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Soil Survey

The Casa Grande Area Arizona

By
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ROBERT WILDERMUTH, and W. G. HARPER
United States Department of Agriculture

UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF PLANT INDUSTRY
In cooperation with the
University of Arizona Agricultural Experiment Station

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SOIL SURVEY OF THE CASA GRANDE AREA, ARIZONA

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

AREA SURVEYED

The Casa Grande area is in Pinal County in south-central Arizona (fig. 1). It has a total area of 864 square miles, or 552,960 acres, and comprises most of the agricultural and potentially arable lands in those parts of the valleys of the Santa Cruz and Gila Rivers that lie within Pinal County and are not included in Indian reservations. Casa Grande, in the northwestern part of the area, is 60 miles from Phoenix and 135 miles from the Mexican border.

The area joins the Tucson area (*15*)[2] previously surveyed on the southeast and includes the area covered by an earlier soil survey of the middle Gila Valley (*4*).

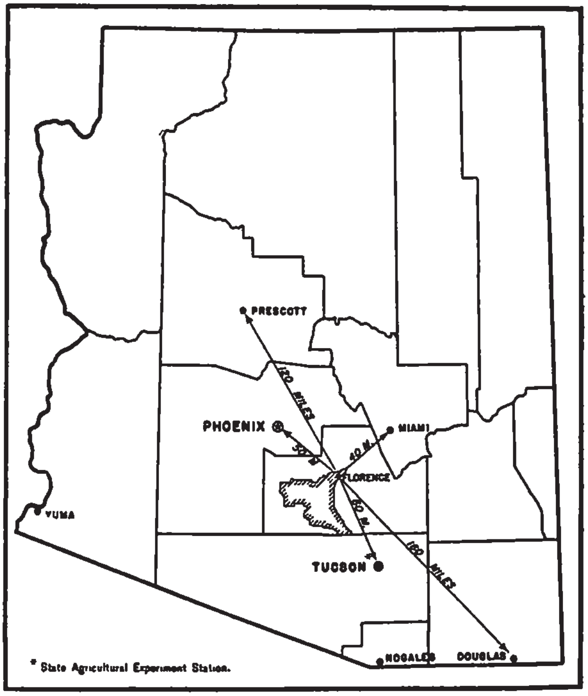


FIGURE 1.—Sketch map showing location of the Casa Grande area, Ariz.

This part of Arizona lies in the Sonoran Desert section of the Basin and Range physiographic province south of the high Colorado Plateaus. Physiographically, it consists of northward and southward trending ranges of mountains with intervening broad basins or valleys. With the exception of the Casa Grande Mountains and the isolated Picacho Peak, none of these ranges lies entirely within the area surveyed. In general, the area skirts only the edges or spurs of the ranges, and the elevation nowhere exceeds 3,000 feet above sea level. All the valleys lie less than 2,000 feet above sea level and descend to about 1,200 feet at the northwestern boundary of the area.

Floodwaters of the Santa Cruz River cross the area in a northwesterly direction and join the Gila River through numerous shallow ill-defined channels and elongated playalike depressions, and these two streams have largely determined the relief. The Gila River has cut into the old valley fill and is confined to a stream flood plain skirted by eroded terraces that do not rise very abruptly from the flood plain. The irregular channel is choked with sand and gravel

[2] Italic numbers in parentheses refer to Literature Cited, p. 94.

and carries water only during flood periods. At such times the lower cultivated land of the flood plain may be inundated and silted.

The Gila River has cut a definite channel, but the chief activity of the Santa Cruz River is deposition of materials during floods. Though water does not remain long on the surface of the land after floods, the soil materials are charged to various degrees with salts left by the evaporating water. Evidence of past high ground-water levels is apparent from the extensive and successive underground strata of caliche; but at present the water table is nearly everywhere more than 25 feet below the surface, and it is 150 feet or more below the surface in the higher parts of the valleys. It seems probable that the water table has been lowered by the cutting of the channel of the Gila River. Many of the intermittent streams, or desert washes, do not reach the main streams but spread out in sheets, sorting and depositing the materials—the coarser ones first and the finer ones later on lower ground.

Casa Grande, in the Santa Cruz Valley, is at an elevation of 1,396 feet above sea level. The broad valley ranges from about 1,200 feet in the northwestern part of the area to about 1,900 feet. Florence, the county seat, on the Gila River, lies at an elevation of 1,493 feet.

As much of this area is still in a virgin desert condition, most of the native vegetation persists, although some changes doubtless have taken place, owing to overgrazing since the arrival of the white man. In general the native cover (pl. 1) consists of shrubs, small trees, cacti, annual grasses, and annual herbs (*3*, *13*). This vegetation is in marked contrast to the sagebrush vegetation of the northern desert areas.

The trees grow mainly along the stream courses. The more important trees are mesquite (*Prosopis velutina*), paloverde (*Cercidium microphyllum*), catclaw (*Acacia greggii*), ironwood (*Olneya tesota*), and cottonwood (*Populus fremontii*).

Of the shrubs, creosotebush (*Covillea tridentata*) is the dominant vegetation on the higher mesas (pl. 2, *A*), and desert sage (*Atriplex polycarpa*) and saltbushes (*Atriplex* sp.) prevail in the flat lowland basins. Associated with creosotebush in many places are bur-sage (*Franseria deltoidea* and *F. dumosa*), burroweed (*Aplopappus hartwegi*), cholla cacti (*Opuntia* sp.), giant cactus or saguaro (*Carnegiea gigantea*), Arizona water cactus, or barrel cactus (*Echinocactus wislizeni*), and ocotillo (*Fouquieria splendens*). A creosotebush and galleta grass (*Hilaria rigida*) association occurs in the sand dune area of the Santa Cruz River flood plain. In the desert sage area, there are also fourwing saltbush, or chamiso (*Atriplex canescens*), greasewood (*Sarcobatus vermiculatus*), seepweed (*Dondia moquini*), Fremont wolfberry, or squawbush (*Lycium fremontii*), squawbush (*L. berlandieri* f. *parviflorum*), broom baccharis (*Baccharis sarothroides*) locally known as desert broom, seepwillow (*B. glutinosa*) locally known as water motie, and arrowweed (*Pluchea sericea*).

Most of the annual herbs and grasses are short lived, growing only during or immediately after the rainy periods of winter and late summer. They are widely distributed over most of the area and are the important grazing plants. The more important winter annuals are alfileria (*Erodium cicutarium*), desert Indianwheat (*Plantago* *fastigiata*), Indianwheat (*P. ignota*), milkvetch (*Astragalus nuttallianus*), borage (*Pectocarya linearis* and *P. penicillata*), *Ansinckia tesselata* and *A. intermedia*, slender fescue (*Festuca octoflora* var. *hirtella*). Of the summer annuals, most of which are grasses, six-weeks grama (*Bouteloua barbata*) and needle grama (*B. aristidoides*) are important.

Prehistoric canals and ruins of pueblos are evidences of occupation of the valley by an ancient people whose subsistence came mainly from irrigated crops. The Indians were carrying on a crude type of irrigation agriculture when the Spaniards made their first appearance in this section. With the arrival of Father Kino in the latter part of the sixteenth century began the first attempts by white men to make permanent settlements, in the form of ranches, along routes to California and interior parts of the unexplored country. The period of Spanish and Mexican rule was uncertain and was endangered by warlike activities of hostile Indians, chiefly Apaches. Permanent settlement was retarded even after American control until subjugation of these Indians by military force.

The town of Florence was founded between 1865 and 1870. The white settlers began to irrigate their land about this time. The activities of the Florence Canal Co., beginning in 1886, aided permanent settlement and agricultural activity, but the main impetus came after the completion, in 1929, of the Coolidge Dam by the United States Department of the Interior, for irrigation of Indian lands.

Pinal County was organized in 1875, but its present boundaries were not established until 1881. In 1930 the population was 22,081, all classed as rural, with a density of 4.1 persons a square mile. Native whites, many of whom came from the Midwest and South, constitute 43.3 percent of the population; Mexicans constitute 37 percent; Indians, 15.5 percent; and foreign-born whites, Negroes, and people of other races, the rest. The laborers are chiefly Mexicans and Negroes. The Indians live principally on the reservations adjacent to the area.

Florence, the county seat, with a population of 1,318 in 1930, lies within the area. Casa Grande and Coolidge are important trading and shipping centers. The former has a population of 1,351, according to the Federal census for 1930, and the latter, which was not reported by that census, now has almost as many inhabitants. These towns have good transportation facilities both by railroad and highway. Main and branch railroads of the Southern Pacific Co. contact these points. The main highways are paved, and a few of the connecting roads are surfaced with gravel. The principal roads in the agricultural sections are graded, but much of the area is accessible only by trails.

Graded schools and high schools are maintained at Florence, Coolidge, and Casa Grande. School busses serve the country surrounding these towns, but a few outlying districts still maintain schools. Churches and assembly halls are in the towns and community centers.

Electric power and telephone service are available throughout the greater part of the area. Midwestern and Pacific coast markets absorb most of the exportable produce.

CLIMATE

The climate is characterized by long hot summers and short mild winters. The precipitation and humidity are low. The general absence of moisture, smoke, or clouds accounts for the high percentage of sunshine and wide range of temperature.

The rainfall occurs mostly in winter and late summer, and the amount fluctuates considerably from year to year. Dry years are hazardous to range forage and to storage of irrigation water. The rainfall varies somewhat from place to place owing to the surrounding mountain ranges and differences in elevation (*11*). These factors also are responsible for the slight general increase in rainfall eastward.

The mean annual precipitation at Casa Grande is 8.30 inches, at Florence 9.88 inches, and at Redrock 9.61 inches, according to the records of the United States Weather Bureau.

The mean annual temperature, on the other hand, decreases eastward. At Casa Grande this is 71.1° F., at Florence 69.1°, and at Redrock 70.6°. The growing season is long throughout the area. Occasionally it is shortened by frosts in late spring or early fall. At Casa Grande the average frost-free season extends from March 6 to November 18, a period of 257 days, but frosts have been recorded as late as April 10 and as early as October 8. Because of better air drainage on the mountain fan slopes and mesas, such places generally are more frost-free than the lower valley lands. An example of this condition is at Redrock where the mean annual temperature is lower yet the growing season seems to average about a month longer than at Casa Grande. Hardy crops survive the mild winters of this area, and a year-round succession of crops is possible. Citrus fruits are grown successfully in some of the more frost-free localities.

Wind movement generally is low. It is somewhat intensfied during spring when occasional windstorms occur.

Table 1 gives the normal monthly, seasonal, and annual temperature and precipitation at Casa Grande, as reported by the United States Weather Bureau.

TABLE 1.—*Normal monthly, seasonal, and annual temperature and precipitation at Casa Grande, Pinal County, Ariz.*

[Elevation, 1,400 feet]

Month	Temperature			Precipitation		
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year (1885)	Total amount for the wettest year (1905)
	° *F.*	° *F.*	° *F.*	*Inches*	*Inches*	*Inches*
December	52 3	91	13	0.98	0.00	0.80
January	50 7	87	19	.75	.00	2 76
February	55.2	95	19	.89	30	4.99
Winter	52.7	95	13	2.62	30	8.55

TABLE 1.—*Normal monthly, seasonal, and annual temperature and precipitation at Casa Grande, Pinal County, Ariz.*—Continued

[Elevation, 1,400 feet]

Month	Temperature			Precipitation		
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year (1885)	Total amount for the wettest year (1905)
March	61 4	99	26	.78	.10	1.98
April	69.0	110	28	.30	.00	1.27
May	77.5	120	40	.08	.00	.00
Spring	69.3	120	26	1.16	.10	3.25
June	87.5	119	40	.21	.00	.42
July	91.5	122	60	1.24	.75	.36
August	90.1	120	57	1.31	.64	.02
Summer	89.7	122	40	2.76	1.39	.80
September	84.6	114	40	.73	.00	.60
October	72.2	106	25	.24	.00	.00
November	60.6	93	24	.79	.23	6.32
Fall	72.5	114	24	1.76	.23	6.92
Year	71.1	122	13	8.30	2.02	19.52

AGRICULTURAL HISTORY AND STATISTICS

The agriculture of the Indians, preceding the white man's settlement of this section, consisted of a crude type of farming by means of irrigation to provide subsistence crops, such as corn, beans, squashes, melons, and millet. Other crops, principally small grains, were introduced when the country was under Spanish and Mexican rule.

The American settlers adopted many of the agricultural methods that had already become established and continued to produce similar subsistence crops. With more permanent settlement, additional hay, vegetable, and fruit crops were introduced and the ranges were stocked with cattle and sheep.

The pioneer type of agriculture expanded into the desert sections when canals were constructed following 1886, and wells were drilled on homesteads in the desert, especially after 1910. The available supply of irrigation water, however, was overestimated, and it fluctuated widely with variations in the annual seasonal rainfall. Water rights to the Gila River were in controversy, also. Owing to these hazards much land was abandoned.

The present agricultural development dates from the completion of the Coolidge Dam in 1929 by the Government and the control and delivery of the storage waters by the Office of Indian Affairs. Data from the United States census for Pinal County and for the local San Carlos project administered by the Office of Indian Affairs are not strictly applicable to the area surveyed, but they indicate the trend of agricultural expansion.

Data from the United States census are given in tables 2 and 3.

TABLE 2.—*Acreages of important crops in Pinal County, Ariz., in stated years*

Crop	1879	1889	1899	1909	1919	1929	1934
	Acres	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
All hay	880	2,734	4,572	4,113	11,031	[1] 6,600	[1] 13,843
Alfalfa			2,412	776	6,469	2,902	10,918
Grains cut green			1,568	2,721	4,144	1,365	1,078
Cotton					2,420	17,718	22,712
Grain sorghums					1,293	1,065	1,387
Wheat	2,302	457	1,284	4,762	6,223	2,163	6,690
Barley	2,311	1,897	1,556	2,552	2,425	838	3,584
Corn	176	275	346	1,275	526	450	624
Market vegetables					321	1,907	2,726

[1] Includes sorghums for forage and silage.

TABLE 3.—*Numbers of livestock on farms in Pinal County, Ariz., in stated years*

Livestock	1920	1930	1935	Livestock	1920	1930	1935
All cattle	46,000	22,037	43,137	Sheep	11,321	9,097	14,251
Dairy	1,333			Goats	3,885	17,685	15,414
Beef	44,667			Hogs	5,948	1,817	2,388
Horses	3,412	4,507	5,246	Chickens	13,902	23,481	34,939
Mules	418	795	1,060				

By 1919 both cotton and grain sorghums had been introduced and become important crops. The high prices obtaining during the World War stimulated the production of cotton. The noteworthy increase in acreage of all crops after 1929 is due to the increased and stabilized water supply and the extension of irrigation after the completion of the Coolidge Dam. Truck crops also became important at this time. The numbers of livestock show an increase in 1935 after an appreciable decrease in 1930.

In 1935, according to the Office of Indian Affairs at Coolidge, crops grown on 62,000 acres under the gravity irrigation sytem had a total value of $1,750,000. This acreage was devoted to the following crops: Cotton, 19,200 acres; alfalfa hay, 16,700 acres; small grains, 9,600 acres; and other crops, including maize, hegari, fruits, and garden produce, the remainder. Of the land within the gravity irrigation project, only 37,000 acres are included in this area, the remainder is included in the Gila River Indian Reservation. Data for crops grown on the 22,000 acres irrigated by wells are not available.

The acreages and acre yields of crops on the entire gravity project are given in table 4.

TABLE 4.—*Acreage and acre yields of crops in the San Carlos project, Ariz., in 1935*

Crop	Acres	Average yield per acre	Crop	Acres	Average yield per acre
		Pounds			*Tons*
Short-staple cotton	14,519	426	Alfalfa (hay)	8,316	3 26
Long-staple cotton	4,681	267	Alfalfa (pasture)	8,069	
Maize (grain sorghum)	901	1,941	Pasture (grain)	736	
Hegari (grain sorghum)	1,046	1,668	Garden crops	123	
		Bushels	Deciduous fruits	81	
Barley	1,358	26.3	Citrus fruits	73	
Wheat	1,341	22 8			
Corn	224	17.9			

There were 1,522 horses, 465 mules, 5,523 cattle, 775 hogs, 4,757 sheep, 22,144 fowls, and 406 hives of bees on farms within the project in 1935.

Little commercial fertilizer is used. Only 8 of the 1,008 farms in Pinal County reported the purchase of fertilizer at a total cost of $1,518 in 1929, or $189.75 per farm reporting.

In most years Mexican and Negro laborers are sufficient for farm demands. At the peak of the cotton-picking season transient labor from the Southern States is hired. In 1929 a total expenditure of $562,675 for labor was reported by 227 farms in Pinal County, or $2,478.74 per farm.

According to the 1935 census, the average size of farms in Pinal County is 631.9 acres, of which only 10.1 percent is improved. In 1920 the average size of the 293 farms was 521 acres, of which 27.5 percent was improved. The number and size of farms is increasing and the average acreage of improved land per farm is decreasing, although the total improved acreage is larger. These changes mark the expansion of agriculture from the Gila River bottoms to the desert plains where holdings are larger but the improved acreage per farm is smaller.

The size of farms under the gravity irrigation project ranges from 80 to 160 acres. The present tendency is toward larger farm units, owing to the increased use of power machinery and an increased and more stable water supply.

The 1935 census reports 74.7 percent of the farms in Pinal County operated by owners, 22.1 percent by tenants, and 3.2 percent by managers.

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 soil[3] and its content of lime and salts are determined by simple tests.[4] Drainage, both internal and external, and other external features, such as relief, or lay of the land, are taken into consideration, and the interrelation of soils and vegetation is studied.

The soils are classified according to their characteristics, both internal and external, special 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 into mapping units. The three principal ones are (1) series, (2) type, and (3) phase. Areas of land, such as coastal beach or

[3] 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 indicate alkalinity, and lower values indicate acidity.

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

bare rocky mountainsides that have no true soil, are called (4) miscellaneous land types.

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, Pima, Gila, and Anthony are names of important soil series in this area.

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 soil type. For example, Pima clay and Pima silty clay are soil types within the Pima 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 it is generally the soil unit to which agronomic data are definitely related.

A phase of a soil type is a variation within the type, which differs from the type in some minor soil characteristic that may have practical significance. Differences in relief, stoniness, and the degree of accelerated erosion frequently are shown as phases. For example, within the normal range of relief for certain soil types, some areas are adapted to the use of machinery and the growth of cultivated crops and others are not. Even though there may be no important difference 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 crops. 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

In the Casa Grande area, moisture is the principal natural factor limiting plant growth. Under natural conditions only desert types of vegetation can survive, except along stream courses. Production of crops has been rendered possible in part of the area by irrigation, but a large part of the land must remain uncultivated because of lack of water. Soil characteristics greatly influence the supply of moisture available to plants, the feasibility of irrigating the land, and the yield of crops which may be obtained from the use of the limited supply of water for irrigation.

Certain dominant characteristics of the soils are due to the hot desert environment under which they have been formed. They are comparatively poor in organic matter (humus) and nitrogen but are rich in the comparatively soluble mineral compounds, including the carbonates of calcium (lime)[5] and magnesium, calcium sulfate (gypsum), and the still more soluble salts of sodium, potassium, and other bases, popularly called alkali. In places these salts occur in such excessive quantities as to injure vegetation or entirely prohibit its growth. Phosphorus probably is present in sufficient quantity for normal plant growth, but in places it is rendered largely unavailable by an excessively calcareous, alkaline, or puddled condition of the soil.

The prevailingly light color of the soils is due to their low content of organic matter, and the red or pink tinge characteristic of most soils is caused by the high degree of oxidation of the iron compounds they contain. In the soils in which some soil development has taken place, the surface soils have been slightly leached and lime carbonate and other soluble compounds have been carried down and accumulated in the subsoil, in places forming a more or less compact or cemented lime hardpan layer, or caliche. Caliche layers, where very well developed, hard, and thick, are probably formed by the evaporation of lime-charged subsoil water and, in some places, may indicate a former high water table. In a large part of the area, the older soils have a red heavy tough subsurface or upper subsoil layer that in places constitutes a claypan. In some of the alkali (sodium-saturated) soils, a tight impervious structure has developed.

Differences in soils in the area are due largely to differences in texture and mineralogical composition of the parent soil materials, differences in drainage and moisture conditions, differences in the calcium and sodium content of the soils and soil colloids, and differences in length of time the soil materials have been exposed to weathering and soil-forming forces. The sparse vegetation has had comparatively little influence on soil development.

The soil materials have accumulated on alluvial fans and flood plains, and many of them have a very mixed mineralogical origin. Their composition and texture depend largely on their location in relation to their source. The farther these soil materials have been transported, the finer textured they are and the greater is the possibility of mixture with material from other sources. The coarser-textured soil materials from individual parent rocks lie high on the alluvial-fan slopes, and the finer-textured materials of mixed origin are on the lower slopes and alluvial plains. Some of the soils consisting of comparatively recent alluvium, such as the Pima soils, contain comparatively large quantities of organic matter inherited from the soils from which the materials were eroded. In places recent alluvium has covered the older, less pervious soils, and on irrigated land layers of silt have been deposited by muddy irrigation waters.

The deficiencies of these soils in organic matter and nitrogen can be corrected readily by growing alfalfa or other leguminous crops in

[5] The term "lime," as used in this report, refers to calcium carbonate.

the rotation and by plowing under crop residues and manures. The availability of phosphorus may also be increased by application of manures and maintenance of good tilth, although addition of soluble phosphate fertilizers is advisable in places, especially on the more highly calcareous and alkaline soils. Defects, such as coarse texture, excessively porous or dense impervious structure, hardpan, excess of salts, and high alkalinity, are not overcome easily; and it is probable that most of the soils with these defects should not be considered fit for development under irrigation.

As previously stated, availability of water for irrigation has been the principal factor in determining what lands should be irrigated. In addition to this, economic factors, chiefly the demand for and price of crops, have had an important bearing. Too often agricultural development and expansion have been determined almost entirely by these factors, and proper consideration has not been given to the character of the soils. Many failures have resulted from attempts to farm soils that were not suited naturally to cultivation or lacked an adequate water supply. Since the completion of the Coolidge Dam, the lands irrigated or proposed for irrigation have been classified and steps have been taken to use the water supply only on the best land. Pumping districts now are rather limited and are being expanded very cautiously, because the limitations of the water supply and the extreme diversity of the soils are appreciated.

The present-day agriculture is diversified, with cotton, both long and short stapled, as the main cash crop. This is in response to a number of factors, dominantly climatic and economic, as, in general, apparently little consideration is given to the soils in the selection of areas planted to this crop. Cotton is one of the marketable crops that ordinarily can be disposed of readily for cash or, if stored, used as security for loans. The long growing season and present assurance of a more stable water supply insure maturity of the crop. Also, the extended favorable picking season of early winter alleviates critical peaks of demand for labor.

Alfalfa, which ranks next in importance to cotton, is valuable in rotation with cotton and other crops, because it supplies organic and nitrogenous residues essential to the maintenance of productivity. Furthermore, it is one of the best hay crops, both in yield and in quality, and can be grown without the use of fertilizers or amendments. It furnishes the necessary supplement to range pasture in feeding farm and range cattle and sheep. It is depended on in part for finishing cattle for market. Sheep are brought in for early lambing, and the early lambs are marketed from the pastures. Hay that is not used in feeding livestock finds a ready market in outside cities and towns.

Small grains and grain sorghums are important crops associated with livestock enterprises, and they furnish supplementary feed and pasture. The grain sorghums are used for grain, fodder, and silage, and they are pastured after the grain crop has been harvested. This crop is finding favor in the reclamation of alkali land as it is fairly tolerant of salts and furnishes a great deal of organic matter needed to make these soils more permeable. Since the small grains are grown during winter, grain sorghums follow them very well in the hot summer. Their short growing season, low requirement for water, and high yields of both grain and fodder make grain sorghums ideal crops for this season.

Wheat for grain and barley for pasture are the most important small grains. Barley is also grown in the reclamation of salty or alkali soils because of its tolerance to salts. This and other grains are often seeded in alfalfa stands, in order to provide additional pasture when the growth of alfalfa is retarded or checked by the colder winter weather.

Truck crops, such as head lettuce and asparagus, are grown commercially in the vicinity of Eloy, where the dark deep friable highly organic soils of this section are ideally suited for the production of such crops.

Since the productivity and land-use capability of the soils of the area are determined largely by their structure, permeability, water-holding capacity, alkalinity, and content of calcium and sodium salts, the soils may be grouped on the bases of these characteristics in the general order of their desirability for agricultural use, as follows: (1) Soils without lime accumulation; (2) soils with slight lime accumulation; (3) soils with moderate lime accumulation; (4) soils with high lime accumulation; (5) soils with lime hardpans; (6) solonetzlike ("alkali") soils with moderate lime accumulation; (7) solonetzlike soils with lime hardpans; and (8) miscellaneous land types.

These soil groups and the individual series,[6] types, and phases are described in detail in the following pages; their location and distribution are shown on the accompanying soil map; and their acreage and proportionate extent are given in table 5.

TABLE 5.—*Acreage and proportionate extent of the soils mapped in the Casa Grande area, Ariz.*

Soil type	Acres	Percent	Soil type	Acres	Percent
Pima silty clay	11,968	2.2	Gila silt loam, shallow phase (over Imperial soil material)	6,400	1.2
Pima silty clay, shallow phase (over Gila soil material)	8,640	1.6	Gila loam	5,120	.9
Pima silty clay, shallow phase (over Imperial soil material)	3,136	.6	Gila silty clay loam	27,264	4.9
Pima silty clay, shallow phase (over Anthony soil material)	1,280	.2	Gila silty clay loam, shallow phase (over Mohave soil material)	1,920	.3
Pima silty clay, shallow phase (over Mohave soil material)	8,704	1.6	Gila loamy fine sand	9,152	1.7
Pima silty clay, shallow phase (over Tubac soil material)	1,408	.3	Gila fine sand	5,248	.9
Pima silty clay, shallow phase (over Laveen soil material)	2,432	.4	Gila fine sand, low-bottom phase	192	(1)
Pima silty clay, shallow phase (over Coolidge soil material)	192	(1)	Cajon gravelly coarse sandy loam	832	.2
Pima silty clay loam	13,824	2.5	Imperial silty clay	6,144	1.1
Pima clay	3,328	.6	Imperial silty clay, silted phase	3,392	.6
Gila fine sandy loam	13,056	2.4	Imperial silty clay, shallow phase (over Gila soil material)	3,264	.6
Gila fine sandy loam, hummocky phase	128	(1)	Imperial silty clay, shallow phase (over Mohave soil material)	1,984	.4
Gila fine sandy loam, low-bottom phase	256	(1)	Imperial silt loam	1,600	.3
Gila very fine sandy loam	5,440	1.0	Anthony sandy loam	22,784	4.1
Gila silt loam	19,328	3.5	Anthony sandy loam, silted phase	320	.1
			Anthony sandy loam, shallow silted phase	640	.1
			Anthony sandy loam, shallow phase (over Mohave soil material)	1,152	.2
			Anthony sandy loam, eroded phase	64	(1)

[1] Less than 0.1 percent.

[6] The classification and mapping of the soils of this area do not fully agree with the classification and mapping in the earlier included soil survey of the middle Gila Valley area. Many conflicts in boundaries and nomenclature are apparent. These are the result of the rapid progress in the science of soil classification, the much more detailed character of the present study, and the actual changes in the character of soils through recent accumulation of alluvial materials from stream floodwaters and from muddy waters used in irrigation.

