsolidated substrata. These tight subsoils greatly impede root development and water penetration. Group IV includes secondary soils with strongly developed profiles with hardpans. These soils have dense impervious cemented hardpans generally underlying dense clay layers. Group V includes secondary soils having dense clay subsoils resting on consolidated substrata; and group VI, primary soils underlain by bedrock. These soils are developed from the decomposition and disintegration of the underlying bedrock and occupy rolling, hilly, or mountainous relief.

The successive steps by means of which the index ratings for the various soil types and phases are obtained are explained in the publication to which reference has already been made (*6*) and will not be repeated here.

For convenience in grouping soils according to their index ratings, Weir and Storie (*7*) have graded the soils with specified ranges into six soil grades as follows:

Grade 1, index rating 80–100; excellent soils suitable to a wide range of field, orchard, and truck crops.

Grade 2, index rating 60–79; soils suitable to most crops of the area, although not quite so desirable as those of grade 1.

Grade 3, index rating 40–59; soils of this grade are limited in their use and productivity, although they may give good or even excellent results with specialized crops or where some condition other than the soil is especially favorable These soils do not have the wide range in suitability of those of grades 1 and 2

Grade 4, index rating 20–39; soils that have very narrow range in agricultural possibilities.

Grade 5, index rating 10–19; soils that have very limited use except for pasture.

Grade 6, index rating less than 10; nonagricultural areas—rough mountainous lands, riverwash, and made lands

Soils of grades 1 and 2 are capable of extensive development under irrigation, and ordinarily soils of grade 3 are capable of such development but with reservations. Soils of grade 4 are definitely marginal lands whereas those of grades 5 and 6 should not be subjected to cultivation.

Results of index rating of the soils of this survey by this system are given in table 3.

TABLE 3.—*Index rating of the soils of the Tracy area, California*

Soil type	Profile group	Index	Grade	Remarks concerning important characteristics
Altamont adobe clay	VI	47	3	Average depth 3 feet, slightly eroded
Altamont adobe clay, steep phase	VI	25	4	Average depth 3 feet, slightly to moderately eroded.
Altamont clay loam	VI	43	3	2 to 3 feet deep, moderately eroded.
Altamont clay loam, steep phase	VI	17	5	Average depth 2 feet, moderately severe erosion
Ambrose clay	III	46	3	Very heavy subsoil
Ambrose clay, slightly alkali affected	III	39	4	Very heavy subsoil, soluble salts in slightly harmful concentration
Ambrose clay, moderately alkali affected.	III	23	4	Very heavy subsoil, soluble salts in moderately harmful concentration.
Ambrose clay loam	III	68	2	Moderately compact subsoil
Antone clay	III	29	4	Compact subsoil, bad gullies
Burns clay loam	I	61	2	High water table.
Columbia fine sandy loam	I	90	1	Friable, underlain by Sacramento soil
Columbia silty clay loam	I	81	1	Do
Contra Costa loam	VI	35	4	2 to 3 feet deep, moderately eroded
Contra Costa sandy loam	VI	29	4	Average depth 2 feet, eroded
Denverton adobe clay	III	49	3	Very friable surface soil heavy subsoil.
Denverton adobe clay, slope phase	III	44	3	Friable surface soil, slightly eroded
Denverton gravelly clay	III	25	4	Very slightly eroded
Denverton gravelly clay, slope phase	III	21	4	Slightly to moderately eroded
Denverton gravelly clay, steep phase	III	8	6	Nonagricultural; steep, moderately to severly eroded
Herdlyn loam	III	47	3	Heavy, compact subsoils, hog-wallow microrelief
Kettleman clay	VI	25	4	2 to 3 feet deep; moderately to rather severely eroded
Kettleman fine sandy loam	VI	21	4	1 to 2 feet deep, steep, considerably eroded
Kettleman fine sandy loam, rock-outcrop phase	VI	7	6	Nonagricultural, poor pasture
Linne adobe clay	VI	44	3	3½ feet deep, slightly to moderately eroded
Linne adobe clay, steep phase	VI	25	4	Average depth 3 feet, slightly to moderately eroded
Linne clay loam	VI	43	3	2 to 3 feet deep, moderately eroded
Linne clay loam, rock-outcrop phase	VI	19	5	Nonagricultural, fair pasture
Los Osos sandy loam	VI	29	4	Average depth 2 feet, somewhat eroded.

TABLE 3.—*Index rating of the soils of the Tracy area, California*—Continued

Soil type	Profile group	Index	Grade	Remarks concerning important characteristics
Made land		2	6	No agricultural value.
Mocho loam	I	67	2	Stratified subsoil
Montezuma adobe clay	III	46	3	Friable surface soil, heavy subsoil.
Olcott clay loam	III	43	3	Heavy compact subsoil.
Pescadero clay	II	31	4	Compact subsoil, high water table.
Pescadero clay, slightly alkali affected	II	26	4	Do
Pescadero clay, moderately alkali affected.	II	15	5	Do.
Pescadero clay, strongly alkali affected	II	5	6	Do.
Piper fine sandy loam	II	86	1	Friable; underlain by Sacramento soil.
Piper fine sandy loam, moderately to strongly alkali affected.	II	19	5	Alkali; underlain by Sacremento soil
Positas gravelly clay loam	III	39	4	Gravelly throughout; heavy subsoil
Ramada fine sandy loam	I	90	1	Friable, underlain by Sacramento soil
Ramada silty clay loam	I	81	1	Do.
Rincon clay	II	56	3	Moderate compaction in subsoil.
Rincon clay loam	II	72	2	Do.
Rincon gravelly clay loam	II	51	3	Do.
Riverwash		8	6	Some pasturage.
Roberts muck	I	54	3	High water table; acid, danger of burning.
Sacramento clay	I	64	2	Very friable surface soil, high water table.
Sacramento clay loam	I	69	2	High water table.
Sacramento loam	I	81	1	Do.
Solano loam, moderately alkali affected	III	25	4	Compact subsoil; high water table.
Solano loam, strongly alkali affected	III	6	6	Do
Sorrento clay	I	70	2	Friable, deep.
Sorrento clay loam	I	100	1	Do.
Sorrento gravelly clay	I	50	3	Gravel not excessive.
Sorrento gravelly clay loam	I	60	2	Gravelly; deep, friable.
Sorrento gravelly loam	I	70	2	Do.
Sorrento loam	I	100	1	Friable, deep.
Sorrento silty clay	I	85	1	Do
Vallecitos stony clay loam	VI	17	5	2 feet deep; mountainous.
Vallecitos stony clay loam, rock-outcrop phase.	VI	7	6	Nonagricultural, poor pasture.
Vallecitos stony clay loam, steep phase	VI	12	5	Average depth 2 feet; steep, slightly eroded
Vallecitos stony loam	VI	17	5	1 to 2 feet deep, mountainous.
Zamora gravelly clay loam	II	57	3	Gravelly throughout

EROSION IN RELATION TO LAND USE

Water is the principal erosive agent in the Tracy area, although some few small areas, particularly cultivated hilltops in the vicinity of Altamont, may have been affected by wind erosion.

