

UNITED STATES DEPARTMENT OF AGRICULTURE

Soil Survey
of
The Upper Gila Valley Area
Arizona

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and
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Bureau of Chemistry and Soils
In cooperation with the
University of Arizona Agricultural Experiment Station

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SOIL SURVEY OF THE UPPER GILA VALLEY AREA, ARIZONA

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AREA SURVEYED

The upper Gila Valley area lies along the Gila River, in Graham County, Ariz. (fig. 1). Safford, the county seat, is 184 miles east of Phoenix and 245 miles west of El Paso. The area has a length of about 45 miles, ranges from about 1½ to 4½ miles in width, and comprises a total area of 106 square miles, or 67,840 acres. It includes the area covered by the earlier soil survey of the Solomonsville area of 1903.

This area is part of the Basin and Range physiographic province which is characterized by scattered groups of mountains surrounded by larger areas of valley lands filled largely by alluvial fans. Across the axes of some of these valleys, streams of either permanent or intermittent flow make their way. These are bordered by flood plains and in places by higher terraces. Some of the larger streams

have cut definite channels or troughs through the valleys, as in the upper Gila Valley where Gila River has cut a very definite trough.

The survey is confined principally to the valley bottom, or trough, along the river, where diversion of water by gravity for irrigation is feasible. The valley trough is cut to considerable depth and hemmed in by terrace fronts that rise abruptly to a height of several hundred feet in places. Tributary streams have cut lateral valleys deep into lime-cemented old valley alluvium capping old lake

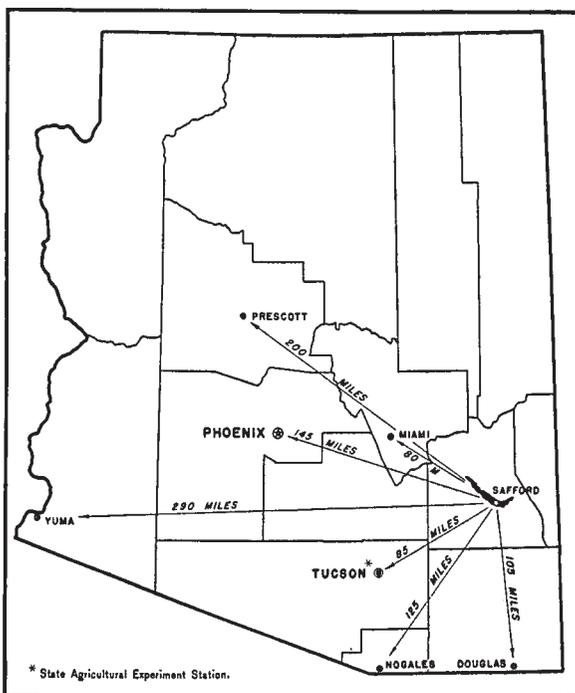


FIGURE 1.—Sketch map showing location of the upper Gila Valley area, Arizona.

clays. These streams rise chiefly in the Santa Teresa and Pinalino Mountains, on the west and south, and in the Gila Mountains on the northeast. These rugged paralleling mountain ranges define the valley proper. Mount Graham of the Pinalino range has an elevation of 10,500 feet above sea level and is covered with snow during the winter and until late in the spring.

The Gila River enters the valley about 17 miles above Safford at an elevation of about 3,050 feet above sea level and leaves about 28 miles below that town at an elevation of about 2,600 feet. The elevation at Safford is 2,906 feet.

Gila River has a rather uniform gradient of about 10 feet to a mile, and although the river meanders considerably, the immediate flood plain is bordered by low terraces which give it a rather straight course throughout the valley. The flood plain averages about one-half mile in width and is overflowed only at exceptional flood periods. Tributary streams have clearly defined gently sloping alluvial fans or stream bottoms, and on the whole the valley is well drained. The relief has been ideal for the distribution of water under irrigation, and only a few areas are waterlogged.

The native vegetation is of desert types and is comparatively sparse. The upland mesa soils support creosotebush extensively and associated scattered growths of cacti, chamiza, ocotillo, desert sage, rabbitbrush, burroweed, and some flowering annuals. The alluvial fans and terraces of the valley depression are more densely covered with mesquite, squawbush, chamiza, desert sage, saltbush, burroweed, and cacti. Saltgrass and seepweed grow on the "alkali" flats. Areas along the river flood plain support scattered cottonwood trees and dense growths of willow, tamarisk, and arrowweed. In permanently wet depressions saltgrass and tules grow.

This part of the Gila Valley was the scene of early exploration by the Spaniards, but the warlike Apaches prevented or retarded appreciable settlement until the early eighties. The earliest permanent inhabitants were Mexicans who settled in the upper part of the valley. Much of the population in this section is still Mexican or Spanish-American. In the latter part of the eighties, Mormon colonizers came into the area from Utah and established communities in different parts of the valley. These people and their descendants now form the principal part of the population.

Graham County was organized in 1881 and was reduced to its present size in 1911. The Federal census for 1930 gives the population as 10,373, the greater part of which lives within the area surveyed. This valley is rather thickly settled. The greater number of the people live in the more intensively cultivated area extending from Eden and Glenbar south and east. Towns and community centers are situated at intervals of only a few miles, and many of the farmers live in these centers. The larger incorporated towns are Safford, the county seat, with a population of 2,033, Pima, with 980, and Thatcher, with 889.

The Miami branch of the Southern Pacific Railroad and United States Highway No. 70, a paved road, in addition to a number of good graveled roads, provide adequate transportation facilities. Electric power and telephone service are supplied throughout the greater part of the area. Public schools and churches are located

in the towns and rural communities. There are three high schools and two junior high schools, and a junior college is located at Thatcher.

CLIMATE

The upper Gila Valley area lies in that part of Arizona included in the arid southwest region, where clear, bright weather and intense sunlight are predominant during the greater part of the year. The precipitation and humidity are low, and hot, though not oppressive, weather prevails during the summer. The prevailing winds are from the southwest, and during the spring wind movement is rather high.

The mean annual precipitation, as recorded at Thatcher, is 9.04 inches. The amount of rainfall varies greatly from year to year. The lowest recorded rainfall is 2.98 inches and the highest 17.38 inches. The greater part of the precipitation comes as torrential rains during July, August, and September, and the rest chiefly as gentle winter rains from December to March. Snow in measurable quantities seldom falls.

The mean annual temperature is 62.6° F. The daily range in temperature is wide, and the nights are usually cool, even during hot weather. The highest temperature recorded is 115° and the lowest 9°. The coldest weather occurs during January when the ground becomes slightly frozen, thereby retarding farm work. During the rest of the winter the weather is favorable for farm work.

The average date of the last killing frost is April 11 and of the earliest is November 2, giving an average frost-free season of 205 days. This comparatively long season favors the production of cotton, yields of which are heavy. The growing of vegetables for home use is possible during a long season. This district, however, cannot compete with warmer sections at lower elevations, such as the Imperial, Salt River, and Yuma Valleys, in growing winter vegetables on a commercial scale. Alfalfa thrives in this climate, and corn and small grains do fairly well, but most tame grasses, with the exception of Bermuda, Sudan, and Johnson grasses, do not thrive.

Table 1 gives the normal, monthly, seasonal, and annual temperature and precipitation at Thatcher which is centrally located in the area surveyed.

TABLE 1.—Normal monthly, seasonal, and annual temperature and precipitation at Thatcher, Graham County, Ariz.

[Elevation, 2,800 feet]

Month	Temperature			Precipitation		
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year (1924)	Total amount for the wettest year (1905)
	°F.	°F.	°F.	Inches	Inches	Inches
December.....	44.2	79	12	0.78	0.54	0.75
January.....	43.4	80	9	.59	.00	1.66
February.....	48.4	87	15	.79	(¹)	2.85
Winter.....	45.3	87	9	2.16	.54	5.26
March.....	54.1	93	18	.64	.73	3.21
April.....	60.6	98	24	.33	.22	.93
May.....	68.9	107	27	1.16	.12	.00
Spring.....	61.2	107	18	1.13	1.07	4.14
June.....	78.4	115	37	.28	.00	.71
July.....	83.4	113	49	1.88	.57	.04
August.....	80.8	110	43	1.26	.80	.85
Summer.....	80.9	115	37	3.42	1.37	1.60
September.....	74.6	104	36	.84	.00	1.82
October.....	62.8	98	20	.76	(¹)	(¹)
November.....	51.3	87	17	.73	.00	4.56
Fall.....	62.9	104	17	2.33	.00	6.38
Year.....	62.6	115	9	9.04	2.98	17.38

¹ Trace.

AGRICULTURE

As early as 1873, the first settlers began supplying small quantities of charcoal, hay, and grain to nearby mines. With increased settlement and with the expansion of the canal systems for irrigation, a self-sufficing type of agriculture was established, with alfalfa, corn, small grains, fruits, and vegetables, as the main crops, supplemented by livestock. Increased mining activities and the building of railroads created markets for surplus products and livestock. The nearby markets have continued to absorb much of these products. The outlying range has been an inducement to the raising of livestock, and feeding and fattening of livestock has provided much of the cash income, more recently augmented by special crops, mainly cotton.

Although crop production figures are available only for Graham County as a whole, they express the trend in agriculture of the area, since this valley is the main agricultural district of the county. The 1890 Federal census gives the main crops as hay, corn, barley, and wheat, ranking in acreage in the order named. By 1900, the wheat acreage had taken first place, followed in order by alfalfa, barley, and corn. In 1910, alfalfa was the leading crop, followed by barley, wheat, and corn. In 1920, alfalfa still held the leading acreage, with the acreage in wheat next. The acreage devoted to wheat was materially increased over that used in previous years. Barley and corn were next in order, and grain sorghums, which had become an

important crop, occupied an acreage equal to that of corn. By this time cotton also had been introduced and had become a significant crop. By 1930 the acreage devoted to cotton exceeded that of all other crops. It was twice as large as the acreage in alfalfa. The acreage in barley, wheat, corn, and grain sorghums each decreased about one-tenth from that reported in the 1920 census.

Horticultural crops, as apples, pears, peaches, plums, prunes, cherries, apricots, grapes, and strawberries, seem to have attained their peak in 1910 and have since declined. There are now no large orchards, but a few trees are in most of the home gardens. Sweet-potatoes and other vegetables have followed the same general trend.

Among the livestock products, an increase, especially in dairy and poultry products, is noted between 1900 and 1910 and between 1910 and 1920. Dairy products decreased and poultry products increased between 1920 and 1930. Because of the intensive agriculture carried on under irrigation, the average size of farms is small, probably about 40 acres. The range in size is from a few acres in the vicinities of towns and villages to several hundred acres in the outlying districts.

According to the 1935 census, 75.4 percent of the farms were operated by owners, 20.4 percent by tenants, and 4.2 percent by managers. Tenants either pay cash or a crop rental.

Mexican laborers are used extensively on the farms throughout the year. The peak of labor demands is during cotton picking, when both Mexican and colored laborers are employed.

In the more intensively farmed and thickly settled sections, good types of residences and farm buildings are prevalent. The demand for outbuildings is small because the winters are mild. In these sections the towns and villages are so near together that many farmers live in town. When such is the case most of the farm buildings are open-sided sheds for the protection of hay and machinery. In the more remote sections and Mexican villages the houses are poorly constructed, and most of them are built of adobe.

Most of the farms are equipped with up-to-date tools and machinery, as the intensive type of agriculture demands them. On many of the larger farms, tractors are used.

The horses and mules are in general of good size and are well kept. Livestock is being bred up to a good quality, and some pure-bred animals are kept, especially for breeding purposes.

Cotton is a very important cash crop in the lower irrigated valleys of Arizona. In this area it has held dominance over other crops since the time of the World War when the demand for cotton was great. During the year of this survey (1933) at least 11,000 acres were planted to cotton. This represents about one-third of the irrigated area. Other crops, including feed crops for cattle and food for home consumption, are grown in rotation with cotton, and the whole system is one of diversified agriculture. The diversification is limited very largely to alfalfa, wheat, barley, corn, and hegari. Subsistence crops of fruits and vegetables are grown only for consumption in the home.

Alfalfa is used with cotton and other crops in rotation for maintaining or increasing fertility, although this practice is not so essential here because of the fertility artificially produced by silting.

Wheat and barley are cool-weather crops that do not thrive in the heat of summer but survive the winter. By seeding spring varieties in late fall and harvesting in midsummer, these crops can be grown successfully. During the rest of the season climatic conditions are favorable for corn and hegari, and these crops are grown following the small grains in the same year. The small grains are either used entirely for pasture or are pastured for a time and then allowed to grow for grain.

Cotton gins are established in the valley at points of heaviest demand. The baled cotton is shipped to the Orient and eastern markets.

Feed crops are consumed mainly on the farm where grown. Wheat is milled in the valley for consumption in the home. Surplus alfalfa finds a ready sale in nearby markets.

The extensive outlying range is stocked with cattle and sheep, that are sometimes fed or fattened in the valley. They consume most of the surplus alfalfa, corn, hegari, and barley. The mild winters make it possible for livestock to pasture on these crops the year round, and the raising and fattening of livestock is important in certain sections. Hereford is the predominant breed of beef cattle in the valley and on the range. High-grade bulls are kept.

Dairying and poultry raising are generally associated with the individual farm units, and the products are consumed at home or sold in nearby cities and towns. Fruits and vegetables are grown almost entirely for home use.

SOIL-SURVEY METHODS AND DEFINITIONS

Soil surveying consists of the examination, classification, and mapping of soils in the field.

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 distinct 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 soil¹ and its content of lime and salts are determined by simple tests. Drainage, both internal and external, and other external features, such as the relief, or lay of the land, are taken into consideration, and the interrelation of soil and vegetation is studied.