TABLE 5.—*Acreage and proportionate extent of the soils mapped in the Casa Grande area, Ariz.*—Continued

Soil type	Acres	Percent	Soil type	Acres	Percent
Anthony loam	4,160	0.8	Toltec loam, deep phase	2,688	0.5
Anthony loam, silted phase	256	(1)	Toltec loam, silted phase	1,152	.2
Anthony loam, shallow silted phase	768	.1	Toltec loam, shallow silted phase	1,472	.3
Anthony fine sandy loam	1,536	.3	Toltec loam, brown silted phase	2,944	.5
Anthony silty clay loam	1,280	.2	Toltec silty clay loam	1,408	.3
Anthony gravelly loamy sand	2,560	.5	Pinal sandy loam	4,480	.8
Papago sandy loam	3,200	.6	Pinal sandy loam, deep phase	1,152	.2
Papago fine sandy loam	13,376	2.4	Pinal sandy loam, silted phase	256	(1)
Papago loam	2,624	.5	Pinal sandy loam, eroded phase	960	.2
Sawtooth gravelly sandy loam	3,520	.6	Pinal gravelly clay loam	640	.1
Nunez sandy loam	8,320	1.5	Pinal gravelly clay loam, eroded phase	1,600	.3
Nunez loam	2,368	.4	Coolidge sandy loam	832	.2
Mohave sandy loam	35,136	6.4	Coolidge sandy loam, deep phase	512	.1
Mohave sandy loam, silted phase	576	.1	Coolidge sandy loam, silted phase	768	.1
Mohave sandy loam, shallow silted phase	6,912	1.3	Coolidge sandy loam, shallow silted phase	1,152	.2
Mohave sandy loam, deep phase	20,224	3.7	Coolidge sandy loam, eroded phase	64	(1)
Mohave sandy loam, hummocky phase	256	(1)	Casa Grande sandy loam	19,200	3.5
Mohave loam	17,856	3.2	Casa Grande sandy loam, deep phase	192	(1)
Mohave loam, silted phase	5,696	1.0	Casa Grande sandy loam, silted phase	6,208	1.1
Mohave loam, shallow silted phase	3,136	.6	Casa Grande sandy loam, brown silted phase	3,776	.7
Mohave loam, brown silted phase	3,520	6	Casa Grande sandy loam, hummocky phase	6,272	1.1
Mohave loam, deep phase	256	(1)	Casa Grande sandy loam, eroded phase	64	(1)
Mohave fine sandy loam	960	.2	Casa Grande fine sandy loam	8,320	1.5
Mohave clay loam	9,920	1.8	Casa Grande fine sandy loam, deep phase	512	.1
Mohave clay loam, silted phase	576	.1	Casa Grande loam	10,240	1.9
Mohave clay loam, shallow silted phase	128	(1)	Casa Grande loam, deep phase	1,344	.2
Mohave silty clay	15,296	2.8	Casa Grande loam, silted phase	11,200	2.0
Tubac clay loam	1,856	.3	Casa Grande loam, brown silted phase	6,272	1.1
Tubac clay loam, silted phase	384	.1	Casa Grande silty clay loam	10,560	1.9
Tubac clay loam, shallow silted phase	256	(1)	Casa Grande silty clay loam, silted phase	5,248	.9
Vekol clay	6,144	1.1	Casa Grande silty clay loam, brown silted phase	2,112	.4
Vekol clay, deep phase	1,984	.4	Topaz fine sandy loam	320	.1
Continental sandy loam	2,240	.4	Topaz fine sandy loam, deep phase	2,368	.4
Continental sandy loam, shallow silted phase	320	.1	Topaz fine sandy loam, hummocky phase	512	.1
Laveen fine sandy loam	5,312	1.0	Topaz fine sandy loam, eroded phase	896	.2
Laveen fine sandy loam, silted phase	960	.2	Topaz loam	1,920	.3
Laveen fine sandy loam, shallow silted phase	1,920	.3	Topaz loam, silted phase	960	.2
Laveen fine sandy loam, deep phase	7,744	1.4	Topaz silty clay loam	1,792	.3
Laveen fine sandy loam, hummocky phase	704	.1	Topaz silty clay	1,472	.3
Laveen fine sandy loam, eroded phase	1,088	.2	La Palma fine sandy loam	832	.2
Laveen silt loam	2,112	.4	La Palma loam	2,176	.4
Laveen silt loam, silted phase	4,288	.8	La Palma silty clay loam	2,496	.5
Laveen silt loam, shallow silted phase	1,792	.3	Rough stony land (granite, gneiss, and schist materials)	5,248	.9
Laveen silty clay loam	1,088	.2	Rough stony land (basalt, andesite, and rhyolite materials)	2,368	.4
Palos Verdes sandy loam	832	2	Riverwash	3,136	.6
Teague gravelly loam	6,912	1.3	Dune sand	1,088	.2
Toltec fine sandy loam	1,920	.3			
Toltec fine sandy loam, silted phase	256	(1)			
Toltec fine sandy loam, hummocky phase	640	.1			
Toltec fine sandy loam, eroded phase	1,472	.3			
Toltec loam	4,544	8	Total	552,960	

[1] Less than 0.1 percent.

SOILS WITHOUT LIME ACCUMULATION

The soils without lime accumulation are members of the Pima, Gila, Cajon, and Imperial series. These soils consist of comparatively recent alluvium, which in most places is friable, favorable to the penetration and storage of moisture, and favorable to deep development of roots. As a group, they have the greatest inherent fertility and highest content of organic matter of the soils of this area. Gila fine sand, Gila fine sand, low-bottom phase, and Cajon gravelly coarse sandy loam, however, are relatively poor soils and have a low moisture-holding capacity; and the Imperial soils absorb water slowly but have a high moisture-holding capacity.

Most of the soils of this group are, or have been until recently, subject to occasional overflow, and in this way the mineral plant nutrients and organic matter are periodically replenished by sediments, many of which have been transported from distant grasslands in higher more humid country. Irrigated lands are being built up by dark highly organic silty deposits from muddy irrigation waters. Most of the heavy-textured soils of the group are well granulated and are not so intractable as most soils of such heavy texture.

These soils are calcareous, but the lime is largely disseminated and not accumulated in the subsoil to an appreciable extent. In the Santa Cruz flood plain, some slight lime accumulation exists where the materials have not been disturbed for a long time. Apparently, the lime in most of these soils does not interfere greatly with plant nutrition, although it may have some detrimental effect in some of them.

The more soluble salts accumulate in places where moisture does not penetrate deeply and on evaporation leaves the dissolved salts in the soil. They also accumulate in places where a high water table causes their concentration at or below the surface through capillary rise and evaporation of moisture. These salts are mainly saline or neutral salts, commonly called white alkali. The alkaline salts, known as black alkali, generally are not present except in some of the heavier-textured soils. Because of the friable permeable open structure of most of these soils, salts are leached out readily in most places or can be prevented from accumulating if adequate underdrainage is provided. This is not so true of the heavier less pervious soils, such as those of the Imperial series.

Most of the land is smooth, relatively flat or gently sloping, and favorable for irrigation. Wind action has developed hummocks and a few dunes in some areas. A few places along the Gila River occasionally are overflowed and channeled by floodwaters.

Most cultivated areas of the Pima and Gila soils produce high yields of the crops commonly grown, owing, doubtless, to their inherent fertility and good water-holding capacity. Little attention is given to rotation of crops because the inherent fertility is replenished by silting from gravity irrigation waters. Cotton, small grains, grain sorghums, and truck crops are the important crops. They produce higher yields than on most other soils of the area. Alfalfa is grown to some extent on the lighter-textured soils but is not so well suited to the heavier-textured soils. The generally low position of the soils of this group, especially along the Gila River, makes them more subject to frost than many of the higher soils and thereby shortens somewhat the growing and producing season of alfalfa and subtropical crops.

The Pima soils are the most productive of this group. They are well supplied with both mineral and organic plant nutrients and absorb and retain moisture well. The dark dull-brown heavy-textured surface soils continue to a depth of several feet, where they are underlain in most places by lighter-colored and lighter-textured stratified subsoils of lower organic content. In a few places heavy-textured dark-colored materials continue to a great depth or are interstratified with the light-textured materials.

The Gila soils differ from the Pima soils principally in color of the surface soil, which is lighter, owing to a lower organic matter content; and they also are predominantly lighter textured. The soil materials are variably stratified and are light grayish brown, tinged with red in many places, especially those of heavier texture. In places clay layers are present in the subsoil and substrata. The Gila soils are less fertile than the Pima but have a wider range of crop adaptation, owing to a wider range in texture. The Gila soils along the Gila River have a higher organic content and a slightly darker and more red color than most of those in the Santa Cruz River flood plain. The darker color and higher content of organic matter has been accentuated in many places by the deposition of sediment from irrigation waters from the Gila River, which carry suspended silt and clay materials comparatively rich in organic matter. The Pima soils are being formed in this way. The Gila soils along the Santa Cruz River are predominantly light grayish brown with a yellow tint.

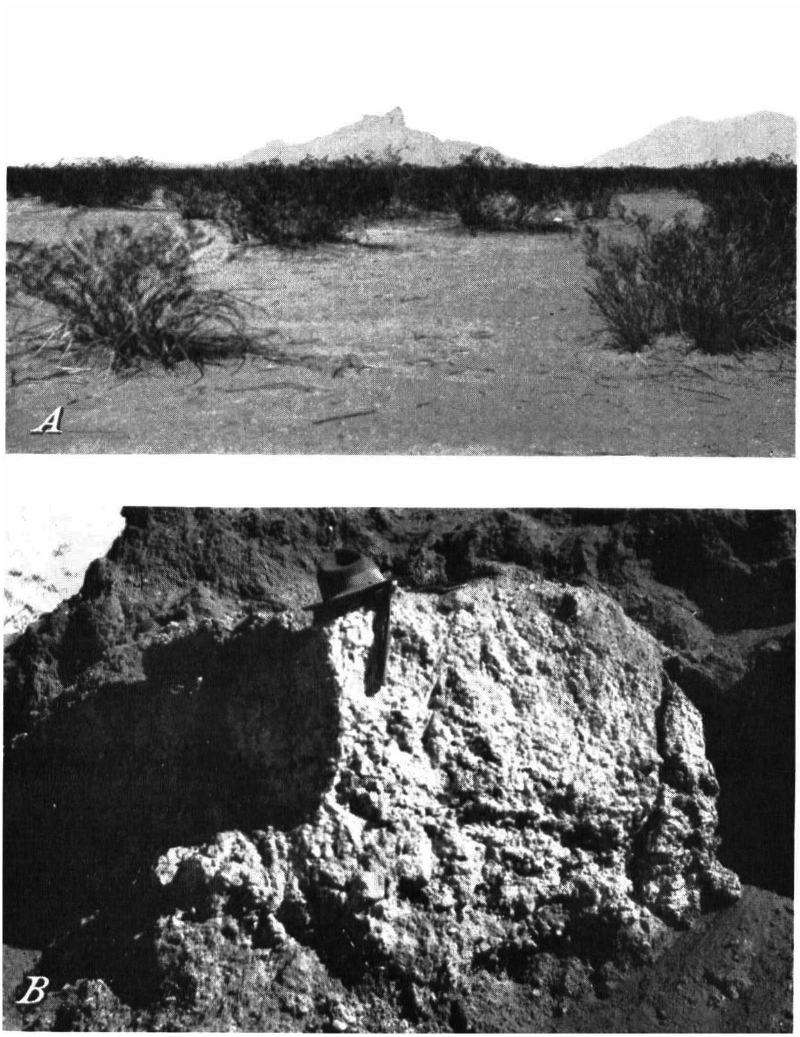
The Cajon soils in this area are coarse textured and hence droughty. They lie high on the fan slopes near the mountains and have no agricultural importance. They resemble the coarser-textured Gila soils, especially those developed on the Santa Cruz River flood plain. They are light grayish brown and are formed from granites and similar rocks, whereas the Gila and the Pima soils have their geological source in many different rocks.

The Imperial soils range from pale reddish brown to rich reddish brown, are heavy textured, and are massive and compact. The lower subsoil layer and substratum are stratified with lighter-textured material in most places below a depth of 5 feet. They resemble the heavy-textured Gila soils, except for their massive clay subsoils and somewhat lower content of organic matter. They are intractable, comparatively impervious, and, in many places, charged with salts. Moisture penetrates these soils slowly, but they retain it well. Roots penetrate with difficulty; therefore these soils are best suited to shallow-rooted crops or grains. At present, they are not cultivated.

Pima silty clay.—To a depth of about 16 or 18 inches Pima silty clay is very dark brown silty clay appearing almost black when moist. It contains a comparatively large quantity of organic matter, is granular and friable, and is as easily cultivated and as readily penetrated by roots and moisture as many lighter-textured soils. The moisture-holding capacity is high. Below this layer and continuing to a depth ranging from 3 to 4 feet is a laminated or banded layer, or succession of layers, in which the dark heavy materials alternate with slightly lighter-colored and lighter-textured materials. The material in this layer is friable and readily permeable. The lower part of the subsoil, predominantly a silty clay loam, is light grayish brown, but it is stratified with lighter-textured silty materials, which are mellow, friable, and not so plastic as those in the layers above. The whole soil is definitely calcareous. It does not contain salts in injurious quantities, except in a few places southwest of Toltec.

The textural banding in the soil, which is due to stratification, varies considerably from place to place. There is also considerable range in color from the normal dark brown of the surface soil to reddish brown or lighter brown.

Wide variety of vegetation in the southern Arizona, or Sonoran, Desert. Grass in the foreground, cholla cacti in the middleground, and giant cacti in the background.



A, Creosotebush on the well-drained, highly calcareous Laveen soils. Note the wide spaces between plants, the result of competition for moisture. *B*, Exposed section in a Pinal soil, showing the firmly cemented lime hardpan.

This soil covers a total area of 18.7 square miles. Fairly large bodies are south of Eloy, and smaller areas are scattered over the Santa Cruz River flood plain.

The land is smooth or gently sloping and is ideal for the distribution of irrigation water. Much of it, where not protected by dikes, is subject to flooding by the Santa Cruz River floodwaters during rainy periods. In many places flooding is encouraged in order to promote deposition of the fertile organic silty sediments. Natural underdrainage is good, owing to the permeable materials in the substrata. The supply of ground water for irrigation is available at a depth ranging from 100 to 124 feet.

This soil is used principally for the production of cotton and truck crops. Cotton occupies the largest acreage. Short-staple cotton yields an average of about 1½ bales an acre. With sufficient irrigation and proper management, it yields at least 2 bales. Pima cotton, a long-staple variety, produces about 1 bale an acre. Lettuce is the most important truck crop and occupies the next largest acreage to that of cotton. The appearance of slime in lettuce has caused shifting to cotton and other crops. Barley is often used in rotation when two crops are grown on the same soil in a season. Because of the inherent fertility of the soil it is not necessary to grow alfalfa or other legumes in the rotation.

Pima silty clay, shallow phase (over Gila soil material).—This soil is similar to Pima silty clay except that in most places the heavy dark organic surface materials range from only 12 to 16 inches in thickness. Below these are friable light-textured materials similar to those of the Gila soils which make the shallow phase less retentive of moisture and less fertile than the typical soil. The more friable subsoil, on the other hand, makes the phase more desirable than the typical soil for certain deep-rooted crops. The two soils are associated, but the shallow phase is less extensive.

Pima silty clay, shallow phase (over Imperial soil material).—In this soil, a 2- to 3-foot layer of dark organic Pima silty clay overlies Imperial silty clay material. The soil therefore is not very well suited for other than cotton and grain crops, although truck crops and alfalfa doubtless could be grown successfully. At present none of the land is farmed. It lies along the Santa Cruz River and is much less extensive than typical Pima silty clay.

Pima silty clay, shallow phase (over Anthony soil material).—This soil has a dark-colored heavy surface soil, which in most places is not more than 2 feet thick. It is underlain by soil material of the Anthony series. The heavy-textured surface soil granulates to form fine aggregates, and the soil responds to cultivation in the same manner as a silty clay loam. Most of it has been deposited or built up by irrigation with turbid stream waters, and the thickness of the surface material varies within individual fields. The upper ends of the fields commonly are silted to a slight depth, whereas the lower ends are deeply silted.

All crops except alfalfa return high yields on this soil. The texture is too heavy for best results with alfalfa, and deposition of soil material in irrigation tends to bury and destroy the crowns of the plants. Cotton yields from 1 to 1½ bales an acre. Small grains produce from 20 to 50 bushels, and grain sorghums 1½ or more tons.

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Pima silty clay, shallow phase (over Mohave soil material).—This soil consists of a surface layer of Pima silty clay which has been deposited, mainly from turbid waters in irrigation, overlying older materials of the Mohave soils. The deposits of dark-colored sediments range in thickness from 18 inches to 3 feet, and in a very few places are as much as 4 feet thick. In three small areas, from 3 to 4 miles southwest of Florence, the Pima sediments overlie Continental soil materials, which are somewhat tougher and less pervious than the Mohave materials. This included soil is less productive.

The surface soil, although heavy textured, is well granulated under cultivation. The organic-matter content is high, and the underlying material is permeable to roots and moisture.

Important areas in the vicinity of Eloy are used for the production of cotton and truck crops. Some of the low areas are overflowed during flood periods if not protected by dikes. Yields of cotton range from 1¼ to 1½ bales an acre. Alfalfa yields from 2 to 5 tons. The soil is not, however, so well suited to alfalfa and vegetable crops as are some of the lighter-textured soils. Small grains yield well, generally from 35 to 60 bushels an acre. Grain sorghums yield from 1½ to 2½ tons of grain.

Pima silty clay, shallow phase (over Tubac soil material).—This soil consists of Pima silty clay to a depth ranging from 6 inches to 3 feet. It is underlain by the Tubac soils. Most of the surface soil has been accumulated artificially by deposition from turbid irrigation water similar in character to the floodwaters of the Santa Cruz River, from which the typical Pima soil material has developed. The surface soil is heavy textured but is granular and fairly friable under favorable moisture conditions and cultivation. The underlying Tubac material is not so permeable as some of the other soil materials, but the soil as a whole is highly productive for cotton and small grains.

Cotton yields about 1½ bales an acre, small grains 40 to 60 bushels, and grain sorghums 1 to 2 tons of grain.

Pima silty clay, shallow phase (over Laveen soil material).—This soil consists of dark-colored Pima silty clay material deposited over the older Laveen soil material to a depth ranging from 6 inches to 3 feet. The greater part of the surface material has been accumulated artificially from irrigation. The surface soil is dark rich-brown granular silty clay similar to Pima silty clay of the Gila River bottoms.

This is a productive soil. The texture is rather heavy, however, for alfalfa, and many of the root crowns are injured on account of being buried by the heavy-textured sediments in the low positions in which this soil occurs. Yields of alfalfa range from 2½ to 4½ tons an acre, small grains 25 to 50 bushels, cotton 1 to 1½ bales, and grain sorghums 1½ to 2 tons of grain. Winter lettuce is an important crop.

Pima silty clay, shallow phase (over Coolidge soil material).—This soil consists of dark-colored Pima sediments, mainly from irrigation waters, which have been superimposed over older Coolidge soil materials. The surface soil is dark rich-brown granular silty clay. The subsoil contains many hard lime nodules and is more or less cemented by lime. This compact subsoil doubtless interferes with the penetration of water and roots, and it is unfavorable for deep-rooted crops.

This soil is used mainly for the production of cotton, small grains, and grain sorghums. Cotton yields from two-thirds to three-fourths of a bale an acre, small grains 15 to 35 bushels, and grain sorghums ¾ to 1½ tons of grain.

Pima silty clay loam.—Pima silty clay loam has a lower organic-matter content, a lighter texture, and therefore a lighter brown color than the other Pima soils, but in other features it resembles those soils. This soil is not so productive as some Pima soils for cotton and grains, but it is more desirable for crops that grow best in a more friable soil. It is intermediate in color and character between the Gila and the Pima soils. It lies principally on the alluvial plain of the Santa Cruz River. A few small areas are on the Gila River bottoms. It is more extensive than typical Pima silty clay, but less of it is farmed. Toxic accumulations of salts occur in places.

Pima clay.—Pima clay has a surface soil of dark-brown clay tinged with red, having a comparatively high organic-matter content. The thickness of this layer varies considerably, as a large part of it has been deposited by irrigation; the range in most places is from 18 to 24 inches. The clay material is highly colloidal and is sticky and plastic when wet. It granulates into fine aggregates in most places, and under cultivation it works like a silty clay loam. The subsoil in general is somewhat lighter brown than the surface soil, but in some places it is as dark as that layer. Its texture is silty clay, but it is not so granular as the surface soil. In the lower part of the subsoil, at a depth ranging from 40 to 48 inches, the color changes to light reddish brown or, in places, yellowish brown, the texture becomes lighter, and the consistence becomes more friable. In most places the materials are rather intensely stratified with bands of silty clay loam, silt, and very fine sand. This soil has a high content of lime and a somewhat high content of soluble salts, which in some places occur in toxic quantities, especially in the subsoil and substratum.

This soil occurs only along the Gila River bottoms where it occupies the back bottoms. Its total area is not large.

The land is smooth and ranges from gently sloping to flat. These characteristics favor the even distribution of irrigation water, as well as the penetration of water, which otherwise might prove difficult in such a heavy-textured soil. Moisture is retained very well. Underdrainage is sufficient, although not so perfect as in the Pima soils on the Santa Cruz River flood plain. The parent materials are of mixed origin. It is probable that much of the colloidal organic material has been carried in suspension hundreds of miles from its point of origin.

This soil is devoted chiefly to the production of short-staple cotton, small grains, and grain sorghums. Under ordinary management cotton yields 1½ bales an acre, but under very good management and with sufficient water the soil could produce at least 2 bales. Small grains are grown for pasture, hay, and grain. They yield about 2 tons of hay and from 25 to 60 bushels when harvested as grain. Grain sorghums can be grown in the same year in rotation with winter crops of small grains. Hegari and milo varieties of sorghums are commonly grown for grain, silage, and fodder. These produce from 1½ to 2 tons of grain or from 15 to 18 tons of silage.

Irrigation water for this soil is obtained by gravity flow from the Gila River.

Gila fine sandy loam.—Gila fine sandy loam is most extensive on the Santa Cruz River flood plain. The 10- to 12-inch surface soil consists of light grayish-brown mellow friable fine sandy loam. To a depth of about 4 feet the subsoil is a slightly darker brown than the surface soil and has a slight red tinge. The material is a loam in most places, but it is stratified with lighter- and heavier-textured materials in many places. It is slightly compact but pulverizes readily. The lower part of the subsoil consists of light grayish-brown soft or loose materials that are more definitely stratified than those above and range from fine sandy loam to fine sand. The soil is definitely calcareous throughout.

As developed on the Gila River bottoms the soil is light reddish brown and appears to contain more organic matter than the soil described above, which probably is due in part to silting from irrigation waters. For this reason the soil here probably has greater fertility.

Gila fine sandy loam has a smooth gently sloping surface that is favorable for the distribution of irrigation water. This soil consists of mixed parent materials, which have been deposited in comparatively recent times. Internal drainage is good on the Santa Cruz River flood plain, although the soil is subject to periodic flooding in places. The ground-water level ranges in depth from 50 to 125 feet. In the Gila River bottoms, the soil contains toxic quantities of salts in places and, in general, is not so well drained as elsewhere.

None of this soil on the Santa Cruz River flood plain is under cultivation. If supplied with water, it probably would have about the same capabilities as it has along the Gila River, where it is farmed. Here it produces well and is devoted chiefly to cotton, small grains, and grain sorghums. It is also well adapted to alfalfa, but comparatively little of this crop is grown. Moisture is absorbed readily and is fairly well retained. The soil is easily tilled and is especially suited for row crops that need frequent cultivation. Cotton produces about ¾ to 1 bale an acre, small grains 15 to 40 bushels, and grain sorghums 1½ tons of grain.

As mapped, Gila fine sandy loam includes a few small areas in which the surface soil is redder than the corresponding layer of the Gila soils on the Santa Cruz River flood plain and slightly redder than the surface layer of the Gila soils on the Gila River bottoms. In subsoil features, however, such areas are very similar to typical Gila soils. This redder soil occupies basinlike bodies within larger areas of lighter-textured Gila soils and owes its origin to deposition of more red sediments from floodwaters. These areas are not cultivated but have capabilities similar to the typical soil.

Gila fine sandy loam, hummocky phase.—The hummocky phase designates areas of Gila fine sandy loam in which small hummocks have been piled by the wind. None of this soil is cultivated, and leveling for irrigation would involve considerable more expense than preparing the typical soil for cultivation.

Gila fine sandy loam, low-bottom phase.—The floodwaters of the Gila River periodically overflow this soil and sometimes do considerable damage by channeling and by depositing materials. This is due to its low position near the stream channels. The texture of the surface soil ranges from fine sandy loam to silty clay loam. The subsoil in most places consists of loose sandy riverwash. Some of the land is cultivated and generally planted to winter grain crops for pasture, but, because of flood damage, the agricultural value is low.

Gila very fine sandy loam.—The 12-inch surface soil of Gila very fine sandy loam is light grayish-brown very fine sandy loam slightly tinged with yellow. It is mellow, friable, and, in many places, micaceous. The subsoil to a depth of about 56 inches is thickly stratified with silty clay loam, silt, and very fine sand and has a slight red cast. At a depth of about 56 inches the material becomes light-brown loose fine sandy loam that lacks compaction and in most places is micaceous. The soil is low in organic matter and mildly calcareous throughout.

The greater part of this soil is on the Santa Cruz River flood plain. The small bodies along the Gila River are slightly redder and contain more organic matter than the areas along the Santa Cruz River.

This soil occupies smooth, nearly level areas and in origin is similar to Gila fine sandy loam, with which it is associated. Only the small areas on the Gila River bottoms are farmed. Here, the same crops are grown and similar yields are obtained as on Gila fine sandy loam. It has somewhat better moisture-holding capacity than the fine sandy loam.

Gila silt loam.—Typical Gila silt loam has a light grayish-brown highly micaceous friable mellow surface soil about 12 inches thick. It is underlain, to a depth of about 50 inches, by thickly stratified layers of silty clay loam, silt, and very fine sand. The material has a slight red cast and is more compact than the surface soil. Below this are looser and more conspicuously stratified layers of loam and fine sandy loam. The soil is slightly calcareous. Small areas are included on the map, in which the surface soil is more red than typical and in which small white specks of accumulated lime are present.

Gila silt loam occupies large areas on the Santa Cruz flood plain. The land is smooth and ranges from gently sloping to rather flat. The moisture-holding capacity is excellent, yet underdrainage is good. In some places protection from periodic floodwaters is needed. The water level is from 50 to 125 feet below the surface, depending on the location of this land in relation to the Santa Cruz River.

None of this soil is farmed, but under irrigation it would be suited to the same crops as the other Gila soils. It should be highly productive because of its excellent moisture-holding capacity. Its principal deficiency is organic matter, which could be supplied by using manures and by growing alfalfa and other legumes in the crop rotation.

Gila silt loam, shallow phase (over Imperial soil material).—This soil consists of a thin layer of light grayish-brown alluvial silt loam similar to the corresponding layer in typical Gila silt loam, underlain, at a depth ranging from a few inches to 2 feet, by Imperial silty clay. Moisture penetrates the surface layer readily but is retarded by the heavy subsoil. None of the land is farmed. If it were farmed, it probably would be managed in much the same manner as the other Gila soils but would be adapted to a somewhat narrow range of crops.

Gila loam.—To a depth of about 1 foot typical Gila loam consists of light grayish-brown loam that is friable but fine textured and somewhat sticky when wet. The upper part of the subsoil comprises stratified loam, silty clay loam, and lighter-textured materials. The color is slightly more red than in the surface soil, and a slight compaction is evident. The lower part of the subsoil, beginning at a depth of about 4 feet, is composed of light-brown stratified fine sand and fine sandy loam. The soil is slightly calcareous throughout.