Rainfall records kept at Tracy show an average annual precipitation of 10.26 inches. Similar records at Livermore show 13.70 inches. No record of precipitation is available for the hilly region west, southwest, and south of Tracy, where practically all of the erosion in the area has occurred. It is probable that the rainfall here, particularly in the vicinity of Altamont and south to Crane Ridge, is equal to or slightly greater than that recorded at Livermore and that its characteristics are similar.

Distribution and intensity of rainfall are important factors in the relation between rainfall and erosion. Most of the precipitation in the Tracy area comes in the form of winter rains. Approximately 80 percent of the annual precipitation falls between November 1 and March 31. Seldom is there a rain of severe intensity, and rarely is there sufficient runoff to swell the small intermittent streams that issue from the hills to such volume that they extend entirely across their fans to the San Joaquin River.

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The annual precipitation that falls between April 1 and October 31 is generally in the form of rather widely distributed light showers that not only do not cause runoff but have little effect on plant growth.

In the vicinity of Altamont and Patterson Pass there are approximately 5,500 acres that are used to produce grain and grain hay. The Altamont and Linne soils predominate. Slopes range from 20 to 35 percent, most of them being about 30 percent. In the vicinity of Midway there are approximately 2,000 acres that are used similarly. The Linne soils predominate here, and few of the slopes exceed 20 percent (pl. 3, *A*).

The most common practice in these areas is to follow a 2-year rotation. The grain is planted after the first fall rains, generally late in November or early in December. The crop is harvested early the following summer. Then the stubble is pastured until the next spring, generally until April or May, when the land is plowed and left fallow until the next crop is planted the following December.

This practice insures having a vegetative cover, either growing grain or stubble, on the soil during the period of heaviest and most intense rainfall. It apparently is effectively preventing erosion except on a few small bodies of Contra Costa loam, Linne clay loam, and Altamont clay loam. On slopes of 25 percent or more these soil types show perceptible rilling, whereas adjacent to them, on similar slopes and under the same management, there is no rilling on the clay types of the Linne and Altamont series.

In the vicinity of Mountain House there are approximately 5,000 acres, predominantly the Linne and Altamont soils, that were used for the production of grain hay when there was a larger demand for that product. Curtailment of the hay market, and the facts that the rainfall is less and the grain-shattering winds are more destructive in this vicinity than in the vicinity of Altamont, are factors that led to the return of these lands to permanent pasture.

In a few of the fields it was observed that large gullies had formed, presumably during the period of cultivation. At present practically everyone of these gullies has been grassed over, so that they are now almost completely stabilized.

In the hilly range lands most of the moderately severe and severe sheet erosion and excessive gullying is in the vicinity of a series of geologic contacts and fault lines that extend eastward and southeastward from a point a short distance north of the old town site of Tesla (now abandoned). The soils principally affected are members of the Linne, Contra Costa, and Kettleman series. The bedrock underlying the soils is so shattered that it is more easily eroded than the soil layers above it. This natural condition has made the district susceptible to the formation of deep, destructive gullies. Many of them have been cut to a depth of 20 feet or more and are rapidly becoming more destructive when they have cut through the comparatively thin upper layers of soil that are more stable than the substratum. Erosion of the looser substrata results in undercutting, caving, and sloughing. The effective control of gully erosion will be a major problem, because of the unstable condition of the bedrock.

Many hills in this same general vicinity are eroded much more severely on their southern and western exposures than elsewhere. This is partly the result of too early grazing, as detailed in a later paragraph. But in many places there have developed pot holes and underground channels that eventually cave in and become deep, destructive gullies. The presence of gypsum crystals in considerable quantities in the subsoil and substratum may have some relation to this condition. Not only is gypsum somewhat soluble in cold water, but it has a marked flocculating effect on the soil. This creates a peculiar structure that causes the soil to break down and wash away easily. If this solution and washing occur along underground drainageways, cavities develop in the subsoils and substrata. The soil above the cavities eventually caves in, and pot holes are the result. As the pot holes are enlarged, they join and become gullies. In many places there are long underground channels before the surface is disturbed. Naturally, the action is more rapid in the hillside troughs, where the runoff is concentrated and ground water is more abundant. This condition occurs to a rather large extent in bodies of Denverton gravelly clay, but it is by no means limited to that soil. It occurs also in soils of the Linne and Kettleman series.

Except where pot holes or deep gullies have been formed, erosion on these soil bodies can probably be controlled best through a program of range management. The usual system is to put sheep or cattle on the range lands very soon after the first fall rains. The determining factor too often is not the condition of the range but the presence of sufficient drinking water for the livestock in the small streams and water holes. Often the pasturage is insufficient to support the livestock, and the natural result is an overgrazed condition, especially on the southern and western exposures, where higher soil temperatures have induced more rapid plant growth. When the heavier and more intense rains come a few weeks later the surface soil often does not have enough vegetative cover to protect it. This condition is aggravated by the practice of keeping the livestock on the range late in the spring, until either the forage or the drinking water is entirely exhausted. A plan of range management based on the maintenance of sufficient vegetative cover during the season of heaviest rainfall should control all the sheet erosion and the shallower gullies.

The soil types mapped in this area are classified in six groups with respect to their erodibility under the existing conditions of slope, use, cover, and rainfall. No attempt is made to rank the several soil types within each group.

Group A consists of the most erodible soil types: Contra Costa sandy loam, Antone clay, Denverton gravelly clay, Kettleman clay, Kettleman fine sandy loam, Los Osos sandy loam, and Solano loam.

The Contra Costa, Kettleman, and Los Osos soils have developed in place on shale, sandstone, and conglomerate rock, on slopes of 15 percent or more. Even where they are not underlain by shattered bedrock they appear to be very susceptible to both sheet and gully erosion. Moderate to severe sheet erosion and gullies of all classes have occurred. Denverton gravelly clay is subject to extensive formations of pot holes. Both the Denverton and the Antone soils are on terraces. Surface slopes range from about 5 percent to as high as 45 percent where the terraces have been badly dissected. Wherever accumulated runoff drains over the lower rim of a bench, a gully starts and rapidly cuts headward across the bench. Examples of this type of gullying, some of them rather extensive, are common in bodies of Denverton gravelly clay and Antone clay. Only a small acreage of Solano loam is mapped in this area. Notwithstanding its rather gentle slope, less than 5 percent, this soil appears to be very susceptible to both sheet and gully erosion.