The soils are classified according to their characteristics, both internal and external, especial emphasis being given to those features influencing the adaptation of the land for the growing of crop plants, grasses, and trees. On the basis of these characteristics, soils are grouped in classification units. The three principal ones are (1) series, (2) type, and (3) phase. There are areas of land, such as coastal beach or bare rocky mountain sides, which have no true soil; and these are called (4) miscellaneous land types.

¹ 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.

The most important group is the series which includes soils having the same genetic horizons similar in their important characteristics and arrangement in the soil profile and developed from a particular type of parent material. Thus the series includes soils having essentially the same color, structure, and other important internal characteristics, and the same natural drainage conditions and range in relief. The texture of the upper part of the soil, including that commonly plowed, may vary within a series. The soil series are given names of places or geographic features near which they were first found. Thus Norfolk, Hagerstown, Barnes, Miami, Houston, and Mohave are names of important soil series.

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

A phase of the soil type is recognized for the separation of soils within a type, which differ in some minor soil characteristic that may, nevertheless, have important practical significance. Differences in relief, stoniness, and the degree of accelerated erosion are frequently shown as phases. For example, within the normal range of relief for a soil type, there may be areas which are adapted to the use of machinery and the growth of cultivated crops and other areas which are not. Even though there may be no important differences 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 respect to the growth of cultivated plants. In such an instance the more sloping parts of the soil type may be segregated on the map as a sloping or 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 county or 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 the upper Gila Valley area in their virgin state have general properties similar to those of the soils of most sections of the arid Southwest. They are comparatively low in content of organic matter (humus) and nitrogen, and high in mineral plant nutrients, lime carbonate, and salts of sodium, potassium, and other alkali and alkaline earth minerals. In places these salts are present in excessive quantities and are harmful to vegetation. Phosphorus, although probably present in most of the soils in fairly large quantities, is largely in rather insoluble form not readily available to plants.

The soils represent a wide range in age, or stage of development, from very recently deposited alluvial material to old soils with some accumulation of clay and colloids in the subsoil and firmly cemented lime hardpans. The younger soils are on the valley floor and on alluvial fans, whereas the older ones are on the higher terraces and upland mesas or benches.

Most of the soils that are important agriculturally are formed from materials which are of rather recent deposition and represent young or immature stages in development. They retain many of the inherent properties of the parent soil materials which are readily traced to the rocks from which they are derived.

The dominant parent geological materials are of four classes as follows: (1) The soil materials south and west of Gila River and San Simon Creek are almost totally granitic and are derived from the Santa Teresa and Pinalino Mountains; (2) north and east of Gila River and San Simon Creek, the soils are developed largely from rocks of mixed origin, but dominantly basalt, andesite, and rhyolite; (3) the unconsolidated salty old lake clays which occur as terraces and remnants adjacent to the lower or northeastern part of the alluvial valley have had a very important influence in the development of the soils in that section; and (4) the material of mixed origin brought in from outside sources by Gila River and San Simon Creek gives rise to the soils of their flood plains and lower terraces.

The upper Gila Valley area, like many other irrigated sections in the Southwest, is covered largely by "made soils." These are artificially made soils in the sense that they have been deeply covered by silt from irrigation water, and the original surface soils have lost their identity. They have been subjected to leaching accompanying irrigation and silting, and this leaching is important in the improvement of soils containing an excess of salts.

In the agricultural development of the valley, the soils having more favorable relief, texture, fertility, and freedom from salts naturally were chosen first for farming; but, as the irrigation canals define the limits of agricultural development in this area, it has become necessary, with increase in settlement, to expand this development onto poorer soils. The tendency has been to concentrate development in small areas before more isolated lands were developed elsewhere under conditions of less certain water rights and more difficult reclamation. For this reason, the more deeply silted soils are in the section which has been settled and cultivated longest, extending from the upper end of the valley to the vicinity of Glenbar and Eden. This also is the widest part of the area and the most favorable in relief, and it has dominated the agriculture of the valley throughout its development.

It is apparent that with the silting, which in places has reached a depth of more than 3 feet, the original topsoil has been changed completely and the soil retains only its original subsoil characteristics. With continued silting, the identity of the original soil becomes more obscure and its effect on crop production more limited; its greatest influence is on internal drainage and retention of moisture.

The silt brought in by the turbid irrigation waters is of fairly high organic-matter content and builds up a topsoil of high fer-

tility which has a granulation like that of a Prairie soil. It has great fertility because of a high content of mineral plant nutrients and organic nitrogen. Associated with the high fertility are the excellent structure and water-holding capacity in the dominant soils of heavy texture. The depth of the silting and the texture of the material varies greatly from field to field and even within the same field. It depends not only on the length of time the land has been irrigated but also on the slope. Areas where water stands at the lower end of a field are more deeply silted and of heavier texture than the rest of the field; and in many fields sandy materials are present at the upper end of the field where the water leaves the head ditch.

These artificially built soils are adapted to a wide range of crops, and the selection of crops is determined largely by preference of the individual farmer and by economic conditions.

Most of the irrigated soils of agricultural importance are very gently sloping and are favorable for distribution of water and to surface drainage and underdrainage. With artificial leveling and silting the configuration of the surface has been somewhat modified, but, over most of the area, the conditions that made these soils well drained in the natural state still exist.

With the exception of those in the vicinity of San Simon Creek, the soils of the eastern half of the area have never contained an excessive quantity of salts. The salt-affected areas have been reclaimed by leaching and silting with the muddy irrigation waters. In the northwestern half of the area, especially from the vicinity of Glenbar northwestward, where the tributary streams are deeply entrenched in the old lake clays, the parent materials derived from these salty clays dominate and the percentage of so-called alkali soils is large.

It may be said that generally moisture, rather than fertility or inherent productivity of the soil, is the limiting factor of crop growth. As has been stated, the silting makes the soils more uniform and more productive. This increased fertility is especially important in connection with growing cotton, as it tends to produce a long uniform cotton fiber much in demand by buyers. Cotton is the most important crop on the silted soils. On the lighter textured soils or those less altered by silting, alfalfa, corn, and hegari are comparatively important, as they do well on these soils which are not so productive for cotton. The salty, or "alkali", soils gradually are being improved and rendered more productive by irrigation with the silty waters. Hegari, small grains, corn, and alfalfa are grown on these soils during the process of reclamation, and finally they become fit for the production of cotton. On these soils the raising of livestock works in well with the farming operations.

In a discussion of the soils of this area, as related to agriculture, the soils may be grouped on the basis of common characteristics which influence crop production. Although the soils have a tendency to become more uniformly productive because of silting, the characteristics of the subsoils are especially important in their relation to the retention of moisture in this region of high temperature and excessive evaporation. They are also important in relation to root

penetration, internal drainage, and salt content of the soil. The relation between the lime content of soils and plant nutrition is important and should be considered in soil classification. Lime accumulation, comparatively high clay content, and compaction in the subsoils are common characteristics of many of the older soils.

On the basis of these characteristics the soils are classified in three major groups as follows: (1) Soils without definite accumulation of lime in the subsoils; (2) soils having moderate accumulation of lime in the subsoils; and (3) soils of high lime accumulation.

In the first group are the Gila, Pima, Cajon, Imperial, and Land soils; in the second are the Anthony and Mohave soils; and in the third are the Laveen and Cave soils. The first group is subdivided into soils with friable subsoils and soils with compact salty subsoils.

In the following pages, the soils of the upper Gila Valley area are described in detail, and their agricultural importance is discussed; their distribution is shown on the accompanying soil map; and their acreage and proportionate extent are given in table 2.

TABLE 2.—*Acreage and proportionate extent of soils mapped in the upper Gila Valley area, Arizona*

Soil type	Acres	Per- cent	Soil type	Acres	Per- cent
Pima silty clay loam.....	5,376	7.9	Anthony gravelly sandy loam.....	1,536	2.3
Pima silty clay loam, heavy-textured phase.....	448	.7	Anthony gravelly sandy loam, gray phase.....	1,152	1.7
Gila loam.....	1,856	2.7	Anthony stony sandy loam.....	2,368	3.5
Gila clay loam.....	384	.6	Anthony loam.....	640	.9
Gila fine sandy loam.....	1,600	2.3	Anthony fine sandy loam.....	2,240	3.3
Gila fine sand.....	1,280	1.9	Anthony fine sandy loam, silted phase.....	1,408	2.1
Gila fine sand, silted phase.....	512	.8	Mohave sandy loam.....	576	.9
Cajon sandy loam.....	1,984	2.9	Mohave sandy loam, silted phase.....	448	.7
Cajon sandy loam, silted phase.....	3,712	5.5	Laveen loamy sand.....	1,600	2.3
Cajon sandy loam, deep-silted phase.....	3,392	5.0	Laveen loamy sand, silted phase.....	384	.6
Cajon sandy loam, shallow-silted phase.....	2,240	3.3	Laveen loamy sand, steep broken phase.....	640	.9
Cajon loam.....	1,600	2.3	Cave gravelly loam.....	3,520	5.2
Imperial silty clay.....	832	1.2	Cave gravelly loam, steep broken phase.....	2,048	3.0
Imperial silty clay, silted phase.....	4,928	7.3	Rough broken land.....	3,136	4.6
Imperial silty clay, shallow phase.....	832	1.2	Riverwash.....	6,592	9.7
Land silty clay.....	1,408	2.1			
Land silty clay, silted phase.....	1,856	2.7	Total.....	67,840	-----
Land silty clay loam.....	1,536	2.3			
Anthony sandy loam.....	1,536	2.3			
Anthony sandy loam, silted phase.....	1,088	1.6			
Anthony sandy loam, shallow-silted phase.....	1,152	1.7			

SOILS WITHOUT DEFINITE ACCUMULATION OF LIME IN THE SUBSOILS

The soils of this group are high in lime, but this in most places is uniformly distributed or disseminated through the material with little downward leaching and accumulation. In some of the Cajon soils, a slight gray color, or indication of slightly higher lime content, may exist in the subsoil, but there is little definite structure or compaction. Salt accumulations occur in many areas of the Imperial and Land soils, but there is little accumulation of lime carbonate.

Owing to differences in the inherent nature of the soil material, this group of soils is subdivided into those with friable subsoils, including the Gila, Pima, and Cajon soils; and those with compact subsoils—the Imperial and Land soils. The soils of the second

subgroup differ widely in their heavy refractory subsoils and high salt content from the friable and more fertile soils of the first subgroup. All the soils lie within the valley trough bordered by steep escarpments of the terrace or mesa. Most of them are widely distributed, but some occur only along certain streamways or in certain sections.

The Pima and Gila soils are associated throughout the entire length of the valley along Gila River. The Cajon soils are developed from granitic materials and lie south and west of the river, where large washes from the Pinalino and Santa Teresa Mountains have carried these materials far out into the valley. These soils dominate the agriculture from San Simon Creek to Cottonwood Creek. Small areas are along Black Rock Wash at Fort Thomas and along Goodwin Wash at Geronimo.

The Imperial soils have a wide distribution. The larger continuous bodies are in the vicinity of Solomonville and north of Central. Scattered areas occur around Glenbar. The larger part of the Land soils lies northwest of Mathews Wash.

Over most of the area, the soils with friable subsoils are well drained, as they occupy positions having good drainage and gently sloping relief. The Gila soils lie nearest the river, in comparatively low-lying positions, and they are likely to have the poorest drainage. The Pima soils occupy higher positions and are, therefore, seldom waterlogged. The Cajon soils have good internal drainage, and their sloping relief insures good surface drainage.

Of the subgroup of soils with compact subsoils, the Imperial soils have the poorest drainage, caused both by their low-lying positions and their slow internal drainage in the deep clay subsoil. The Land soils are better drained, both because they occupy higher positions and because of the greater porosity of their stratified subsoils. Both the Imperial and Land soils have a high content of salts derived from parent materials or of later accumulation.

In the unsilted state all these soils may be readily distinguished by vegetation and soil characteristics. The Gila soils are grayish- or pinkish-brown light-textured soils; the closely related Pima soils are darker grayish brown or dark chocolate brown and are heavy textured. The vegetation ranges from mesquite and squawbush on the better drained lands to willow and cottonwood in the lower lying places. The Cajon soils are lighter colored, due to lack of organic matter. They are dull yellowish brown or dull light brown. The soil material is granitic and contains large quantities of angular fragments and mica. The native vegetation is dominantly mesquite, squawbush, chamiza, and desert sage. Under irrigation, silting obscures the soil features, and eventually all these soils become like the Pima soils.

Owing to the heavy-textured materials and high salt content, the Imperial and Land soils have a surface "alkali structure" characterized by a thin surface crust, in many places underlain by a thin mulchlike layer, giving rise to slick-appearing surfaces; and the soils are sticky and plastic when wet. These topsoil features become obscured by silting. The native vegetation is sparse—mostly alkali-tolerant desert sage, chamiza, and saltbush. Seepweed grows on cleared but abandoned areas.

SOILS WITH FRIABLE SUBSOILS

The Pima and Cajon soils of this subgroup are the most extensive and important agricultural soils in the area, and they have contributed more to the agricultural development than have the soils of any other group. The Gila soils cover a smaller area than either the Pima or Cajon soils, and, therefore, are of minor agricultural importance. All the Pima soils are silted, all the Cajon soils lying under the canals are silted, and a large part of the Gila soils is more or less silted. The chief distinguishing feature between the Gila and Pima soils is the darker color and heavier texture of the Pima, due largely to the silt deposit. The Pima soils are more highly productive.

The soils of this subgroup are in general well-suited to the production of all the crops commonly grown, and cotton is the most important crop.