As mapped in the Santa Cruz River flood plain, Gila loam includes a variation having a definitely light reddish-brown surface soil to a depth of about 12 inches. White specks of accumulated lime occur throughout this material, which is somewhat compact and plastic. It is underlain abruptly by paler reddish-brown thickly stratified loose or friable sandy loam or loamy sand. Below a depth ranging from 2 to 3 feet is light yellowish-brown loose sand. This included soil is more extensive than typical Gila loam.

Also included is a very small area on the Gila River bottoms about 1 mile north of the Casa Grande National Monument, in which hummocks of wind-blown sand have accumulated around brush. None of this land is cultivated, and it would require considerable expense to level the surface for irrigation. Once leveled, however, this soil would have about the same physical characteristics and land use adaptations as the more typical areas.

Gila loam is not so extensive as the other Gila soils, but it is widely scattered over the Santa Cruz River flood plain and the Gila River bottoms. It is farmed only in the latter locality. The crops grown are the same as on the other Gila soils. This soil rates a little higher in productivity than Gila fine sandy loam, owing to better moisture-holding properties.

Gila silty clay loam.—The surface soil of typical Gila silty clay loam, to a depth of about 16 inches, is light grayish-brown or somewhat y llowish brown silty clay loam, which is compact and breaks into clods. Between depths of 16 and 18 inches the material is similar in color to the surface soil and consists of stratified silty clay or clay loam interbedded with lighter-colored and lighter-textured silty and very fine sandy loam materials. Below this are stratified lighter-colored and lighter-textured materials. The surface soil is compact yet friable under cultivation. The soil throughout is slightly calcareous and is deficient in organic matter.

Like other members of the Gila series in this area, Gila silty clay loam includes variations of more red color containing white specks of accumulated lime. In places these included soils are also somewhat heavier textured, more intractable, and less permeable than the typical soil. On the Gila River bottoms the surface soil also has a somewhat red tinge, but it has a higher organic-matter content and more friable consistence than elsewhere. The greater part of Gila silty clay loam is on the Santa Cruz River flood plain.

In many places this soil occupies gently sloping flood plains, and in others it occupies rather flat or shallow basinlike areas along drainageways. In the latter positions it is flooded frequently during the rainy period and in a few places contains toxic quantities of soluble salts. Drainage through this soil is slow, but underdrainage is sufficient, owing to the more porous subsoils and substrata. The ground-water level ranges from about 50 to 125 feet below the surface, depending on the location of the areas along the Santa Cruz River.

At present only the land in the Gila River bottoms is farmed. It is planted chiefly to cotton and small grains. Cotton yields an average of about 1 bale an acre. Small grains yield from 15 to 45 bushels. The comparatively high yields are partly due to the silt deposited by irrigation waters. On the Santa Cruz River flood plain the soil contains less organic matter, is more intractable, absorbs water more slowly, and, if it were farmed, probably would be somewhat less productive than that along the Gila River. In the Marana district of the adjoining Tucson area, however, this soil produces good yields of all the crops commonly grown.

Gila silty clay loam, shallow phase (over Mohave soil material).—This soil consists of areas in which the Gila silty clay loam surface soil has been deposited over older Mohave clay loam material to a depth ranging from 3 to 6 feet. The texture therefore is heavy throughout, making it difficult for roots to penetrate and retarding the penetration of moisture. This soil is not cultivated, but, if it were, it probably would be somewhat inferior to typical Gila silty clay loam.

Gila loamy fine sand.—Gila loamy fine sand has a 16-inch surface soil of light grayish-brown loamy fine sand. A greater part of the surface is crusted over and resists wind erosion, but there are numerous low wind-blown hummocks. Below the surface soil are thickly stratified sediments of fine sand, sand, and finer-textured materials of similar color. The soil is slightly calcareous throughout, but no concentrations of soluble salts are present.

This soil is developed principally on the Santa Cruz River flood plain, where it occupies comparatively flat to sloping positions. The materials are of mixed mineralogical origin but are high in quartz and mica.

The soil is not farmed and has a low agricultural value owing to its droughtiness. It resists wind erosion much better than does Gila fine sand.

Gila fine sand.—Gila fine sand, to a depth of about 18 inches, is light grayish-brown loose shifting fine sand characterized by numerous wind-blown hummocks. Below this layer are thick strata of fine sand and medium sand. The soil materials are slightly calcareous. On the Gila River bottoms the soil is light reddish brown. Gila fine sand has a very low value for agriculture, and none of it is farmed.

Gila fine sand, low-bottom phase.—Gila fine sand, low-bottom phase, occupies low positions near the channel of the Gila River and is frequently flooded. Deposition of material and considerable channel erosion during floods make the surface very irregular. In many places this soil is underlain at a slight depth by riverwash consisting of sand and gravel.

Cajon gravelly coarse sandy loam.—Cajon gravelly coarse sandy loam, to a depth of about 16 inches, is light grayish-brown coarse sandy loam with a high content of angular gravel. This material generally is very slightly calcareous, although in some areas it contains no lime. The subsoil is considerably stratified and consists of loose, sharp or gritty sand, coarse sand, and loamy coarse sand, Small subangular gravels are abundant, the color is lighter grayish brown than that of the overlying material, and the material is slightly calcareous.

This soil occurs on the higher alluvial fans at the base of the Sacaton Mountains. The parent materials consist of granitic outwash laid down on moderately sloping alluvial fans. The surface is cut by channels of intermittent streams, and the soil is subject to both erosion and deposition. Drainage is excessive, and the moisture-holding capacity is low. This soil lies above available irrigation water from any source and is not farmed. It is in an almost frost-free belt and, at irregular intervals, receives some moisture from run-off from the mountains. Ironwood and paloverde grow along the stream channels; and saguaro and cholla cacti, creosotebush, annual grasses, desert Indianwheat, and low flowering annuals grow in the interstream areas.

Imperial silty clay.—The surface soil of Imperial silty clay, to a depth of about 18 inches, is dull reddish-brown tough plastic silty clay. This breaks vertically into massive blocks, the surface covering of which cracks into a mosaic pattern and sloughs off. The entire mass is harsh and brittle when dry. Between depths of 18 and 60 inches is dense tough plastic soil material like that above but commonly slightly veined with white threadlike accumulations of lime. Below this is slightly more red dense tough massive clay, which rests on more definitely stratified predominantly heavy textured materials at a depth of about 6 feet.

The color of this soil ranges from dull reddish brown to somewhat yellowish brown, depending on its position. Areas, in which lateral intermittent streams, or washes, contribute the materials, are generally more red than others. The organic-matter content is low.

This soil is developed on the flood plains of the Santa Cruz River and Santa Rosa Wash.

Most of the basins and drainage depressions occupied by this soil are almost flat. Erosion occurs, however, on account of the numerous deep vertical cracks, and, in places, gullies spread from the stream channels into the basins and flats, leaving the surface greatly broken. As water penetrates slowly, surface run-off is rapid, and this also induces rapid erosion. The soil is calcareous throughout, and slow internal drainage has caused accumulation of soluble salts. In many places the quantity of salts is toxic; in other places natural leaching has moved the salts to lower parts of the soil, where they are less harmful to plants.

None of this soil is farmed. Cultivation would be difficult, and water penetration would be very slow. The land is best suited to shallow-rooted crops.

Imperial silty clay, silted phase.—In the silted phase of Imperial silty clay, dark-colored silty clay materials with a high organic-matter content have been deposited over the normal Imperial silty clay to a depth ranging from a few to 12 inches. This surface layer is the same as the surface soil of Pima silty clay loam, is very fertile, and is more permeable and tractable than the surface soil of typical

Imperial silty clay. None of this soil is farmed, although it seems probable that the surface layer would increase its productivity over that of the typical soil according to the depth of the deposit. This soil occurs only on the flood plain of the Santa Cruz River.

Imperial silty clay, shallow phase (over Gila soil material).—In this soil the heavy-textured massive Imperial silty clay material is underlain at an average depth of about 3 feet by the lighter-colored fine sand or fine sandy loam representing buried material of the Gila series.

The underlying material renders the soil more permeable, better suited to the development of deeper rooted crops, and less likely to contain excessive quantities of salt than the typical soil. None of it is farmed, however. It is not very extensive and occurs only on the flood plain of the Santa Cruz River.

Imperial silty clay, shallow phase (over Mohave soil material).—This shallow soil differs from typical Imperial silty clay in that it is underlain at a depth ranging from 3 to 4 feet by Mohave clay loam material. It occurs in a few areas on the Santa Cruz River flood plain. It is probable that, under irrigation, it would be about as productive as typical Imperial silty clay.

Imperial silt loam.—The surface soil of Imperial silt loam is lighter brown, or pale reddish brown, lighter textured, and more friable than the corresponding layer of Imperial silty clay. It is much less plastic when wet than that layer, breaks up to a granular consistence under favorable conditions of moisture and cultivation, and resembles the surface soil of Gila silt loam. The subsoil, however, is dense heavy-textured silty clay loam or silty clay characteristic of the Imperial soils. As internal drainage is retarded, this feature might prove hazardous under irrigation. If cultivated this soil would be best adapted to small grains and cotton.

SOILS WITH SLIGHT LIME ACCUMULATION

The soils with slight lime accumulation are extensive, but, owing largely to their higher position, a smaller proportion is cultivated than of the soils of the group previously described. If the canal system were extended, a large part of their area could be brought under cultivation. The present water supply, however, does not justify inclusion of more of this land in irrigation projects; and the great depth to the water-bearing strata makes it economically infeasible to pump water. These soils are relatively freer from frost than the soils of the first group, owing to their higher position and consequent better air drainage.

The texture of the soils and of their stratified parent materials varies considerably. Some members of the group are coarse textured and droughty, and several contain large quantities of gravel. Such soils, however, lie too high for irrigation and agricultural development.

Typically, lime is leached to a depth of 1 foot or more. Floodwaters frequently carry in calcareous materials from higher areas, but the lime content thus built up is not sufficient to reduce materially the availability of plant nutrients, especially phosphate. The subsoils, in which both lime and clay have accumulated, have increased water-holding properties because of these accumulations, are friable, and are favorable for the penetration of roots.

Under natural conditions, mineral elements of fertility are abundant, but organic matter and nitrogen are deficient and need to be supplied by manures and legume crops where the land is cultivated. Drainage is good, and toxic quantities of soluble salts do not accumulate.

The moderate and gentle slopes of the lower areas of these soils are favorable to the distribution and penetration of irrigation water. Their porosity aids in absorption of moisture, yet they contain different fine materials in the subsoil to hold adequate moisture for the growth of crops.

These soils are adapted to a wide range of crops, including those sensitive to cold and frost. They are especially suited to vegetable and truck crops, tree fruits, grapes, berries, and other crops that thrive best in comparatively light textured friable soils.

At present, crops are grown only on the soils that lie under the gravity irrigation system, principally in the Gila River Valley in the vicinity of Florence. In such areas these soils are all more or less covered by depositions of silty materials from irrigation water and are being modified rapidly in texture and fertility to approach the soils of the Pima and Gila series. Cotton, alfalfa, small grains, and grain sorghums are the principal crops.

This group includes members of the Anthony, Papago, Sawtooth, and Nunez series. The Anthony and Sawtooth soils have very similar noncalcareous surface soils and slight accumulations of lime and clay in the subsoils. They differ, however, in origin of their parent materials. The predominating parent materials of the Anthony soils are derived from light-colored rocks that are high in feldspars and quartz, such as granites, gneisses, and schists. The parent materials of the Sawtooth soils are derived from dark basic rocks that are high in iron, such as basalt and andesite. Therefore, the Anthony soils are light reddish brown, whereas the Sawtooth soils are a more pronounced reddish brown or darker reddish brown. In some areas where gravels are abundant, the Sawtooth soils are much darker, owing to the inherent color of the parent rocks. The soils of both series are distinctly stratified, and these strata materially modify the texture from place to place.

The parent materials and profile of the Papago soils are similar to those features of the Anthony soils, except that the surface soils are less leached, are moderately calcareous, the lime being disseminated, and the color is slightly lighter and more pronounced gray.

The Nunez soils are developed from mixed acid and basic igneous material. The high content of iron colloids is due either to parent materials high in iron-bearing minerals or to deposition of colloidal material from suspension in turbid surface waters. These soils apparently are older than those of the other three series, lie lower on the alluvial fans bordering the flat basin areas, and are subject to inundation by floodwaters, which penetrate well into the soils because of the low gradient. Leaching, therefore, is to a greater depth, more colloidal material is incorporated, and the water-holding capacity is better than in the other soils of this group. Like the other soils of the group, the Nunez soils are deficient in organic matter.

Anthony sandy loam.—Anthony sandy loam, to an average depth of about 12 inches, is pale reddish-brown, light grayish-brown, or pinkish-brown sandy loam containing little or no lime in most places. The soil consists throughout of light-colored granitic material containing much sharp angular sand or grit. Between depths of 12 and 48 inches the material is slightly compact gritty loam that has a soft-cloddy structure and is netted with fine threadlike accumulations of lime. This material breaks into clods of a slightly more red color than that of the surface soil. Below a depth of 48 inches the material is loose light grayish-brown gritty loamy sand that is definitely calcareous but lacks conspicuous accumulations of lime. Organic matter is deficient throughout.

This is the most extensive soil of the group. It lies at the foot of the Sacaton and Picacho Mountains, and in the southeastern part of the area on gently sloping alluvial fans, which are cut in places by the channels of meandering intermittent streams. These channels, however, are not deep enough to interfere with cultivation of the land. Drainage ranges from good to excessive, but floods of short duration occasionally occur during the rainy season.

Near the Sacaton Mountains the predominating parent material is derived from granites, and on the fan slopes from the Picacho Mountains it is derived chiefly from schist and gneiss.

Practically none of typical Anthony sandy loam is cultivated at present. Areas cultivated under the gravity irrigation system have been silted and are separated as silted phases. In most places the depth to underground water makes the cost of pumping for irrigation prohibitive.

Anthony sandy loam, silted phase.—In the silted phase of Anthony sandy loam the silty deposit largely determines the character of the soil to a depth of 6 or 8 inches. In most places the material in this layer consists of dark reddish-brown gritty clay loam. The organic matter and nitrogen contained in the silt make this soil more fertile and improve its moisture-holding capacity. Cotton yields about 1 bale an acre, alfalfa 3 to 5 tons, small grains 20 to 40 bushels, and grain sorghums 1 to 1¼ tons of grain.

Anthony sandy loam, shallow silted phase.—This soil represents areas of Anthony sandy loam that have been modified by a shallow deposit of dark-colored silty material over the surface of the original soil, thereby changing both the texture and color of the surface soil. In most places, the deposited silty material is silty clay or clay and, where mixed with the underlying material by cultivation, has changed the texture of the surface soil to heavy sandy loam or loam. In this soil, the deposit is only a few inches thick, except where mixed with the original materials through cultivation. The color of the mixed materials is medium brown.

The productivity of the soil is materially increased by the deposit over the surface, principally because of an increase in organic matter and nitrogen. This soil is used in the production of cotton, alfalfa, small grains, and grain sorghums. Cotton yields about three-fourths of a bale an acre, alfalfa 3 to 4 tons, small grains 15 to 30 bushels, and grain sorghums ¾ to 1 ton of grain.

Anthony sandy loam, shallow phase (over Mohave soil material).—This soil consists of areas in which typical Anthony sandy loam surface soil overlies a subsoil of dull-red more compact Mohave sandy loam material. The buried soil increases the moisture-holding capacity. None of the land is farmed. It occurs principally on the alluvial fans north of Casa Grande.

Anthony sandy loam, eroded phase.—This soil represents areas of Anthony sandy loam that have been modified by erosion. The rolling to irregular relief is generally unfavorable to irrigation. The soil occurs chiefly in one small area southeast of Picacho Reservoir and has no agricultural value.

Anthony loam.—Anthony loam, to a depth of about 10 or 12 inches, is pale reddish-brown friable gritty loam containing little or no lime. In places the thin soft platy bleached surface layer is underlain by more compact and somewhat cloddy material. Below this is a more red compact cloddy heavy gritty loam or clay loam, that is veined with lime. At a depth of about 40 inches this material is underlain by reddish-brown calcareous loamy sand containing much grit and angular gravel. Parent materials derived from granites predominate in the surface soil and subsoil. Organic matter is deficient throughout.

This soil is much less extensive than Anthony sandy loam, with which it is associated in scattered bodies along the lower edges of the alluvial fans. It has a somewhat smoother surface than the sandy loam because it is cut by fewer drainage channels. Its lower position, however, makes it more subject to flooding. Drainage ranges from good to excessive, but moisture is retained somewhat better than in the sandy loam.

The great depth to ground water limits irrigation by pumping, and very little of the land is farmed. After this soil has been irrigated a few years by gravity, it is considered a silted phase, a description of which follows.

Anthony loam, silted phase.—In this soil, the surface soil of Anthony loam has been modified by deposition of silt from irrigation to a depth of 6 or 8 inches. This deposit changes the surface soil to gritty dark reddish-brown clay loam and increases the productivity of the soil for all crops. Cotton yields a little more than 1 bale an acre, and alfalfa produces from 4 to 5½ tons.

Anthony loam, shallow silted phase.—In the shallow silted phase of Anthony loam the dark silty sediments from turbid irrigation waters form a layer only a few inches thick, but the color of the surface soil is darkened and the texture changed to a heavy loam in cultivated fields. The deposited material with its higher organic-matter and nitrogen content increases the productivity of the soil.

The important crops of the area are grown on this soil and return slightly better yields than on the shallow silted phase of Anthony sandy loam, principally because of better moisture-holding capacity.

Anthony fine sandy loam.—The surface soil of Anthony fine sandy loam, to a depth of about 1 foot, contains little or no lime and is pale reddish brown or light grayish brown. It is slightly compact and breaks into friable clods. Underlying this and continuing to a depth ranging from 40 to 48 inches, is a somewhat more red and slightly more compact gritty loam, in which lime has accumulated in faint threadlike veins. The lower part of the subsoil is composed of light grayish-brown definitely calcareous friable or loose stratified gritty loamy fine sand and sand. Small angular gravel is present in these strata in many places.

This soil, which is not extensive, occurs in small scattered bodies in association with other Anthony soils. The origin of the parent materials and the relief of all the Anthony soils are similar. If this soil were farmed, its productivity probably would be similar to that of Anthony sandy loam.

Anthony silty clay loam.—Anthony silty clay loam is redder and heavier textured throughout than the other Anthony soils in this area. The 10-inch surface soil is dull reddish-brown rather compact silty clay loam. The subsoil is slightly redder and more compact than the surface soil and is faintly veined with accumulated lime. It is underlain at a depth of about 30 inches by strata of gravelly and gritty fine sandy loam, banded with variously textured silty and sandy materials. This material is more friable and is lighter reddish brown than the material above. This soil occupies flat land bordering the Santa Cruz River flood plain, where it is transitional between the upland soils and those of the bottoms.

A few small areas are included, in which light-colored and light-textured materials, similar to those of the Gila soils, underlie the reddish-brown surface soil.

This soil occurs in only two bodies, both of which are in the southeastern part of the area. Similar soils in other areas in southern Arizona are fairly productive under irrigation.

Anthony gravelly loamy sand.—Anthony gravelly loamy sand, to a depth of about 12 inches, is light grayish-brown gravelly loamy sand, in which angular gravel is abundant. The materials are loose and porous and contain little or no lime. Pale reddish-brown or light reddish-brown gritty loam extends to a depth of about 4 feet. Lime has accumulated in fine veins forming a netlike pattern. Below a depth of 4 feet are light grayish-brown stratified materials, which are less calcareous than those above and consist largely of fine gravels and loamy sands.

This soil occupies the upper parts of the alluvial fans in the Sacaton Mountains. The relief is moderately to gently sloping. Numerous shallow stream channels traverse the areas and erode and deposit materials during rainy periods. The soil materials are derived entirely from granites.

This soil lies too high for obtaining water from any source for irrigation, and, therefore, none of it is farmed. It is too droughty to be desirable for agricultural development.

Papago sandy loam.—Papago sandy loam is closely related to Anthony sandy loam, from which it differs in being grayer and in containing more lime throughout. The surface soil is calcareous, and the somewhat red color of the Anthony soils is absent. In some places greater quantities of lime seem to be accumulated in the subsoil than in the subsoil of Anthony sandy loam, but the material nevertheless is friable and permeable.

This soil lies principally west of Santa Rosa Wash, but smaller areas are near Florence.

The land is not farmed, but, if it were, average yields probably would be somewhat lower than on Anthony sandy loam, owing to the high lime content.

Papago fine sandy loam.—The surface soil of Papago fine sandy loam, to a depth of 12 or 14 inches, is light grayish-brown mellow calcareous fine sandy loam. Angular fine gravel is sprinkled over the surface in most places. The surface soil is underlain to a depth ranging in most places from 36 to 40 inches by a layer of material with a higher content of lime and clay. This layer consists of light grayish-brown fine-textured loam and includes some small angular gravel. Fine veins of accumulated lime are discernible. Below this the materials are loose porous stratified fine sandy loam and fine sand with a sprinkling of angular gravel. These materials are slightly grayer and have a higher lime content than the surface soil. The stratified materials become coarser with depth. The parent rock materials are predominantly schist and gneiss.

Large areas of this soil lie west of Santa Rosa Wash on gently sloping alluvial fans broken by numerous shallow intermittent drainage channels. The texture varies greatly in places, owing to the erratic deposition of materials from these channels.

This soil is not farmed. Lift of water for irrigation and cost of pumping probably would be excessive, and the high content of lime in the soil might interfere somewhat with the availability of phosphorus and other mineral plant nutrients.

As mapped, Papago fine sandy loam includes a few lower areas of a somewhat finer textured soil. Here, the depth to ground water is less and the moisture capacity is slightly better than in the typical soil.

Papago loam.—Papago loam is grayer and more calcareous throughout than Anthony loam, which it resembles. The surface soil contains much lime, and the soil, as a whole, is similar to the other Papago soils. The land is not farmed, and the high lime content might decrease the availability of some of the mineral plant nutrients.

Sawtooth gravelly sandy loam.—The 10-inch surface soil of Sawtooth gravelly sandy loam is dull rusty reddish-brown friable noncalcareous sandy loam with a high content of gravel. The upper part of the subsoil is dull reddish-brown compact cloddy gravelly gritty loam faintly veined with lime. Below this and continuing to a depth of about 40 inches is reddish-brown gritty loam or clay loam that breaks into massive clods. Lime has accumulated in a faint network. Below this layer is a lighter reddish-brown, looser, lighter-textured, and more gravelly material that becomes more porous and droughty with depth. The parent materials are derived from dark-colored rocks, including basalt, andesite, and somewhat red rhyolites.

This soil is not extensive. The largest areas are on the fan slopes of the Sawtooth Mountains, and a few small bodies are near Picacho Peak.

This soil lies on moderately to gently sloping alluvial fans traversed by numerous shallow drainage channels. Surface drainage is rapid, and internal drainage ranges from good to excessive. None of this soil is farmed, and its future agricultural development is questionable, owing to the high pump lift, which would be necessary for irrigation. The productivity of this soil under irrigation should compare favorably with that of Anthony sandy loam. The gravel content and texture vary considerably from place to place, depending on the position. The most favorable parts lie at the lower elevations where the texture is somewhat heavier and the water-holding capacity is more favorable than is typical.

Nunez sandy loam.—The surface soil of Nunez sandy loam, to a depth of about 6 inches, is pale reddish-brown or pale-red noncalcareous gritty sandy loam having a friable soft cloddy structure. A very thin platy layer of light-colored material covers the surface. The upper part of the subsoil, between depths of about 6 and 26 inches, is pale-red or reddish-brown noncalcareous gritty loam that contains considerable colloidal clay and is plastic when wet. The layer below this extends to a depth of about 36 inches and consists of reddish-brown heavy loam. Faint veins of accumulated lime are present, and the clods are thinly coated with reddish-brown colloidal materials. These two layers are moderately compact and somewhat cloddy. Beginning at a depth of about 36 inches and extending to a depth of about 60 inches the material is reddish-brown or dull-red compact clay loam veined with accumulated lime. Lime and red and brown iron colloids coat the somewhat angular soil aggregates, which are hard and brittle when dry, although the material is very plastic when wet. Below this the material is pale-red loose loamy sand containing a little gravel.

Typically, the parent materials are dominantly from granitic rocks. As mapped in the vicinity of Picacho Peak, however, small areas are included, in which the soil is developed from dark-colored basalt, andesite, and rhyolite rocks. These included soils have a similar development and sequence of horizons as the typical soil, but the soil materials are darker. Had these areas been more extensive, they would have been recognized as soils of a different series.

The largest areas of this soil are in the northwestern part of the area on the alluvial fan slopes of the Sacaton Mountains. Small bodies lie southeast of Coolidge and in the vicinity of Picacho Peak. The total area is not large.

The very gently sloping surface is favorable for the distribution of irrigation water. Flooding may occur during rainstorms, but surface drainage is rapid. Internal drainage is good, and the moisture-holding capacity is very good. Injurious quantities of soluble salts have not accumulated.

Very little of this soil is farmed, owing to its general position above the level of available water by gravity. If supplied with water, it probably would be rather highly productive.

Nunez loam.—The 10- to 12-inch surface soil of Nunez loam is pale reddish-brown plastic gritty loam containing little or no lime. The thin platy surface layer breaks vertically into massive clods. The upper part of the subsoil is reddish-brown noncalcareous gritty clay loam. The layer between depths of 24 and 36 inches is slightly calcareous plastic gritty clay loam and is a more pronounced red than the material in the layer above. The slightly angular soil aggregates and clods are stained with reddish-brown colloidal coatings. This layer is underlain, to a depth of about 56 inches, by compact silty clay loam that is veined with accumulated lime and breaks into harsh angular soil aggregates. Reddish- and rusty-brown colloidal material high in iron coats the aggregates and quartz and other mineral grains. Below this are loose friable light reddish-brown sandy and sandy clay materials.

This soil is not so extensive as Nunez sandy loam, with which it is associated. The relief and drainage of the two soils are similar. The moisture-holding capacity of the loam is greater than that of the sandy loam. The loam probably would be a productive soil if irrigated, but it is not farmed, owing to its high elevation and lack of a supply of water for irrigation.

SOILS WITH MODERATE LIME ACCUMULATION

Soils with moderate lime accumulation are extensive and agriculturally important. The surface layers contain little or no lime, and the subsoils are compact and have moderate accumulations of lime.

Leaching probably has not greatly altered these soils, but apparently it has been sufficient to remove what little lime has accumulated in the surface layers to a depth ranging from 12 to 18 inches. In places some limy material has been deposited on the surface by drainage waters or has been brought up by burrowing rodents and insects, but generally the lime content is not sufficient to interfere seriously with the availability of phosphorus for plant growth. In general, the reaction of the surface soils is neutral or slightly alkaline. Mineral plant nutrients are comparatively abundant, but organic matter and nitrogen are deficient. These deficiencies may be overcome under irrigation farming, by using manures and by growing legumes in the crop rotation.

The soils of this group lie on alluvial fans and valley plains, which include low playa flats or depressed areas along drainageways. The lighter-textured soils occupying the fan slopes are well drained and permeable to plant roots and moisture, whereas the heavier-textured soils of the flats are subject to overflow or collection of surface drainage waters following rainstorms. Most of the areas are, however, free from injurious accumulations of salts.

This group includes the Mohave, Tubac, and Vekol soils.

The Mohave soils are characterized by 12- to 14-inch reddish-brown noncalcareous surface soils. The upper part of the subsoil is redder than the surface soil, has a considerable accumulation of clay, and contains little or no lime, but below this, lime is accumulated in light-colored veins and mottles and is concentrated just above the underlying more friable and porous parent materials. The lime segregations form soft to rather hard nodules on exposure. The entire subsoil is somewhat plastic and colloidal.