Practically all bodies of these soil types are grazed. Control measures will depend on improvements of methods of range management.

Group B consists of soil types slightly less erodible than those in group A. These are Altamont clay loam, Contra Costa loam, Denverton adobe clay, Linne clay loam, and Montezuma adobe clay. All these soils are on slopes of more than 12 percent. Generally the dominant slope is nearly 25 percent. Wherever these soils are cultivated on slopes steeper than 20 percent, serious rilling has occurred. They appear to be much more stable when kept under a permanent grass cover.

Group C is made up of soil types slightly less erodible than those in group B. They include Altamont adobe clay, Linne adobe clay, and Positas gravelly clay loam.

The Positas soil occupies high terraces that are rather severely dissected. Sheet erosion is generally moderate or even slight, but there are occasional rather active deep gullies that may or may not extend into the friable substratum.

The other soils in this group are developed from residual materials over bedrock. The relief is moderately to steeply rolling, with dominant slopes of 20 to 35 percent. Sheet erosion is more often slight than moderate. Gullies are rather infrequent, and few of them are deep enough to prevent crossing with farm implements or to impede the movement of livestock. Considerable areas of the Altamont and Linne soils are cultivated, in the vicinities of Altamont, Patterson Pass, and Midway, without appreciable loss of soil. Under a plan of management that offers less protection to the surface during the rainy season, these soil types might not prove as stable as they now appear to be.

Group D consists of soils slightly less erodible than those of group C. They are Ambrose clay, Ambrose clay loam, Olcott clay loam, Herdlyn loam, Rincon clay, Rincon clay loam, Rincon gravelly clay loam, Vallecitos stony clay loam, Vallecitos stony loam, and Zamora gravelly clay loam.

The Vallecitos soils are shallow soils on hard bedrock. They occupy steep hilly areas in the southern part of this area. They support a fairly good cover of grass, with occasional patches of brush and an uneven growth of trees—mainly oak and juniper. They are used exclusively for grazing. Erosion is not a problem except in isolated spots where gullies have formed in livestock trails or as a result of excessive runoff from sheep bedding grounds that have been denuded of their natural vegetation.

The other soil types in this group occupy gently sloping alluvial fans and are generally cultivated. The dominant slope of these soil areas ranges from less than 1 percent to not more than 5 percent, with at least 80 percent of their surface having a slope of less than 2 percent. All drainageways are slightly entrenched. Gullies are practically absent. Sheet erosion is very slight. Under conditions as the white man found them, there was probably a very slight normal soil movement from the upper part of the fans toward their lower margins. Now the fans are crossed by numerous obstructions to surface runoff—roads, fences, irrigation canals, and irrigation borders. So far as surface movement of water and soil is concerned, no entire fan can now be considered a unit, but each small area between the man-made obstructions must be observed. On a number of these smaller units, after heavy rains, it was noted that muddy water accumulated on their lower margins and left there a thin deposit of very fine soil. It was estimated that the upper nine-tenths or more of each unit had been very slightly eroded and the lower one-tenth or less had received a very slight deposition of soil material.

Group E consists of soils subject to neither erosion nor deposition. Under natural conditions most of these soils were subject to deposition. Under present conditions of protection from floodwaters by levee, the soils are no longer built up by sediments from overflow, neither are they subject to erosion. These soils are Burns clay loam; Pescadero clay; Columbia fine sandy loam; Columbia silty clay loam; Ramada fine sandy loam, shallow phase; Ramada silty clay loam, shallow phase; Piper fine sandy loam; Roberts muck; Sacramento clay; Sacramento clay loam; and Sacramento loam.

These are all soils of the delta and flood plains except Pescadero clay, which occurs on the rim of the basin, on the lower margins of alluvial fans.

Group F consists of soils generally subject to deposition. In most parts of the area where they occur they are being very slowly but definitely built up by the deposition of sediment from the floodwaters of small intermittent streams that issue from uplands. Following is a list of these soils: Mocho loam, Sorrento clay, Sorrento silty clay, Sorrento loam, Sorrento gravelly clay, Sorrento gravelly clay loam, Sorrento clay loam, and Sorrento gravelly loam.

All these soils occur on recent alluvial fans. The floodwaters of the small streams that are still building the fans, principally Corral Hollow Creek, are diverted into the irrigation canals and are spread over the land. The amount of sediment that is dropped by the water in one season is very slight. It is never in harmful quantities and is considered a definite benefit to the soil.

Table 4 gives the mechanical analysis, salt content, and moisture content of two samples of Kettleman fine sandy loam. One sample was collected on the northern slope of a 52-percent hillside where the vegetation was good; the other was collected 60 feet away on the southwest side of the same hill, with a 40-percent slope. The vegetation was very poor, and erosion was very severe (pl. 4, A). These samples were collected in February 1938 after a rather extended rainy period. On the good grassed area on the north slope, moisture had penetrated to a depth of 26 inches, but on the south slope on the nearly barren area moisture had penetrated to a depth of only 12 inches. A thin veneer of vesicular crust overlying friable yellowish-brown silt material characterized the soil on the south slope, whereas the soil on the north slope was similar except that it was friable from the surface to bedrock.

TABLE 4.—*Mechanical analysis,[1] salt determination, and moisture content[2] of two samples of Kettleman fine sandy loam, one collected on nearly barren eroded south slope, the other collected on good grassed area on north slope 60 feet away*

Sample No.	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt[3]	Clay[4]	Organic matter	Salt by bridge[5] 20:1	Salt by bridge[5] 100:1	Moisture content
	Inches	*Pct*	*Pct*	*Pct.*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct.*	*Pct*
37332	0 to 6 (bare)	0.7	0.9	0.8	6.8	23.9	46.1	20.8	0.2	0.04	------	13.6
37328	0 to 6 (grass)	.5	1.1	1.1	5.6	15.0	52.1	24.6	.8	.03	------	23.0
37333	6 to 12 (bare)	.6	1.0	.6	6.6	22.0	47.2	21.1	0	.03	------	16.1
37329	6 to 12 (grass)	.9	1.1	.9	4.4	16.6	50.5	25.6	.1	03	------	20.1
37334	12 to 24 (bare)	.3	.7	.6	7.2	25.6	59.5	6.1	.2	1.46	7.7	9.1
37330	12 to 24 (grass)	.9	1.0	.8	4.5	17.7	50.7	24.4	0	.05	------	17.7
37335	24+(bedrock, bare)	.6	.9	.5	9.5	48.2	33.1	7.2	.1	93	6.2	------
37331	24 to 30 (grass)	.9	.8	.7	4.6	21.0	70.6	1.4	0	2.03	10.9	12.0