Pima silty clay loam.—Pima silty clay loam is one of the most extensive and important soils in the area. It is inherently one of the more fertile and productive soils in the valley, as even before silted by irrigation it consisted of deep dark-colored fertile alluvium brought in by the river. The excellent friable structure of the entire soil makes it ideal for the penetration of roots and provides an unlimited feeding zone. The materials in the subsoil range in texture from fine sandy loam to clay loam, contain much organic matter, and retain moisture for long periods.

The topsoil, due to the deposition of silt in irrigation of the individual fields, ranges in texture from heavy silty loam or silty clay loam to silty clay, but it is very granular and friable, and when dry or at optimum moisture content resembles in physical character fine sandy loam or loam. When wet, however, the material is slick and plastic, and it is important that it be cultivated under proper moisture conditions. It is one of the most deeply silted soils in the area, both because of the long period it has been under cultivation and the flat or gently sloping relief which is conducive to silting.

Though comparatively flat, the land is generally well drained and free of "alkali", or salts, due to its terrace position above the river. In this respect it is better than the lower lying Gila soils, although it is not so free of damage from salts as are the Cajon soils.

In average development, the silted topsoil of Pima silty clay loam, to a depth ranging from 16 to 20 inches, is dark dull-brown or grayish-brown silty clay loam of excellent mellow, friable, granular structure. Below this, and continuing to a depth of about 30 inches, the soil material is duller dark brown loam, probably representing the original surface soil and transitional material. The material, below a depth ranging from 30 to 35 inches, is stratified. It consists of layers of loose friable fine sandy loam, loam, and silty materials. Below a depth ranging from 50 to 60 inches, the stratified materials become lighter colored and increasingly coarser textured. The subsoil becomes more porous with depth, and the lower part of the substratum in many places is gravelly, which insures free movement of under-drainage.

This soil occurs in long narrow belts parallel to Gila River throughout the length of the area. Practically all of it is under cultivation. Cotton is the principal crop, and, owing to the high fertility of the soil and its replenishment by silting, this crop is grown many

years in succession with little decline in yields. Yields of cotton are high, ranging from $1\frac{1}{2}$ to $2\frac{1}{2}$ bales an acre. This is also an excellent soil for wheat and barley. Wheat yields from 30 to 45 bushels an acre and barley from 30 to 50 bushels. These crops are followed by corn or hegari the same season. Corn yields from 30 to 60 bushels an acre, and yields of hegari are equally high. These last two crops are grown mainly on the lighter textured soils, but they are grown on this soil when needed to fit into the rotation. Ordinarily, alfalfa is not grown except in a few places where forage crops are needed. Alfalfa is an excellent rotation crop for this soil, especially on the deeper silted heavy-textured areas, as the roots break up the compaction, thereby increasing the penetrability. Excellent yields are obtained, the five seasonal cuttings yielding a total of 5 or 6 tons an acre. There is a tendency, however, for the crowns of alfalfa to become silted over on this flat land.

As mapped, this soil includes a number of small areas in which the subsoil is slightly or decidedly redder and of slightly heavier texture. This is a condition associated with the adjoining reddish-brown soils of the Anthony, Land, and Imperial series, and such areas might be considered deep-silted phases of various soils in those series. This included soil is of small extent—about 200 acres—but all is farmed, principally to cotton and small grains. Such areas may have a tendency to be slightly less pervious in the subsoil and slightly less productive than the more typical Pima silty clay loam. They occur as narrow strips northeast of and parallel to Gila River. One small body lies just northwest of Eden in sec. 29, T. 5 S., R. 24 E.; an area is three-quarters of a mile west of Bryce in sec. 12, T. 6 S., R. 24 E.; and a long strip lies about 2 miles northeast of Pima in secs. 16, 17, and 21, T. 6 S., R. 25 E.

Pima silty clay loam, heavy-textured phase.—Pima silty clay loam, heavy-textured phase, is similar to the typical soil, but it has a heavier textured surface soil and subsoil. It generally lies in lower positions than the typical soil and therefore is more deeply silted. The topsoil, although of silty clay or clay texture, is well granulated and friable. The subsoil is more compact and darker than that in the typical soil, and the texture ranges from silty clay to clay. This is a deep fertile soil and is especially suitable for the production of cotton and small grains. Yields are similar to those obtained on typical Pima silty clay loam. The total area of this soil is very small, and most of the land is farmed.

Gila loam.—The surface soil of Gila loam is mellow dull grayish-brown loam having some plasticity caused by silting. The subsoil, to a depth of about 50 inches, is thickly stratified predominantly fine sandy loam of pale reddish-brown color and of loose friable structure. Below a depth of 50 inches, the stratification is thinner, and the material consists of lighter reddish brown or grayish-brown loam, fine sandy loam, and sandy loam. At greater depths the material is decidedly coarser and of lighter color.

The total area of the Gila soil is small as compared with that of the Pima soil, but it has equally wide distribution along the river. In places where Gila loam is associated with Pima silty clay loam, much of the land is planted to cotton. Because of its lighter texture, however, it is favored for alfalfa, corn, and hegari. Yields of cotton

range from 1 to 1½ bales an acre, alfalfa 4 to 6 tons, and corn 30 to 50 bushels. Small areas of the more poorly drained and salt-affected land are of lower value for crop production.

Gila clay loam.—Gila clay loam differs from Gila loam principally in the heavier texture of the topsoil, which ranges from heavy loam to clay loam. In most places it is a transitional soil between the Gila and Pima soils, and it is favored for crops similar to those grown on Pima silty clay loam. Yields are slightly less on the Gila soil. Some areas are low and are affected by poor drainage and salts. This soil occurs in a few small scattered bodies near Gila River.

Gila fine sandy loam.—Gila fine sandy loam occupies an area about equal to that of Gila loam and has similar distribution. As with the loam, the principal crops are alfalfa, corn, and hegari. Yields are similar or slightly less than on Gila loam.

The topsoil is pale reddish-brown or grayish-brown loose friable fine sandy loam. The subsoil consists of stratified layers of light pinkish-brown or grayish-brown fine sandy loam and sandy loam. The coarser and more porous materials increase with depth. Some low-lying areas are poorly drained and contain salts.

Gila fine sand.—Gila fine sand occupies only a small total area, but it is widely distributed along the flood plains of Gila River. It is low and is very unstable because of overflow and the action of wind. Most of the land is poorly drained and broken by channels, streaks of gravel, and hummocks. In its virgin state it is of little or no agricultural value. In a few places where the land is level or can be leveled and there is little danger of overflow, this soil is being built up artificially by extensive silting operations. In many places, irrigation water is used to tear down the adjacent heavier textured Gila and Pima soils and to wash the material over the surface of this soil. Many small areas have been built up in this manner and have become good agricultural soils of the Gila and Pima series. The thinly silted areas of this soil, however, are very droughty.

The typical surface soil consists of dull grayish-brown loose porous, though uniform, sand to a depth of about 12 inches. The subsoil, which consists of coarser stratified sands of similar color, extends to great depths.

Gila fine sand, silted phase.—Gila fine sand, silted phase, consists of a very thin veneer of dark-brown clay or clay loam over the porous leachy fine sand. In few places does it exceed a depth of 6 inches, and it is produced either by natural or artificial silting. Most of it lies in low positions near the river or in back bottoms of the river flood plain. The total area is very small. Only a small portion of the land is farmed, as much of it is subject to overflow, to seepage from higher lying soils, and to accumulations of salts. In the better drained areas, the soil is droughty.

Cajon sandy loam.—Though there were at one time extensive areas of Cajon sandy loam in this valley, most of them have become extensively silted. The silted areas are shown on the map as silted phases of Cajon sandy loam. The unsilted areas now remaining, chiefly above the irrigation canals, are gravelly and porous. Agriculturally the typical unsilted soil is of little importance, as practically none remains under the canals.

The typical surface soil, to a depth of about 12 inches, is light-brown, grayish-brown, or slightly yellowish brown sandy loam containing a large quantity of angular granitic grit and mica. The immediate surface soil is very slightly duller or darker in color than the soil below. Between depths of 12 and 38 or 40 inches, the material is similar in texture but of slightly lighter color. In most places there is a more definite reaction for lime beginning with this layer. Below a depth of 40 inches, the materials become slightly coarser textured. Internal drainage is normally good, but it may be excessive at the heads of the fans extending out from the terrace fronts. Areas near Geronimo are darker at the immediate surface, owing to a higher content of organic matter resulting from the comparatively dense vegetation.

Cajon sandy loam, silted phase.—The silted phase of Cajon sandy loam is one of the more extensive and more important agricultural soils in the area. Its extent is nearly as large as that of Pima silty clay loam, and the two soils are about equally productive. The Cajon soil is extensive south of the river between San Simon Creek and Glenbar. It is a well-drained soil and free from salts. Due to its gently sloping surface, it is ideal for the distribution of irrigation water and also allows sufficient underdrainage.

The properties of the silted surface soil are similar to those of the Pima soils. This layer is characterized by high fertility and high organic content, favoring granulation and excellent tilth. The fineness of the mineral particles and organic material are ideal for the retention of both fertility and moisture. The lime content is high enough for excellent soil structure but not so excessive as to limit plant nutrition. The mellow friable subsoil of the original soil is ideal for the penetration of roots, yet not sufficiently porous to be droughty.

This soil is silted to an average depth of about 12 inches, thereby giving a topsoil of dark-brown or dark grayish-brown silty clay loam texture. Angular granitic fragments and mica of the original Cajon soil material occur in many places. The features of the topsoil are not essentially different from those of the Pima soil. Below the surface soil is a transitional layer of the old soil modified by silty material of dark grayish-brown color and clay loam or loam texture. Below a depth of about 18 inches, the subsoil consists of the unaltered granitic Cajon soil of dull grayish-brown or slightly yellowish brown gritty sandy loam. Below a depth of 40 inches are thick stratified layers of sandy loam and loam, similar in color and mineral composition to the materials in the layer above.

Many different crops are grown on this soil. It is one of the important soils of the area for the production of cotton. On farms where only this soil occurs, it is used for diversified farming, that is, the production of cotton, alfalfa, small grain, corn, and hegari. In the vicinities of Safford, Thatcher, and Central, where there are large continuous bodies, all these crops are grown, but in places where there is greater diversity of soils, this soil is usually chosen for cotton. Acre yields of cotton range from 1 to 2 bales, of alfalfa 5 to 6 tons, of wheat 30 to 40 bushels, of barley 25 to 50 bushels, and of corn 30 to 65 bushels.

Pima silty clay loam undoubtedly has greater inherent fertility than the silted phase of Cajon sandy loam, but under continued silting this is not very apparent in the crop yields. Both these soils have a porous well-drained substratum, but, due to its lower lying position, the Pima soil is, in a few places, more poorly drained and more subject to damage by seepage and accumulation of salts, or alkali. Because of the more sloping relief of the Cajon soil the individual fields may not be so uniformly silted as the Pima soils. Commonly there is considerable difference in the depth of silting and the texture between the soils in the upper and lower ends of the fields.

Cajon sandy loam, deep-silted phase.—The deep-silted phase of Cajon sandy loam is about equally as extensive as the silted phase. It is the most important soil in the vicinity of Safford, where it is extensively developed. The relief and drainage features are similar to those of the silted phase. The deeper silting has occurred, both because of favorable position for silting and because of the long time the soil has been farmed and silted by the turbid irrigation waters. There are also included silted areas in low positions, which originally were heavier textured and darker than typical Cajon sandy loam.

In many places the silt layer attains a thickness of 3 feet or more, depending on the slope and position of the land, especially in the individual fields. The texture ranges from silty clay loam to silty clay. The granulated structure is excellent for such a heavy soil. There is little or no evidence of granitic material in this deep topsoil, and the color averages a little darker than in the silted phase. Below a depth ranging from 2 to 3 feet there is a transitional layer between this and the original Cajon material.

The dominant crop is cotton, but the soil is used also for the production of other crops, as it covers the entire area of many farms on which a diversified type of agriculture is carried on. It is a deeper and more fertile soil than the silted phase and also holds moisture longer. Therefore, it is ideal for the production of cotton and has greater economy of irrigation water per crop unit. From $1\frac{1}{2}$ to $2\frac{1}{2}$ bales of cotton an acre are obtained. This is also a good soil for small grains. Wheat yields from 30 to 40 bushels an acre and barley from 30 to 50 bushels. When these crops are grown, corn and hegari follow, and high yields are obtained although the soil is of heavy texture for the latter crops.

With the continued silting, all the Cajon soils under irrigation will eventually become modified and be deeply covered by this heavy-textured material; and, even though it granulates well at the surface, the continued increase in depth is accompanied by compaction and becomes a problem in cultivation. It is therefore advisable to use alfalfa in the crop rotation, even though higher yields of alfalfa can be obtained on lighter textured soils. This will supply coarser organic matter, alleviate the compaction, and increase fertility.

Cajon sandy loam, shallow-silted phase.—The shallow-silted phase of Cajon sandy loam is much less extensive than the other silted phases, but it has a wide distribution. It occupies high positions on the fans near the terrace fronts or the more aggraded positions along the washes. This soil is not so deeply silted as the

others, owing to the shorter time that it has been irrigated or because of its less favorable relief for silting.

The surface soil is dull-brown gritty clay loam, in which the color and granitic character of the Cajon soil are not totally obscured. This material continues to a depth of about 6 or 8 inches where it overlies the original typical Cajon soil. The subsoil materials are in many places a little coarser than in the more deeply silted areas of these soils.

In many places where this soil occurs in association with the more deeply silted soils, it is planted to cotton, but it is favored for alfalfa, corn, and hegari. Yields of about 1 to 1½ bales of cotton an acre can be obtained, but the water requirement for this crop is higher than on the other silted phases. Alfalfa flourishes, but it also demands more water than on other soils. In areas where the land is sufficiently irrigated, from 4 to 7 tons of alfalfa may be obtained. Corn yields from 30 to 60 bushels an acre.