The Tubac series includes soils which are a deeper reddish brown than the Mohave soils, in places purplish brown or maroon. They are similar in appearance to Solonetz soils (in which sodium plays an important part in the soil development), although they are now free of toxic soluble salts and do not contain sodium clay. The heavy plastic subsoil has a high content of colloidal clay and a columnar structure. It is dense and refractory, and water and roots penetrate slowly, although they may find their way through vertical cracks.

The Vekol soils are dark reddish brown, the darker coloring being especially pronounced in the surface layer. They are heavy textured throughout yet are fairly friable and gritty. They are in a similar stage of development as the Mohave soils but are not so deeply leached of lime. In many places segregations of lime, on exposure, form soft nodules. The darker color appears to have originated from the deposition of dark-colored soil materials and organic matter by floodwaters.

Mohave sandy loam.—Mohave sandy loam has a surface soil, ranging from about 8 to 14 inches in thickness, of dull or pale reddish-brown friable gritty sandy loam, containing little or no lime and little organic matter. In most places gravel is scattered over the surface. The upper part of the subsoil, between depths of 8 to 14 inches and 14 to 18 inches, is reddish-brown noncalcareous gritty loam or clay loam that breaks into soft friable cloddy masses. Below this and continuing to a depth of 40 inches is a compact layer of plastic clay loam that has a more pronounced red color than the overlying layer, is moderately calcareous, and is veined and mottled with accumulated lime. The layer of greatest lime accumulation lies between depths of about 40 and 66 inches. It consists of grayish-brown somewhat variegated and splotched gritty sandy loam or loam. Below this are loose light-gray and reddish-brown calcareous stratified sands and subangular gravel. The predominant parent materials are from granite and related rocks, but there is also a scattering of dark-colored rock materials. A few pieces of gravel are present in most areas of this soil.

Like the other members of the Mohave series, this soil appears to be more deeply and uniformly leached in the vicinity of Picacho Peak and southward. Much of the soil contains no lime to a depth ranging from 16 to 20 inches, and it supports mainly an annual grass vegetation to the exclusion of other plants. Several miles west of Casa Grande this soil appears to have a more pronounced profile development than typical. Here, soft nodules of lime are accumulated in the subsoil and, in many places, are scattered over the surface. Gravel is thickly strewn over the surface in some areas, which are indicated on the map by gravel symbols.

This is the most extensive soil in the area and is widely developed. The larger bodies extend from Picacho southeastward to the county line. Large areas are in the vicinity of Casa Grande and southeast of Coolidge.

The land is comparatively smooth with very minor undulations and small hummocks, many of which must be leveled before irrigation water can be distributed satisfactorily. The slope, however, is generally favorable for irrigation, and moisture and plant roots penetrate readily.

Surface drainage is rapid, and internal drainage is good, in places somewhat excessive. The depth to underground water is in few places less than 40 feet, in most places much greater. In the northern part of the area it is economically feasible to lift water for irrigation, but in the southern part the greater depth to water renders the cost prohibitive. At present, most of the cultivated part of this soil is supplied by gravity water, supplemented by water pumped from wells.

Comparatively little of the typical Mohave sandy loam is farmed. Most of the cultivated areas have been modified by the silting that takes place under irrigation and are classified as silted phases, which are described separately. In the unsilted condition this soil is especially suitable for alfalfa, garden crops, and fruits that thrive best on comparatively light textured soils. Organic matter is deficient and must be supplied for continued satisfactory yields. Water requirements are comparatively high. Cotton yields from about ½ to ⅔

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of a bale an acre, alfalfa 2 to 5½ tons, small grains 20 bushels, and grain sorghums 1,000 to 1,500 pounds of grain.

Mohave sandy loam, silted phase.—The silted phase of Mohave sandy loam has been modified by silting to plow depth (6 or 8 inches), and the surface layer has been changed to dark reddish-brown gritty clay loam. Organic matter is more abundant and the productivity is higher than in the shallow silted phase. A small area of a silted phase of Continental sandy loam, about 4 miles southwest of Florence, is included with this soil as mapped. The subsoil of this included soil is somewhat tougher and less pervious than the corresponding layer of Mohave sandy loam, silted phase, and crop yields are slightly lower than those obtained on that soil.

Alfalfa yields are high on this soil, generally ranging from 4 to 6 tons an acre. Cotton produces an average of 1 bale. Yields of small grains range from 35 to 45 bushels and of grain sorghums from 2,000 to 3,000 pounds. The total area of this soil, however, is less than 1 square mile.

Mohave sandy loam, shallow silted phase.—This soil represents areas of Mohave sandy loam, in which dark organic silty material has been deposited over the Mohave material to a depth of only a few inches. In plowed fields this deposit has darkened the surface soil considerably and changed it to heavy sandy loam or gritty loam. The fertility of the soil has been increased and the moisture-holding capacity has been improved by the silting.

Productivity depends to some extent on the depth of the silt deposit and the degree to which legumes are used in the crop rotation. Alfalfa yields 2½ to 5½ tons per acre, cotton ¾ of a bale, small grains 20 to 35 bushels, and grain sorghums 1,600 to 2,000 pounds of grain. This is a productive soil for fruits, berries, and those vegetables that grow best on a light-textured friable soil.

This soil is widely distributed under the canal system, especially in the vicinity of Casa Grande.

Mohave sandy loam, deep phase.—This soil comprises areas of Mohave sandy loam, in which the friable noncalcareous surface soil is thicker than typical. The subsoil is more compact than the surface soil and in most places begins at a depth of more than 2 feet. Roots penetrate somewhat more rapidly, more frequent irrigation is required for the production of crops, and, in some places, the gravel content is greater than in typical Mohave sandy loam. The land is suitable for alfalfa and garden and fruit crops that are favored by a sandy, permeable soil.

Large bodies of this deep soil are in the northwestern part of the area.

Mohave sandy loam, hummocky phase.—The surface of this soil is modified by the presence of numerous wind-formed sandy hummocks, generally around the bases of desert shrubs. Most of the areas consist of lighter-textured loamy sand or sand, and some areas are included in which the sandy materials are piled into distinct dunes. As the expense of leveling this land for irrigation is prohibitive in most places and the water-holding capacity is low, the land probably should be excluded from irrigation projects.

Mohave loam.—The surface soil of Mohave loam is dull reddish-brown somewhat cloddy gritty loam that contains little or no lime and extends to a depth of 6 or 7 inches. Much of the surface is covered with a thin bleached vesicular crust. Although the material is somewhat plastic when wet and tends to bake in exposed fields, it is friable and can be maintained in good tilth under favorable conditions of moisture and cultivation. The upper part of the subsoil, extending to a depth ranging from 18 to 24 inches, is clay loam of a more pronounced reddish-brown color than the surface soil, contains little or no lime, is plastic when wet, and breaks vertically to a cloddy or indistinct prismatic structure. This material is underlain to a depth of about 40 inches by paler reddish brown clay loam that is netted with veins of accumulated lime and breaks into hard clods. At a depth of about 60 inches, this, in turn, gives way to lighter grayish brown gritty clay loam containing spots and seams of segregated lime, which in places in somewhat cemented or forms hard nodules. Below this layer are grayish-brown more friable and looser calcareous materials. The parent soil materials are derived mainly from granitic rocks.

In general, this soil has a somewhat smoother surface than Mohave sandy loam as it commonly occupies lower areas between the long, more elevated bodies of that soil. The slope is sufficient in most places for efficient distribution of irrigation water. Surface and internal drainage are good. The moisture-holding capacity of this soil is better than that of the sandy loam.

In the Santa Cruz River flood plain much of this soil is modified by dark-colored silty materials from floodwaters, and, where irrigated under the gravity system, it has been silted by irrigation waters. The modified soils are described as silted phases under separate headings. Typical unmodified Mohave loam is less productive than its silted phases but produces somewhat larger yields than Mohave sandy loam, especially in years of water shortage. Cotton yields about ⅔ of a bale an acre, alfalfa 3 to 5½ tons, small grains 25 bushels, and grain sorghums 1,200 to 1,800 pounds of grain. Garden crops, fruit trees, and berries grow well. Deficiencies in organic matter and nitrogen generally are supplied by legume crops in the rotation.

The total area, although fairly large, is less than that of Mohave sandy loam, with which this soil is associated. The supply of ground water for irrigation is about the same in the two soils.

Mohave loam, silted phase.—In most areas of the silted phase of Mohave loam, dark-colored silty and clayey materials with a high organic-matter content have been deposited from turbid irrigation waters over Mohave loam material to a depth of 6 or 8 inches. The silted phase, however, includes areas on the Santa Cruz River flood plain, in the vicinity of Eloy, in which the surface materials have been deposited from natural floodwaters. In parts of these areas the surface deposit is somewhat thick, in places as much as 12 inches thick.

The surface soil is darkened considerably and the texture is changed to clay loam or silty clay by these deposits. Owing to the high organic-matter content of the deposits and to the admixture of gritty material from the original surface soil, the heavier texture does not hamper cultivation or seriously retard the penetration of moisture.

Cotton yields from 1 to 1¼ bales an acre, alfalfa 4 to 6 tons, small grains 30 to 50 bushels, and grain sorghums 1½ to 2 tons of grain.

Areas on the Santa Cruz River flood plain in the vicinity of Eloy are used mainly in the production of cotton and truck crops and are irrigated by pumping from an underground source. The lift generally exceeds 80 feet, but during flood periods the lower areas are subject to overflow where not protected by levees.

Mohave loam, shallow silted phase.—In the shallow silted phase of Mohave loam dark highly organic silty deposits from floodwaters of the Santa Cruz River or from irrigation waters overlie normal Mohave loam to a depth of only a few inches. Where undisturbed, this produces a thin surface layer of highly fertile silty clay with a fine granular structure. If the land is plowed, the plow layer is heavy loam or clay loam. The silty materials from the Santa Cruz River are darker, more highly organic, and more granular than the materials deposited by irrigation waters from the Gila River.

This soil is more productive than typical Mohave loam and is considered desirable for cultivation wherever water is available for irrigation. In some places floodwaters have been artificially diverted over the original Mohave soil to build up the silted surface soil. Toxic quantities of soluble salts have not accumulated, except in a very few places, and internal drainage is good. In most places dikes and storm drains are necessary to protect the land from floodwaters. The underground water lies at a depth of more than 80 feet so that pumping for irrigation is expensive and infeasible.

This soil is suitable for a wide range of crops. Alfalfa yields from 4½ to 5½ tons an acre, cotton about 1 bale, small grains 30 to 40 bushels, and grain sorghums 2,000 to 3,000 pounds of grain. In the vicinity of Eloy the land, where farmed, is used principally for cotton, but much of it is still in an undeveloped desert condition.

Mohave loam, brown silted phase.—The brown silted phase of Mohave loam has a surface layer, ranging in thickness from less than 4 inches to 12 inches, of medium-brown or grayish-brown silty clay loam, apparently containing a moderate quantity of organic matter. This material, which has been deposited by floodwaters on the Santa Cruz River flood plain, is not so dark as Mohave loam, silted phase, in the same section or as the silty materials deposited by the Gila River. The brown silted phase of Mohave loam is associated with Pima silty clay loam, and it has a similar surface soil.

This soil is more productive than typical Mohave loam but not so productive as the silted phases of darker color and higher organic-matter content. Compared with these phases, however, it is somewhat lighter textured, more friable, and probably somewhat better suited to crops that are adapted to lighter-textured soils.

Small areas of this soil are scattered at wide intervals over the Santa Cruz River flood plain. Only a small acreage is farmed. Water lies more than 80 feet below the surface in most places; therefore, the cost of irrigation is high.

The land is comparatively well drained and free from salts and alkali, though low areas occasionally are flooded unless protected by dikes or levees.

Mohave loam, deep phase.—This soil has a thicker surface soil than typical Mohave loam, and in general the heavier subsoil is below a depth of 2 feet. Water and plant roots readily penetrate the subsoil. The soil is especially suitable for alfalfa and garden and fruit crops that are favored by a deep permeable surface soil, and larger yields of such crops are produced than on typical Mohave loam, although water requirements may be slightly higher for the deeper soil.

The small bodies of this soil, with a total area of less than one-half square mile, occur principally west of Casa Grande, within larger areas of the deep phase of Mohave sandy loam.

Mohave fine sandy loam.—The topmost 7 inches of Mohave fine sandy loam is friable pale reddish-brown uniform-textured fine sandy loam containing little or no lime. Below this is a more compact layer of heavy loam, which is noncalcareous and of more pronounced reddish-brown color. Beginning at a depth of 12 or 14 inches the material is reddish-brown calcareous clay loam. The layer of highest lime accumulation lies between depths of 4 and 5 feet and consists of grayish-brown plastic loam veined and spotted with accumulated lime. The underlying material is stratified loose porous fine sand, medium sand, and gravel. The parent materials are derived predominantly from granites and related rocks.

This is not an extensive soil. It occurs principally in one area west of the Santa Cruz River (new channel) in the extreme northwestern part of the area. Relief and drainage conditions are similar to those features of Mohave sandy loam. The land is not farmed but should have about the same productivity as the sandy loam.

Mohave clay loam.—The 4-inch surface soil of Mohave clay loam is dull reddish-brown or pale reddish-brown friable gritty clay loam containing little or no lime. It breaks up into rather hard clods. A thin bleached laminated layer covers the surface. The upper part of the subsoil, extending to a depth of about 18 inches, is more pronounced reddish brown than the surface soil and consists of gritty clay loam containing no lime. It is fairly compact, but the clods break down readily under pressure. Below this and continuing to a depth of about 35 inches is pale reddish-brown calcareous gritty clay or clay loam containing light-colored veins of accumulated lime. This material is more compact and harsh than that of the layer above. It grades into reddish-brown or brownish-red gritty clay or clay loam, in which lime is concentrated and, in the lower part of the layer, becomes more prominent as spots and seams. These lime accretions harden on exposure. Below a depth of about 70 inches is brown clay loam that is more friable than the overlying material and changes with depth to stratified clayey sands and sand. The parent soil materials are derived mainly from granitic rocks.

The smooth and flat to gently sloping surface in most places is favorable for the distribution of irrigation water. The position of the land subjects it to frequent flooding during the rainy season, but run-off is rapid. The soil absorbs water slowly but retains it very well and is free from toxic soluble salts.

The largest areas are in the vicinities of Picacho and Redrock, and small bodies are east of Coolidge. Most of the land that is farmed has become silted by irrigation sediments. In the unsilted state the deficiency of organic matter impedes cultivation, but, with the use of legume crops, green manures, and barnyard manure, the tilth can be materially improved and the soil made fairly productive. This soil is best suited to cotton and small grains.

Mohave clay loam, silted phase.—In the silted phase of Mohave clay loam the surface soil has been modified by silting to a depth of 6 or 8 inches. The deposit changes the color of the surface soil to dark reddish brown and the texture to gritty heavy clay loam of fairly granular structure. This is a highly productive soil, but, because of its heavy texture, it is better suited to cotton and small grains than to alfalfa and other crops favored by lighter-textured soils. Cotton yields 1¼ to 1½ bales an acre, small grains 35 to 55 bushels, and grain sorghums 1½ to 2 tons of grain.

Mohave clay loam, shallow silted phase.—In this soil the dark highly organic sediments deposited from turbid irrigation waters have accumulated to a depth of several inches, and in plowed fields the soil appears materially darkened. The texture is not appreciably changed by the shallow deposit of silt, but the productivity of this soil is greater than that of the virgin soil and fairly good crops of cotton and small grains are obtained.

Mohave silty clay.—The 6-inch surface soil of Mohave silty clay is pale reddish-brown or dull reddish-brown tough silty clay containing little or no lime. The depth of this layer varies, however, and in places the texture and color are modified by an overwash of foreign materials. In some such places the material is calcareous and light grayish brown. Between depths of about 6 and 14 inches, the material is dull reddish-brown compact cloddy silty clay containing little or no lime, except in places where limy overwash has made it slightly calcareous. The next lower layer continues to a depth of about 50 inches and consists of reddish-brown dense plastic silty clay. Lime is accumulated in veins and spots, and red colloidal material coats the angular soil aggregates. Below this is a layer that has a higher lime content and consists of light-brown silty clay mottled with lime. The clayey fine sand and silt parent materials, derived mainly from granites and related rocks, are reached at an average depth of about 70 inches.

This soil is more extensive than the associated Mohave clay loam. The largest area is between Picacho Peak and Redrock.

As the land is rather flat, surface drainage is slow. The soil occurs in playas and basins, many of which are barren of vegetation and are subject to flooding during rainy periods. Internal drainage is slow, but the deeper underdrainage is good so that toxic salts have not accumulated in most places. The ground-water level stands at a depth of 70 feet or more below the surface.

This soil is more intractable and resists penetration of water to a greater extent than Mohave clay loam. The same treatment could be used to overcome these undesirable features as is practiced on Mohave clay loam. None of this soil is farmed. It lies above any source of gravity water for irrigation, and the cost of pumping water from wells is prohibitive. With irrigation, cotton and grain crops could be grown, but probably only fair yields would be obtained.

Tubac clay loam.—The 2-inch surface layer of Tubac clay loam consists of pale-brown or light reddish-brown gritty clay loam that contains little or no lime and has a friable vesicular structure. It is underlain abruptly by dark-red or maroon gritty clay loam or clay with a columnar structure. The tops of the columns are somewhat rounded and thinly coated with grayish-white siliceous material. The soil aggregates are coated along fractures with dark reddish-brown colloidal stains. This layer extends to a depth of about 14 inches and contains little or no lime. Beneath it is less pronounced red gritty clay that has a prismatic structure and breaks into cubelike fragments. White specks of accumulated lime are scattered through this layer. At a depth of about 40 inches, the material grades into more friable reddish-brown clay loam with a higher lime content and less definite structure. Between depths of about 60 and 72 inches is the layer of greatest lime accumulation, which consists of somewhat compact and softly cemented gritty clay loam. It is paler reddish brown than the material above. Below a depth of 96 inches lime appears to be disseminated in loose strata of clayey sand and coarse sand, which become more porous with depth. In this area the parent materials are dominantly granitic.

This soil is not extensive. It is associated with the Mohave soils east and southeast of Coolidge.

The broad flats or depressions in the extensive alluvial fans occupied by this soil are flooded during rainy periods, but run-off is rapid. As internal drainage is slow, water is absorbed very slowly. The deeper underground drainage is good. No toxic salt accumulations exist at present, but the unfavorable structure may be due to a previous condition of sodium-saturated clay.

The soil has been farmed only where gravity irrigation water is available, and this has given rise to silted phases. In the unsilted state the soil is very tough, intractable, and difficult to maintain in good tilth, but, owing to the high content of gritty sand, it is sheared fairly well in plowing under favorable moisture conditions and becomes more friable with cultivation. Incorporation of organic matter from barnyard manure, green manure, and legumes in the crop rotation is essential in its use. In many places on the lower parts of the flats, the soil has a clay texture and is even more difficult to manage than the typical soil.

Tubac clay loam, silted phase.—In this soil the silty deposits extend to plow depth, that is, to a depth of 6 or 8 inches. The surface soil is changed to dark-brown heavy but granular clay loam, and the productivity of the soil is definitely improved by the deposits. The total area of this soil is very small. Cotton yields about 1 bale an acre, small grains 25 to 45 bushels, and grain sorghums 1 to 1¼ tons of grain.

Tubac clay loam, shallow silted phase.—This soil is modified by dark highly organic silty material from irrigation waters to a depth of several inches, which changes the properties of the surface soil, so that in plowed fields it is materially darkened. Although the virgin soil contains much plastic clay, it also contains much gritty sand, which renders it more easily cultivated. Sandy materials from higher lighter-textured soils have been carried over the surface in many places in the process of leveling the land for irrigation, and these, together with the dark-colored sediments, improve the soil materially and make it more productive. The shallow silted phase of Tubac clay loam is even less extensive than the silted phase.

Cotton, small grains, and grain sorghums can be grown successfully. Cotton yields about three-fourths of a bale an acre, small grains 20 to 35 bushels, and grain sorghums 2,000 pounds of grain.

Vekol clay.—The 12-inch surface soil of Vekol clay is rather dark reddish-brown clay containing a large quantity of granular and gritty material that makes it fairly friable. It contains little or no lime. There is a thin platy surface layer, below which the material has a cloddy or prismatic structure. Below this is a more red compact clay veined with accumulated lime. The clods are stained with red colloids. This material is somewhat gritty, but the grittiness is obscured when the soil is wet, owing to the high clay and colloid content. At a depth of about 30 inches, this layer is underlain by paler red very plastic gritty sandy clay or clay. The red colloidal stains are less pronounced than in the layer above. The accumulated lime forms distinct spots and on exposure hardens to form soft nodules. Loosely stratified grayish- and reddish-brown clayey sands and gravel are reached at a depth of about 96 inches.

This soil lies on the alluvial plain west of Casa Grande where it occupies smooth playa flats and basins in association with long slightly higher ridges of the Mohave soils. It is developed from mixed parent materials, in which dark-colored constituents appear to be more abundant than in most of the other soils of the area, with the exception of the Pima and other recent alluvial soils and superficial layers of silty material.

Many of these areas are flooded during the rainy season, but run-off is fairly rapid. Internal drainage is slow, but the underdrainage is good. The water table stands between 50 and 70 feet below the surface in most of the areas. The greater part of the soil is free from toxic accumulation of soluble salts. The barren areas in this soil are caused by repeated flooding, baking of the surface soil, and the difficulty with which plants become established in such a heavy and compact soil.

None of this soil is farmed. It is in a section where gravity water is not available, and the cost of pumping is prohibitive. It is not so difficult to cultivate as is Mohave silty clay, owing to its better granular structure and permeability. With proper cultivation and crop rotations fair yields could be obtained under irrigation.

Vekol clay, deep phase.—In the deep phase of Vekol clay a recent deposition of colloidal clay materials seems to have taken place, which has increased the depth and plasticity of the surface soil. This soil occurs chiefly along drainageways where it is subject to frequent flooding. The possibilities for agricultural development are less than for typical Vekol clay, owing to the deep intractable and impervious surface soil.

SOILS WITH HIGH LIME ACCUMULATION

Soils with high lime accumulation have comparatively mature profiles and a pronounced accumulation of lime in the subsoils. The Continental soils contain no lime in the surface layer, whereas the Laveen soils are highly calcareous throughout.

The Continental soils are a somewhat more pronounced rusty reddish brown, have greater accumulations of clay and colloid in the subsoil, and contain more lime than the Mohave soils. The lime layer is not cemented, and water and roots penetrate it readily, but, apparently, the high concentration of lime has a certain inhibiting effect on plant nutrition and root development. The surface soil is deep enough, however, to provide a feeding zone, in which lime does not interfere with the availability of plant nutrients. The elevation of the Continental soils generally is slightly higher and the relief is more undulating and sloping than the Mohave soils. These soils are inextensive and unimportant.

The high lime content throughout the Laveen soils probably interferes with the availability of certain mineral plant nutrients, especially phosphates. The subsoils, especially, are very highly calcareous, rather compact, and contain many hard lime-cemented nodules.

Organic matter is very deficient in both the Continental and Laveen soils in their natural state, but these deficiencies may be overcome by using barnyard manure, green manures, and legumes in the crop rotations. Organic residues tend to reduce the alkalinity of the soil and to increase the availability of plant nutrients.

Many of these soils have a gently sloping surface well suited to the efficient distribution of irrigation water. Moisture is readily absorbed and well retained, and good yields of crops are obtained under irrigation. The irrigated areas have become silted by dark-colored sediments, and the content of organic matter, as well as the moisture-holding capacity, has been increased thereby. Most of the farmed areas lie under the gravity canal system. In this same location underground water also is available at a depth of about 35 to 70 feet.

All the crops commonly grown in this section are grown on these soils. Crops, especially alfalfa, that require comparatively large quantities of phosphates may suffer from a deficiency of this nutrient, but this is minimized by the addition of the fertile sediments from irrigation waters.

Continental sandy loam.—The 6-inch surface soil of Continental sandy loam is rusty reddish-brown friable gritty sandy loam containing little or no lime. A thin light-colored crust covers the surface. The surface soil is underlain to a depth of 14 inches by reddish-brown or dull-red noncalcareous highly colloidal gritty clay loam or clay with a cloddy structure and irregular vertical cracks. Angular soil aggregates are coated with dull colloidal stains. Below this is a layer of redder and more colloidal material, which extends to a depth of 32 inches. A few lime seams appear in the lower part of this layer, and shiny reddish-brown iron colloidal stains occur on the surfaces of soil aggregates and throughout the soil mass. The greatest accumulation of lime is in the next lower layer, which is a light pinkish-gray gritty mass of clayey sand and fine angular gravel. Loose strata of sands and gravel are reached at a depth of about 56 inches below the surface. The parent soil materials are derived predominantly from granites and related rocks.

Variations are more numerous in this soil than in the younger soils. In places the surface soil is very thin. The colloidal clay layer varies considerably in thickness and in places is not distinctly separated from the lime layer. Here, lime generally is associated with accumulations of reddish-brown clay and appears as large spots or splotches.

The total area is not large, but the soil is widely distributed. Most of it lies high on the alluvial fan slopes near the mountains. Only the areas under the gravity canal east of Coolidge are farmed. Some of these have been modified by the irrigation sediments and are separated as a shallow silted phase.

Surface drainage is rapid, owing to the high sloping position; internal drainage is slow but sufficient; and the moisture-retaining properties are good. No toxic salts have accumulated.

As mapped east of Coolidge this soil includes a few very small areas in which erosion has thinned the surface soil and subsoil. The subsoil is exposed along many of the drainageways, where this highly calcareous material hardens to soft nodules or fragments.

Continental sandy loam, shallow silted phase.—In this soil the dark-colored sediments deposited from gravity irrigation water are laid over the original Continental sandy loam to a depth of several inches, the surface soil is materially darkened, and the texture generally is a gritty loam. The productivity of the soil is increased in proportion to the depth of the silting. Yields are somewhat less than on the corresponding phase of Mohave sandy loam.

Laveen fine sandy loam.—The surface soil of Laveen fine sandy loam, to an average depth of about 10 inches, is highly calcareous light grayish-brown soft friable fine sandy loam containing a few small firmly cemented nodules of lime. Below this and continuing to a depth of about 20 inches is a slightly more brown and slightly more compact gritty fine-textured loam that has a pink or pale-red cast and contains many hard lime nodules. The next lower layer is light gray, is rather compact, and consists largely of hard lime nodules embedded in softer material. Moisture and roots readily penetrate the layer. Below a depth of 44 inches are light grayish-brown friable or loose loamy sand and sandy loam materials with some lime infiltration. The parent materials originated predominantly from granite, schist, and gneiss. The high lime content has been acquired in the process of soil development.

Bodies of this soil are widely scattered throughout the area. It occupies both alluvial fans and flood plains, but, as it generally occupies the more elevated parts, it is comparatively free from flooding. Internal drainage is good, and underdrainage is sufficient. Water is absorbed fairly rapidly and is retained well.

Most cultivated areas of this soil are under the gravity-canal system, and much of the original Laveen fine sandy loam has been silted by irrigation or is rapidly becoming so. All crops common to the area are grown on this soil, but cotton, small grains, and grain sorghums are the most successful. Alfalfa yields 1½ to 3 tons an acre, cotton one-half to three-fourths of a bale, small grains 15 to 25 bushels, and grain sorghums ½ to 1 ton of grain.

Laveen fine sandy loam, silted phase.—This soil represents areas of original Laveen fine sandy loam material that has been covered by dark sediments from irrigation water to a depth of 6 or 8 inches. These sediments darken the color of the surface soil to dark grayish brown; generally change the texture to gritty clay; and, owing to their high organic-matter content, greatly increase the productivity of the soil. Alfalfa yields about 2½ to 5 tons an acre, cotton ¾ to 1¼ bales, small grains 20 to 40 bushels, and grain sorghums 1 to 1½ tons of grain.