[1] Mechanical analysis by T. M. Shaw, then of the Soil Chemistry and Physics Division, Bureau of Chemistry and Soils, U. S. Department of Agriculture.
[2] Moisture content determined by R. C. Cole, of the California Agricultural Experiment Station.
[3] Silt—0.05–0.002 mm. diameter.
[4] Clay—less than 0.002 mm. diameter.
[5] In some instances a wide disagreement was found between the salt determined by the electrolytic bridge and the mineral matter dissolved by H_2O_2 when conventional water to soil ratio (20:1) was used. In a few instances data for 100:1 ratios are given. The results indicate that at the lower ratios a saturated solution of $CaSO_4$ was obtained.

It is readily seen from the analysis that the content of organic matter of the surface soil to a depth of 6 inches is four times as high on the northern slope as on the southern slope. The silt and clay content also are greater in the upper 12 inches on the northern slope than on the eroded southern slope. The depth to the parent material is much less on the southern slope. The salt content is approximately the same for the two soils. The high content of $CaSO_4$ is probably particularly responsible for the formation of the pot-hole gully conditions as indicated in plate 4, *B*.

One of the most important results of table 4 is the moisture content of the various layers. It is readily seen that the north slope has much more available moisture for plant growth than the sun-exposed south slope, which has the greater evaporation. This soil is in an area where moisture is the limiting factor for plant growth, and therefore the grass on the south slope is distinctly handicapped compared with that on the north slope. The plants grow slowly, and there is much barren land. Erosion is therefore high, fertility is low, evaporation is intensified, and the number of plants gradually becomes less and less, and this vicious cycle continues.

Table 5 gives the mechanical analysis, salt content, and moisture content of two samples of Antone clay. One sample was collected on a very gentle slope where the vegetation was good; the other sample was collected about 20 feet away (pl. 4, *C*), where the land was barren and gently sloping and had the appearance of being affected with salt or alkali. These samples were collected the same day that the Kettleman samples were collected. Water had penetrated to a depth of 12 inches on the good grassed area and only 3 inches on the barren area.

The grassed area was characterized by a nearly black plastic wet clay surface soil, the upper 3 inches of which was much more sandy than the lower part and more friable. The subsoil was plastic and heavy textured, and it was lighter in color than the surface soil. The barren area had a distinctly white surface crust that was puddled.

Immediately below this veneer was a gray vesicular layer about one-sixteenth of an inch thick, which rested on nearly black plastic clay about 3 inches thick. This layer was underlain by nearly black dense hard dry alkaline clay with many visible salt crystals. This material gradually changed with depth to a lighter colored more friable material that was high in salt and gypsum.

TABLE 5.—*Mechanical analysis,[1] salt determination, and moisture content[2] of 2 samples of Antone clay, one collected on eroded nearly barren salty area, the other collected on good grassed area 20 feet away, but both on the same gentle slope*

Sample No	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt [3]	Clay [4]	Organic matter	Salt by bridge [5]		Moisture content
										20 1	100 1	
	Inches	*Pct.*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct.*	*Pct.*	*Pct.*
37336	0 to ¼ (bare)	2.6	7.6	5.9	12.1	12.7	29.2	29.9	0.0	0.10		-----
37337	0 to 3 (bare)	1.0	4.9	5.4	12.9	12.4	24.4	39.0	1.0	.65	-----	21.9
37341	0 to 3 (grass)	1.8	6.3	6.7	18.4	13.0	33.6	20.2	1.4	04	-----	25.0
37338	3 to 12 (bare)	1.4	4.6	4.6	11.4	11.0	25.1	41.9	2	76	1.06	9.7
37342	3 to 12 (grass)	.8	3.5	3.9	10.4	10.2	27.7	43.5	0	04	-----	39.6
37339	12 to 24 (bare)	1.4	4.7	5.0	20.4	11.2	17.9	39.4	.1	1.33	3.00	11.2
37343	12 to 24 (grass)	1.4	4.4	4.0	9.8	9.8	26.4	44.2	4	15	-----	15.0
37340	24 to 36 (bare)	1.5	6.6	6.4	14.2	12.2	25.0	34.1	0	1.41	3.70	12.4
37344	24 to 36 (grass)	1.4	4.9	5.0	12.2	11.1	24.8	40.6	0	.61	-----	17.0

[1] Mechanical analysis by T M Shaw.
[2] Moisture content by R. C Cole
[3] Silt—0 05-0 002 mm. diameter
[4] Clay—less than 0 002 mm diameter
[5] In some instances a wide disagreement was found between the salt by bridge and the mineral matter dissolved by H_2O_2 when conventional water to soil ratio (20.1) was used In a few instances data for 100 1 ratios are given The results indicate that at the lower ratios a saturated solution of $CaSO_4$ was obtained.

Table 5 shows that there is high content of salt (principally gypsum) in the barren area and a very small amount in the grassed area. The moisture content of the grassed area is much higher than that of the barren area. The surface soil to a depth of 3 inches in the grassed area has much more sand and silt and less clay than in the barren area. There has been more erosion in the barren area than in the grassed area, and the sandier material may have been washed away. The lack of grass on the barren area appears to be due originally to a high content of salt. When the grass did not grow erosion became severe; then, too, owing to the puddled crust and the vesicular layer, water does not penetrate the barren area nearly so well as the grassed area, and therefore there is not sufficient water in the barren area to leach the salt or for plants to grow. There is also greater evaporation from the barren area than from the grassed area, so plant life is distinctly handicapped in comparison with the adjacent grass cover of less salty areas.

IRRIGATION AND DRAINAGE

Because of the hot, rainless summers, most field crops grown in the Tracy area must be irrigated. Grain, chiefly wheat, barley, and oats, is grown successfully without irrigation by the practice of summer fallowing. Winter peas, grown during the rainy season and picked for green peas, are also grown without irrigation. In normal seasons there is sufficient rainfall to supply the needs for this crop. Occasionally flax planted at the beginning of the rainy season may mature without irrigation, but normally one irrigation is necessary for the crop to mature.