Cajon loam.—Cajon loam is of small extent. Its distribution is about the same as that of the shallow-silted phase of Cajon sandy loam. Under the canals this soil is slightly silted, but its surface soil retains its identity as a Cajon soil. A small proportion of this soil lies above the canals. Because of its position or, in some instances, because of its coarse texture, this soil has not been farmed long, and it is but slightly silted. It is of lighter texture, is less fertile, and has lower moisture-holding capacity than the silted phases of the Cajon soils. Some cotton is grown, but the soil is utilized largely for such crops as alfalfa, corn, and hegari. Cotton yields from three-fourths to 1 bale an acre, alfalfa 4 to 6 tons, and corn 30 to 50 bushels.

The 6- to 8-inch surface layer is medium-brown or dark grayish-brown gritty loam showing some effects of silting in some places but retaining the granitic character and the slight yellow tint of the virgin soil. Between depths of 8 and 24 inches the material is dull grayish-brown or dull-brown gritty sandy loam. Below a depth of 2 feet the subsoil is rather thickly stratified gritty sandy loam and loamy sand, and the material becomes more porous with depth.

SOILS WITH COMPACT SALTY SUBSOILS

Of the soils having compact salty subsoils the Imperial soils are the toughest and most refractory, although they do not everywhere carry as large quantities of salts as the Land soils. The soils of both series are underlain by more porous open strata in the deeper part of the subsoil and the substratum, but the compact heavy subsoil continues to greater depths in the Imperial soil. Although the lower part of the subsoil of the Land soils is rather plastic and heavy, it is less compact and is stratified with somewhat lighter textured materials.

The soils of both series, in the virgin state, contain large quantities of salts, are low in organic matter, heavy in texture, and are inclined to be more or less tough and plastic in the subsoils and in spots at the surface, although, in many places, the surface soils are granular and "puffy." Only a sparse growth of salt-tolerant vegetation survives, and there are many large bare spots. These soils check and

crack deeply when dry, making them very susceptible to fissure erosion and hence deep gullying. Vertical-sided gullies and drainageways are prominent features in the otherwise rather smooth plains.

These soils have slow internal drainage, together with the high salt content, especially in the subsoil. They are very poorly drained in the low-lying positions, where drainage and seepage waters accumulate.

The Imperial soils occur in scattered areas extending from San Simon Creek northwest to the lower end of the area, but the Land soils extend north and west from the vicinity of Pima. The Imperial soils east of Glenbar owe their origin mostly to segregation and deposition of heavy-textured alluvial materials from various sources, but west of this section both Imperial and Land soils have developed dominantly from the reddish-brown salty old lake clays. For this reason the Imperial soils have a redder cast in that part of the valley.

Where adverse drainage conditions did not exist in the virgin state and have not developed since irrigation, these soils have been successfully reclaimed, even though they contain large quantities of salts, especially in the subsoils. The high content of lime and organic matter in the turbid irrigation waters facilitates this reclamation. Some of these soils, especially the Imperial, which have been farmed the longest, are deeply silted and fertile, and they produce excellent crops:

Imperial silty clay.—Only a few unsilted areas of Imperial silty clay remain. Therefore this soil is not agriculturally important. Such areas lie scattered in small bodies throughout the valley.

In the virgin state the surface soil, to a depth of about 30 inches, is dull slightly reddish brown silty clay loam or silty clay of massive brittle or hard cloddy structure (pl. 1). The thin surface crust is duller in color and has a slick, smooth appearance. Beneath this and continuing to a depth of about 2½ inches is a granular mulch overlying more compact material. Below a depth of 30 inches is the subsoil of slightly more reddish brown silty clay or clay, which has a somewhat more massive structure than the material above, and in which seams of salt accumulation are numerous. When wet, the entire soil mass is very sticky, plastic, and intractable. The deeper part of the substratum, as seen in deep exposures, is stratified, more open, and porous.

This soil has a rather high salt content, and, because water penetration is slow, it can be reclaimed only very slowly. Crop yields are not very satisfactory until the soil is leached of its salt and built up with silty deposits by irrigation water.

Bodies of Imperial silty clay, in that part of the valley where the soils have been influenced by materials eroded from old red lake clays, are underlain by more pronounced red subsoils than those in other parts of the area. The subsoil here is plastic, refractory, tough, and high in content of salts. This variation is of small extent—only about 160 acres—all which lies under the canals, and much of the land has been reclaimed. It lies north of Glenbar in a number of small bodies in secs. 1, 2, 3, 11, and 12, T. 6 S., R. 24 E.

Imperial silty clay, silted phase.—As previously stated, Imperial silty clay does not become productive until leached and silted. The



GULLY TYPE OF EROSION AND CHARACTERISTIC STRUCTURE IN IMPERIAL SILTY CLAY IN THE LOWER PART OF THE VALLEY.

silted phase is the reclaimed soil and is important for the production of cotton and small grains. It is developed extensively in a continuous body near Solomonsville. A large area lies north of Central, and smaller areas are scattered throughout the valley.

The body near Solomonsville is silted to a depth ranging from 1 to more than 2 feet, and it has become an important agricultural soil. Cotton yields as high as $2\frac{1}{2}$ bales an acre, and small grains produce well. Continued leaching through irrigation reduces the salt content in the root zone, and the simultaneous silting builds up a very fertile topsoil of excellent structure. Thus, an artificial soil that has a subsoil which is very retentive of moisture is built up, and it is ideal for the production of cotton. Such a heavy-textured soil is less suited to alfalfa and corn, although good yields of these crops are obtained.

In other parts of the area this soil is not so deeply or uniformly silted, and its leaching and reclamation have not been so successful. Most of the less successfully reclaimed areas are those in which unfavorable subdrainage already existed or has developed since irrigation began. Subsoil water moving through the more porous higher lying soils reaches this deep heavy soil and its movement is retarded, causing the rise in the water table and consequent oversaturation. Capillarity reverses the movement of the salts, and they become concentrated at the surface. Therefore it is very essential that the status of the subdrainage be ascertained and, if necessary, a proper system of main and intercepting drains be established before reclamation is attempted. It is also essential to keep poorly drained areas of this soil under cultivation, otherwise salts again concentrate at the surface.

Areas totaling nearly 200 acres, one west of Bryce in secs. 1 and 12, T. 6 S., R. 24 E., and one about one-half mile northwest of Eden are underlain by a red clay subsoil. These areas have been rather difficult to reclaim but have been silted and brought to a fair state of productivity. The crops are similar to those grown on the other silted Imperial soils, but yields are generally less.

Another variation in the silted phase of Imperial silty clay occurs in areas where sandy or gravelly stratified materials underlie the soil within 4 feet of the surface. Such a condition exists in an area of about 400 acres west and southwest of Safford, in secs. 12 and 13, T. 7 S., R. 25 E., and secs. 7 and 18, T. 7 S., R. 26 E.; in a body of about 100 acres at the northeastern edge of Glenbar; and in very small areas southwest of Pima and $2\frac{1}{2}$ miles northwest of Safford. The productivity of this soil is about the same as that of the more typical silted phase of Imperial silty clay, and the land is even better adapted to the production of alfalfa. It is more pervious, better drained, and comparatively free from excessive quantities of salts.

Imperial silty clay, shallow phase.—In some places, especially along streamways and playas in the lower part of the area, are small areas of Imperial silty clay, in which the heavy soil is shallow over coarse-textured and gravelly strata. These bodies are associated with the Land and Anthony soils and are mapped as Imperial silty clay, shallow phase. Their total area is not large, and most of the land lies above the present canals but is not without possibility of irrigation. A few areas are under cultivation and have become silted to a fairly productive state.

The soil consists typically of silty clay to a depth ranging from 3 to 4 feet, where it is underlain by more porous strata. Some of the upper part of the stratified material is rather fine textured, but the coarseness increases with depth and the material is very gravelly in some places. Where occupying the higher positions, this soil does not contain such large quantities of salts as typical Imperial silty clay. For this reason and because of the more porous subsoil, land of this kind is more readily reclaimed. Areas lying in the upper part of the valley are duller or more yellow in color than the others.

Land silty clay.—The larger areas of Land silty clay are in the valley below Glenbar, mainly between Ashurst and Fort Thomas, where the Land soils predominate. All these soils lie on alluvial flats. The materials have been deposited by lateral drainageways and are eroded from the old lake clays which lie along the edge of the valley. These alluvial flats lie well above the Gila River flood plain, and surface drainage is well developed.

Typically this soil consists of light reddish-brown or light chocolate-brown silty clay loam or silty clay, in which the upper 4 inches is loose and granular but is glazed over by a smooth thin crust. From a depth of 4 and extending to a depth of 24 inches the material is predominantly compact dull reddish-brown silty clay. In places it is stratified somewhat with yellowish-brown material and marked by definite veins or seams of accumulated salts. Between depths of 2 and 4 feet the heavy silty clay is stratified with fine-textured more porous materials, and the soil is slightly more friable. The color is lighter or more yellow, and only slight seaming by salts is apparent. Below a depth of 50 inches the subsoil is stratified silty clay loam, loam, and fine sandy loam, of similar or slightly lighter color, and the materials are increasingly more porous and friable.

This soil has an inherent high salt content, derived from the parent lake clays, which, together with the heavy impervious material, makes it difficult to reclaim. Reclamation is successfully carried on, however, by intensive leaching and silting over extended periods. Reclamation of this soil is similar to that of the Imperial soils, but it is generally less difficult because of the better drained position and the more permeable stratified subsoil of the Land soil. Once reclamation is effected there is less danger of a rise of the water table and the return of salts, provided the salts are kept moving downward by irrigation. Partial reclamation results in failure and further accumulation of salts from irrigation on adjoining lands.

The first crops selected to be grown on this soil when it is reclaimed are the small grains and hegari, and, after several years of leaching and silting, the land is planted to alfalfa and sweetclover. Once these legume crops are established, silting is more rapid and the fertility is increased. Yields of small grains and hay are small at first, but they increase materially as reclamation is effected.

Land silty clay, silted phase.—The extent of the silted phase of Land silty clay has increased over that of the unsilted and unmodified areas of Land silty clay, and this shows that reclamation has been carried on to a large extent. In some areas which have been silted as long as 15 years, the silt extends to plow depth. Such areas produce from 3 to 5 tons of alfalfa an acre and from about one-half to 1 bale of cotton. Wheat yields from 15 to 30 bushels and barley

a little higher. There is a wide range in the depth of silting, and a definite correlation exists between crop yields and depth of silting. It is probable that when the silt becomes nearly as deep on this soil as on the Imperial soils of the upper valley, this soil will be as productive as the Imperial soils and adapted to a wider range of crops because of its more porous subsoil. Internal drainage also is somewhat better than in the Imperial soils.

Land silty clay loam.—Land silty clay loam is about as extensive as Land silty clay. It is not quite so widely distributed, but it occurs in the same general localities. Certain textural characteristics distinguish the silty clay loam from the silty clay. The topmost layer, which averages about 18 inches in thickness, is silty clay loam. The subsoil in most places includes a greater quantity of stratified silty and fine sandy loam materials, and it is not so compact as the subsoil of the silty clay. In some small included areas, the topsoil contains rather large quantities of fine sand and the texture ranges from fine sandy loam to clay loam.

Land silty clay loam is equally as high in salts as Land silty clay, but it may be reclaimed more readily, because of the lighter texture of the surface soil and subsoil. Reclamation practices and crop selection are similar to those for the silty clay. The silty clay loam is more susceptible to erosion under irrigation, and small heads of water are necessary in the early stages of reclamation. The reclaimed areas are inextensive and are included with the silted phase of Land silty clay on the soil map.

SOILS HAVING MODERATE ACCUMULATION OF LIME IN THE SUBSOILS

The group of soils having moderate accumulation of lime in the subsoils includes the Anthony and Mohave soils. These soils are developed in places less subject to overflow and erosion, along the margins of the valley trough where they occupy terraces and alluvial fans. Small areas of the Mohave soils lie outside the valley trough on higher terraces. The Anthony soils are extensive and important. They are widely distributed in small areas throughout the valley. The Mohave soils are less extensive and relatively unimportant. They occur in small scattered bodies in the upper part of the area.

Although the Anthony soils are very stony and gravelly on the steeper alluvial fans, in the lower and less steeply sloping areas the surface soils are fine textured, but the subsoils everywhere are gravelly and in places stony in the lower part, or substratum. The Mohave soils are equally gravelly and stony and are more compact in the subsoil.

Soils of both series are pale reddish brown or dull reddish brown, but the Mohave soils, being older, are redder throughout the profile. These soils are older than the soils without accumulated lime but not so old as the highly developed soils of the high terraces or mesas. With age, certain weathering and soil-development processes have caused accumulation of lime and clay in the subsoil, especially in the Mohave soils. Some of the Anthony soils retain a high content of lime in the surface soil and, consequently, are rather gray.

Owing to their high-lying position, these soils have excellent surface drainage, and drainage is good or excessive throughout the soil.

These soils in general are not in danger of accumulation of salts, or alkali.

Agriculturally the Mohave soils are insignificant. Their total cultivated area is less than 1 square mile. They occur in small areas near San Jose, Solomonsville, and Pima. The Anthony soils rank next in agricultural importance to the Pima, Gila, and Cajon soils, and they are somewhat similar to those soils in physical characteristics. They are equally free of excessive salts. For the most part the Anthony soils are widely scattered in small areas. The larger, more continuous areas of cultivated soil are near Solomonsville and Bryce.