Laveen fine sandy loam, shallow silted phase.—This soil is silted to a depth of several inches by dark sediments from irrigation waters, which have modified the surface soil to plow depth, materially darkened the soil, changed the texture to loam, and increased the productivity of the soil. Alfalfa yields from 2 to 4 tons an acre, cotton about three-fourths of a bale, small grains 20 to 30 bushels, and grain sorghums ¾ to 1¼ tons of grain.

Laveen fine sandy loam, deep phase.—The deep phase of Laveen fine sandy loam is deeper, more friable, less calcareous, and more brown or red than the typical soil. Lime nodules are sprinkled over the surface and throughout the soil and are concentrated in a layer that lies below a depth of 4 feet in most places. This layer is more open and friable and contains fewer nodules than the corresponding layer of the typical soil. Moisture penetrates deeply and is retained well. The greater depth, greater friability, and smaller lime content of this soil make it slightly more productive compared with typical Laveen fine sandy loam.

Laveen fine sandy loam, hummocky phase.—The fine sandy surface soil of this soil has been blown into numerous hummocks, mostly around brush. The cost of leveling for irrigation is greater than for the typical soil and in most places is prohibitive. This is an inextensive soil, which is used only for the meager grazing it affords.

Laveen fine sandy loam, eroded phase.—Areas of Laveen fine sandy loam that are severely eroded and whose relief is too rolling and steep for irrigation farming are separated as an eroded phase. The thickness of the surface soil varies greatly, and the highly calcareous nodular subsoil is exposed in many spots. This is an inextensive soil which is used only for the scant grazing it affords. It is unsuited to agricultural development.

Laveen silt loam.—The 14-inch surface soil of Laveen silt loam is light grayish-brown highly calcareous fine-textured silt loam. It is rather friable, contains scattered lime nodules, and breaks up into soft clods. Below this is a light grayish-brown nodular layer with a slight pink tinge. The nodules are hard and occupy a large part of the space but are embedded in soft only slightly compact fine-textured silt loam materials. This layer extends to a depth of 44 inches where it rests on soft or loose fine sandy loam and loamy fine sand containing some lime nodules. The color is light gray or light grayish brown with a pink tinge. The parent soil materials are derived chiefly from schists, gneisses, and granites. The high lime content of the materials is not inherent in the parent rocks but is the result of soil development.

This soil is less extensive than Laveen fine sandy loam, but it is distributed just as widely throughout the area on fan slopes and flood plains. It lies at slightly lower elevations than that soil and occasionally is flooded. The slope is sufficient, however, to allow rapid run-off. Water is absorbed rapidly. This soil has a better moisture-holding capacity and, consequently, slightly higher productivity than Laveen fine sandy loam.

Laveen silt loam, silted phase.—In the silted phase of Laveen silt loam the deposit of dark silt and clay materials from the flood or irrigation waters ranges in thickness from 4 to 12 inches. The texture is changed to silty clay or clay loam, and the fertility is increased according to the depth of silting. The modified surface soil has a granular structure. Underdrainage is good in most places. Much of the land is subject to overflow during floods, and dikes and storm drains are essential for protection against this hazard. A few small areas in the lower part of the Santa Cruz River flood plain contain toxic quantities of salts, and here the material is slick and intractable in some places.

In the areas near Eloy, water may be obtained for irrigation by pumping from a depth ranging from 80 to 100 feet. This is a high lift, and only high-priced crops justify the expense of pumping. Cotton and truck crops are the principal crops grown. Cotton yields about ¾ to 1¼ bales an acre, small grains 20 to 35 bushels, and grain sorghums 1 to 1½ tons of grain.

Laveen silt loam, shallow silted phase.—The shallow silted phase of Laveen silt loam consists of areas of Laveen silt loam which have been modified by deposition of sediments from floodwaters of the Santa Cruz River or from turbid irrigation waters to a depth of only a few inches. This material has, however, been incorporated in the surface soil through cultivation, giving rise to darker color, heavier texture, and more plastic consistence than are characteristic of the unmodified soil. The materials deposited from floodwaters of the Santa Cruz River are very fertile sediments similar to the Pima soils of this section. They have a silty clay texture and a fine granular structure. They are darker, more highly organic, and more granular than those originating from the Gila River. The fertility of the soil is markedly improved by these deposits, and the land is cultivated wherever it is economically feasible to lift water for irrigation. Most of this soil is near and west of Eloy where the water lift ranges from 80 to 100 feet. Although the soil occupies comparatively low flat areas, it is well drained and generally free from toxic accumulations of salts. The cultivated land should be protected from flooding by storm drains and dikes.

Laveen silty clay loam.—The 8-inch surface soil of Laveen silty clay loam is light grayish-brown compact cloddy plastic silty clay loam containing a few lime nodules. The layer below this consists of slightly browner and more compact silty clay loam, in which lime is accumulated in seams and nodules. Between depths of 20 and 50 inches is fairly compact light grayish-brown or light-gray silty clay loam. This rests on light-gray loose fine-textured loam and fine sandy loam materials.

This is an unimportant soil and is associated with the other Laveen soils in small widely scattered areas. Its low position along drainageways subjects it to flooding during rainy periods. Internal drainage and absorption of water are slower than in the other Laveen soils. Underdrainage is sufficient, however, and toxic quantities of soluble salts collect in but few places. The farmed areas have been silted by sediments from irrigation waters. Cotton and small grains are the most successful crops, but yields are less than on the other Laveen soils.

SOILS WITH LIME HARDPANS

Some of the soils with indurated lime hardpans have little or no lime in the surface soils, and others have highly calcareous surface soils.

The soils with noncalcareous surface soils are neither extensive nor important. Two series, the Palos Verdes and the Teague are included in this subgroup. They occupy fans and foot slopes surrounding the mountains and have little or no potential value for agriculture, owing to their poor quality and the lack of a water supply for irrigation. The slope in general is steep, and the surface is broken by drainage channels. The soils are shallow and are underlain by lime-cemented and indurated hardpans, which are exposed at the surface in some places.

The Palos Verdes soils are developed on old valley-filling deposits mainly from granites and related rocks. They have reddish-brown or brownish-red surface soils over somewhat darker brownish-red tough colloidal upper subsoil layers, which contain considerable angular grit. Colloids high in iron penetrate into and stain the underlying indurated hardpan, which apparently is cemented largely by lime.

The Teague soils are formed largely from basaltic and andesitic materials. The surface soils are rather dark reddish brown, or maroon red, and the upper subsoil layers are commonly redder than the surface soils, tough, plastic, and highly colloidal, and have a shiny vitreous appearance on the surfaces of the clods. The indurated lime hardpan is glazed where it comes in contact with the overlying layer and shows some iron staining in the upper part.

The soils in which surface soils, as well as subsoils, contain much lime include soils of the Toltec, Pinal, and Coolidge series. The Toltec and Coolidge soils have somewhat softer or more fragmental hardpans than the Pinal soils, which are underlain by massive cemented material of rocklike hardness. All these soils have a restricted rooting zone and comparatively low water-holding capacity. Organic matter and nitrogen are deficient but may be supplied by manure, green manure, and legumes in the crop rotation. Addition of organic matter also tends to reduce the alkalinity, thereby making plant nutrients, especially phosphates, more readily available. The position of most of these soils above the level of the gravity canal system, however, together with their comparatively low productivity, especially of the Pinal soils, has prevented the agricultural development of most areas.

The Toltec series includes soils in which the lime has accumulated and segregated into cemented fragmental hardpans, apparently under the influence of a former high but fluctuating water table. These fragmental layers alternate in many places with layers of soft, or loose, fine-textured materials. The water table stands more than 40 feet below the surface in most places, and successive strata of caliche and clay to such depths are evidence of its periodic subsidence. The soluble salt content is comparatively high, especially in the lime strata, but in most places salts have not accumulated in toxic quantities. Under irrigation the salts may move and concentrate. The cemented materials are fragmental and, in contrast to the dense lime hardpan in some soils in this group, allow the penetration of roots and especially water to greater or less degree. The friable surface soils absorb moisture readily and retain it well, and, since the lime hardpan layers do not seriously impede the penetration of water, these soils have fairly good moisture-holding capacity. Most of them have a smooth and gently sloping surface, a comparatively high position, and good surface drainage. Only small areas lie below the gravity canal system. North of Eloy on the Santa Cruz River flood plain, natural dark silty deposits have greatly increased the fertility of the soil, and, here, irrigation by pumping is developing rapidly.

At a slight depth the Pinal soils are underlain by massive conglomeratelike hardpan (pl. 2, B), which is almost impenetrable to both roots and water and continues to considerable depth. Hardpan outcrops on the surface in spots. The land ranges from smooth to rough and dissected. The high position of the soils above sources of water supply, as well as their low quality, renders them almost valueless for agricultural development.

The Coolidge soils have light grayish-brown friable surface soils over compact limy subsoils that consist largely of almost white very hard round concretions of lime, about ½ to 1 inch in diameter, set in softer browner uncemented or only softly cemented sandy material. The subsoils are underlain by porous gravelly stratified materials at a depth ranging from 5 to 10 feet. The nodular layer generally is somewhat more firmly cemented where it comes in contact with the porous substratum. The alluvial fans or terraces occupied by these soils range from smooth to somewhat rough and dissected. Surface drainage is good, but internal penetration of moisture is slow. Only small areas are under cultivation, and the soils are not so productive as most of the soils without hardpans.

Palos Verdes sandy loam.—Typical Palos Verdes sandy loam, to a depth of about 6 inches, is reddish-brown gritty sandy loam containing no lime. It commonly includes considerable quantities of angular granitic sands and fine gravel. In a few places recent overwash makes the material slightly calcareous. The next lower layer consists of brownish-red or rusty reddish-brown softly cemented gritty material. The cementing materials appear to be colloids and lime, and they increase with depth, forming glazed surfaces on structural aggregates at the top of the underlying indurated layer. The grayish-white indurated lime hardpan lies at a depth of about 24 inches. It is comparatively soft and iron-stained in the upper part but grades into a hard conglomeratelike mass, which continues to an undetermined depth.

In some areas, indicated on the soil map by gravel symbols, large quantities of gravel are present in the surface soil. Also included in mapping are severely eroded areas in which the layer of uncemented soil material is very thin and the underlying hardpan is exposed in numerous spots. This soil is not under cultivation, its total area is small, and its potential agricultural value is very low.

Teague gravelly loam.—The 2½-inch surface layer of Teague gravelly loam is dull reddish-brown gravelly loam of vesicular structure, containing little or no lime. The surface is covered by a "desert pavement" of dark-colored rocks, mostly basalt, andesite, and purplish-brown rhyolite. Between depths of about 2½ and 20 inches the material is dark brownish-red highly colloidal tough plastic gravelly clay. Shiny colloidal glazing coats the soil particles or aggregates throughout the soil mass, which is broken by vertical and horizontal cracks. This layer contains little or no lime in most places but is faintly calcareous where the land has been overflowed by water containing limy materials. Massive conglomeratelike hardpan lies at a depth of about 20 inches and continues indefinitely. This hardpan has some iron staining where it comes in contact with the subsoil. Stones are strewn over the surface of some higher lying areas shown on the soil map by stone symbols.

This soil occurs chiefly in the vicinity of Picacho Peak and to less extent near the Sawtooth Mountains.

The lower slopes of the alluvial fans are smoother, are more gently sloping, and are cut by fewer drainage channels than the alluvial fans occupied by the typical soil. Here the surface soil is thicker and contains less gravel than elsewhere and in places is sandy loam instead of loam.

Teague gravelly loam is not under cultivation and is not suited to agricultural development, because of its shallowness and high position away from possible sources of irrigation water.

Toltec fine sandy loam.—The surface soil of Toltec fine sandy loam, to a depth of about 14 inches, is light grayish-brown or pale reddish-brown highly calcareous uniform-textured fine sandy loam containing small angular lime-cemented fragments. The next lower layer consists of hard brittle slightly cemented accumulations of lime and iron that break into mottled grayish-brown, reddish-brown, and red fragments. This gives way, at a depth of 30 inches, to looser material of pale pinkish-brown fine sandy loam in which iron-stained and lime-cemented fragments occur. Between depths of 54 and 80 inches is a layer of mottled gray and rusty-brown softly cemented material with a platy fragmental structure. Looser materials are between the fragmental plates. This layer, in turn, rests on highly calcareous sands and gravel with an infiltration of lime. The parent materials are predominantly derived from schists, gneisses, and granites.

This soil occurs mainly northward from Eloy along the western side of McClellan Wash, in the general section of the Toltec soils. It occupies the higher smooth areas and has more rapid surface drainage than most of the Toltec soils. For the most part internal drainage is not greatly restricted by the fragmental hardpan under natural conditions, and water is readily absorbed and retained. Clay and caliche strata may, however, restrict percolation of water if the land is heavily irrigated.

This soil is not extensive. Only small areas are under the gravity canals, and the pumping lift is too high to be economically feasible. Ground water lies at a depth ranging from 60 to 100 feet in most places. The soil is used chiefly in the production of cotton and grain sorghums. It is less productive than Laveen fine sandy loam.

Toltec fine sandy loam, silted phase.—In this soil, dark-colored sediments from irrigation waters have been deposited to a depth of only a few inches but have materially darkened the surface soil and changed the texture to loam. The productivity of the soil is materially improved, especially by the increase of organic matter and nitrogen. Cotton, small grains, and grain sorghums are the chief crops. Cotton yields one-half to three-fourths of a bale an acre, small grains 15 to 25 bushels, and grain sorghums ½ to 1 ton of grain. Alfalfa returns low yields, but it is valuable in crop rotations to add organic matter and nitrogen. This soil occurs chiefly in three small areas southwest of Florence.

Toltec fine sandy loam, hummocky phase.—This soil represents areas of Toltec fine sandy loam that are covered by numerous hummocks of wind-blown fine sandy material, which has lodged around the brush. This feature adds materially to the expense of leveling the land for irrigation, and the soil is not adapted to agricultural development under present economic conditions.

Toltec fine sandy loam, eroded phase.—Badly eroded areas of Toltec fine sandy loam are steep and rolling and are unsuited for agricultural development. The soil material is very highly calcareous, and there are many exposures of fragmental lime hardpan. Most of this soil is southwest of Florence.

Toltec loam.—The surface soil of Toltec loam, to a depth of about 18 inches, is mellow light grayish-brown or pale pinkish-brown loam or fine sandy loam. Light-gray and red-stained lime-cemented fragments are scattered throughout this layer. Below this is a fragmental hardpan layer consisting of hard but brittle angular masses with looser interstitial material. When moist, the material in this layer is rather red, veined with brown; but, when dry, it is grayish brown. Between depths of 24 and 40 inches is light pinkish-brown fine sandy loam or silty clay loam, containing angular hardpan fragments. This material gives way to a layer of mottled gray and reddish-brown hard brittle angular fragmental lime-cemented material that extends to a depth of about 60 inches, where it rests on grayer material that is softly cemented by lime and contains many fragments. The parent soil materials are predominantly from schist and gneiss.

This soil occurs mainly northward from Eloy west of McClellan Wash and is more extensive than Toltec fine sandy loam. It lies on the higher parts of the flood plain and is comparatively free from flooding. Water is absorbed readily and is retained well by the surface soil, but, as in other Toltec soils, penetration of roots and moisture, as well as internal drainage, probably are retarded by the compact cemented subsoil and substratum.

Where farmed, most of this soil is irrigated by water pumped from wells. The lift ranges from 60 to 100 feet. Cotton and grain sorghums are the main crops. Slightly better yields are obtained than on Toltec fine sandy loam.

Toltec loam, deep phase.—In the deep phase of Toltec loam the fragmental hardpan lies more than 4 feet below the surface. This allows more ready penetration of moisture and roots and increases the productivity, compared with typical Toltec loam. It is about as extensive, lies in the same general section, and is used in the production of the same crops as Toltec fine sandy loam. Yields are about the same as those obtained on Laveen fine sandy loam.

Toltec loam, silted phase.—Areas of Toltec loam modified by a deposit of dark highly organic silt and clay to a depth ranging from 4 to 12 inches are separated as a silted phase. This surface soil material is very fertile, and the soil is valuable for agriculture. It lies in the same general section and has about the same water lift as the shallow silted phase of Toltec loam. Cotton, the principal crop, yields from ¾ to 1 bale an acre.

Toltec loam, shallow silted phase.—The shallow silted phase of Toltec loam consists of areas of Toltec loam that have been covered by a thin layer of dark granular silt and clay sediments of high organic-matter content from the Santa Cruz River. The fertility is increased over that of the typical soil in proportion to the depth of the deposit, which reaches a maximum of 4 inches. Much of this soil is being developed and is planted to cotton. It occurs mainly north of Eloy where the water level is from 70 to 100 feet below the surface. The soil is subject to flooding during rainy periods but otherwise is well drained and generally free from toxic quantities of soluble salts.

Toltec loam, brown silted phase.—In the brown silted phase of Toltec loam the surface sediments from floodwaters of the Santa Cruz River contain less organic matter than the sediments of the other silted Toltec soils. They are of medium-brown to grayish-brown color and are silty clay loam in texture. The deposit of sediments, which ranges in thickness from a few inches to as much as 3 feet, is less fertile than the darker silts and in many places contains toxic quantities of salts or overlies original soil materials of high salt content. In general, this soil is less favorable for farming and is less productive than the shallow silted phase of Toltec loam. Most of it lies north of Eloy and near Toltec. The lift in pumping for irrigation is from 65 to 100 feet.

Toltec silty clay loam.—Toltec silty clay loam, to an average depth of about 16 inches, is light grayish-brown calcareous silty clay loam that breaks into friable clods. Angular lime nodules stained reddish brown are scattered over the surface and throughout the surface soil. The surface soil is underlain to a depth of 40 inches by dull reddish-brown or pale reddish-brown fragmental lime-cemented hardpan stained with iron. This material breaks into hard fine angular fragments. Below this is grayish-brown fragmental rather softly cemented lime hardpan. Light grayish-brown loose stratified fine sand and medium sand are reached at a depth of about 72 inches.

Long flat areas of this soil border drainageways, principally west of McClellan Wash. Flooding occurs during rainy periods, but runoff is rapid. Underdrainage is fair, although under irrigation caliche and clay strata in the subsoil and substratum would retard the free percolation of water and pentration of roots. This soil is less productive than the other Toltec soils, and very little is farmed. The water lift for irrigation ranges from 55 to 90 feet.

As mapped a few very small areas are included, in which the layer of uncemented soil material is thicker than typical and is more permeable to roots and moisture.

Pinal sandy loam.—To a depth of about 14 inches, Pinal sandy loam is light grayish-brown or light pinkish-brown highly calcareous friable gritty sandy loam containing hardpan fragments and gravel. The lower part is somewhat compact and cloddy. The surface soil rests on a conglomeratelike lime-cemented hardpan that continues to an undetermined depth. At a lower depth, coarser gravel and stone are embedded in the hardpan and successive layers with glazed surfaces are present. The parent materials are of mixed origin, with granite and related rocks predominating.

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The surface soil shows considerable variability in both thickness and color from place to place. Some areas are somewhat red and have some clay concentration over the hardpan. Areas that have excessive surface gravel or stone are shown by appropriate symbols on the map.

This soil occurs mainly near Coolidge and on the alluvial fan slopes of the Sacaton and Casa Grande Mountains.

This soil, like all the Pinal soils, occupies high terraces and alluvial fans, on which considerable erosion has taken place. The relief is undulating, rolling, and in places definitely sloping. Surface run-off is rapid, and moisture cannot penetrate very deeply because of the massive, firmly cemented hardpan. The moisture-holding capacity is very poor, and root penetration is restricted. A few small areas of this soil are included in cultivated fields, but crops usually fail because of the shallowness of the soil.

Pinal sandy loam, deep phase.—In this soil the hardpan occurs at a depth ranging from 2 to 3 feet. The moisture-holding capacity is slightly better and the zone for root development is thicker than in the typical soil. Although the growth of crops is limited, the productivity is slightly better than that of typical Pinal sandy loam. Only a small part of this soil is farmed.

Pinal sandy loam, silted phase.—In the silted phase of Pinal sandy loam dark sediments from irrigation waters have been deposited to a depth of several inches over typical Pinal sandy loam, darkening the surface soil and changing the texture in most places to gritty loam. The surface generally is smoother and flatter than that of the typical soil. Although the fertility of the soil is improved by these deposits, the moisture-holding capacity is so poor that crops return low yields or fail completely. The soil is best suited to shallow-rooted crops. Cotton produces from one-fourth to one-half of a bale an acre, small grains 10 to 25 bushels, and grain sorghums one-half ton of grain.

Pinal sandy loam, eroded phase.—The eroded phase of Pinal sandy loam has rolling, steep, and rough broken relief, characterized by steep terrace-front escarpments. The layer of uncemented soil material is thin, and outcrops of the hardpan are numerous. The soil has no agricultural value.

Pinal gravelly clay loam.—The 10-inch surface soil of Pinal gravelly clay loam is light grayish-brown or pale reddish-brown highly calcareous slightly compact loam that breaks into rather friable clods. Gravel and lime hardpan fragments have accumulated on the surface, producing a thin dark desert pavement. Gravel also are embedded in the surface soil. Below this and continuing to an undetermined depth is a conglomeratelike lime hardpan, which becomes coarser with depth and in which gravel and stone are embedded. Granites and related rocks predominate in the mixed parent soil materials.

The thickness and color of the surface soil vary considerably, owing to the strongly undulating to rolling relief and natural erosion. The thicker soil generally is more red, and the shallower soil includes a large quantity of gravel and lime hardpan fragments. As typically developed, this soil is shallower than Pinal sandy loam and, like that soil, has little or no agricultural value. It occurs principally southwest and northwest of Florence. The total area is small.

Pinal gravelly clay loam, eroded phase.—Areas of Pinal gravelly clay loam in which the relief is more definitely rolling, the soil is thinner, and outcrops of hardpan are more numerous than typical are designated as an eroded phase. This soil is more extensive than the typical soil, although its total area is small. It is not suited to farming.

Coolidge sandy loam.—The 18-inch surface soil of Coolidge sandy loam is light grayish-brown soft friable gritty sandy loam. A few spherical or irregular-shaped hard rocklike lime-cemented nodules, ranging from one-fourth to one-half inch in diameter, are present throughout this layer. This layer grades into a layer of high lime accumulation, in which spherical hard rocklike lime nodules are closely packed and are embedded in light pinkish-brown softer or looser highly calcareous material. This material gives way, at a depth of 48 inches, to a layer of similar or more brown color, that is more marly or cemented and contains fewer nodules in the sandy loam soil materials. The substratum begins at a depth of 72 inches and consists of loose porous stratified gravelly materials with some lime infiltrations in the upper part. The mixed parent soil materials are derived predominantly from granites.

This soil lies principally north of Coolidge. It is not extensive but is included in many fields because of its close association with other cultivable soils or because of the accessibility of water for irrigation. It is served mostly by gravity irrigation and has been more or less modified by silting. Distinctly modified areas are mapped and described as silted phases of Coolidge sandy loam.

The elevated old terraces occupied by this soil range from smoothly undulating to sloping. Run-off is rather rapid, internal drainage in general is sufficient though in some places it is retarded, and the deeper underdrainage is excessive. This soil is planted to most of the principal crops of the section, which return similar or slightly lower yields than on Toltec fine sandy loam.

Coolidge sandy loam, deep phase.—The deep phase of Coolidge sandy loam contains fewer hard lime nodules than the typical soil, and the zone of excessive accumulation of lime and nodules generally lies more than 3 feet below the surface. This makes a deeper, more permeable, and more productive soil than typical Coolidge sandy loam. The greater part of it has very favorable relief for irrigation and, where farmed, has been modified by deposition of sediments from irrigation, giving rise to Coolidge sandy loam, silted phase.

Coolidge sandy loam, silted phase.—The silted phase of Coolidge sandy loam has a 6- or 8-inch surface layer of dark highly organic sediments, which change the texture of the surface soil to gritty clay loam, make the color a dark grayish brown, and increase the productivity materially over that of the typical soil. Cotton yields from one-half to three-fourths of a bale an acre, small grains 15 to 30 bushels, and grain sorghums ¾ to 1 ton of grain.

Coolidge sandy loam, shallow silted phase.—In Coolidge sandy loam, shallow silted phase, the dark irrigation sediments have been deposited over the original surface soil to the depth of only a few inches. This deposit darkens the surface soil, changes the texture to gritty loam, and improves the fertility and moisture-holding capacity. Higher yields are obtained than on the typical soil. Cotton yields from one-half to two-thirds of a bale an acre, small grains 15 to 25 bushels, and grain sorghums ¾ to 1 ton of grain.

Coolidge sandy loam, eroded phase.—The eroded phase of Coolidge sandy loam consists of severely eroded areas in which the relief ranges from rolling to steep. The thickness of the surface soil and the content of lime nodules vary considerably. The land is generally unsuited for agricultural development. Only 64 acres are mapped, mainly in two very small areas northeast of Coolidge.

SOLONETZLIKE ("ALKALI") SOILS WITH MODERATE LIME ACCUMULATION

The group of solonetzlike ("alkali") soils with moderate lime accumulation is extensive in the lower part of the Santa Cruz River flood plain, where these soils occupy a large part of the area under the gravity canal system. In this position they complicate agricultural development and land use because of their adverse physical and chemical properties and because of their close association with soils of more favorable character. They are represented by the soils of the Casa Grande series.

These soils have developed under the influence of poor drainage and a high concentration of soluble salts. They are highly alkaline, contain sodium-saturated clay, which is dispersed and tough, and are unfavorable, both chemically and physically, for the growth of plants. Natural leaching has taken place to some extent subsequent to the lowering of the water table, which has accompanied deepening of the Gila River channel. In this process, surface salts have been carried away by floodwaters or have moved downward, so that in many places little or no salts remain at the surface. Only salt-tolerant plants, however, grow on these soils, and barren slick spots are numerous.

The barren slick spots present the most adverse conditions for plant growth. Here, the soils are dense and exclude both air and water to a great extent. They become baked, hard, and difficult to till when dry and are so plastic and sticky when wet that they cannot be plowed or cultivated satisfactorily. Slick spots are fewer in the lighter-textured soils than in heavier-textured soils.

The greatest salt concentration or greatest content of sodium clay commonly occurs in the heavier-textured soils. The higher-lying soils are lighter-textured and have lower salt concentration. As the maximum clay content is in the subsoil of the lighter-textured soils, the growth of plants is not inhibited to such an extent nor is reclamation so difficult as in the heavier-textured soils. Farmed areas of sandy soils are slowly being reclaimed, and some are fairly productive, especially where modified by dark silty deposits from gravity irrigation waters.

These so-called alkali soils are in some places further modified by deposition of dark-colored silty materials from the floodwaters of the Santa Cruz River, especially in the lower areas. The deposits are in places several feet thick. To a certain extent the silty deposits have acquired properties similar to those of the underlying soil, and they have slick surfaces and conditions adverse for the penetration of moisture and growth of plants. Under alkaline conditions much of the organic matter has been dissolved and leached out, and the original granular structure of these materials has disappeared. Such silted soils present a different problem in development than those in which a deposit of fertile sediments overlies soils with normally developed profiles.