The comparatively smooth gently sloping alluvial fans and the flat basin areas are the only areas on which irrigation is practicable. Irrigation water on the alluvial fans and on the southern part of the basin area is supplied through organized irrigation districts that obtain their water from the San Joaquin River or some slough or channel directly connected with it. The San Joaquin Delta region is one of high water table, and both irrigation and drainage are accomplished by carefully controlling the height of the water table. This is done by protecting the land from overflow and regulating the water table through a series of open ditches that serve for both irrigation and drainage purposes.

The alluvial fans, except where they border the basin areas, have good drainage and are normally free from alkali. However, the water table is not very deep, but the sediments on the fans are for the most part fine and water cannot flow through them fast enough to allow unrestricted pumping. There are, however, a number of drainage wells installed along the main ditches on the lower edge of the fans, which are used in pumping water into the ditches. In these locations the water table has been raised by heavy irrigation of the fields and seepage from the irrigation ditches. These wells are fairly shallow and very successfully prevent the water table from getting too high. In one irrigation district the water pumped into the main ditches from the drainage wells amounts to 20 or 25 percent of the total water sold in the district.

There are approximately 41,000 acres of land in the seven irrigation districts serving this area. Five of the districts are located wholly within the Tracy area, but two of them serve water to lands outside. Table 6 gives a list of the irrigation districts, together with some statistical information regarding each.

TABLE 6.—*Total area, area actually using water, source of water, and water charges of irrigation districts in the Tracy area, Calif.*

District	Office	When organized	Source of water	Area	Area actually using water (1937)	Water charges per acre-foot
		Year		*Acres*	*Acres*	*Dollars*
Byron-Bethany	Byron	1914	Italian Slough	7,203	2,500	3.50
West Side	Tracy	1915	Old River	11,821	7,146	3.25
Naglee-Burk	do	1911	do	2,900	2,044	(1)
Tracy-Clover	do	1922	Tom Paine Slough	1,100	412	(1)
Fremont (Irrigation association)	do		Old River	900		(1)
Banta-Carbona	Carbona	1925	San Joaquin River	15,003	14,319	3.00
West Stanislaus	Westley	1920	do	1,953	(2)	3.00

[1] Flat rate of about $6 an acre. [2] Nearly all.

Beans and alfalfa are by far the most extensively grown crops in this area. Alfalfa is generally produced for hay for sale. It is grown from 4 to 6 years on a field, then plowed under, and usually the field is planted to beans for several seasons before reseeding to alfalfa. Flax, grown for seed, is rapidly becoming an important crop. Some grain is irrigated, and there are a few plantings of orchards and vineyards, which require irrigation. From the records kept by the Banta-Carbona, West Side, and West Stanislaus irrigation districts, the water used each season for these crops is as follows: Alfalfa, 2 to 4 acre-feet; beans, 2 to 3 acre-feet; orchards and vineyards, 1 to 2 acre-feet; grain (wheat and barley), ½ to 1 acre-foot; and flax, ½ to 1 acre-foot.

With the exception of beans, a row crop, these crops are irrigated by the check-basin system, made by throwing up low levees around an area and flooding the enclosed basin with water. The normal irrigation is from 5 to 10 acre-inches of water for each irrigation. Normally, grain and flax are irrigated only once, whereas the other crops receive from two to five irrigations each season.

ALKALI

The term "alkali" as used in this report refers to a harmful accumulation of soluble salts without regard to chemical composition and reaction. There are two types of soil alkali. White alkali is composed mainly of sodium chloride (table salt) and sodium sulfate (Glauber's salt), both of which are white crystalline substances that are neutral in reaction.[7] High concentrations of these salts in the soil are injurious to plants, in that they interfere with the normal intake of moisture and plant nutrients, thus stunting the growth of the plants or killing them. Black alkali is composed chiefly of sodium carbonate (sal soda). This substance is a true alkali and has a corrosive action on plants, destroying their tissues. It also has a very strong deflocculating action on the soil, causing it to be almost impervious to water and to bake very hard, and on drying out it forms black crusts and discolorations on the surface.

Accumulation of alkali is not a serious problem in this area, and only a few of the soils are affected. The salts accumulate in areas having a high water table, which during the dry summer period is sufficiently near the surface of the ground to allow continual evaporation of water from the surface. The salts in solution in the water are thus brought up, and they accumulate in the soil material above the water table.

Soils of the Solano series are normally rather high in salts, whereas those of the Pescadero series contain some salts and there are a few small bodies where large quantities have accumulated. Some areas affected by alkali are composed of the Sacramento, Ambrose, and Piper soils. For the most part the salts in the Tracy area consist of white alkali, but there is some black alkali in most areas of the Solano soils.

Samples of soils for determination of total salts by the electrolytic bridge method were taken in places indicated on the soil map. The amount of soluble salts is indicated in the form of a fraction. The number above the line indicates the percent of soluble salts in the topmost foot of soil, and the number below the line indicates the weighted average percent of salts in the entire soil profile, generally sampled to a depth of 5 feet. Occurrence of black alkali (sodium carbonate) in the sample tested is indicated by the red letter B to the right of the fraction. Three grades of alkali accumulation are

[7] Strictly speaking, soils high in content of these salts are more properly saline soils, rather than alkali soils.

mapped in this area and are indicated on the map by symbols, W, M, or A, in red. Boundaries of alkali-affected areas are indicated by dashed lines in red. The alkali grades are as follows:

W=weakly affected with alkali, 0.2 to 0 39 percent for white alkali and 0.1 to 0.29 percent for black alkali. Soils containing this amount of alkali may be farmed to normal crops with only slight decrease in yields but are likely to be spotted and need to be managed carefully, otherwise the alkali problem will become more serious.

M=moderate alkali, 0.4 to 0.99 percent soluble salts for white alkali and 0.3 to 0.6 percent for black alkali. These areas are definitely limited in their agricultural possibilities and suitable only for a limited cropping system or pasture. They are definitely marginal lands and must be carefully managed or the alkali condition will become more serious.

A=strong alkali, above 1 percent of soluble salts for white alkali and above 0.6 percent for black alkali. These areas are definitely nonagricultural, and most of them afford poor pasturage at best.

Areas of white alkali can be reclaimed by prolonged flooding and leaching, provided drainage conditions are corrected and the physical properties of the soils are such as to allow ready penetration of water. Even black alkali areas can be reclaimed, but the reclamation of such areas is costly and the expense involved is seldom justified by returns. For discussion of alkali soils and their reclamation see Kelley (*4*).