The soils of this group are more leached than the soils of the younger group, but, as with all the farmed soils in the area, the productivity is greatly modified by the silt deposit from irrigation waters. Their productivity, however, is lowered by the more porous gravelly subsoils which do not retain moisture so well. The quantity of clay that has accumulated in the subsoil of these soils is variable. This variation, together with the gravel content, makes an appreciable difference even within bodies of the same soil and in many places gives rise to a less uniform growth of crops than on soils with fine-textured mellow friable subsoils. These soils probably have less natural fertility than the soils of the Pima, Gila, and Cajon series.

Anthony sandy loam.—The greater part of Anthony sandy loam has become silted, and only small scattered areas of the original unmodified soil remain. The unsilted land has no agricultural importance.

In its natural state the surface soil is slightly gravelly pale reddish-brown or dull reddish-brown sandy loam to a depth of 6 or 8 inches. Between depths of 8 and 24 inches, the material is more compact sandy loam or light-textured loam, and it contains faint seams or specks of lime. The color is distinctly more red. Below a depth of 2 feet, the material is light reddish-brown or grayish-brown stratified gravelly and porous incoherent sand and loamy sand. The gravel are slightly coated with lime. Below a depth ranging from 5 to 7 feet, the substratum in most places is coarse textured, very porous, and open.

As mapped, this soil includes a few areas having a gray color, which are less than one-half square mile in total extent, occurring mostly in the extreme upper end of the valley. None of these areas is farmed. The principal difference between this soil and typical Anthony sandy loam is its grayer color, due to a high lime content, and its lack of appreciable compaction in the subsoil. In general the soil, which contains large quantities of sand and gravel, is more open and porous.

Anthony sandy loam, silted phase.—The silted phase of Anthony sandy loam compares favorably in agricultural value with the silted phase of Cajon sandy loam, though it is of much smaller extent and less continuous. It lies in scattered bodies, mainly in the upper two-thirds of the valley where the deepest silting has taken place. It has always been and still is important in the agricultural development of the area.

In average development this soil is silted to a depth ranging from 12 to 16 inches, but there is a range within individual fields and in

different parts of the area. The silted and modified surface soil is dark grayish-brown silty clay loam or silty clay, which is friable and granular as in the other silted soils. Below this, there is a thin transitional layer, and, in turn, slightly compact light reddish-brown sandy loam or loam, faintly seamed with accumulated lime. A small quantity of gravel is present. Below a depth of about 3 feet the subsoil continues as in the typical soil, a stratified gravelly sandy loam or sand of loose structure and slightly gray with lime.

Although the lower part of the subsoil is more open and porous than in the silted phase of Cajon sandy loam, the compact heavier upper subsoil layer in many places compensates in water-holding capacity. Therefore this soil compares favorably with the Cajon soil in the production of and adaptation to crops, but, because of the less uniform subsoil development of the Anthony soil, yields are somewhat lower. Drainage conditions are good, and there are practically no salt-affected areas.

Cotton is grown extensively on this soil and yields from 1 to 2 bales an acre. Alfalfa yields from 5 to 6 tons, wheat 25 to 40 bushels, barley 30 to 45 bushels, and corn 30 to 60 bushels.

Anthony sandy loam, shallow-silted phase.—Anthony sandy loam, shallow-silted phase, is less extensive than the silted phase, but it has about the same distribution. It represents areas covered by thinner deposits of silt. The silt extends to an average depth of about 8 inches, and the texture is gritty clay loam. This soil is slightly less favored for cotton than the more deeply silted phase, but it is utilized for cotton in areas associated with that soil. This soil is used for the production of alfalfa, corn, and hegari when the more deeply silted soil is available for cotton.

The shallower silting results both from the shorter periods of irrigation and modification and the steeper slope which is less favorable for silting. In some of the higher positions, silting is very shallow and the gravelly subsoil is near the surface, making the soil more droughty and less productive than in average areas.

Anthony gravelly sandy loam.—Anthony gravelly sandy loam is not extensive but is widely distributed in small bodies. It lies chiefly at higher elevations above Anthony sandy loam and above the irrigation canals. It has no agricultural importance.

It is a looser, more porous, and leachy soil than Anthony sandy loam, as it contains large quantities of gravel throughout the surface soil and subsoil. The surface soil is light reddish-brown or grayish-brown loose gravelly sandy loam to a depth of about 14 inches. Between depths of 14 and 40 inches the soil material is grayer, of higher lime content, of sandy loam or sand texture, and has a larger content of gravel. Below a depth of 40 inches, lime is less discernible and the material consists of open and porous stratified sand, gravel, and cobbles.

Anthony gravelly sandy loam, gray phase.—The gray phase of Anthony gravelly sandy loam is similar to the typical soil, except that it has a higher lime content and is grayer throughout the soil profile. It represents areas of Anthony gravelly sandy loam in which lime seems excessively developed in the subsoil, occurring as white coatings on the gravel. The soil is loose and porous throughout. Most of this soil lies south of Sanchez and north of Eden.

The land is not farmed, most of it lies above irrigation canals, and it has little potential value for agriculture.

Anthony stony sandy loam.—Anthony stony sandy loam is similar to Anthony gravelly sandy loam, but it contains larger quantities of stone and gravel throughout. The large content of stone renders the land unsuitable for agriculture. Most of it lies above the canals and occupies steep alluvial fans along the high terrace escarpments. The extent and distribution is similar to that of Anthony gravelly sandy loam. The stony sandy loam is unirrigated and is too loose, leachy, and stony for farming under present conditions.

As mapped, this soil includes small areas which are grayer than typical, due to the high lime content. They occur in association with the gray areas of Anthony gravelly sandy loam, near Sanchez and Eden. A few areas having a large accumulation of lime in the subsoil also are included.

Anthony loam.—Anthony loam is of very small total area, but it is widely distributed in association with the silted Anthony soils. It has been somewhat modified by silting, but the influence of silting has not been sufficient completely to mask the surface soil which still retains the appearance of the Anthony soils. The influence of the silt extends to about plow depth. The surface soil is dull reddish-brown gritty loam, and the subsoil is similar to that layer of Anthony sandy loam. The land is farmed in conjunction with the silted Anthony soils and is best suited to alfalfa, corn, and hegari. Alfalfa yields from 3 to 5 tons an acre and corn from 20 to 40 bushels.

Anthony fine sandy loam.—Anthony fine sandy loam is developed from fine-textured materials laid down on the flatter parts of alluvial fans. This soil lies well out in the valley, has very favorable relief for irrigation, and is well drained. In many places, especially near Bryce and Eden, it resembles the Gila soils, as mapped in this area, except that it has a more pronounced reddish-brown color and contains less organic matter. In most places, a sprinkling of gravel is present in the surface soil, and the lower part of the subsoil is gravelly, whereas gravel is lacking in the Gila soils. A slight accumulation of lime and some compaction are developed.

This soil is extensive west of Mathews Wash. Here it occupies the higher and more sloping areas above the Land soils, and the influence of the heavy-textured parent materials makes the subsoils compact. The subsoils may contain small quantities of salts. In most of these areas, small angular granitic gravel are scattered over the surface and even through the soil. Thin strata of this material occur in most places in the lower part of the subsoil. Accumulation of lime is not very far advanced.

Much of this soil west of Mathews Wash lies above the canals, but where water is available the land is under cultivation and has been extensively silted.

Anthony fine sandy loam, silted phase.—The silted phase of Anthony fine sandy loam is not so deeply silted as the other silted Anthony soils, mainly because it has not been irrigated and farmed so long. The texture of the surface soil has been changed to clay loam or silty clay loam by this silting, which extends to about plow depth, and the material has the dark dull-brown color of the silted soils. The fine-textured subsoil materials have moisture-retaining

properties comparable to those of the Gila, Pima, and Cajon soils, and wherever the deeper silting has taken place this soil approaches those soils in productivity. Crops are selected in relation to the depth of silting. Around Bryce and Eden, where the soil is more deeply silted, from three-fourths to 1½ bales of cotton an acre are often obtained. Alfalfa yields from 5 to 6 tons, corn from 30 to 50 bushels, wheat from 20 to 30 bushels, and barley from 30 to 40 bushels. Alfalfa, wheat, and barley are the principal crops grown west of Mathews Wash.

Mohave sandy loam.—Mohave sandy loam and its silted phase occur in small areas, principally in the vicinities of San Jose and Pima. The unsilted Mohave sandy loam is inextensive and not farmed.

In average development the surface soil, to a depth of 6 inches, is dull reddish-brown or light reddish-brown light-textured friable sandy loam containing a sprinkling of gravel. Between depths of 6 and 18 inches the material is reddish-brown compact cloddy sandy loam or loam, with faint veining and mottling of lime. Below this and extending to a depth of 36 inches, the subsoil is brighter reddish-brown gritty clay loam and the lime veining is thicker and more definite. The lower part of the subsoil is reddish-brown gravelly sandy loam and sand, in which most of the gravel is well coated with lime. In the areas on the higher mesa near Pima and Fort Thomas, the soil is more maturely developed, and the lower part of the subsoil is more compact and has a high accumulation of lime.

As mapped, this soil includes small areas of stony and gravelly character, which are indicated on the soil map by stone and gravel symbols, respectively.

Mohave sandy loam, silted phase.—The silted phase of Mohave sandy loam is very inextensive. It is important agriculturally only because it is associated with the silted Anthony soils. It is used for similar crops, and yields are slightly less than those obtained on the silted phase of Anthony sandy loam. Most areas of the silted Mohave soil are broken by small stony or gravelly areas of typical Mohave sandy loam. Such areas make production less uniform.

SOILS OF HIGH LIME ACCUMULATION

The soils having a high accumulation of lime are not agriculturally important in this area. The Cave soils occur in scattered areas high above the irrigation canals, capping the mesas along the margin of the valley. They afford only scant grazing.

The Laveen soils occupy lower, younger terraces along the terrace escarpments. The only bodies farmed are south of Pima where the canal swings out of the valley onto a low eroded terrace. They are not very well adapted to cultivation because of their unfavorable, uneven relief. Much leveling is necessary for proper irrigation and improvement by silting.

These soils differ from each other in both the surface soil and the subsoil. The surface soils of the Laveen soils are pale reddish gray, caused by a high lime content, whereas the Cave soils are of more pronounced red color. The high lime content continues into the subsoil in the Laveen soils which have developed a horizon high in accumulated lime. There is decided compaction, and hard lime nodules

are in evidence in this horizon which, in the stonier areas, may be slightly cemented. The Cave soils have a firmly indurated lime carbonate, or caliche, hardpan occurring rather abruptly at a slight depth and generally including large quantities of embedded stone and gravel.

Laveen loamy sand.—Laveen loamy sand occurs principally in the vicinity of Pima, where it occupies only a small total acreage. In most places, the surface soil of the virgin material, to a depth of about 6 inches, is friable dull grayish-brown, light grayish-brown, or pale brownish-gray light-textured loamy sand containing a few gravel and small irregular lime carbonate nodules. A pink tinge is discernible in many places. Below this, and continuing to a depth of about 18 inches, is the subsurface soil which is similar to the layer above but is slightly more red or pink, and it contains an increasing quantity of gravel and lime nodules. The next lower layer is one of higher lime accumulation and contains a large quantity of lime nodules. It consists of light-gray or pinkish-gray gritty material, of heavier texture and greater compaction, which may be softly cemented. Below a depth of 40 inches there is a thin transitional layer of lime infiltration, overlying looser and more porous dull reddish-brown gravelly sand or loamy sand.

As mapped, this soil includes small stony and gravelly areas which are indicated on the soil map by stone and gravel symbols, respectively. Very little of the gravelly areas is under irrigation. The stony areas are very stony throughout the soil profile, which is poorly defined, and are of no agricultural importance.

Laveen loamy sand, silted phase.—The silted phase of Laveen loamy sand occurs on a rather broken terrace south of Pima, and the land is not very favorable for irrigation or cultivation. A large amount of leveling has been done for greater ease and efficiency of irrigation and more uniform distribution of irrigation water and silt. The uneven relief has caused a variable depth of silting, and the texture of the surface material ranges from loam to silty clay loam within individual fields.

Variations in character of this soil and the underlying substratum, together with the occurrence of impervious layers in places, have been responsible for the unfavorable underdrainage since irrigation has been practiced, and seepage spots and salt accumulations have resulted here and there.

The fertility is correlated with the depth of silting, which as yet is not very great. A diversified type of agriculture is dominant. Some cotton is grown, but the major crops are alfalfa, small grains, and corn. This soil is so mixed in occurrence with the silted Anthony and Mohave soils that it is hard to determine crop yields specifically.

Laveen loamy sand, steep broken phase.—The steep broken phase of Laveen loamy sand represents areas extremely broken and stony and occupying steep escarpments. It is widely distributed and is associated with the other Laveen soils. It has no agricultural value.

Cave gravelly loam.—Cave gravelly loam is an extensive soil developed on the high terraces or mesas along the valley margin throughout the length of the area. None of this soil lies low enough for irrigation.

Considerable variation occurs in the development of this soil in this area. In average development, however, it consists of thin dull reddish-brown gravelly loam several inches thick, overlying more compact and redder clay loam. The red color and the compaction increase in this layer, and below a depth of about 18 inches the material is veined with accumulated lime above the cemented horizon, or hardpan, which lies at a depth ranging from 2 to 3 feet and consists of a dense, hard lime-cemented conglomeratelike hardpan. The hardpan is underlain by coarse stony strata.

Cave gravelly loam, steep broken phase.—The steep broken phase of Cave gravelly loam consists of broken areas and escarpments along the terrace margins of the Cave soil. These areas are extremely stony, steep, and poorly defined in profile. They have no value for crops and very little value for grazing.