Casa Grande sandy loam.—Casa Grande sandy loam, to a depth of about 4 to 6 inches, is pale reddish-brown friable vesicular sandy loam containing no lime. It is separated from the subsoil by a very thin grayish-white layer or film. The upper part of the subsoil is reddish-brown tough noncalcareous gritty clay loam, which is plastic or sticky when wet. It is so slowly pervious that water stands on the surface for long periods, saturating the surface soil to a slushy consistence. Between depths of 9 and 24 inches is a lime-veined layer of reddish-brown tough gritty clay loam somewhat mottled with red colloidal material. The layer below this consists of paler reddish brown more friable gritty loam or clay loam, spotted with lime. It rests, at a depth of about 60 inches, on pale reddish-brown or grayish-brown looser loamy sand and sandy loam materials. When exposed, the subsoil layers become highly discolored or mottled with gray, yellow, red, and brown. This soil is developed on old alluvial materials having their origin in various, but predominantly granitic, rocks.

The thickness of the surface layer and the surface configuration of the land vary considerably, owing to movement of the sandy surface material by the wind. In most places, the depth to the dispersed sodium clay is less than 1 foot, and the surface is slightly hummocky or undulating. Leveling the land for irrigation produces a more uniform surface soil and covers the tough slick spots, aiding in their reclamation. In some areas higher on the alluvial fans the denser subsoil occurs at a depth of several feet, but the soil contains enough sodium-dispersed clay to form a tight red layer near the surface and a mottled coloring in the sandy loam material below. Where salts have accumulated or where the soil has been covered by overwash or wind-blown materials, the surface soil materials are calcareous.

Large bodies of this soil occupy the lower fans and flood plain of the Santa Cruz River, especially north and northeast of Casa Grande. Other bodies are along McClellan Wash.

The surface is comparatively flat, but it occupies a somewhat higher position on the fans than the other Casa Grande soils, where the gentle slope is more favorable for the distribution of irrigation water.

Surface drainage is imperfect, owing to the numerous small depressions, and internal drainage is very slow, owing to the highly dispersed clay in the subsoil. In places, hardpanlike caliche material at a slight depth interferes with free underdrainage when the land is irrigated. Underground water lies at a depth exceeding 40 feet in most places. The shallower underground water is high in soluble salts and is not desirable for irrigation so that deeper strata are tapped. The water rises in cased wells to a nearly uniform level. Most of this soil is irrigated by gravity. The silty sediments give rise to silted phases, and they aid in reclamation of the land.

This soil is the most easily reclaimed of the Casa Grande soils. Owing to its lighter texture, lower salt and sodium clay content, and greater permeability, it is more easily leached than any of the heavier soils of the series. Grain sorghums and barley are commonly used as first crops in the reclamation of these soils. These crops are fairly tolerant of salts, and the sorghums, especially, add organic matter, which aids in reclamation and in increasing productivity. A continuous cover of vegetation and repeated irrigation throughout the year materially speeds up the removal of salts. When the summer crop of grain sorghum has been harvested, the coarse stalks are left standing and livestock are allowed to feed on them. Those remaining are later plowed under and followed by a winter crop of barley, which is irrigated repeatedly and which may be grazed. Continuous cropping and leaching is carried on until the soil will support legumes, mainly alfalfa.

Casa Grande sandy loam, deep phase.—In this soil the tough highly dispersed clay subsoil lies at a greater depth than in typical Casa Grande sandy loam, in places as deep as several feet. The surface soil, however, is somewhat mottled by reddish-brown colloids. This soil is more readily reclaimed and results in a deeper more fertile soil than typical Casa Grande sandy loam.

Casa Grande sandy loam, silted phase.—This soil includes areas, in which the original surface of Casa Grande sandy loam has been covered to a depth of a few inches by dark-colored sediments, either from turbid irrigation waters or from natural floodwaters of the Santa Cruz River. The sediments from the two sources are somewhat different.

In the areas covered by sediments from irrigation, the texture of the immediate surface soil is changed to loam, the color becomes dark brown, and fair yields of alfalfa, cotton, small grains, and grain sorghums can be obtained. Alfalfa yields from 3 to 4 tons an acre, cotton one-half to three-fourths of a bale, small grains 20 to 30 bushels, and grain sorghums ¾ to 1 ton of grain.

In the areas modified by sediments from natural overflow the surface soil is somewhat heavier textured and resembles the fertile Pima silty clay, but the sediments apparently acquire some sodium saturation from contact with the typical Casa Grande soils in the saline flood plain. Some of the original granular and permeable characteristics of these sediments, therefore, is lost, and the availability of plant nutrients is decreased because of the higher alkalinity. The very smooth slick surface of these areas prevents the penetration of moisture during rainy periods and adds considerably to the difficulty of reclamation. Only a small part of the soil silted by overflow is farmed in association with the typical soil.

Casa Grande sandy loam, brown silted phase.—In this soil the original surface soil of Casa Grande sandy loam has been modified by a deposition of brown sediments, giving rise to a medium-brown or pale grayish-brown surface soil, in which the silting does not exceed a depth of 4 inches in most places. The texture of the material is mainly silty clay loam or silty clay. The sodium saturation is greater, the organic content lower, reclamation is slower, and the fertility of reclaimed areas is less than in the areas modified by the darker-colored sediments.

Casa Grande sandy loam, hummocky phase.—This phase of Casa Grande sandy loam has a surface broken by numerous large wind-blown sandy hummocks accumulated around the brush vegetation. Reclamation would involve the additional cost of leveling for irrigation. This soil is not farmed, and attempts to use it for farming under present economic and water-supply conditions should be discouraged.

Casa Grande sandy loam, eroded phase.—This soil has a strongly rolling relief.. Variable quantities of the surface soil material have been removed, bringing the dense subsoil nearer the surface. The land is not farmed, and physical, chemical, and physiographic conditions make it unsuited to agricultural development. The total area is very small.

Casa Grande fine sandy loam.—The surface layer of Casa Grande fine sandy loam, to a depth of about 3½ inches, is light grayish-brown or pale pinkish-brown noncalcareous fine sandy loam with a soft-cloddy vesicular structure. This layer becomes saturated with water during rainy periods because of the impervious character of the underlying layers. It is underlain abruptly by brown or reddish-brown dense compact clay loam that contains little or no lime. This layer, which extends to a depth of about 7 inches, has a coarse-columnar structure, and the columns are capped by a thin film of ash-gray powder. Below this is reddish-brown lime-veined tough gritty clay loam, which grades, at a depth of 16 inches, into reddish-brown very tough plastic clay spotted with lime. At a depth of about 36 inches this material becomes denser, more colloidal, and darker brown. Colloidal coatings appear along angular fractures, and the material is mottled with lime. Below a depth of 65 inches are gray or pale reddish-brown only slightly calcareous loose sands and gravel. The parent materials are predominantly from schist and granites.

As in Casa Grande sandy loam, the depth of the surface soil varies considerably and barren slick spots are numerous. Near, and especially west, of McClellan Wash, the parent materials are derived from schist and gneiss and are more yellow or gray and, in many places, more calcareous and friable than those derived predominantly from granites. The soil formed from these materials seems to yield more readily to reclamation than the typical soil.

In general the surface of this soil is flat, but in some places the wind has produced an undulating to hummocky relief. Water drains off very slowly because of the numerous basins and the tight sodium clay subsoil, which arrests the penetration of moisture and retards internal drainage. The shallowest water-bearing strata lie from 30 to 40 feet below the surface, but water in these strata in many places is highly charged with salts and is unfavorable for irrigation. Water for irrigation purposes generally is sought in the deeper strata.

This soil occurs in the same general section and is being reclaimed and farmed to about the same extent as Casa Grande sandy loam. Farmed areas are irrigated in part by gravity and in part by pumping. The former areas are being reclaimed more rapidly than the latter as a fertile surface soil is formed by the deposition of dark highly organic sediments from the irrigation water.

The methods used in reclaiming this soil are similar to those for Casa Grande sandy loam. These two soils yield to reclamation more readily than other members of the Casa Grande series, owing to their lighter texture and less tight condition, but reclamation should be attempted only in areas where the content of soluble salts is low. Areas having surface crusts of salt, salt-tolerant natural vegetation, or numerous barren slick spots should be avoided.

Casa Grande fine sandy loam, deep phase.—In this soil the tight subsoil lies at a greater depth than is typical of Casa Grande fine sandy loam, but in few places deeper than 3 feet. The surface soil is thicker, more permeable, and more favorable for the penetration of moisture and roots than in the normal soil. This deep soil, also, is more readily reclaimed than typical Casa Grande fine sandy loam, although it has a fairly high content of dispersed colloidal materials in the surface soil.

Casa Grande loam.—The 3-inch surface layer of Casa Grande loam consists of pale reddish- or light grayish-brown noncalcareous loam with a thin platy surface crust and a vesicular structure beneath. This material is underlain by reddish-brown or dull-brown noncalcareous loam or clay loam, with a columnar structure. The tops of the columns are coated with a grayish-white film of siliceous material. Between depths of about 5 and 12 inches is reddish-brown gritty clay loam that breaks into vertical columns or prisms. Lime appears in faint seams and specks. Below this is a browner, tighter, and tougher clay loam or clay, and the spots and veins of lime become more prominent. Below a depth of 26 inches is dark reddish-brown or chocolate-brown tight tough waxy clay, with large spots of accumulated lime. This rests on a more friable layer of stratified pale reddish- or grayish-brown loamy sand and gravel at a depth of about 60 inches. The lower layers develop a discolored drab appearance when exposed.

This soil is associated with the more calcareous soils west of McClellan Wash, where it has a higher lime content and more gray or yellow color than elsewhere. Such areas are somewhat more friable and permeable and yield a little more readily to reclamation.

Drainage of this soil is poor. Owing to its low position it is occasionally covered by floodwater, which neither runs off the flat surface readily nor permeates the soil because of its tight impervious condition. The surface soil is thin and absorbs very little moisture. Much of the land is barren and smooth, but there are a few low hummocks. Layers of clay and caliche, which are numerous in the deeper substrata, restrict free movement of water. Underground water lies at a depth exceeding 40 feet in most places. This water is generally very salty, and deeper strata must be tapped to obtain water for irrigation.

Only a small part of this land is being reclaimed, and further reclamation should be discouraged. Most of the areas being reclaimed under gravity irrigation are modified by deposition of sediments, giving rise to silted phases.

Casa Grande loam, deep phase.—This soil consists of areas of Casa Grande loam, in which the tough subsoil lies at a greater depth than in the typical soil—generally between 1 and 2 feet. The surface soil is permeable, yet somewhat compact, or puddled, and is mottled with red. This land can be reclaimed more readily than typical Case Grande loam. It occurs west of McClellan Wash, and, where farmed, is being reclaimed with fair success. It is associated with highly calcareous soils and in general is more calcareous and more gray or yellow than the typical soil.

Casa Grande loam, silted phase.—Dark silt and clay sediments from floodwaters of the Santa Cruz River or from irrigation water have been deposited over the original Casa Grande loam to a depth ranging from 4 to 12 inches, resulting in a silted phase. As the deposit was made in a saline flood plain, these sediments have become more or less salty or highly alkaline and in many places are rather highly dispersed and tight. The more adverse properties of this soil, however, are those of underlying tight highly alkaline layers.

This soil is difficult to reclaim. Reclamation has been successful only in areas in which the original underlying soil was less tight and less salty or alkaline than typical, and the spotted appearance of crops indicates the degree to which the original soil was affected by salts or alkali. Measures needed to reclaim this soil are the same as for the other saline soils. Organic residues from manures and crops are needed to increase the permeability, aeration, and bacterial activity. Continued leaching under a crop cover to minimize evaporation and upward movement of salts also is essential. Carbon dioxide released by the decomposition of roots and plant remains reduces the alkalinity, makes plant nutrients more available, and increases the permeability. Grain sorghums for summer crops and small grains (especially barley) for winter crops are fairly tolerent of toxic salts and help supply those requirements. As soon as the soil will support alfalfa, reclamation is continued with this crop. Fertilizing with superphosphate increases the productivity but is expensive in proportion to the increased yields obtained.

This soil is farmed to a small extent, especially where it is associated with more productive soils in the same farm unit. This situation occurs mainly under the gravity canal system where the surface sedimentary deposits are increased from irrigation waters. This aids in the reclamation, and fair success has been experienced. In such places cotton yields from about one-half to three-fourths of a bale an acre, alfalfa 2 to 3 tons, small grains 20 to 30 bushels, and grain sorghums ¾ to 1 ton of grain.

Casa Grande loam, brown silted phase.—In the brown silted phase of Casa Grande loam the depth of silting is about the same as in the silted phase, but the color of the surface deposit is medium brown or grayish brown. The lighter color is caused by a lower content of organic matter, which has either been leached out under the alkaline condition or was lacking when the deposit was made. The texture is predominantly silty clay or silty clay loam. Compared with the silted phase, the brown silted phase generally has a higher sodium saturation, a lower organic-matter content, a less granular and permeable character, a lower inherent fertility, and it is more difficult to reclaim. It is less extensive than the silted phase, with which it is associated in the vicinity of Casa Grande.

Casa Grande silty clay loam.—The 2-inch surface layer of Casa Grande silty clay loam consists of light grayish-brown or pale pinkish-brown silty clay loam. The surface appears slick and is covered with a thin platy crust, but the material below is soft and vesicular. Typically, this material contains little or no lime but is calcareous in places from overwash of foreign material. It is underlain to a depth of 5 inches by reddish-brown tight columnar silty clay loam that is not calcareous and is capped with an ash-gray film. The columnar structure continues into the material below, which is rusty reddish-brown compact gritty clay veined with lime. This gives way, at a depth of 12 inches, to lime-spotted clay, which is similar in color but breaks into angular clods with colloidal-stained surfaces. Between depths of 20 and 65 inches the material is dull reddish-brown clay containing large spots of lime. This layer is highly deflocculated and plastic. It rests on light grayish-brown or pinkish-gray friable highly calcareous loamy sand.

The largest areas are northeast of Eloy and extend northward west of McClellan Wash. In this section the soil occupies low wide drainage flats and playas along poorly defined stream channels and in many places is silted over by grayish-brown sediments. Smaller areas are widely scattered in association with bodies of other Casa Grande soils.

Drainage of this soil is very poor. Water stands on the surface for long periods following heavy rains and penetrates to a depth of only a few inches. Underdrainage is restricted by tight clay and caliche layers.

Very little of the land is being reclaimed. Reclamation is attempted most commonly where this soil forms only a small part of the farm unit. It is generally slow or almost impracticable, owing to the heavy texture, tight structure, sodium saturation, and high salt content of the soil.

Casa Grande silty clay loam, silted phase.—Most of this soil has been modified by dark-colored sedimentary surface deposits from floodwaters of the Santa Cruz River over certain areas of Casa Grande clay loam to a depth ranging from 1 to 3 feet. Like the surface material of the other silted phases in the lower Santa Cruz River flood plain, this has become more or less saturated with sodium, is tight and impermeable, and in many places is highly alkaline. The underlying soil also is highly impermeable and alkaline. These features are unfavorable for agricultural development. Penetration and internal movement of moisture are very limited. In most places the sodium saturation limits the inherent value of the organic matter in the surface deposit. Very little of this soil is being reclaimed and farmed. The method of reclamation is similar to that described in the discussion of the other Casa Grande soils.

As mapped, this soil includes a few small areas, in which the sedimentary deposits are derived from irrigation waters and are only a few inches thick. Such deposits probably add very little to the value of this intractable soil.

Casa Grande silty clay loam, brown silted phase.—In this soil the sediments deposited from the Santa Cruz River floodwaters are medium brown or pale grayish brown, range from 1 to 3 feet in thickness, and have a lower organic-matter content than the sediments deposited over the silted phase of Casa Grande silty clay loam. The latter characteristic may be due to loss of organic matter because of the high alkalinity or to lack of this constituent in the original surface deposit. In most areas the alkalinity is greater than in the silted phase. These conditions make this brown silted phase even more difficult to reclaim than the silted phase, and very little of it is farmed.

SOLENETZLIKE SOILS WITH LIME HARDPANS

Solonetzlike soils with lime hardpans include members of the Topaz and La Palma series. These soils not only have layers of lime-cemented hardpan but also have a tight dense structure, probably owing to sodium saturation of the soil colloids.

The Topaz soils have surface soils and upper subsoil layers similar to those of the Casa Grande soils and, in addition, an underlying fragmental lime-cemented hardpan. Reclamation of these soils is very difficult and has met with fair success only in some of the deep phases having a low salt content. The sodium-saturated clay of the soils is highly dispersed and brings about a condition of comparative impermeability to water. The heavier textured soils of the series are almost or totally barren of vegetation in many places, and the lighter textured soils include numerous barren slick spots. In some places natural leaching has lowered the content of soluble salts, but in most places the salt content is too high to be tolerated by economic plants.

Flooding occurs in many of the areas during rainy weather, and water stands on the surface for extended periods. The sodium clay and cemented caliche layers extend into the substratum, retarding the penetration of water in the deeper material. As the water table stands from 25 to 70 feet below the surface, water for pumping is more readily available than in most soils of the Casa Grande area, but much of the water in the upper strata contains so much soluble salts that it is necessary to tap the lower strata for satisfactory irrigation water. Most of the Topaz soils lie in the drainage basin of McClellan Wash or west of it.

The La Palma soils occupy a large area in the flood plain of McClellan Wash. Their present and potential value for agricultural development is very low, owing to their high salt content, high alkalinity, tight structure, massive lime hardpan, poor drainage, and, here and there, uneven relief. They are very similar to the Topaz soils in the tight structure of the surface soils and upper subsoil layers, but they differ from those soils in having a massive lime hardpan that rests on strata of mottled green and red clay and sand. The mottling of the clay substratum and the precipitation of minerals from solution above the clay to form the indurated lime hardpan apparently took place during an earlier period when the water table, as well as the concentration of salts, was high. The very uneven surface in places apparently is the result of erosion of a former somewhat higher flood plain. The higher areas are rough and choppy and are interspersed with the lower flat playalike areas. In places the lime-cemented hardpan has been exposed by accelerated erosion. Water stands in the shallow playalike basins and on the flats following rains and moves into and through the tight sodium-saturated soils with difficulty. The indurated lime hardpan and clay strata retard or stop the movement of water. Underground water lies from 35 to 60 feet below the surface and generally has a high content of soluble salts. The high salt content and high alkalinity of these soils are toxic to most plants, and in most places only a natural vegetation of seepweed and desert sage survives. Barren slick spots are numerous. Cultivated plants, as a rule, do not make satisfactory growth, and agricultural development of these soils should be discouraged.

Topaz fine sandy loam.—The surface layer of Topaz fine sandy loam is about 8 inches thick and consists of light grayish-brown or pale reddish-brown fine sandy loam covered with a thin surface layer having a platy and vesicular structure. In most places lime fragments are scattered over the surface. The subsoil, to a depth of about 20 inches, is reddish-brown tough plastic clay loam. This layer is more red or somewhat purple in the upper part, but red mottling occurs throughout. Below this is reddish-brown plastic silty clay containing hard angular and platy iron-stained lime-cemented fragments. Between depths of 40 and about 80 inches is a layer of reddish-brown and somewhat green compact iron-and-lime-cemented hardpan fragments embedded in clayey and sandy materials. Below this are light grayish-brown clayey sands and fine gravel, with some lime infiltration. Deeper cuts and wells show successive layers of hardpan. The parent soil materials are derived predominantly from gneiss and schist.

Very small narrow areas are west of McClellan Wash. The rather flat surface is interrupted by barren playas and a few low wind-formed hummocks. Drainage is slow but less so than in the heavier-textured Topaz soils. The water table stands from 25 to 65 feet below the surface. Areas on which reclamation is attempted are usually irrigated by pumped water that is comparatively high in salts. Reclamation of this land is slow and should not be encouraged.

Topaz fine sandy loam, deep phase.—This soil occupies slightly higher ground and has not been affected by poor drainage and salt concentration to the same extent as has typical Topaz fine sandy loam. It contains less sodium-saturated clay, is less tight, and is more permeable than that soil. The dense clay and fragmental lime hardpan lie at a depth ranging from 3 to 4 feet in most places. The overlying materials, however, are mottled with reddish-brown dispersed colloids. This soil is highly calcareous and is light yellowish gray in many places.

Reclamation of the land has been fairly successful in several places. Irrigation water is pumped for most of it and is available at a depth ranging from 30 to 65 feet. The system of reclamation is the same as that described for the other alkali soils. Cotton is grown as a first crop or soon after reclamation. It yields from one-fourth to two-thirds of a bale an acre. Small grains produce from 15 to 25 bushels, and grain sorghums from one-half to three-fourths of a ton of grain.

Topaz fine sandy loam, hummocky phase.—The surface of this soil is covered with numerous wind-blown hummocks. The unfavorable relief, together with other undesirable characteristics, makes the expense of leveling and reclamation of this soil prohibitive in most places, and its use for agricultural purposes is inadvisable.

Topaz fine sandy loam, eroded phase.—In this soil, erosion has been active, and the relief is rough and choppy. In many places the lime hardpan is exposed at the surface, and gravel and fragments of hardpan occur in the soil materials. This land is unsuited to agriculture under irrigation.

Topaz loam.—Topaz loam to a depth of about 10 inches is light grayish-brown or pale pinkish-brown fine-textured loam. It is rather soft, vesicular, and platy in the upper part but is compact and cloddy in the lower part. This material is underlain by reddish-brown indistinctly columnar clay loam containing spots of accumulated lime. Between depths of 20 and 38 inches is a layer of reddish-brown iron-and-lime-cemented material that breaks into platy and very angular fragments and contains thin layers of clay loam. The next lower layer, which continues to a depth of 50 inches, consists of light grayish-brown and red mottled silty clay of banded kaolinlike appearance. Below this is a layer of material with a high lime accumulation, which has a similar color and a more marly appearance and is banded with thin clayey layers. This rests, at a depth of about 85 inches, on light grayish-brown highly calcareous loamy fine sands and sands with infiltrations of lime. The parent soil materials are derived mainly from schist and gneiss.

This soil borders the western side of McClellan Wash, where it occupies somewhat lower and flatter areas and is more frequently flooded than Topaz fine sandy loam. It drains a little more slowly and in general is more difficult to reclaim than that soil. The water table is from 25 to 70 feet below the surface. Small areas are being reclaimed, mostly those supplied by irrigation water from wells. The water has a high salt content in many places.

Topaz loam, silted phase.—In the silted phase of Topaz loam, dark highly organic silty sediments have been deposited by the Santa Cruz River floodwaters to a depth ranging from less than 4 to as much as 12 inches. Because of the tight, comparatively impermeable condition, high salt content, and high alkalinity of the original soil over which it is laid, this layer of fertile silt adds little to the value of the soil. Most of the surface deposit has been saturated with salts and sodium so that it is highly dispersed and comparatively impervious. Reclamation of this soil would be difficult, and its position subjects it to frequent flooding.

Topaz silty clay loam.—Topaz silty clay loam, to a depth of about 4 inches, is light grayish-brown or pinkish-brown silty clay loam containing little or no lime. A thin laminated layer covers the surface, but below this the material is vesicular. Hardpanlike lime fragments are scattered over the surface. Between depths of 4 and 22 inches is reddish-brown compact columnar clay or silty clay, mottled with spots of accumulated lime, which gives way to light pinkish-brown prismatic clay loam mottled with red and gray. Platy and angular lime-cemented hardpan fragments occur throughout this layer and are especially abundant near the bottom. Below a depth of 48 inches light pinkish-gray fragmental lime-cemented layers alternate with layers of light-textured materials. The parent soil materials are predominantly from schists and gneiss.

In a few small included areas the fragmental hardpan lies below a depth ranging from 3 to 4 feet, and the materials above are not so tight as in the typical soil. The included soil is in general intractable and only slowly permeable, however, and it offers only slightly better possibilities for reclamation than the more typical soil.

Topaz silty clay loam occurs west of McClellan Wash on rather low flats along drainageways, where it is subjected to flooding during rainy periods. Water drains off slowly, and the surface soil is slick and wet for long periods. Clay and caliche layers in the substratum retard the free movement of water and probably would cause waterlogging under irrigation. The depth of the present water table ranges from about 25 to 70 feet below the surface.

Very little reclamation has been attempted, owing to the adverse physical properties, high salt content, and high alkalinity of the soil. It should not be included in any agricultural development.

Topaz silty clay.—To a depth of about 2½ inches, Topaz silty clay is light grayish-brown or pinkish-brown vesicular silty clay slightly mottled by red colloids. This material is underlain, to a depth of about 44 inches, by reddish-brown silty clay with a compact columnar structure. The soil aggregates are slightly mottled with lime and stained along fractures with brown colloidal coatings. Below this, light grayish-brown fine sandy loam, bedded with layers of fragmental lime hardpan, extends to a depth of 60 inches, where it rests on friable layers of mottled sands, clay, and clay loam.

Low flat areas of this soil border the drainageways west of McClellan Wash. Flooding occurs during rainy periods, and surface water drains off very slowly. Moisture penetrates and moves downward through the soil with difficulty. The deeper underdrainage also is retarded. The comparatively high content of soluble salts, extremely alkaline reaction, and tight impervious structure make this soil very difficult to reclaim. It should not be considered for farming purposes.

La Palma fine sandy loam.—Typical La Palma fine sandy loam, to a depth of about 12 inches, is light grayish-brown fine sandy loam, which is rather compact when dry, breaking into brittle clods that are rather easily crumbled into powder. Red colloidal stains appear throughout. The material in this layer is calcareous and contains small irregular-shaped fragments of lime hardpan. Below this and extending to a depth of about 24 inches is reddish-brown clay loam that has a compact columnar structure and is brittle when dry. This material is mottled with lime and includes fragments of hardpan. It rests on dense massive lime hardpan with a surface glazing of very hard material. Below a depth of 48 inches and continuing to an undetermined depth is mottled green, brown, and red clay containing some thin sandy strata. These unconsolidated layers below the hardpan are waterlogged. Parent soil materials are derived mainly from schist and gneiss.

Slightly elevated bodies of this soil are scattered throughout the flood plain of McClellan Wash. The relief is choppy, and many wind-blown hummocks and barren slick spots are in evidence. In places the hardpan layer is brought near the surface or is exposed by erosion. The soil is, in general, unsuited for agriculture.

As mapped, La Palma fine sandy loam includes a few areas in which the surface soil is thicker than typical, in places extending to a depth of several feet. This feature offers a somewhat more favorable condition for plant growth but is not sufficient to justify attempts to develop the soil for agricultural use.

La Palma loam.—To a depth of about 9 inches, typical La Palma loam is very light yellowish-brown or pinkish-brown fine-textured compact loam that breaks into brittle but rather soft clods. This is underlain, to a depth of about 18 inches, by reddish-brown and gray lime-spotted and mottled heavier-textured tight tough material. This material has a vertical columnar structure, breaks into rough hard clods, and is very plastic when wet. It is underlain by a massive lime-cemented hardpan, the upper part of which is very dense and considerably stained with iron. Mottled gray, brown, green, and red plastic tough clay and clayey sands lie below a depth of 36 inches. The parent soil materials are derived mainly from schist and gneiss rocks.

This soil occurs in the lower flat part of the McClellan Wash flood plain. Overflow is frequent, and the content of soluble salts is high. It should not be included in the agricultural development of this area.

As mapped, La Palma loam includes a few bodies in which the surface soil is thicker than that of the typical soil and the plastic tough subsoil and hardpan lie at a depth of several feet. The content of soluble salts is somewhat less than in the typical soil, but other properties very definitely limit its agricultural development.

La Palma silty clay loam.—Typical La Palma silty clay loam, to a depth of about 8 inches, is light grayish-brown or yellowish-brown silty clay loam somewhat mottled with red colloidal stains. It breaks up into brittle clods. The next lower layer consists of reddish-brown compact columnar clay loam and is mottled with light-gray specks of lime. At a depth of 38 inches it rests on a light-gray massive lime-cemented hardpan with a glazed upper surface. Iron stains are more abundant in this hardpan layer than in the corresponding layer of the other La Palma soils. Beginning at a depth of 66 inches and continuing to an undetermined depth are light grayish-brown tough plastic clay strata that are mottled with red and green, presumably as a result of waterlogging and deoxidation. Weathered schist and gneiss rocks constitute the principal parent materials.