LABORATORY STUDIES [8]

All samples for laboratory analysis were screened through a 2-millimeter sieve. The aggregates were crushed with a rubber-tipped pestle, and the gravel and stones larger than 2 millimeters were rubbed comparatively clean. The sieved material was thoroughly mixed, and aliquot parts were used for the laboratory analyses.

A mechanical analysis of the surface horizon of each soil was made by a proximate method. The sieved soil was shaken overnight in distilled water, using ammonia as a dispersant, then wet sieved through a 300-mesh sieve to separate the sands from the silts and clays. The sands were weighed and reported as total sands. The suspension of silt and clay that passed through the sieve was made up to 1 liter, allowed to stand, and sampled by means of a pipette at the proper time intervals to give maximum diameters of silt at 50 microns, coarse clay at 5 microns, fine clay at 2 microns, and colloidal clay at 1 micron. The results shown in table 7 are used to check the field textural classification.

TABLE 7.—*Mechanical analyses of the surface horizon of certain soils in the Tracy area, Calif.*

Sample No.	Soil type	Total sand 2 mm.-50μ	Silt 50-5μ	Clay		
				<5μ	<2μ	<1μ
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
579201	Burns clay loam	21 47	26 20	54 12	33.50	18 57
579207	Roberts muck	19 06	39 03	43 01	26 12	15 05
579212	Pescadero clay	16 76	31 63	52 81	40 30	27 14
579217	Sacramento clay	5 02	44 57	52 03	29 11	15 09
579222	Piper fine sandy loam	66 02	21 91	12 01	7 59	6 36
579226	Sorrento silty clay	16 18	49 80	36 00	21 07	11 81
579230	Ambrose clay	24 31	28 19	49 61	38 83	26 69

[8] This section was prepared by E. P. Perry, division of soil technology, department of agriculture, University of California.

TABLE 7.—*Mechanical analyses of the surface horizon of certain soils in the Tracy area, Calif.*—Continued

Sample No	Soil type	Total sand 2mm -50µ	Silt 50–5µ	Clay		
				<5µ	<2µ	<1µ
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
579234	Denverton adobe clay	15 59	46 30	40 22	27 88	18 37
579239	Rincon clay	24 45	36 82	37 02	23 99	17 38
579244	Linne adobe clay	43 70	30 94	25 58	16 48	12 87
579248	Solano loam	32 15	48 93	17 55	13 08	12 83
579253	Herdlyn loam	36 23	41 76	21 36	10 00	9 10
579258	Altamont adobe clay	8 55	57 95	34 85	21 81	14 55
579262	Contra Costa sandy loam	75 24	8.97	16 07	13 61	12 18
579265	Los Osos sandy loam	75 09	12 93	11 23	8 20	7 30
579268	Antone clay	46 78	19 63	34 81	29 77	24 03
579275	Sorrento clay	30 85	33 62	36 74	21 40	13 53
579278	Kettleman clay	29 63	37 20	34 56	18 08	9.84
579282	Vallecitos stony clay loam	46 22	26 45	25 63	15 58	10 09
579285	Sorrento clay loam	46 26	31 61	22 67	14 27	10.74
579288	Rincon clay loam	32 67	42 38	25 46	14 72	10 25
579292	Sacramento clay loam	5.57	32 15	61 09	33 13	21 28
579296	Zamora gravelly clay loam	44 37	34 02	22 02	16 07	11 40
579299	Montezuma adobe clay	24 71	31 44	44 12	28 78	21 61
5792103	Positas gravelly clay loam	35.94	41 94	20 46	11 93	9.18
5792108	Columbia fine sandy loam	53 99	34 18	12 22	5 86	4 84
5792112	Olcott clay loam	33 98	41 33	24 19	13 61	10 09
5792117	Ramada fine sandy loam, shallow phase (over Sacramento soil material)	59 94	30 93	7 99	3 20	2 87
5792124	Mocho loam	56.88	22 64	21 36	16 73	13 12

The moisture equivalents were determined by the standard method whereby 30 grams of saturated soil is subjected to a force of 1,000 times gravity in a centrifuge. A few soils are sufficiently impermeable so that the water is not thrown out by centrifugal force and remains on the surface of the soil. In such instances the determination of moisture equivalent is repeated in the usual moisture-equivalent cups with paraffined paper linings added to the sides to allow the excess water to drain away. The moisture equivalents are reported in percentage of moisture calculated on the basis of oven-dry soil. They represent approximately the normal field-moisture capacity, or the amount of water that is held in a soil after a heavy rain or irrigation, where downward drainage is free and uninterrupted (table 8).

TABLE 8.—*Moisture equivalents, carbonates, and reactions of samples of typical soil profiles from the Tracy area, Calif.*

Soil type and sample No.	Depth	Moisture equivalent (1,000 gm.)	pH [1]	Carbonates [2] (as $CaCO_3$)
	Inches	*Percent*		
Burns clay loam.				
579201	0–20	63 38	5 5	1.1
579202	20–24	44 29	5 3	1 2
579203	24–33	45 71	5 4	1 1
579204	33–45	42 52	6 1	1 2
579205	45–50	53 38	6 5	1 3
579206	50–60	[3] 34 09	6 7	1.8
Roberts muck:				
579207	0–13	69 03	5 3	1 2
579208	13–15	73 91	4 8	9
579209	15–26	70 32	4 0	4
579210	26–33	89 51	4 2	.6
579211	33–60	45 72	4 3	.8

[1] All pH determinations made at complete saturation in a tall 4-ounce screw-top bottle with the soil about 2 cm. deep, by Beckman pH meter.
[2] By the McMiller method.
[3] Determinations made using waxed-paper linings in centrifuge boxes to allow escape of water

Table 8.—*Moisture equivalents, carbonates, and reactions of samples of typical soil profiles from the Tracy area, Calif.*—Continued