MISCELLANEOUS LAND CLASSES

In addition to soils classified in the several soil series and soil types, two classes of miscellaneous lands that do not lend themselves to such classification have been recognized and mapped. These are riverwash and rough broken land.

Rough broken land.—Rough broken land represents eroded, broken areas and steep escarpments along the terrace fronts, consisting mainly of exposed old lake-bed materials. The land is not used for crops and has little or no value for grazing.

Riverwash.—Riverwash consists mainly of unstable intermingled fine sediments, sands, gravel, and stony materials lying in the immediate flood plain of Gila River and its tributary streams. The total area is large. A belt of this material, averaging about one-half mile in width, extends throughout the length of the valley. In the river flood plain, the land is periodically flooded. The material consists mostly of washed sands, with occasional lenses and streaks of gravel and stone. An irregular relief indicates the severity of disturbance and erosion by wind and water. The more extensive areas are more stable and support a dense growth of arrowweed, tamarisk, willow, and a few cottonwood. The grasses on this land afford some grazing. On some of the more stable areas artificial silting has been attempted, and possibly some small areas may be reclaimed by protection from overflow followed by silting.

AGRICULTURAL METHODS AND MANAGEMENT

Cotton is the most important crop, and it is essential that the other crops fit in well in relation to and rotation with it. The cotton crop demands a growing season covering the entire frost-free period. The next important crop, alfalfa, occupies the land several years. Because of the mild winters two crops of grain may be grown in a year, with wheat or barley in winter and spring, followed in summer by corn or hegari.

Because of silting by the fertile and highly organic sediments in the irrigation water, there is less need for crop rotation than in most irrigated sections, and commercial fertilizers are seldom used. Cotton can be grown almost continuously because of this replenishment

of fertility. Because of the highly colloidal character of the mineral and organic constituents of the sediments, considerable compaction may result in the deeper soil, especially where laid over heavy subsoils. This condition can be alleviated by growing alfalfa 3 or 4 years in rotation with cotton. The benefit results from the penetration of the alfalfa roots and the incorporation of coarse organic residue with the heavy soil material. This seems to become more essential as deeper silting takes place, especially on heavy subsoils.

Cotton is planted the first part of April, and it is generally harvested in September and October. Because climatic conditions are favorable, cotton picking often lasts well into the winter. The short-staple variety, Acala, is grown.

In the growing of alfalfa, the silty deposit buries and rots the crowns so that the stand thins rapidly after several years. This is more pronounced on flatter land. Therefore, it has become economical as well as beneficial to the soil, to establish a rotation with alfalfa as a 3- or 4-year crop.

Wheat and barley usually are seeded in September or October but sometimes as late as December. They may be pastured during the winter and afterward allowed to grow and mature. Barley is pastured more often than wheat, and on many farms it is used only for pasture. Harvesting of grain crops takes place in May and June. Early Baart is the chief variety of wheat grown. Barley is mainly California Feed, a six-row variety. Corn and hegari follow these small grains the same season and mature to grain or sometimes are cut for silage. There is little demand for silage because of the year-round pasture available.

On the salty lands being reclaimed by irrigation, the first crops commonly grown are hegari and small grains, and on some farms the land is used largely for pasture. Alfalfa usually may be grown with a fair degree of success after a few years of leaching and silting of the soil by the use of the muddy irrigation waters. Finally the land becomes fit for the production of cotton. Livestock farming has been adopted on the more successful farms in the lower part of the valley where lands are being reclaimed. This type of farming is especially suitable in this locality, as it furnishes a market for the feed crops and helps to build up the productivity of the soil. Many of the farmers, however, grow cotton as a cash crop and have little interest in other crops. Few of them keep livestock. They depend on the gradual improvement of their lands by leaching and the deposition of silt.

IRRIGATION, DRAINAGE, AND ALKALI

The irrigation water for the irrigable acreage of from 35,000 to 40,000 acres is supplied by diversion from Gila River. There are no storage reservoirs, therefore only the natural flow of streams is available. After the spring flow from the mountain areas subsides, the water is low, and the water available for certain parts of the area becomes very limited until the summer rains replenish the supply. Priority rights dominate the available supply, and distribution is under control of a water commissioner.

Eleven diversion canals or ditches are shown on the map. Very unstable diversion headings are built, and these are frequently torn out by floods. They are easily rebuilt, however, and adjusted to the flow and diversion allowable.

Numerous spillways allow for the flow of excess water to other canals or back to the river, from whence it is redistributed. This feature, together with the return flow from irrigation, provides for very economical use of water, though some farmers in the lower end of the valley complain of the high salt content of the water during low stages of the river.

Over the greater part of the area, the relief is excellent for the distribution of irrigation water. Both the flooding and border methods of irrigation are employed to a large extent for most field crops, but the furrow method is preferred for row crops. In the border method, small corrugations are often employed between the borders with excellent results.

In the valley above Thatcher, very little drainage or alkali trouble has developed since the land has been irrigated, and several areas having a high salt content have been reclaimed. This is because of the favorable relief and good underdrainage. In small areas below Thatcher, however, drainage and accumulation of salts have become problems. This is probably due to the low position and flatness of the land, great variation in character and permeability of the substrata, and deep heavy subsoils, through which water moves slowly.

The largest area of poor drainage and salt accumulation is north of Central. There is an extensive system of drains in this area, and the tendency is for the greater part of the area to show improvement. Small areas remain, however, that have a high water table which comes dangerously near the surface, especially during the irrigation season. It is very likely that this central drainage system is insufficient and that successful drainage cannot be obtained until a system of intercepting drains is established at right angles to the slope, along the line of contact between the more permeable, higher lying soils and the heavy Imperial soils. Subsurface drainage waters, moving down the slope, reach these deep heavy soils, and their movement is checked, thereby causing a rise of the water table. Similar conditions and associations of soils exist elsewhere in the area but to a much smaller extent. The cost of additional intercepting drains may be prohibitive, however, if they involve only a small area.

The river has cut deeply enough that it does not waterlog any except a few unimportant low areas. In such areas poor drainage generally is aggravated by inflow of water from natural or irrigation sources and here and there by salt springs from old lake clays.

Salt accumulations in this area are from two sources: From the ground water, due to insufficient drainage; and from salt-impregnated parent soil materials, chiefly the old lake clays. The Imperial and Land soils are those most seriously affected. These heavy-textured soils contain large quantities of salts throughout the surface soil and subsoil.

From whatever source, the salts consist almost totally of the saline or "white alkali" salts—sodium chloride and sodium sulphate. Slight indications of sodium carbonate, or "black alkali", are found in the virgin soils of heavy texture and sometimes in leached soils,

the greater quantity appearing in the subsoils. In few places, if any, are there sufficient alkali carbonates to have an appreciable effect on plant growth or to impair the physical structure of the soil. The formation of black alkali becomes troublesome in many places, especially in the heavier textured soils, with the progress of reclamation through leaching. In this area, however, reclamation is carried out with remarkable efficiency, and the formation of alkali carbonates is probably suppressed by the high calcium content of the soil and the turbid silty waters of high calcium and organic-matter content. The efficiency of reclamation may be attributed also to the fact that an entirely new salt-free fertile topsoil is formed, and, if the salts are kept moving downward or kept below the root zone, crop production is not jeopardized. This reclamation is successful, however, only in places where the underdrainage is good. The areas having an inherent salt content are less likely to be poorly drained than those in which accumulated salts have developed with irrigation.

During the progress of the survey critical studies were made of related plant, soil, and drainage conditions, in order to establish the boundaries of salt-affected areas. The areas are delineated on the map under two grades of severity, one representing areas of high concentration, in which the growth of vegetation, except saltgrass and other highly salt-tolerant plants, is impossible; and the other, areas of slight or spotted accumulations of salts. In many places the boundary lines are defined by field boundaries separating the reclaimed from unreclaimed areas.

Samples of soil were taken, and the total salt content determined with the electrolytic bridge. The results of the more important of these determinations are expressed on the map in the form of a fraction, in which the upper figure gives the salt concentration of the soil to a depth of 1 foot and the lower figure gives the average salt concentration to a depth of 6 feet. Some of these samples were taken in nonaffected areas and in areas in which total or partial reclamation had been effected, to establish the degree of tolerance of plants to the combination of salts existing in the area.

Since the earlier soil survey of 1903,² the Imperial soil near San Simon Creek has been leached and silted, so that this soil, which at the time of the earlier survey ranged in salt content from 0.2 to 0.6 percent, now shows a concentration well below 0.2 percent in many places and in the more severely affected areas an average of only 0.23 percent to a depth of 6 feet. Representative samples from a virgin area along San Simon Creek were found to have 0.2 percent in the topmost 12 inches and an average of 0.44 percent to a depth of 6 feet. This is significant, as it indicates what can be accomplished in the reclamation and silting of these heavy soils if underdrainage is sufficient. This reclaimed soil is now producing excellent yields of cotton.

Similar evidence of reclamation is seen in the district west of Mathews Wash, where heavy soils predominate. The reclamation is slow at first, but with continued leaching and silting, especially after alfalfa becomes established, the returns become more remunerative.

² LAPHAM, M. H., and NEILL, N. P. SOIL SURVEY OF THE SOLOMONSVILLE AREA, ARIZONA. U. S. Dept. Agr., Bur. Soils Field Oper. 1903, Rept. 5: 1045-1070, illus. 1904.

The soils in this locality have a wide range in salt concentration, running up to more than 3 percent in a few places that are most favorable for an accumulation of salts. In most places the maximum content is in the subsoils of these heavy soils. The reclaimed areas are producing good yields of crops.

A virgin area was found to contain 1.14 percent of total salts in the topmost 12 inches and an average of 2.42 percent to a depth of 6 feet. In a nearby field of the same soil the salts had been reduced to less than 0.2 percent in the topmost 12 inches, 1.32 percent between 3 and 6 feet, and an average of 0.76 percent to a depth of 6 feet. This soil was producing only fair alfalfa, but even this is significant as indicating partial reclamation. A partly leached area not producing crops showed a concentration of 0.55 percent of salts in the topmost 12 inches of soil, 1.58 percent between 3 and 6 feet, and an average of 0.79 percent to a depth of 6 feet. An adjacent area of similar soil, but more thoroughly silted, said to have produced a bale of cotton an acre, showed a concentration of 0.42 percent in the 12-inch surface layer and an average of 1.06 percent to a depth of 6 feet.

Several areas of Land soils near Bryce showed significant results in reclamation. One area of extreme salt accumulation showed a 3-percent average to a depth of 6 feet. An adjoining silted field was producing excellent alfalfa. In this field, the salt content had been leached below 0.2 percent to a depth of 3 feet and averaged 1.3 percent between 3 and 6 feet. Another sample from a virgin area contained 1.1 percent of salts in the surface soil and averaged 1.19 percent to a depth of 6 feet. A silted field adjoining was producing good alfalfa and had been leached to an average of less than 0.2 percent to a depth of 6 feet. In all these soils examined in this district of heavy soils, the "black alkali" content became slightly noticeable or increased with leaching, especially in the lower part of the subsoil; in none of them does the toxicity of the salts appear increased or the soil more puddled and dispersed by this small quantity of black alkali.

In interpreting the results of the tests in regard to the possibility of soil reclamation and determining the tolerance of plants, it is apparent that there is great variation of concentration of salts within the individual fields and in their distribution throughout the soil profile. The determinations of the salt content of the samples tested are therefore indicative only of more general conditions. Soils having a high water table, especially light porous soils, usually have a high concentration of salts near the surface, whereas heavy-textured soils usually have the greater concentration in the subsoil, and these are the conditions that predominate in this area. Plants have a greater tolerance for alkali in the heavier textured soils.

With the associated silting that takes place in the process of leaching and reclamation of the salty soils in this survey, the tolerance of plants to salts is different from that in most other areas, as a different topsoil is created that aids in tolerance, especially in the early stages of growth before the roots reach the more concentrated and toxic zone of salt accumulation. With this silted surface soil, the plant can make fair growth with an extremely high concentration of salts in the subsoil, because the concentration in the surface soil usually remains

well below 0.2 percent unless leaching is stopped or there is a high water table causing the salts to return to the surface. Under this condition the concentration in the surface soil is, therefore, very important. About 0.4 or 0.5 percent of salts in the topmost 12 inches seems to be the limit of tolerance for most plants under these conditions. At a concentration of 0.3 percent many crops seem seriously retarded in growth. If there be concentration of 0.4 to 0.5 percent in the second or third 12-inch layer, crop growth may not be successful, even though that in the topmost layer be less than 0.2 percent. Fair growth seems to be obtained with shallow-rooted crops, however, with a leached surface soil even with a concentration of more than 1 percent at depths ranging from 3 to 6 feet.

RATING OF SOIL TYPES AND PHASES ACCORDING TO PRODUCTIVITY

Table 3 gives a rating of the soil types and phases in the upper Gila Valley area according to their productivity for the more important crops grown under the prevailing system of irrigation farming. Under natural desert conditions these soils have practically no agricultural value, but under irrigation many of them are exceedingly productive.