This soil occupies low positions along McClellan Wash, where the surface is broken by drainage channels and overflows occur during rainstorms. Water drains away very slowly and may stand on the surface for long periods. This soil has the most adverse properties of any La Palma soil and should not be considered for agriculture.

Areas are included with this soil on the map, in which the massive hardpan lies at a greater depth than in the typical soil. The material overlying the hardpan is so tight and highly alkaline and the content of soluble salts is so high, however, that the included soil has the same limitations for agricultural use as the typical soil.

MISCELLANEOUS LAND TYPES

In addition to the soils that are classified in soil series and types and that are more or less closely identified with agricultural development and economic use, four miscellaneous land types of nonagricultural character are identified and mapped. These include two types of rough stony land, riverwash, and dune sand.

Rough stony land (granite, gneiss, and schist materials).—Rough stony land (granite, gneiss, and schist materials) consists of rocky buttes and rugged mountain ranges in which the geological materials are mainly granite, schist, and gneiss rocks. These are coarsely crystalline and contain a high proportion of quartz, feldspars, and micas. The rate of decomposition under the prevailing low rainfall is not rapid. On the other hand, the crystalline materials respond differently to internal stresses of expansion and contraction set up by the rapid changes in temperature, characteristic of the desert climate, resulting in processes of disintegration by means of which the rocks are broken up and split apart. Some of these, especially the coarser-textured granite rocks, are broken down by exfoliation, slabs and concentric layers being peeled or broken from exposed surfaces which are reduced to rounded forms in many places. Numerous higher ridges and peaks, however, do persist as irregular angular jointed outcrops of barren rock. Many of these are partly buried by talus accumulations of blocks and slabs of rock about their bases, whereas the finer particles are removed by wind or water and contribute to soil materials of the Cajon, Anthony, and associated soils of the alluvial fans and plains of the desert below. A steep rugged relief, an arid climate, and the processes of weathering and soil development do not promote a rapid formation of soil material, which has accumulated only in cracks and pockets or protected places.

Erosion is severe on the steeper slopes, and vegetation is limited to scattered cacti and desert shrubs, with few grasses. These areas of rough stony land have no agricultural importance and furnish only the most scanty grazing. The larger and more typical areas are in the Sacaton, Casa Grande, and Picacho Mountains.

Rough stony land (basalt, andesite, and rhyolite materials).—This type of rough stony land is developed on fine-textured rocks, mainly dark-colored old volcanic andesitic and basaltic rocks that are comparatively low in quartz and high in iron, but these rocks include rhyolitic rocks that are lighter colored and higher in quartz. Weathering is slow, and the processes of physical disintegration apparently take place less rapidly than in the coarser-textured rocks. The relief is dominated by irregular outcropping ledges, cliffs, and talus slopes, and most of the surface is bare or only thinly covered with soil material. Cacti, ocotillo, and other desert shrubs have gained an uncertain foothold where soil has accumulated to a depth of a few inches. Slopes are prevailingly steep, and the slowly forming soil material is rapidly swept away by rains and winds where not protected in crevices and hollows or by the sparse vegetation. Grasses and shrubs of value for grazing are uncommon.

This type of rough stony land is less extensive than rough stony land (granite, gneiss, and schist materials). It is developed mainly on Picacho Peak and in the Sawtooth Mountains.

Riverwash.—Riverwash materials occupy the channels of the larger streams and are derived from a wide range of parent rocks. The texture differs greatly from place to place but is predominantly sandy, broken here and there by gravel bars. The surface is eroded and channeled by stream courses and is swept at irregular intervals by floodwaters. Exposed sandy areas are wind-blown, hummocky, and dunelike. Riverwash supports little vegetation, except a few willows and weeds, and it is important only for the few water holes in it that supply water for livestock.

Dune sand.—Dune sand consists of wind-drifted deposits of medium sand and fine sand over the Gila and Casa Grande soils. The surface is characterized by loose shifting dunes that are barren of vegetation and unstable. The land has little or no agricultural possibilities.

LAND USES AND SOIL MANAGEMENT

The principal factor limiting the growth of crops in this area is moisture. The rainfall is insufficient to support anything but desert vegetation, and, without additional water supplied by irrigation, few, if any, plants of economic importance can be grown. Other climatic factors that limit or control the production of plants are temperature and humidity. The summers are extremely hot, the mean annual temperature is high, although frost occurs in winter, and the air is very dry during the greater part of the year. The high summer temperatures, together with the low humidity, produce unfavorable conditions for many species and varieties of plants, and frosts prevent the growth of tender vegetation during the winter. Many crops may be grown, however, by planting at the proper season to take advantage of the more favorable climatic conditions; and others may be successful if the varieties selected are climatically adapted.

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TABLE 6.—*Classification of the soils of the Casa Grande area, Ariz., as to their general suitability to irrigation farming, and recommendations for land use and soil management*

Soil type or phase [1]	Probable best use	Recommended soil management	Soil characteristics affecting productivity and suitability for use [2]	General suitability of soils for irrigation [3]
Pima silty clay	Cotton and truck crops	Careful cultural practices and seedbed preparation.	Very fertile, heavy and rather hard to work.	Soils well suited to irrigation (Only simple soil-management practices required.)
Pima silty clay, shallow phase (over Gila soil material)	do	do	do	
Pima clay	Cotton, small grains, and grain sorghums	do	do	
Pima silty clay loam	Cotton and leafy truck crops	do	do	
Pima silty clay, shallow phase (over Anthony soil material)	Cotton, small grains, and grain sorghums	do	do	
Pima silty clay, shallow phase (over Mohave soil material).	Cotton, leafy truck crops, small grains, and grain sorghums	do	do	
Pima silty clay, shallow phase (over Laveen soil material)	do	do	do	
Pima silty clay, shallow phase (over Tubac soil material)	Cotton, small grains, grain sorghums.	do	do	
Pima silty clay, shallow phase (over Imperial soil material)	do	do	do	
Gila silt loam	do	Manure, rotation with legumes.	Fertile, easily worked	
Gila loam	do	do	do	
Gila very fine sandy loam	do	do	do	
Gila silty clay loam	do	Careful cultural practices and seedbed preparation	Rather hard to work, contains some poorer salty areas	
Gila fine sandy loam	do	Manure, rotation with legumes	Moderate fertility and water-holding capacity, easily worked	

[1] The soils are listed in the approximate order of their general productivity and suitability for use under the prevailing system of irrigation farming Without irrigation they have practically no agricultural value except for the scant grazing and browse that they afford The order is modified somewhat by factors other than productivity—mainly the workability of the soils, their susceptibility to erosion and wind drifting, their water-holding capacity, and the feasibility or ease of distributing irrigation water Some soils include areas that are more salty than typical and therefore less productive (See areas of salt concentration on soil map)

[2] This column describes factors that affect productivity, workability, and suitability of the soils for irrigation farming

[3] This is a general grouping to show the comparative physical suitability of the soils for irrigation farming, assuming that an adequate supply of water is available at a reasonable cost. Some soil types include areas that are more salty or more alkaline and, therefore, poorer than the average, whereas other areas may have been improved by irrigation and the deposition of silt

Mohave loam, silted phase	Cotton, small grains, grain sorghums, and leafy truck crops.	Careful cultural practices and seedbed preparation	Heavy; rather hard to work, very fertile surface layer.	
Anthony loam, silted phase	Cotton, alfalfa, small grains, and grain sorghums.	do	do	
Mohave sandy loam, silted phase	do	do	do	
Mohave clay loam, silted phase	Cotton, small grains, and grain sorghums	do	do	
Anthony sandy loam, silted phase	Cotton, alfalfa, small grains, and grain sorghums.	do	do	
Laveen fine sandy loam, silted phase	do	do	do	
Gila silty clay loam, shallow phase (over Mohave soil material).	Cotton, small grains, and grain sorghums.	do	do	
Mohave loam, shallow silted phase	Cotton, alfalfa, small grains, and grain sorghums.	Manure, rotation with legumes	Easily worked; moderately fertile.	
Anthony loam, shallow silted phase	do	do	do	
Mohave loam, brown silted phase	Alfalfa, cotton, and hegari	do	Somewhat hard to work	
Mohave sandy loam, shallow silted phase	Cotton, alfalfa, small grains, and grain sorghums.	Manure, rotation with legumes	Easily worked; moderately fertile.	
Mohave clay loam, shallow silted phase	Cotton, small grains, and grain sorghums	Careful cultural practices and seedbed preparation.	Rather hard to work; permeability slow	
Anthony silty clay loam	Small grains, grain sorghums, and cotton.	Manure, rotation with legumes.	do	
Mohave loam	Alfalfa, cotton, grain sorghums, small grains, and fruits.	Manure, frequent rotation with legumes.	Easily worked, moderately fertile.	Soils moderately well suited to irrigation (More intensive soil-management and soil-improving practices required)
Mohave loam, deep phase	Alfalfa, vegetables, and fruit crops	do	do	
Continental sandy loam, shallow silted phase	Cotton, alfalfa, small grains, and grain sorghums	do	do	
Nunez loam	Alfalfa, cotton, and general farm crops	do	do	
Anthony loam	do	do	do	
Anthony sandy loam, shallow silted phase	Cotton, alfalfa, grain sorghums, and small grains	do	do	
Anthony sandy loam, shallow phase (over Mohave soil material)	Alfalfa, cotton, and general farm crops	do	do	
Nunez sandy loam	Alfalfa, general farm crops, cotton, vegetables, and fruits.	do	do	
Anthony fine sandy loam	do	do	do	
Anthony sandy loam	do	do	do	
Papago loam	do	Phosphate, manure, frequent rotation with legumes	do	
Papago fine sandy loam	do	do	do	
Papago sandy loam	do	do	do	
Mohave fine sandy loam	do	Manure, frequent rotation with legumes.	do	
Mohave sandy loam	do	do	do	
Mohave sandy loam, deep phase	Alfalfa, vegetables, and fruits	do	do	
Tubac clay loam, silted phase	Cotton, small grains, and grain sorghums.	Deep plowing, careful cultural practices.	Fertile surface layer; heavy; rather hard to work; very slowly pervious.	

TABLE 6.—*Classification of the soils of the Casa Grande area, Ariz., as to their general suitability to irrigation farming, and recommendations for land use and soil management*—Continued

Soil type or phase	Probable best use	Recommended soil management	Soil characteristics affecting productivity and suitability for use	General suitability of soils for irrigation
Pima silty clay, shallow phase (over Coolidge soil material	Cotton, small grains, and grain sorghums.	Careful cultural practices and seedbed preparation.	Fertile surface layer; heavy; rather hard to work; very slowly pervious.	Soils moderately well suited to irrigation (More intensive soil-management and soil-improving practices required)
Tubac clay loam, shallow silted phase	do	do	do	
Laveen silt loam, silted phase	do	do	do	
Laveen silt loam, shallow silted phase	do	Phosphate, manure, rotation with legumes.	Very highly calcareous; moderately fertile.	
Laveen fine sandy loam, shallow silted phase	do	do	do	
Laveen fine sandy loam, deep phase	Alfalfa, cotton, and general farm crops.	do	do	
Continental sandy loam	do	Manure, frequent rotation with legumes.	Moderately fertile; subsoil dense and slowly pervious	
Laveen silt loam	Cotton, small grains, grain sorghums, and alfalfa.	Phosphate, manure, frequent rotation with legumes.	Very highly calcareous; moderately fertile.	
Laveen fine sandy loam	do	do	do	
Sawtooth gravelly sandy loam	Alfalfa, vegetables, and fruits	Manure, frequent rotation with legumes.	Rather low moisture-holding capacity, moderately fertile	
Imperial silt loam	Cotton and small grains	Deep plowing, manure, green manures	Dense, slowly pervious subsoil.	Soils requiring special management under irrigation. (Intensive soil-improving practices, special tillage, and/or care in irrigation to prevent alkali accumulation are required.)
Toltec loam, silted phase	Cotton, small grains, and grain sorghums.	Careful cultural practices and seedbed preparation.	Hardpan restricts penetration of roots and water.	
Imperial silty clay, silted phase	Cotton and small grains	do	Heavy; hard to work; slowly pervious	
Gila silt loam, shallow phase (over Imperial soil material).	do	Manure, green manures	Dense, slowly pervious subsoil.	
Toltec loam, brown silted phase	Cotton, small grains, and grain sorghums	do	Hardpan restricts penetration of roots and water.	
Imperial silty clay, shallow phase (over Gila soil material).	do	Deep plowing, manure, green manures.	Heavy; hard to work; slowly pervious.	
Mohave clay loam	Cotton and small grains	Manure, green manures, rotation with legumes	do	
Vekol clay	do	do	do	
Laveen silty clay loam	Cotton, small grains, and grain sorghums	Phosphate, manure, green manures.	do	
Mohave silty clay	Cotton and small grains	Manure, green manures, rotation with legumes	do	
Tubac clay loam	do	do	do	
Imperial silty clay, shallow phase (over Mohave soil material)	do	Deep plowing, manure, green manures.	do	
Imperial silty clay	do	do	Heavy; hard to work; slowly pervious, more or less salty.	

Coolidge sandy loam, silted phase	Cotton, small grains, and grain sorghums.	Careful cultural practices and seedbed preparation.	Hardpan restricts penetration of roots and water.	Soils requiring special management under irrigation. (Intensive soil-improving practices, special tillage, and/or care in irrigation to prevent alkali accumulation are required.)
Toltec fine sandy loam, silted phase	do	do	do	
Toltec loam, shallow silted phase	do	Phosphate, manures, green manures.	do	
Toltec loam, deep phase	do	do	do	
Coolidge sandy loam, deep phase	do	do	do	
Coolidge sandy loam, shallow silted phase	do	do	do	
Vekol clay, deep phase	Cotton and small grains	Deep plowing, manures, green manures.	Heavy; hard to work; slowly pervious.	
Toltec loam	Cotton, grain sorghums, and small grains.	Phosphate, manure, green manures, frequent rotation with legumes.	Hardpan restricts penetration of roots and water.	
Toltec fine sandy loam	do	do	do	
Topaz fine sandy loam, deep phase	do	Phosphate, manure, green manures, frequent rotation with legumes, leaching of salts.	do	
Mohave sandy loam, hummocky phase[4]	do		Loose, wind-drifted; hard to level, low water-holding capacity.	
Coolidge sandy loam	do	Phosphate, manure, green manures, frequent rotation with legumes.	Hardpan restricts penetration of roots and water.	
Toltec fine sandy loam, hummocky phase[4]	Range grazing		do	
Casa Grande sandy loam silted phase[5]	Cotton, small grains, grain sorghums, and alfalfa	Leaching, deep plowing, phosphate, manure, frequent rotation with legumes.	Strongly alkaline, saline, tight; slowly pervious	
Casa Grande loam, silted phase[5]	do	do	do	
Casa Grande sandy loam, deep phase[5]	do	do	do	
Casa Grande fine sandy loam, deep phase[5]	do	do	do	
Casa Grande loam, deep phase[5]	do	do	do	
Casa Grande sandy loam	do	do	do	
Casa Grande fine sandy loam[5]	do	do	do	
Casa Grande loam[5]	do	do	do	
Casa Grande sandy loam, brown silted phase[5]	do	do	do	
Casa Grande silty clay loam, silted phase	do	do	do	
Casa Grande loam, brown silted phase	do	do	do	
Casa Grande silty clay loam	do	do	do	
Casa Grande silty clay loam, brown silted phase	do	do	do	
Casa Grande sandy loam, hummocky phase	do	Leveling, leaching, deep plowing, phosphate, manure, frequent rotation with legumes.	do	

[4] These soils could be irrigated only if leveled, and the cost of leveling might be prohibitive.

[5] These alkali soils are of very low productivity when first put under cultivation, but by use of special measures for reclamation they may be made fairly productive. Such special measures include deep plowing, flooding with irrigation water—preferably silty water—and plowing under crop residues and manures. (See description of individual soils in section entitled "Soils and Crops.")

TABLE 6.—*Classification of the soils of the Casa Grande area, Ariz., as to their general suitability to irrigation farming, and recommendations for land use and soil management*—Continued

Soil type or phase	Probable best use	Recommended soil management	Soil characteristics affecting productivity and suitability for use	General suitability of soils for irrigation
Topaz fine sandy loam	Range grazing	Special reclamation practices for crops.	Strongly alkaline, tight, shallow over hardpan, feasibility of reclamation doubtful.	Soils requiring special management under irrigation. (Intensive soil-improving practices and care in irrigation to prevent severe leaching and excessive water use are required)
Topaz loam	do	do	do	
Topaz loam, silted hpase	do	do	do	
Topaz silty clay loam	do	do	do	
Topaz silty clay	do	do	do	
Topaz fine sandy loam, hummocky phase	do	do	do	
La Palma fine sandy loam	do	do	do	
La Palma loam	do	do	do	
La Palma silty clay loam	do	do	do	
Anthony gravelly loamy sand	do		Low water-holding capacity, difficult water distribution	
Gila loamy fine sand	do		do	
Cajon gravelly coarse sandy loam	do		do	
Gila fine sandy loam, hummocky phase [4]	do		Loose; wind-drifted, hard to level, low water-holding capacity.	
Laveen fine sandy loam, hummocky phase [4]	do		do	
Gila fine sandy loam, low-bottom phase	Range grazing and small grains.	Flood protection and leveling	Subject to occasional flooding and stream erosion	
Gila fine sand, low-bottom phase	do	do	Subject to occasional flooding and stream erosion, loose; leachy.	
Gila fine sand	Range grazing		Low water-holding capacity; water distribution difficult.	
Pinal sandy loam, silted phase	Cotton, grain sorghums, and small grains.	Phosphate, manure, green manures, frequent rotation with legumes.	Hardpan restricts penetration of roots and water.	Soils requiring special management under irrigation. (These soils are generally poorly suited for irrigation)
Pinal sandy loam, deep phase	do	do	do	
Palos Verdes sandy loam	Range grazing		Shallow over hardpan	
Teague gravelly loam	do		do	
Toltec silty clay loam	Cotton, range grazing, and small grains	Phosphate, manure, green manures.	do	
Pinal sandy loam	Range grazing		do	
Pinal gravelly clay loam	do		do	

[4] These soils could be irrigated only if leveled, and the cost of leveling might be prohibitive.

Anthony sandy loam, eroded phase	Range grazing		Rolling; water distribution difficult; rough land; thin soil.	Land definitely unsuited to irrigation.
Laveen fine sandy loam, eroded phase	do		do	
Toltec fine sandy loam, eroded phase	do		do	
Coolidge sandy loam, eroded phase	do		do	
Casa Grande sandy loam, eroded phase	do		do	
Pinal gravelly clay loam, eroded phase	do		do	
Topaz fine sandy loam, eroded phase	do		do	
Rough stony land (granite, gneiss, and schist materials)	do		do	
Rough stony land (basalt, andesite, and rhyolite materials)	do		do	
Riverwash	do		Coarse; loose; occasionally flooded.	
Dune sand			Loose, wind-drifted dunes	

Table 6 lists the soils in the approximate order of their general productivity and suitability for use under the prevailing system of irrigation farming. It also classifies them as to their suitability for farming under irrigation, indicates the probable best crops or other uses, and gives general recommendations for soil management.

On the best soils, such as those of the Pima series, these climatic factors seem to be the only important ones limiting the growth of crop plants. Many of the soils, however, have certain inherent deficiencies or detrimental characteristics, which limit their productivity to greater or less extent and determine their suitability for agricultural use. Among these deficiencies or undesirable characteristics are: Low content of organic matter and nitrogen, excessive concentration of soluble salts, excessively high alkalinity, unavailability of plant nutrients—principally phosphorus—and insufficient depth of fine pervious soil material. Lack of bacterial activity also may be an important limiting factor in some of the soils. In addition to these internal soil characteristics, in some areas unfavorable external characteristics, such as steep slope, a rough or hummocky surface, or susceptibility to flooding, may be factors limiting the suitability of the land for cultivation.

In developing farms under irrigation it is essential to choose soils that have as few as possible of these deficiencies or limiting factors. Of the virgin soils, the Pima and Gila soils are the most desirable, as they are deep, pervious, comparatively rich in organic matter, and generally rather highly productive. Some seepage and accumulation of salts may occur in these soils under irrigation, but these conditions are rather easy to correct in most places, as the soils are pervious and easily drained and leached.

Most of the soils of the area, however, are markedly deficient in organic matter and nitrogen and need proper crop rotation and fertilization in order to bring out their high potential productivity. Some soils are distinctly unfavorable for the production of crops, and these should, in general, be avoided. Shallow soils over hardpan, such as the Pinal, Teague, and Palos Verdes, do not have sufficient depth or water-holding capacity. The so-called alkali soils, such as most of the Casa Grande, Topaz, and La Palma, are very difficult to reclaim. The farmer is hardly justified in spending his time, effort, and money in trying to farm these inferior soils.

One circumstance is a great aid to reclamation and development of farming and the improvement of the soils in parts of the Casa Grande area. This is the presence of so-called silt in the gravity irrigation waters and in the floodwaters of the principal streams. This silt is composed largely of dark-colored sediments, mostly silt and clay, and apparently has a comparatively high content of organic matter and plant nutrients. Silting of the land in each irrigation or during floods has greatly increased the fertility of the soils and in places has buried the original soil to a depth of several feet. Lands irrigated from wells do not, of course, receive the benefit of this fertile silt.

One of the more important requirements in bringing the soils of this area into profitable productivity is the building up and maintenance of the content of organic matter and nitrogen. This can be done by supplying these constituents in the form of manures and fertilizers, by growing legumes, and by encouraging the growth of bacteria. Commercial fertilizers are expensive, and most of them supply little or no organic matter. Barnyard and stable manures meet all requirements, but only limited quantities are available. Green manures or cover crops are useful because they are high in nitrogen and fix nitrogen in the root nodules. Green manuring, however, is not so popular as growing alfalfa, which allows gradual building up of organic matter and nitrogen over a number of years under a continuous and profitable cropping system. Besides building up the nitrogen and organic matter, the roots penetrate deeply into the soils making them more permeable to both roots and water. If the hay is fed on the farm or the fields are pastured, there is additional value from the manure. Sweetclover, including annual yellow sweetclover, or sourclover, has a high value in building up these deficiencies and can be used in the same manner as alfalfa where moisture conditions or salt accumulations are unfavorable for the latter crop. Where double cropping is practiced, such crops as cowpeas and soybeans can be used as green manures following such hardy winter crops as small grains. Field peas are effective soil improvers and serve as winter cash crops following summer crops. Sourclover after fall lettuce and sesbania after spring lettuce are practicable. Sourclover can be broadcast in cotton in late summer.[7]

Under the arid conditions of the area, mineral elements of fertility have not been leached out of the soils but in many places are in an insoluble form and are not readily available to plants, owing to excessive accumulations of calcium and sodium in the soils, although deficiencies of nitrogen and organic matter exist in all but the Pima and similar soils, and phosphates may enter into insoluble chemical combination where an excess of calcium carbonate is present (*1*). Where extremely high alkalinity exists, probably on account of the presence of sodium clay, it decreases still further the availability of phosphates and possibly of other nutrients. This same condition causes dispersion of the fine soil materials, renders the soils tight and impermeable to air and water, and limits bacterial activity. Carbon dioxide, released from roots of plants and from decomposing of organic matter by bacteria, reduces alkalinity and has a granulating effect on the soil. Therefore practices that serve to supply organic matter and nitrogen to the soil also help to make the mineral nutrients more readily available to the plants and to develop an open permeable structure.

Soils of very high lime content and those with alkali structure ordinarily will not produce the highest yields of alfalfa, although the production may be increased by special measures including the liberal use of superphosphate fertilizer. Soils having small or average quantities of lime in the surface soil but large quantities in the subsoil may become deficient in available phosphorus after a short time and require fertilization to maintain productivity. In the common practice of crop rotation with alfalfa to maintain fertility, it may be necessary on these soils to fertilize with phosphate, accept low yields, or to introduce other organic- and nitrogen-building crops, which demand less phosphate, into the rotation. In phosphate fertilization the double superphosphate is the most effective (*6*).

[7] For additional information on green-manure and soil-building crops, see Arizona Agricultural Experiment Station Bulletin 104 (*12*).

Common (Chilean) and hairy Peruvian varieties of alfalfa are grown almost exclusively. Fall seeding is the most satisfactory. The common practice is to let alfalfa occupy the land 3 or 4 years in the rotation, which is usually sufficient to maintain satisfactory production of cotton and other crops for a similar period. Alfalfa should remain in the rotation at least one-third of the time. Barley frequently is planted in the alfalfa stubble during the winter and gives additional pasture or hay when the alfalfa is held back by frost. This is a common practice to provide winter pasture for cattle and sheep. Oats are used to less extent.

Under irrigation, alfalfa is flooded by the border method. Insufficient leveling and long runs in many places result in poor distribution of water and, consequently, reduced yields. Runs of about one-eighth of a mile are the longest that should be used, in order to obtain efficient distribution and penetration, and on porous sandy soils they should be still shorter. The sediment carried in and deposited from the irrigation water is difficult to handle in alfalfa fields, especially at the lower ends, as it causes silting and sealing over of the crowns of the plants and retards penetration of moisture. Renovation in early spring and in midsummer will loosen this heavy-textured material and allow better aeration and pentration of water. Yields are highest on the lighter-textured soils, but they decline when these soils become deeply silted. Well-drained soils are essential for the satisfactory production of alfalfa.

Yields of alfalfa vary with the amount of water applied. Light-textured soils usually require more frequent irrigation and a larger gross quantity of water than heavy soils for the same yield per acre. This is due largely to the lower moisture-holding capacity of the sandier soils and the greater loss of water by downward percolation. Annual applications of water range from 4 to 5½ acre-feet when available, but average about 4½ acre-feet for five or more annual cuttings. The number of annual cuttings and acre yield are reduced when less water is available. In the Salt River Valley, an application of 3.47 acre-feet produces an average of 5.19 tons an acre and an application of 5 acre-feet, 7.2 tons (*8*).

Cotton is the main cash crop. Short-staple, or upland, varieties occupy the greater part of the cotton acreage. The principal variety is Acala, and a small quantity of Mebane is grown. The long-staple cotton is Pima, an American-Egyptian variety developed by the United States Field Station of the Bureau of Plant Industry at Sacaton, Ariz., just outside the area. The acre yield of the short-staple cotton is usually about one-fourth to one-half bale higher than that of the long staple under the same soil conditions. Pima cotton is better adapted to the lighter-textured soils and withstands heat better than the short-staple varieties. It requires a longer growing season than the Acala and should be planted as early as the season allows. The higher areas are better suited for its production because they have lighter soils and a longer and warmer season. Furthermore, Pima is considered to grow too rank and tall on the heavy fertile soils of the lower areas. Acala cotton can be planted later than Pima and still mature.

Because of the longer growing season and the greater use of water on light-textured soils it is generally considered that Pima requires about one-fifth more water than Acala. Acala commonly requires about 3 acre-feet of water and Pima 3½ acre-feet. The most satisfactory practice is to saturate the soil to a depth of 5 feet before planting or immediately after. This is usually done by flooding by the border method. Water is not applied again until setting of squares (budding) has taken place, after which sufficient water should be applied to maintain continuous good growth and development. During this later period the cotton is watered in furrows. Cultivation is necessary to control weeds and fill shrinkage cracks to prevent undue loss of moisture. Soils are said to become rather impervious after several years in cotton, but alfalfa in rotation overcomes this and causes greater permeability by its deep root penetration and addition of organic matter. For more rapid alleviation of this condition annual yellow sweetclover, or sourclover (*Melilotus indica*), is employed. This is seeded in the cotton in August and plowed under as green manure.