Soil type and sample No	Depth	Moisture equivalent (1,000 gm.)	pH	Carbonates (as $CaCO_3$)
	Inches	*Percent*		
Pescadero clay				
579212	0-12	47.57	7.3	1.6
579213	12-25	42.05	8.0	3.9
579214	25-39	[3] 40.85	8.2	6.8
579215	39-56	36.69	8.1	7.0
579216	56-66	25.14	7.9	2.5
Sacramento clay				
579217	0-11	52.89	6.0	1.1
579218	11-21	38.39	7.0	1.2
579219	21-38	42.13	7.1	1.7
579220	38-46	33.35	7.4	1.7
579221	46-66	31.19	7.3	1.6
Piper fine sandy loam				
579222	0-11	18.58	7.6	2.2
579223	11-32	19.38	7.6	2.9
579224	32-48	32.04	7.2	1.1
579225	48-66	52.08	6.0	1.6
Sorrento silty clay				
579226	0-13	27.84	6.6	1.1
579227	13-23	26.05	7.4	1.5
579228	23-39	25.96	7.7	3.5
579229	39-72	21.87	7.6	1.3
Ambrose clay				
579230	0-21	21.87	7.6	1.3
579231	21-33	35.63	7.9	2.8
579232	33-52	34.29	7.9	2.8
579233	52-70	21.08	7.7	4.0
Denverton adobe clay				
579234	0-17	[3] 31.76	7.5	3.1
579235	17-25	[3] 36.59	7.9	4.6
579236	25-38	[3] 38.05	7.9	6.2
579237	38-54	[3] 40.07	7.9	5.6
579238	54-66	([4])	7.8	12.0
Rincon clay				
579239	0-9	[3] 25.80	5.9	1.0
579240	9-30	[3] 28.70	7.2	1.2
579241	30-48	[3] 24.68	7.9	1.2
579242	48-66	22.36	7.7	2.5
579243	66-76	21.45	7.8	2.9
Linne adobe clay				
579244	0-12	24.13	7.5	4.7
579245	12-24	23.05	7.6	8.4
579246	24-36	[3] 24.40	7.8	16.5
579247	36-48	23.81	7.9	21.7
	[5] 48 +			
Solano loam				
579248	0-15	20.08	6.9	.7
579249	15-22	[3] 35.35	8.7	1.8
579250	22-31	37.64	8.9	6.8
579251	31-46	[3] 37.37	8.7	2.7
579252	[6] 46-84		8.5	4.2
Herdlyn loam				
579253	0-7	24.39	5.4	.5
579254	7-19	[3] 35.29	6.3	1.2
579255	19-31	[3] 27.92	8.0	3.3
579256	31-37	[3] 25.79	7.9	2.9
579257	37-68	[3] 24.69	8.1	2.8
Altamont adobe clay:				
579258	0-14	29.21	6.5	1.7
579259	14-28	27.69	7.5	3.6
579260	28-39	27.74	7.6	8.0
579261	[7] 39-51		7.8	15.6
Contra Costa sandy loam				
579262	0-10	9.68	4.5	.1
579263	10-24	10.26	4.3	.1
579264	[8] 24-30		4.5	
Los Osos sandy loam				
579265	0-14	10.62	5.6	.3
579266	14-31	17.61	5.8	.6
579267	31-37		6.0	.7
Antone clay				
579268	0-12	26.39	6.4	1.1
579269	12-26	[3] 29.51	6.7	1.1
579270	26-40	29.86	7.2	1.2
579271	40-60	29.31	7.3	2.3

[3] Determinations made using waxed-paper linings in centrifuge boxes to allow escape of water.
[4] Gravel.
[5] Disintegrating bedrock.
[6] Stratified material.
[7] Shale.
[8] Sandstone.

TABLE 8.—*Moisture equivalents, carbonates, and reactions of samples of typical soil profiles from the Tracy area, Calif.*—Continued

Soil type and sample No.	Depth	Moisture equivalent (1,000 gm.)	pH	Carbonates (as $CaCO_3$)
	Inches	*Percent*		
Sorrento clay				
579275	0-12	26.24	6.6	1.1
579276	12-35	24.67	7.4	1.2
579277	35-50	22.54	7.7	2.9
Kettleman clay				
579278	0-10	26.80	7.6	4.5
579279	10-24	27.53	7.7	9.5
579280	24-34	27.25	7.7	9.8
579281	[9] 34+		7.6	9.8
Vallecitos stony clay loam				
579282	0- 6	20.60	6.3	1.0
579283	6-15	19.73	6.0	1.1
579284	[5] 15+			
Sorrento clay loam:				
579285	0-21	20.32	7.4	1.0
579286	21-43	17.43	7.7	2.4
579287	43-66	20.29	7.7	2.2
Rincon clay loam:				
579288	0-10	19.02	5.9	.6
579289	10-23	25.63	7.5	1.1
579290	23-44	26.71	7.8	3.5
579291	44-72	20.36	8.0	2.8
Sacramento clay loam				
579292	0-14	61.67	5.1	1.1
579293	14-23	57.03	4.6	.9
579294	23-33	38.35	5.4	1.1
579295	33-60	25.57	7.1	3.0
Zamora gravelly clay loam				
579296	0-18	18.08	6.4	1.0
579297	18-40	17.92	7.2	1.1
579298	[10] 40-72		7.5	.9
Montezuma adobe clay:				
579299	0-12	33.13	6.8	1.7
5792100	12-20	34.48	7.4	1.8
5792101	20-31	[3] 36.66	7.5	1.2
5792102	[11] 31-52		7.8	17.3
Positas gravelly clay loam:				
5792103	0-17	16.75	6.6	.8
5792104	17-33	17.42	6.5	.9
5792105	33-53	22.56	6.8	1.1
5792106	53-68	23.12	7.2	1.2
5792107	68-84	25.59	7.5	1.1
Columbia fine sandy loam				
5792108	0-11	19.24	6.4	.9
5792109	11-19	9.05	6.7	.7
5792110	19-52	9.72	7.1	.8
5792111	52-60	41.55	6.3	1.2
Olcott clay loam:				
5792112	0-10	20.04	6.0	.9
5792113	10-19	20.40	6.7	1.0
5792114	19-32	[3] 25.26	6.9	1.1
5792115	[12] 32-46		7.4	1.1
5792116	[4] 46-60		7.4	1.1
Ramada fine sandy loam, shallow phase (over Sacramento soil material)				
5792117	0-15	[3] 19.77	6.9	.9
5792118	15-40	35.39	6.9	1.2
5792119	40-53	37.45	6.1	1.1
5792120	53-65	74.27	5.0	1.1
Mocho loam:				
5792124	0- 8	23.13	7.4	2.7
5792125	8-40		7.6	2.7
5792126	[13] 40-60		7.3	3.0

[3] Determinations made using waxed-paper linings in centrifuge boxes to allow escape of water.
[4] Gravel
[5] Disintegrating bedrock.
[9] Shale bedrock
[10] Stratified gravel.
[11] Unconsolidated gravel.
[12] Semicemented gravel.
[13] Stratified gravelly sand.

The carbonates were determined by the McMiller method, in which the soil is treated with hydrochloric acid until effervescence ceases and then is titrated back with sodium hydroxide to determine the amount of acid that is consumed in the reaction, calculating the amount as calcium carbonate. It is recognized that this method involves certain errors, particularly when sodium carbonate is present; but it gives an approximate measure of the carbonate content of the soil and usually of the calcium carbonate or lime that is present.