TABLE 3.—*Classification of soils in the upper Gila Valley area, Arizona, according to productivity under irrigation*

Soil type or phase ¹	Crop-productivity index ² for —								
	Cotton	Alfalfa hay	Barley	Wheat	Corn	Grain sorghums	Pasture		General productivity (weighted average of indexes)
							Irrigated	Unirrigated (range)	
Pima silty clay loam.....	200	110	110	120	90	110	150	-----	165
Cajon sandy loam, deep-silted phase.....	200	110	110	115	90	110	150	-----	164
Cajon sandy loam, silted phase.....	185	120	105	115	90	110	150	-----	158
Pima silty clay loam, heavy-textured phase.....	190	100	110	120	85	100	140	-----	155
Imperial silty clay, silted phase.....	190	100	105	115	80	100	140	-----	155
Gila clay loam.....	175	120	105	115	85	105	135	-----	152
Anthony sandy loam, silted phase.....	180	110	100	110	80	100	130	-----	150
Gila loam.....	150	120	100	110	80	100	130	-----	136
Cajon sandy loam, shallow-silted phase.....	150	120	100	100	80	100	120	-----	136
Imperial silty clay, shallow phase.....	150	110	100	100	75	100	120	-----	133
Anthony fine sandy loam, silted phase.....	125	120	85	95	80	100	110	-----	120
Anthony sandy loam, shallow-silted phase.....	120	120	80	90	80	100	110	-----	117
Gila fine sandy loam.....	115	110	90	100	80	100	120	20	112
Mohave sandy loam, silted phase.....	120	105	75	90	75	95	120	-----	110

¹ Soils are listed in the approximate order of their productivity under a system of irrigation agriculture. They have little or no agricultural value without irrigation.

² The soil inherently most productive (without aid of amendments or irrigation) for each specified crop in the United States is given the index 100. Only soils of significant acreage in well-known crop regions have been given this standard index (100). The indexes in this table express the approximate productivity of the soils of this area in percent of the standard. All indexes are for crops under irrigation with the exception of those for unirrigated pasture or range.

TABLE 3.—Classification of soils in the upper Gila Valley area, Arizona, according to productivity under irrigation—Continued

Soil type or phase	Crop-productivity index for —								General productivity (weighted average of indexes)
	Cotton	Alfalfa hay	Barley	Wheat	Corn	Grain sorghums	Pasture		
							Irrigated	Unirrigated (range)	
Anthony fine sandy loam	110	110	75	90	65	80	100	10	107
Laveen loamy sand, silted phase	115	100	70	90	70	90	110	10	107
Cajon loam	105	110	80	80	80	100	110	10	105
Anthony loam	100	90	80	90	60	75	110	10	93
Cajon sandy loam		100			60	75	110	10	90
Mohave sandy loam								10	85
Land silty clay, silted phase	75	85	80	80	75	100	130	10	79
Anthony sandy loam								10	75
Laveen loamy sand								10	65
Imperial silty clay, silted phase (alkali-affected areas)							100	25	55
Land silty clay loam							50	10	50
Imperial silty clay							50	10	50
Land silty clay							50	10	50
Gila fine sand, silted phase							50	20	42
Gila fine sand							50	15	40
Anthony gravelly sandy loam								10	35
Anthony gravelly sandy loam, gray phase								10	35
Anthony stony sandy loam								10	30
Riverwash								20	20
Cave gravelly loam								10	10
Laveen loamy sand, steep broken phase								5	5
Cave gravelly loam, steep broken phase								5	5
Rough broken land								5	5

* Little or none of these soils is cultivated. Their potential productivity is estimated.

The chief factors influencing productivity are temperature, moisture supply, soil, and lay of the land. As crop yields over a long period furnish the best available summation of the factors contributing to soil productivity, they have been used largely as the basis for the determination of the productivity indexes in table 3. Some of the soils in the area are not irrigated but possibly may be irrigated later. Their potential productivity is estimated on the basis of the physical and chemical properties of the soil. Others, because of steepness or roughness, have little value even for grazing.

The rating compares the productivity of each of the soil types and phases in the area for each given crop to a standard—100. This standard, or base index, represents the productivity of the soil type or types in the United States inherently most productive for that crop—that is, most productive without the use of amendments, such as lime, commercial fertilizer, drainage, and irrigation, but under a system of management capable of maintaining the inherent level of productivity. Some unusually productive soils of small acreage will have an index above 100. In this area some of the more productive soils when irrigated have an index as high as 200 for cotton. This means that, under irrigation, they produce twice as much

cotton on an acre as do the best soils of important extent in the Cotton Belt of the South, without irrigation or fertilization.

As the soils of this area seldom, if ever, are given soil amendments, such as commercial fertilizers, no rating has been given to indicate their response to fertilization. The use of manure produced on the land and the growing of legumes, such as alfalfa, are not considered amendments. Irrigation is necessary for crop production, therefore the index numbers in the table refer to the productivity of the soils if and when irrigated. A single exception to this is in the instance of unirrigated pasture or range. Productivity of many of the soils is being increased by the deposition of silt from irrigation water and by the gradual leaching of salts from the soil. Therefore, this table should be considered as giving the relative productivity of the soils at the time the survey was made (1933). Many of the irrigated soils will become more productive as the silting becomes deeper. Poorly drained or salty areas may also become more productive if provided with drainage, followed by irrigation.

The soils are listed in the order of their general productivity in the area, but no attempt has been made to place the soils in groups or classes on the basis of productivity. In determining the general productivity rating, weight is given to each crop according to its relative acreage, much more weight being given to cotton and alfalfa than to the other crops listed.

This rating of soils is not to be interpreted directly into specific land values. It stresses the productivity of the land, which is relatively permanent as compared to transitory economic conditions. In some instances the information on which to base the ratings is not so complete as desired; in these further study may suggest changes.

The following tabulation gives some of the acre yields which have been set up as standards of 100. When applied to the inherently most productive soil types of significant acreage, they represent long-time production averages without the use of soil amendments to alter the inherent productivity of the soil type for a product of satisfactory quality.

Crop:

Cotton	-----pounds--	400
Alfalfa hay	-----do-----	9,000
Barley	-----bushels--	40
Wheat	-----do-----	25
Corn	-----do-----	50
Grain sorghums	-----do-----	40
Pasture	-----cow-acre-days ^a per year--	100

^aThe term "cow-acre-days" is used to express the carrying capacity or grazing value of pasture or range lands. It is the numerical equivalent of the number of cows supported on an acre of pasture for a given number of days.

MORPHOLOGY AND GENESIS OF SOILS

The upper Gila Valley area lies in southern Arizona in the hot, dry semidesert region of the southwest. It is in the soil region which Marbut⁴ has designated as the province of the southern Gray Desert soils. According to Kellogg⁵ the soils of the region are Desert soils

⁴MARBUT, C. F. SOILS OF THE UNITED STATES. U. S. Dept. Agr. Atlas of American Agriculture, pt. 3, Advance Sheets no. 8, 98 pp., illus. 1935.

⁵KELOGG, C. E. DEVELOPMENT AND SIGNIFICANCE OF THE GREAT SOIL GROUPS OF THE UNITED STATES. U. S. Dept. Agr. Misc. Pub. 229, 40 pp., illus. 1936.

and their reddish-brown color is due to slight laterization. The prevailing color is not gray but reddish brown or pale red.

The five principal factors working together to induce soil development are climate, vegetation, relief, parent material, and age. Moisture and vegetation, which are very active factors in more humid climates, are relatively unimportant here, whereas the nature of the parent material and the length of time it has been in place are very important in determining the characteristics of the soils of this region. Relief, or physiographic position, is of importance here largely in determining the length of time the soil materials have been subjected to soil development and the thoroughness of the drainage in different localities.

The annual rainfall of the upper Gila Valley area is low, averaging about 8.85 inches, and most of it falls during the hot summer in the form of torrential rains. Run-off is rapid, and the rate of evaporation is high. For these reasons, penetration of moisture is not to a great depth, moisture supply for plants is limited, and neither moisture nor vegetation has had great effect on soil development. Carbonates of lime and magnesium have been partly leached from the upper part of the soil and deposited at slight depths. Sodium salts have been removed largely from the solum in the more mature soils but are plentiful in some of the alluvial soils, especially where drainage is restricted. The sparse vegetal cover of desert shrubs has added little organic matter to the soil, and much of this has been removed by oxidation.

Most of the soils are very young, have been very little altered by the forces of soil development, and have the characteristics of their parent materials. Even the older soils owe many of their properties to these materials which are unconsolidated transported materials, mostly of rather coarse texture, laid down during the physiographic development of the valley. Granitic materials are dominant in all the older soils lying south and west of Gila River and west of San Simon Creek, and only on some of the recent alluvial soils is there a modifying admixture of materials derived from old lake sediments and other sources. In the higher parts of the extreme eastern and northeastern parts of the area, the materials are derived mainly from basalt, andesite, dark rhyolite, and related rocks. The immediate flood plains of Gila River and San Simon Creek contain an admixture of materials brought in partly from watersheds far removed from this area. Many of the more recent alluvial deposits contain much organic matter washed down from grassy areas at the higher altitudes.

Time has been an important factor in the development of the soils of the area, and the age of the soils is correlated with their physiographic position. The materials on high-lying terraces and mesas have been subjected to soil development much longer than the soils of the lower terraces and valley floor and are more mature. The soils of the lower alluvial fans and flood plains are young and little modified. Natural erosion and deposition are active and influence or modify the age or maturity of the soils.

The soils may be grouped on the basis of their age and the degree of lime carbonate accumulation in the subsoil. The oldest or most mature soils—the Cave and Laveen—have high concentrations of

lime carbonate in their subsoils; the soils of intermediate age or stage of development and of slight or moderate lime accumulation are the Mohave and Anthony; and the youngest soils, including the Gila, Pima, Land, Imperial, and Cajon, have little or no accumulation of lime in the subsoils.

The color of the more mature soils is reddish brown, probably because much of the iron in the decomposition products is in the form of the unhydrated higher oxide. These soils have a concentration of red colloidal material in the upper part of the subsoil, sometimes called the claypan, which, according to Nikiforoff,⁶ is "a result of hydrolytic decomposition of certain minerals, mainly feldspars and hornblende, in situ; their kaolinization; and the subsequent dehydration of the products of decomposition during the hot and dry periods." It is probable that there has been some mechanical downward movement of finer materials from the comparatively coarse porous surface horizon into this denser layer.

These older soils also have a very high concentration of lime carbonate in the subsoil below the red clayey horizon. In many places this forms a very hard layer commonly called "hardpan," or "caliche." Some authors refer to it as the "desert crust," but this term seems inapt, as the layer lies below the surface in most places. This layer may have been developed in different ways in different places. There is little doubt that there has been a leaching of the upper part of the solum and a precipitation or deposition of the lime at or near the depth of average penetration of moisture. The upper few inches of soil are in places free from carbonates, the concentration of which gradually increases with depth, until, in extreme instances, they constitute nearly 100 percent of the soil mass.⁷ It is probable that these more extreme concentrations are due to the bringing in of lime in solution in ground water and its deposition as a distinct layer of hardpan, caliche, or desert crust.

The most mature soils having a highly developed accumulation of lime occupy the margins of the high terraces or mesas bordering the valley floor. They have been more or less subject to erosion and, possibly, have been subject to a high ground-water level at some period in their development. They are, therefore, not necessarily expressive of the normal mature development of soils that lie in more stable positions back from the terrace fronts.

In the Cave soils, accumulation of lime is developed to the stage of an indurated conglomeratelike lime carbonate hardpan. In the Laveen soils, the subsoil is moderately compact or softly cemented but contains many hard-cemented lime carbonate nodules, and in some places these are scattered through the surface soil. The upper part of the profile of the Cave soils, as developed in this survey, is leached of calcium carbonate to the extent that it cannot be detected with dilute hydrochloric acid, and the color is decidedly red. The Laveen soils are gray with a slight pink tinge and contain a large quantity of lime carbonate throughout the profile.

In the older survey, the Cave soils, as well as most other soils of the area, were correlated in the Maricopa series which represented a

⁶ NIKIFOROFF, C. C. GENERAL TRENDS OF THE DESERT TYPE OF SOIL FORMATION. *Soil Sci.* 43: 105-131, illus. 1937.

⁷ BREAZEALE, J. F., and SMITH, H. V. CALICHE IN ARIZONA. *Ariz. Agr. Expt. Sta. Bull.* 131, pp. 417-441, illus. 1930.

rather loose grouping based mainly on broad topographic and geological relationships. Under the later, more scientific classification of soils based on the character of the soil profile, they are now recognized as representing a number of different soil series, some of which are not at all closely related on the basis of pedological development.

In typical development the Cave soil, as represented by Cave gravelly loam, has a 2- or 3-inch surface horizon of reddish-brown gravelly loam, overlying which is a thin bleached crust accompanied by a gravelly desert pavement. The material of this horizon is leached, and the reaction to acid is neutral. Between depths of 3 and 10 inches, the material is more pronounced reddish-brown gravelly loam or clay loam, which breaks up in crumbly clod structure. The reaction is neutral or alkaline. To a depth of about 18 inches the material is similar but is noticeably redder and more compact. There is no effervescence with dilute hydrochloric acid. Between 18 and 24 inches, an accumulation of lime carbonate is discernible in a thinly veined or netted pattern throughout material similar to that above but more gritty and compact and slightly cemented at the bottom. This material rests abruptly on a very highly cemented lime carbonate conglomeratelike hardpan with embedded gravel and stone. This continues to various depths, but in deeper exposures it is seen gradually to become less firmly cemented and has the appearance of lime infiltration into open, porous, extremely stony and gravelly strata.

It is apparent that the leaching process has reduced the lime content in the surface horizon and the upper part of the subsoil, and that a translocation of lime has taken place to the lower part of the subsoil. It seems probable, also, that lime carbonate has been brought into the subsoil by ground water percolating from higher land.

The Laveen soils differ from the Cave in a less advanced stage of development, and they generally occupy younger and lower lying fans or terraces. These soils, too, may have been subjected in some places to a high water table and lime-charged water during development, but to less degree or a shorter time than were the Cave soils. It is probable that the dominant modifying and retarding influence in soil development in the Laveen soils was their original high lime content. This may have been derived from the parent material, which in many places seems to represent a remnant of the subsoil of an old eroded soil, or the lime may have been brought in, in part, by ground water.

In the typical Laveen soil the higher lime concentration is below a depth of 18 inches. The material above is light grayish-brown or pinkish-gray, is highly calcareous, and is sprinkled with lime carbonate nodules. The horizon of lime concentration lies between depths of 18 and 40 inches, and it has appreciable compaction, soft cementation, and a large content of hard lime nodules. Its texture is appreciably heavier, indicating either a translocation of clay to this horizon or hydrolysis of the soil material in place. Below this the subsoil is looser and more porous, but it is marked by lime infiltration in the upper part.

The Mohave and Anthony soils, both included with the Maricopa soils of the earlier survey, are now known to be like the extensive

areas of Mohave and Anthony soils in southern Arizona, New Mexico, and California, since recognized under these series names. These soils occupy lower terraces and alluvial fans in the main valley depression. They are intermediate in age between the higher terrace soils and the lower, younger alluvial soils. Both are reddish-brown soils, but the Mohave is redder than the Anthony. They both show appreciable development of a profile, although they are calcareous throughout and have rather distinct horizons, especially the Mohave. Translocation of lime carbonate has taken place, and the subsoils are heavier and more compact than the surface soils.

The profile of Mohave sandy loam is as follows: The topmost 6 inches of material consists of calcareous reddish-brown sandy loam sprinkled with gravel. In most places there is a thin bleached vesicular crust at the immediate surface. Between depths of 6 and 18 inches the material is redder loam which is more compact and cloddy, with faint specks of lime at the bottom of the layer. Between depths of 18 and 36 inches lies the horizon of maximum concentration of lime and clay. This consists of rich reddish-brown gritty clay loam definitely veined, mottled, or seamed with white lime carbonate. This material breaks as harsh brittle clods. Below this, the material in the profile is rather loose and incoherent stratified reddish-brown sandy loam, in which the gravel are coated with lime, and in places infiltration of lime is evident.

This profile seems to represent the natural trend of profile development in this area. It has been unmodified by excessive lime in the parent material, by the influence of lime-charged waters, or by a high water table. It is more highly developed than the Anthony soils. A more mature soil of this type would probably have the horizons more definitely developed. An approach to this stage is found here and there at higher elevations in older materials. This soil is not leached to the extent that the Cave soils are, and it still shows effervescence with hydrochloric acid. There is, however, evidence of definite accumulation of clay and lime in the subsoil.

The Anthony soils are less mature than the Mohave, and the soil-developing processes have made less impression on the soil materials. The Anthony soils differ from the Mohave in that they generally are of decidedly duller or less pronounced reddish-brown color and in places are decidedly grayish brown. The leaching process has translocated lime to the subsoil to less degree, there has been less accumulation or development of clay in the subsoil, and the upper horizon is higher in lime and not so red as in the Mohave soil. There is little appreciable compaction or accumulation of clay in the Anthony, and this material is veined or grained with lime at slighter depths.

The third group—the unmodified soils—are young alluvial soils occupying recent alluvial stream bottoms and alluvial fans in the main valley depression. Their characteristics are largely dominated by the original geologic material and its manner of deposition and stratification. Differences in character of parent materials, textural profile, color, and, to less extent, organic matter and salt content are the bases of differentiation of the various series within the group.

The Cajon, Imperial, and Land soils, also included with the Maricopa in the earlier survey, differ widely in profile and stage of development from the Cave and Mohave and less widely from the Anthony soils. They all are correlated with areas of these soils mapped in surveys made during the intervening period, in which the more restricted and definite series relationships have become apparent and established.

The Cajon soils occupy the higher positions, and the soil materials are wholly granitic in origin. Angular granitic particles and mica are abundant. Their color is dull grayish brown, and in most places a slight yellow tint is discernible in the fresh material. These soils are somewhat darker than the typical Cajon soils of previous surveys. They are definitely calcareous throughout the profile. In places the subsoil is very slightly grayer and of slightly higher lime content. The material throughout the profile is mellow, friable, and rather uniformly segregated.

The Imperial and Land soils are heavy-textured compact soils derived from transported materials eroded from silty old lake clays and deposited in basins and flood plains where the flow from streams and surface water has been partly arrested. Consequently they are high in salts and have developed profiles having a Solonchak structure, in which a surface crust and mulch are very pronounced. They still retain large quantities of salts, except where reclaimed. They are dull brown or light reddish brown—in most places a little redder in the lower part of the subsoil. Accumulated salts are generally evident as specks or seams in the subsoil. In the Imperial soil, heavy tough refractory clay continues throughout the profile (pl. 1). The Land soils are thickly stratified with clay and lighter textured materials.

The Gila and Pima soils are along or near the Gila River and consist of recently deposited materials brought in by flood waters. They are darker colored than any other soil, due to a higher content of organic matter which has been brought in largely as finely divided and colloidal suspended matter in the river waters. This type of material is still being transported into the valley through irrigation, and it gives rise to the extensive silted soils. The Pima soils have the higher organic-matter content and, therefore, are the darker soils, generally dark grayish brown, whereas the Gila are lighter brown, of a slightly redder cast. The soils of both series are fine textured and thickly stratified, the Pima having the thicker and heavier textured stratification. Even though the Pima soils are heavy textured, the materials throughout are friable and mellow, due to their organic and calcareous nature, which gives rise to excellent aggregation or granulation.

In the survey of 1903, the looser sandy soils now recognized as Gila, were recognized under the name of Pecos sand, and the darker heavier textured soils, now recognized as Pima, were included with the Gila soils. The conflicts in classification of these more recently accumulated alluvial soils of the Gila, and more especially of the Pima, series, are, however, not entirely the result of the later more detailed mapping and more extensive and intensive study, but are in part the direct result of actual changes in soil character, due to

deposition of sediments from turbid irrigation waters and stream-borne alluvial materials of later date.

SUMMARY

The area covered by the soil survey of the upper Gila Valley area includes most of the irrigated agricultural lands in Graham County, Ariz. It is in the arid Southwest where summer temperatures are high and the annual rainfall low. As a result of the low precipitation, farming is dependent on irrigation. Cotton is the dominant crop. The more diversified type of farming consists of the growing of alfalfa and of grains including wheat, barley, corn, and hegari.

The main agricultural part of the surveyed area lies in a section of recent alluvial stream-valley and alluvial-fan soils along Gila River which traverses a deeply entrenched drainage trough bordered by old terraces and alluvial fans sloping upward to mountain ranges paralleling the valley. The elevation of the area ranges from 2,600 to 3,000 feet above sea level.

The physiographic development of the valley is correlated with stages in soil development. The oldest soils occur on high terraces, soils of intermediate age on secondary terraces and alluvial fans, and the youngest alluvial soils along the river. The stage of development of soils in this area is identified with the accumulation or concentration of lime in the subsoil, which is spoken of as calcification. This is of interest mainly from a technical point of view, but, since it is also accompanied by the accumulation of clay and both clay and lime are important from the point of view of plant nutrition, permeability, and moisture-retaining capacity of the soil, this age, or stage, in soil development is also significant in the agriculture.

In this area, the soils are artificially silted. The silt and other fine mineral and organic materials have been brought in by the turbid irrigation waters and deposited on the soil. Thus a new topsoil is created, and the depth of silting and the yearly accumulation of silt greatly influence its fertility. The silt is high in mineral and organic fertility, and it gives rise to topsoils which are heavy textured but have a granular structure comparable to that of soils developed under a grass cover, such as the Prairie soils and the Chernozem soils of the Great Plains.

Because of the general silting of the agricultural soils and its fertilizing value, all the soils tend to become alike in soil characteristics and productivity, although the character of the subsoil influences the permeability and water-holding capacity of the soil and is an important factor in crop production. On the basis of differences in subsoil characteristics, involving accumulation of lime and clay and the retention of moisture, the soils are placed in three groups: (1) Soils without definite accumulation of lime in the subsoils, (2) soils having moderate accumulation of lime in the subsoils, and (3) soils of high lime accumulation.

The soils of the first group are the Gila, Pima, Cajon, Imperial, and Land soils. In these young soils the lime carbonate developed under arid conditions has not yet been leached from the surface soil and accumulated in the subsoil, but it is rather uniformly distributed

or disseminated through the soil mass or profile. These are the most extensive and important agricultural soils in the area. They are readily reached by diversion of gravity water and are of very favorable relief for irrigation. The subsoils are mostly of rather fine texture, are more or less friable, and are absorptive and retentive of moisture. Therefore, when silted, these are very productive soils. The Gila, Pima, and Cajon soils have friable and mellow subsoils, whereas the subsoils of the Imperial and Land soils are heavier and less permeable. Associated with this heaviness is a high salt content, and in many places these soils must be reclaimed before they are productive.

The second group includes the Anthony and Mohave soils. The Anthony soils are extensive and agriculturally important. The lower subsoil layers of these soils are coarser and more porous than the corresponding layers in soils of the first group, and in general they have poorer water-retaining properties. The range in subsoil texture is, however, wide, and many of the Anthony soils are similar to soils of the first group. An accumulation of clay in the subsoils, especially in the Mohave soils, modifies and improves the retention of water in places where the materials are more porous.

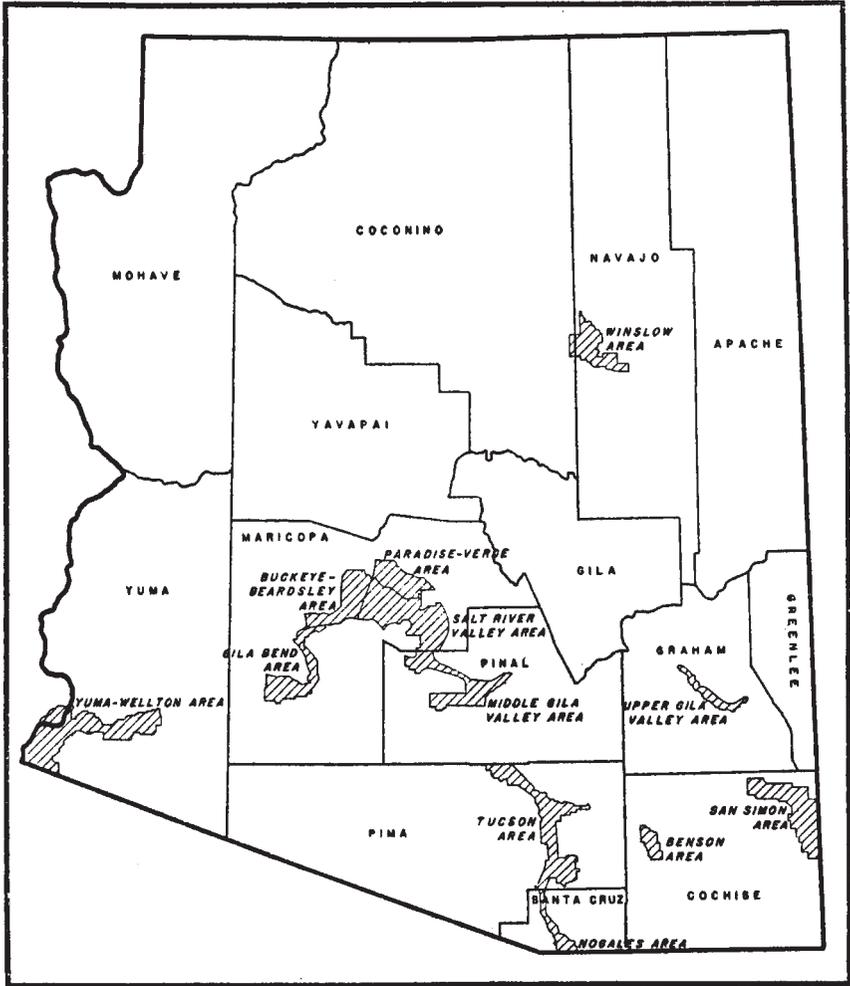
The soils of the third group are the Laveen and Cave soils. The Laveen soils are of little agricultural importance, and the Cave soils have none, as they lie above the water supply for irrigation. Even if it were possible to irrigate the Cave soils their productivity would be low, because of the indurated hardpan which lies at a slight depth. Though of high lime accumulation the subsoils of the Laveen soils are not firmly cemented, and when silted these soils are fairly productive.

The widespread fertility caused by silting and the predominance of permeable soils of high water-holding capacity amply support the dominant crop—cotton—under the conditions of irrigation and high evaporation. Yields of cotton are high and readily compensate the additional cost of irrigation, and this crop is very profitable in normal seasons. Alfalfa, wheat, barley, corn, and hegari are important crops. Wheat and barley are used with corn and hegari in double cropping of the soils. These crops are necessary for feed on the farms and are grown on soils not chosen for cotton in the rotation, on less fertile soils, or on those undergoing reclamation from alkali. Fruits and vegetables are grown to a small extent for home consumption. The fertility of the land is maintained sufficiently high, by the silting process, for double cropping, and the moisture is supplied by irrigation.

Hay and grain crops are grown in connection with the feeding and fattening of cattle, dairying, and poultry raising. Much of the livestock produced is consumed within the area.

Authority for printing soil survey reports in this form is carried in the Appropriation Act for the Department of Agriculture for the fiscal year ending June 30, 1933 (47 U. S. Stat., p. 612), as follows:

There shall be printed, as soon as the manuscript can be prepared with the necessary maps and illustrations to accompany it, a report on each soil area surveyed by the Bureau of Chemistry and Soils, Department of Agriculture, in the form of advance sheets bound in paper covers, of which not more than two hundred and fifty copies shall be for the use of each Senator from the State and not more than one thousand copies for the use of each Representative for the congressional district or districts in which a survey is made, the actual number to be determined on inquiry by the Secretary of Agriculture made to the aforesaid Senators and Representatives, and as many copies for the use of the Department of Agriculture as in the judgment of the Secretary of Agriculture are deemed necessary.



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