Determinations of the reaction [9] of these soils were run by the Beckman pH meter at saturation in a tall 4-ounce bottle with the soil about 2 centimeters deep. Values vary from that of the Roberts muck, which showed a pH value of 4.0 at 15 to 26 inches, to the subsoil of Solano loam, with a pH value of 8.9 in the horizon of lime accumulation. The pH values reflected the lime content, the poor drainage, and the organic content of the various series.

As determined by the McMiller method, soils of the Mocho, Kettleman, Linne, Denverton, and Piper series have a calcium carbonate content ranging from 2.2 to 4.7 percent in the A horizon. Upland soils of the Kettleman and Linne series have a very high carbonate concentration in the lower subsoil layer and the parent material (9.8 to 21.6 percent).

Many of the soils of the area, including those of the Montezuma, Sacramento, Rincon, Sorrento, Altamont, Herdlyn, Solano, Ambrose, and Pescadero series, do not show a great deal of calcium carbonate in the surface layers but generally have from 2.5 to 8.0 percent in the subsoil.

SUMMARY

The Tracy area of 385 square miles is in the southwestern part of San Joaquin County and the eastern part of Alameda County. Slightly less than two-thirds of the area lies in the northern part of the San Joaquin Valley, and the remainder is composed of hilly and mountainous areas bordering the western edge of the valley. The soils are divided into the following five groups according to physiographic divisions: Group 1, soils of the hilly and mountainous areas; group 2, soils of the recent alluvial fans; group 3, soils of the older alluvial fans; group 4, soils of the high terraces; and group 5, soils of the basin and flood plains. The soils in groups 2 and 3 are formed on confluent alluvial fans from minor streams draining the hilly areas occupied by groups 1 and 4. All these soils are derived from sedimentary rock sources. The soils in group 5 are formed on the overflow plains and in the delta of the San Joaquin River. The mineral material in these soils is derived chiefly from granitic rock sources. Some of the soils in the delta are very high in organic matter and are distinctly peaty in character. Twenty-five soil series, represented by 43 soil types and 11 phases, together with 2 miscellaneous land types, are mapped in this area.

The problem of soil erosion is confined almost wholly to the hilly and mountainous areas. The soils of the very steep mountainous areas are better protected by vegetation and are by nature less erod-

[9] The degree of acidity or alkalinity of the soil mass is expressed in pH values or in words as follows:

	pH
Extremely acid	Below 4.5
Very strongly acid	4.5–5.0
Strongly acid	5.1–5.5
Medium acid	5.6–6.0
Slightly acid	6.1–6.5
Neutral	6.6–7.3
Mildly alkaline	7.4–8.0
Strongly alkaline	8.1–9.0
Very strongly alkaline	9.1 and higher

ible than those of the rolling or hilly areas of the high terraces. Erosion is very closely associated with overgrazing and mismanagement, but there are a few areas of very severe erosion that are directly attributable to faulting or to very soft geologic formations. Some erosion occurs on the older valley soils of less than 1-percent slope where the concentration of alkali is moderate or severe.

Irrigation water is available only on some of the lower lying valley lands. These areas are used for a wide variety of field and truck crops. Unirrigated areas are used either for range pasture or for dry-farmed grain or grain hay.

The detailed soil map carries information of soil conditions including slope and erosion. Areas affected by alkali in various degrees are also indicated.

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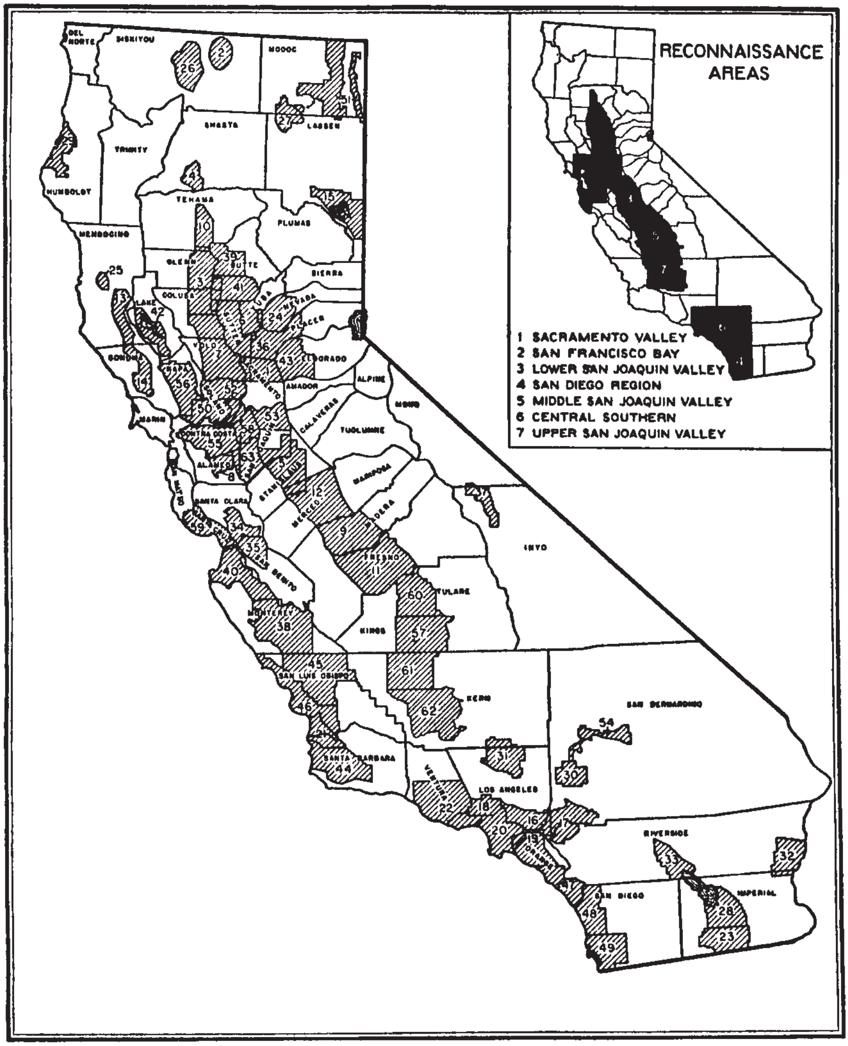
U. S. GOVERNMENT PRINTING OFFICE: 1943



Areas surveyed in California, shown by shading.

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

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