The Pima soils, which are the most fertile, will produce at least 2 bales an acre of short-staple cotton under good management and with sufficient water. The average yield for the area is much less. The productivity of the silted soils approaches that of the Pima soils and should be capable of increase in proportion to their increase in silting.[8] Cotton seems to have wide adaptability to soil conditions and is not so severely affected as some other crops by an excessive lime content and an alkali structure in soils.

Several diseases, especially root rot, affect the cotton in this area. Rotation with alfalfa does not control root rot, as this disease also attacks the alfalfa roots. Growing shallow-rooted crops that do not have a taproot, such as small grains and sorghums, is recommended for its control. Experiments for its control and that of other diseases are being carried on at the Sacaton experiment station (*5*).

The variety of barley grown is Common Six-Row. It is grown for grain, pasture, and hay. For pasture and hay it is often seeded in alfalfa stubble. In all instances it occupies the land during winter. It is seeded either before the first of December or after the middle of January. Other crops occupy the land during summer.

Irrigation water is applied to barley by flooding, controlled by borders. It generally requires about 2½ acre-feet of water, but, if also pastured, it requires about 3 acre-feet. It is used extensively in the reclamation of saline and alkali land and is then flooded more frequently if water is available.

Barley does best on the heavy-textured soils and silted soils of the area. It is not so readily influenced by excessive concentrations of lime and soluble salts as other crops and, therefore, is adapted to many of the soils in the area. The average yield of barley under all soil conditions was about 26 bushels an acre in 1935. Yields of barley on the Gila or Pima soils at the Sacaton station have been as high as 74 bushels in favorable years (*5*). Under good management and with sufficient water the yields could be materially increased.

Oats are grown in a similar manner to barley, but the acreage is very small.

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[8] Additional information on cotton can be obtained from Arizona Agricultural Experiment Station Bulletin 150 (*9*).

Wheat, chiefly of the Baart variety, is grown. More land is devoted to wheat than to barley. A large acreage of wheat is used for pasture and hay. Wheat is a winter crop and is seeded before the first of December or after the middle of January for best results. It is irrigated by the border method, and generally about 2½ acre-feet of water are used. If pastured, it requires about 3 acre-feet.

The heavier-textured soils and the heavily silted phases return the best yields of wheat. This crop has a wide range of adaptability and is not so seriously affected by the excessive lime content of soils as are alfalfa and cotton. Its shallow rooting habit allows fair growth where a high water table or other subsoil condition prevents the deep penetration of roots. It is not quite so tolerant of salts as is barley. An average yield of about 23 bushels an acre was obtained in 1935. The high yield of 63.7 bushels of the Baart variety at the Sacaton station on the Gila and Pima soils (*5*) indicates the marked improvement that can be expected on the soils of this area under good management and sufficient water for irrigation.

Hegari and Double Dwarf Yellow milo are the principal varieties of grain sorghum. Hegari returns a slightly lower yield of grain than Double Dwarf Yellow milo, but, owing to its higher silage and fodder value, it is planted more extensively. Double Dwarf Yellow milo has a lower water requirement than hegari and is rather tolerant of salts. It grows with fair success on heavy-textured soils into which moisture penetrates with difficulty. Both of these sorghums add considerable organic matter to the soil and are especially valuable when pastured after the grain has been harvested. In adding organic matter to heavy tight soils, the grain sorghums also increase the permeability, aeration, and the bacterial population of the soils. They are superior to corn, in this climate, for the production of grain, silage, and fodder, in support of livestock raising. Pit silos are used for silage. From 10 to 15 tons of sorghum silage an acre are obtained on good soils under good management. Very little corn is grown in this area.

Grain sorghums do best on the medium- and heavy-textured soils. They have a wide range of adaptability, growing in soils having high concentrations of lime, salts, and alkali. They have a low water requirement and survive droughty periods. The furrow method is used in irrigation, and from 2 to 2½ acre-feet of water are usually applied for maximum yields.

Grain sorghums are used as a summer crop in double cropping with small grains and other crops. Results at the Sacaton experiment station indicate that better yields are obtained when the sorghums are planted in June than when planted earlier (*5*). Results at this station also indicate that both grain sorghums and cereal grains exhaust fertility rapidly and return rapidly declining yields unless planted on the Pima soils or other soils that are becoming silted by irrigation water. The average yield of grain sorghums in this area is less than 1 ton of grain an acre, but they are grown on a wide variety of soils, many of which have a scant water supply. Better selection of soils, improved cultural methods, and a uniformly sufficient water supply would increase the average yield materially. In 1935, at the Mesa farm of the Arizona Agricultural Experiment Station at Yuma, in the Salt River Valley, hegari yielded 5,256 pounds and Double Dwarf Yellow milo 5,282 pounds of grain an acre.

Head lettuce is grown chiefly on the Pima soils in the Eloy district. These soils and the heavy dark-colored silted soils of the area are the best suited for the production of lettuce. Areas of these soils and medium-textured Gila soils, which would produce excellent yields, are available if market competition can be met. Slime, a fungus disease, affects spring lettuce, and for this reason fall lettuce usually is grown. Lettuce is irrigated by the furrow method, and from 2 to 3 acre-feet of water generally are required. Peas also can be grown during the cool season.

Asparagus is grown in this district on soils similar to those adapted to head lettuce. Shipment of the asparagus begins in March. This crop is more or less salt-tolerant and could be grown on the Pima, Gila, and the silted soils where high in saline salts.

Cantaloups are grown extensively in the Salt River Valley under soil and climatic conditions similar to those in this area, and, if market competition could be met, they could be grown here, especially on the soils of the alluvial bottoms and flood plains of the Gila and Santa Cruz Rivers. Extensive areas of these soils could be used for a wide variety of other truck and garden crops, as has been demonstrated at the Sacaton station (*5*). In the spring, if the weather is not too hot, satisfactory yields of such varieties of potatoes as Irish Cobbler, Bliss Triumph, and Early Ohio have also been obtained at this station. The water requirement of truck and garden crops is considered to be about 2 acre-feet.

Peaches, apricots, and Japanese plums grow well. Several orchards of figs have been planted and with proper care should do well. Among the small fruits, strawberries are the most successful. Orchards of deciduous fruits require about 3 acre-feet of water.

At the Sacaton experiment station, experiments are being carried on with the culture of citrus fruits, olives, dates, pecans, and grapes. The results of these experiments should prove very valuable as a guide for development in this area (*5*). Many higher lying soils in this area have better air drainage and are less susceptible to frost than the land on which the Sacaton station is located. Areas at higher elevations having lighter-textured soils of low lime content might prove valuable for citrus culture if water were available. The water requirement for citrus trees is about 4 acre-feet.

IRRIGATION AND DRAINAGE

Irrigation is essential to the production of crops in this area, and agricultural development is limited by the supply of water available. Water is obtained from the natural flow of streams, from storage reservoirs, and from wells. These supplies depend on the annual rainfall as well as on the rainfall over a period of years. Water is stored in the San Carlos Reservoir, impounded behind the Coolidge Dam on the Gila River 100 miles to the east, but the flow of the Gila River at the reservoir is not sufficient to provide water for a period of drought lasting several years. Only with supplementary dams and storage reservoirs elsewhere could a dependable carry-over supply be retained from year to year. A dam below the junction of the San Pedro and the Gila Rivers is proposed. Although there is much good unirrigated land within this area, an adequate supply of water for that already cultivated should be assured before further expansion takes place.

The San Carlos project receives part of this stored water, together with that from other sources below the dam. This is a Government project under the supervision of the Office of Indian Affairs, which controls the distribution of water on the Gila River Indian Reservation. The project is planned to irrigate 100,000 acres, one-half within the Indian reservation, the other half for lands in the Casa Grande area. In 1935, 37,000 acres in this area were supplied with irrigation water. The San Carlos Reservoir has a storage capacity of 1,190,000 acre-feet, of which 1,164,500 acre-feet can be drawn for irrigation. Besides this, from 40,000 to 50,000 acre-feet generally can be diverted from the San Pedro River below the dam. During rainy periods, floodwaters from the desert are diverted by canals and storm drains to augment the supply.

Forty-six wells have been drilled on the San Carlos project since 1934 to tap underground water supplies and control the rise of the water table under irrigation. These wells parallel the canals, into which water is pumped for distribution. Much of this underground water is high in soluble salts and is diluted with the water obtained by gravity. At present the pumps tap water strata at a depth ranging from 19 to 94 feet below the surface. In 1935, 33,000 acre-feet were supplied from this source. This lowered the water table about 4 feet.

An initial construction charge of $2.50 an acre is made. The annual water assessment is $2.15 for the first 2 acre-feet; $0.50 for the third acre-foot, and $1 for the fourth acre-foot. The average annual assessment is about $3 per acre.

The immediate diversion of water takes place on the Gila River above Florence by a diversion dam completed in 1922. The new and extended system of canals including the Florence-Casa Grande canal and Pima lateral was completed in 1928. The Coolidge Dam was completed a year later. The higher Florence-Casa Grande canal also serves as a storm drain for floodwater draining off the desert, and it controls the distribution of that water. A small amount of water is stored in Picacho Reservoir. The North Side canal serves the farm lands north of the Gila River. Tributary laterals carry water from the main canals to various parts of the project.

Power is developed for pumping and other electrification for the San Carlos project at a 16,000-horsepower hydroelectric plant at Coolidge Dam. A supplementary Diesel electric plant is located at Coolidge. Power for the organized electric pumping districts outside the San Carlos project is obtained from the Salt River Valley Water Users' Association. The average cost for pumping is $1.10 an acre-foot, for a 60-foot lift.

Although the supply of underground water is not subject to so rapid annual fluctuation as the supply of surface water, it may readily become lowered with expansion of irrigation and water demands. Water should be allocated only to those lands that are most worthy of development. Such policy of allocation has been adopted by the San Carlos project officials and should be encouraged in the outlying districts. The total area of good land far exceeds the area that can be irrigated by the limited available water supply, and much of it is situated where the water lift is too high for profitable development.

Unsuccessful efforts have been made to farm areas of inferior alkali soils in the low-lying belt where underground water is close to the surface but in general is very salty. In spite of the low cost of pumping it has not proved feasible to reclaim this land. The higher areas within this low belt, in which deeper strata of less saline water have been tapped, and the wells cased against seepage from the shallower water table, have been more successfully developed. Even in these higher positions, however, sodium-saturated soils are present in many places, and these require extended leaching and reclamation before favorable yields can be obtained. Such reclamation by pumping is expensive, and, in the long run, the cost probably would exceed the expense of developing the more productive soils at higher elevations where the water lift is greater but the salt content of the soil is less.

Since the irrigated acreage is so small and scattered in comparison with the total land area, it is not anticipated that the development of irrigation will give rise to widespread drainage problems. In the section of most concentrated irrigation development, the wells and pumps that have been installed in the San Carlos project for drainage and irrigation should be sufficient to keep the water table at sufficient depth to preclude extensive waterlogging of the soils.

Desert storm waters, which collect rapidly in low areas and drainageways during rainy periods, have to be guarded against. In the San Carlos project, the outer canal, together with an efficient storm-drain system, gives adequate protection. Land lying outside of this protection in many places must be individually protected by dikes and storm drains, especially in low-lying positions or near the larger drainageways.

SALTS AND ALKALI

In arid sections, most soils are comparatively high in soluble salts, and, in places, these salts are highly concentrated. A large part of the salts, set free by the decomposition of the soil minerals, remains in all but the most porous soils, as rainfall is too light and evaporation too high to allow deep penetration of water and consequent leaching of the soils. High salt concentrations that are toxic to plants commonly develop only in lower areas where drainage is poor. In such places the evaporation of salt-charged waters results in a gradual accumulation of salts in the soils. Where the water table is high, water rises through the soil by capillarity and leaves dissolved salts at the level where it evaporates. These salts are readily dissolved and moved in solution to any part of the soil profile, and, especially under irrigation, they are constantly shifted.

Toxic soluble salt concentrations are commonly spoken of as alkali. In its general or popular application this is an inclusive term including both neutral or saline and the alkaline salts. The former are often called white alkali because they form white salt crusts, and the latter are called black alkali because in places they form dark crusts stained by organic matter. The saline salts consist largely of the neutral salts of sodium, predominantly the chloride and sulfate; whereas the black alkali, or alkaline salts of sodium, usually are expressed as sodium carbonate. The analyses of a composite sample of alkali crust from various parts of the area, given in table 7, show the predominance of the chloride, sulfate, and carbonate of sodium among the soluble salts of this area.

TABLE 7.—*Chemical analysis of alkali crust* [1]

[In parts per 100,000]

Constituent	Quantity	Constituent	Quantity
Ions.		Conventional combinations	
Mg	(2)	$CaSO_4$	(2)
Na	16,673	$MgSO_4$	(2)
K	208	K_2SO_4	463
SO_4	8,408	Na_2SO_4	12,066
Cl	16,080	NaCl	26,535
HCO_3	424	$NaHCO_3$	584
CO_3	2,792	Na_2CO_3	4,937
Ca	(2)		

[1] From Soil Survey of the Middle Gila Valley Area (4).
[2] Trace.

The accumulation of salts in the soil is spoken of as salinization. So long as a high concentration of salts exists, the alkalinity of the soil is relatively low and the soil is granular. When leaching occurs, the concentration of salts is lowered, the alkalinity is increased, and sodium clay is formed. This causes a dispersion, or breaking down, of the soil particles (granules), closing of the pore spaces, a dense impervious condition that resists the penetration of roots, air, and water, and more or less sterility of the soil. The process is called alkalization, or solonization, and the resulting soils are known as alkali soils, or Solonetz soils. Solonetz or solonetzlike soils become more or less fixed, or stable, under natural conditions in this arid climate.

Such a condition exists in the older of the alkali soils in the Casa Grande area, especially in the Santa Cruz River flood plain and along McClellan Wash, where the soils have undergone a certain degree of natural leaching, have been partly freed of salts, have become highly alkaline, and have acquired a tight dense structure. Only in the lower part of the area do they have surface salt crusts, although native salt-tolerant plants and barren slick spots indicate their alkaline condition. The absence of surface salt crusts has led to much unfortunate selection of soils for farming. Such soils have distinct structural characteristics that serve to identify them. In many of them the excess of salts has been removed by leaching, whereas in others the salts lie under impervious clay subsoil layers. Some of the soils have been buried under sediments, from irrigation or floodwaters, some of which have become tight because of their contact with the underlying alkaline material.

These soils of solonetzlike or alkali structure are recognized as toxic alkali soils even where their total content of soluble salts is low, the true alkali (black alkali) salts being much more toxic to plants than the neutral or saline salts. In addition to this, the tightness and toughness of these soils limit the growth of plants. Most of the soils of the area having toxic salt concentration are of the highly toxic black alkali type with adverse alkali structure. The younger soils of the flood-plain areas have not yet developed the alkali structure, even though some of them do contain black alkali.

The tolerance of plants to salts depends on many factors, including the kind of plant and its stage of growth, the kind and concentration of salts in the soil and their location in the soil profile, the texture of the soil, moisture conditions, temperature, evaporation, and the salt content of the irrigation water. A concentration of salts in the lower part of the subsoil may not interfere with the growing of shallow-rooted crops, such as small grains and sorghums, whereas it will interfere with deep-rooted plants, such as alfalfa and fruit trees. Sprouting seeds and young seedlings are much more susceptible to injury than are well-established plants. A given quantity of soluble salt is more toxic in a sandy soil than the same quantity in a heavy-textured soil, as the soil solution is more concentrated in the former. Salts produce more serious effects when the soils are comparatively dry and the weather hot and dry. The use of salty irrigation water will, of course, add to the toxic effect of a soil solution already high in salts.

The chemical and physical properties of the soils should be given first consideration in the problem of reclamation. It is more or less impracticable to reclaim alkali-structured soils that have a heavy texture, in fact all alkali soils that have a heavy texture throughout are difficult to reclaim.

The general distribution and concentration of salts and alkali in the Case Grande area are shown on the soil map by boundary lines and symbols in red.[9] Practically all of the soils in this desert section are relatively high in soluble salts, compared with the soils of humid sections, but the concentration varies greatly. Four general conditions or concentrations are indicated on the map: (1) Areas in which the concentration of salts is not sufficient to produce toxic effects upon crop plants, shown by the symbol N; (2) slightly or moderately affected areas in which some harmful effects on crop plants may be expected, shown by the symbol M; (3) areas affected only in the lower part of the soil, shown by the symbol A; and (4) areas strongly affected, shown by the symbol S.

The N areas, in which no toxic effect on vegetation is apparent, have a concentration of soluble salts below 0.2 percent of the weight of the dry soil in the upper 6 feet, moderate alkalinity, and no tight alkali (solonetzlike) structure. The slightly or moderately affected (M) areas include soils of alkali structure but rather low salt content and all other soils in which the average soluble salt content is in excess of 0.2 percent and reaches a maximum of about 0.7 percent in the more strongly affected spots. These soils are either producing crops or seem capable of reclamation. The content of salts and their location within the soil profile vary considerably from place to place, and crops are generally more or less affected—in some places having an uneven or spotted appearance. The areas in which only the subsoils are affected (A) have moderate concentrations of salt in the subsoil but have leached, fairly nontoxic surface soils. This has been brought about either by natural leaching or leaching by irrigation in partial reclamation. Shallow-rooted and salt-tolerant crops produce fair yields. The feasibility of reclamation depends on the character

[9] Based in part on field investigations, as reported in the following: HARPER, W. G. SOIL SURVEY AND CLASSIFICATION OF WHITE LANDS OF SAN CARLOS PROJECT, ARIZONA. 1934. (Unpublished manuscript.)

of the soil profile. The strongly affected (S) areas contain large quantities of soluble salts and generally include soils of alkali structure and high alkalinity. They are readily recognized by white surface crusts of salts or by slick spots and a tight tough consistence. They have very little possibility for reclamation and should be avoided for agriculture.

This mapping of salt concentration is based on field observation of the relief, growth of vegetation, surface appearance, and profile characteristics of the soils, also on determinations, made by the electrolytic bridge,[10] of total soluble salt content of the dry soil in a 6-foot section.

Reclamation of the various soils affected by salts and alkali have been considered in previous parts of this publication. It will suffice to say here that leaching with irrigation water is the most important part of any system of reclamation. Besides the methods usually employed, various chemical treatments have been shown to be effective in reclamation, especially where the alkalinity of the soil is very high. The treatments generally given are gypsum and sulfur. These have a tendency to neutralize the alkaline salts and make the soil more permeable. Where soluble calcium is low, gypsum usually is very beneficial and most commonly used.[11]

MORPHOLOGY AND GENESIS OF SOILS

The Casa Grande area lies in the southern desert soil region (*7*) or the region of Red Desert soils (*14*), which is characterized by a hot arid climate and a sparse desert shrub vegetation.

The soils of this area, like those of other areas in the arid Southwest, have certain general characteristics in common in spite of the variations in character of parent materials, relief, drainage, and the time the materials have been exposed to weathering and soil development. All the soils except those of the Pima series are comparatively poor in organic matter and have a more or less distinct reddish-brown color, probably owing to iron oxide. They are very little leached and contain a comparatively high percentage of salts of the alkali and alkaline earth elements. Calcium carbonate is present in most of these soils, and in some of them the content of sodium salts is very high. In all the soils, except those from the more recent alluvial and wind-laid deposits, calcium carbonate forms a definite light-gray layer of accumulation, in places cemented into a hardpan of caliche, although in some of them a thin surface layer is free from calcium carbonate and is neutral or slightly acid in reaction. In these same soils, the subsurface layer generally is neutral or slightly alkaline and the subsoil is distinctly alkaline. Many of the well-developed soils have a subsurface layer or upper subsoil layer, which is redder and more compact than the surface soil and contains a comparatively high concentration of colloidal clay.

The parent materials from which the soils of this area have developed have been transported by water and wind, and most of them

[10] The results of the individual determinations by the electrolytic bridge are not shown on the map. Anyone interested in these may have access to them in the files of the Division of Soil Survey, Bureau of Plant Industry, U. S Department of Agriculture, Washington, D. C.

[11] For additional information on the reclamation of alkali soils, see Arizona Agricultural Experiment Station Bulletin 123 (*2*).

have been laid down in alluvial fans and alluvial plains, especially in the former. The country rock is predominantly of granitic or of related metamorphic character and gives rise to a high percentage of angular quartz and feldspathic minerals in most of the soils; small areas of basic rock have contributed ferromagnesian minerals, from which distinct soils have developed; but in most places the soil materials have come from both kinds of rocks in various proportions, the rocks of the higher quartz content being dominant, owing to their wider distribution. The larger streams entering the area carry sediments that contain a wider variety of minerals than do the local materials, and many of them contain much organic matter eroded from the grasslands of the higher country near the headwaters of the streams.

Much of the surface of the area is composed of alluvial fans which descend from the rugged barren mountains, slope at first steeply, then more gradually and, as they approach the axes of the valleys, flatten and coalesce with alluvial plains, or playas. The coarse, stony, gravelly, or sandy materials are dropped by drainage waters on the higher, steeper parts of the fans, whereas the finer materials are carried farther down, and the silt, clay, and colloidal materials finally settle on the alluvial flats and playas, where drainage is slow. Almost impervious clays charged with salts lie in many of these low flat areas. The valleys are very deeply filled with alluvium, and the stream channels are constantly shifting, cutting, and filling. Many well-developed soils are buried by fresh sediments, and, in other places, erosion is removing the upper layers and exposing old claypans, hardpans, and other soil horizons.

The aridity of the area is conducive to only very little or very shallow leaching of the soils, although concentration of run-off from the higher areas causes flooding and somewhat more leaching on low flat alluvial plains and playas. The sparse vegetation contributes only small quantities of organic residues. Oxidation is rapid under the prevailing conditions of heat and sunshine, causing rapid disappearance of organic matter and an intensive oxidation of iron compounds. Boulders and gravel exposed on the surface for long periods are coated with dark "desert varnish," a highly burnished and almost black coating of oxidized iron and manganese minerals (*10*, *p. 244*). The well-developed soils have a very thin light-colored surface layer underlain by a layer containing oxidized iron compounds which give it a distinctive reddish-brown color, which also characterizes plowed fields and exposed cuts. Soils with the higher ferromagnesian mineral content are generally the more red. The content or concentration of calcium carbonate in the soils varies according to the character of the parent material and the stage of profile development. Calcium carbonate is lacking or is uniformly disseminated throughout in soils that consist of recent wind- or water-deposited materials; whereas it is concentrated in the highly indurated caliche, or hardpans, in some of the older soils, which, however, contain little or no calcium carbonate in the surface soil. Intermediate between these conditions, it is accumulated in seamed, netted, or nodular forms.

The normally developed mature soils occur in comparatively smooth well-drained areas that are practically free from erosion or deposition and are seldom, if ever, overflowed by waters charged with calcium carbonate and soluble salts. Such soils do not contain sufficient calcium carbonate to effervesce with acid in the topmost 10 to 18 inches, this depth probably depending on the texture of the soil and the quantity of water entering the soil. In the lower part of this noncalcareous zone, however, clay and colloids are concentrated in a layer, which is more dense, compact, and plastic than the surface layer. It is rather bright reddish brown or brownish red, whereas the surface soil is light reddish brown or dull reddish brown. The heavy tough material extends downward into the zone of calcium carbonate accumulation, which is in the form of veins, mottlings, or spots of light gray or white in the plastic compact generally brownish-red or red material. The lower part of the solum contains a high concentration of calcium carbonate more uniformly distributed, and both the plasticity and red color diminish with depth. Very slight cementation occurs in places just above the porous substratum, which in most places lies within 6 feet of the surface. Gray and brown colors are dominant in the layer where calcium carbonate is concentrated.

The normally developed soil profile is represented by Mohave sandy loam, a description of which follows:

0 to 8 inches, dull reddish-brown or light reddish-brown friable noncalcareous gritty sandy loam covered by a thin light-colored surface crust. The upper few inches are darkened by organic residues from the sparse grass cover.

8 to 18 inches, reddish-brown noncalcareous heavy gritty loam or clay loam, which breaks into rather hard or tough clods that can be crumbled without great difficulty.

18 to 40 inches, bright reddish-brown moderately calcareous tough colloidal clay loam containing a few concentrations of calcium carbonate in the form of fine gray veins, spots, or splotches.

40 to 66 inches, light pinkish-gray or very light pinkish-brown highly calcareous sandy loam or loamy sand, which is somewhat mottled and splotched.

66 to 96 inches, light grayish-brown loose stratified calcareous angular sands and gravel, predominantly from granites.

Table 8 gives the results of chemical and mechanical analyses of a profile of Mohave loam from the adjacent Salt River Valley and indicates some of the general characteristics of the Mohave soils of this area.

TABLE 8.—*Composition of Mohave loam from Maricopa County, Ariz.*[1]

Sample No.	Horizon	Depth	CHEMICAL[2]													
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	N	CO_2 from carbonates
		In.	*Pct*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
510944	1	0-6	[3] 67 44	0 60	5 31	14 40	0 100	2 04	1 52	2 72	1.73	0.22	0 10	3.35	0 030	0 20
			[4] 69.78	.62	5 49	14 90	.100	2 11	1 57	2 82	1 79	23	10	-----	-----	-----
510945	2	6-14	[3] 68 27	61	5 35	13 86	086	2 51	1 53	2 59	1 86	12	11	3 47	.010	.56
			[4] 70.69	.63	5.54	14.35	089	2 60	1 58	2.68	1 93	12	18	-----	-----	-----
510947	3	20-50	[3] 51 15	.45	3 77	9.39	.040	16.07	1 60	1 80	90	17	14	14 06	.006	11.10
			[4] 59 54	52	4 40	10 94	.050	18 70	1 86	2 09	1.05	.20	.16	-----	-----	-----
510949	4	68-78	[3] 70 70	.48	5 10	12 40	056	2 98	1 09	2 18	1 92	15	13	2.38	000	.71
			[4] 72 44	49	5 22	12 70	057	3 05	1 12	2 24	1 97	.15	13	-----	-----	-- --

[1] Collected by W. G. Harper and F. O. Youngs. [2] Analyzed by G J. Hough
[3] Values obtained by analysis. [4] Values calculated on an organic-matter and water-free basis.

TABLE 8.—*Composition of Mohave loam from Maricopa County, Ariz.*—Continued

Sample No.	Horizon	Depth	MECHANICAL [a] Fine gravel (diameter 2-1 mm.)	Coarse sand (diameter 1-0.5 mm.)	Medium sand (diameter 0.5-0.25 mm.)	Fine sand (diameter 0.25-0.1 mm.)	Very fine sand (diameter 0.1-0.05 mm.)	Silt (diameter 0.05-0.005 mm.)	Clay (diameter 0.005-0.000 mm.)
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
510944	1	0-6	4.2	8.2	5.2	26.2	20.4	23.0	12.7
510945	2	6-14	3.1	7.1	3.9	21.0	28.3	21.6	15.1
510947	3	20-50	10.5	11.0	4.2	11.2	15.5	33.1	14.5
510949	4	68-78	11.9	23.4	13.1	25.3	12.1	11.4	2.8

[a] Analyzed by V. Jacquot.

Table 9 contains data on the salt content, reaction (pH), moisture equivalent, and rate of percolation of several soils from the Casa Grande area.

TABLE 9.—*Analytical data on soils of the Casa Grande area, Ariz.*[1]

Soil type and sample No.	Depth	Total soluble salts	pH	Moisture equivalent	Percolation (time for first drop to pass through 8-inch column)
	Inches	*Parts per million*		*Percent*	*Minutes*
Anthony sandy loam					
5116131	0-14	245	8.5	8.5	----------
5116132	14-48	1,180	9.2	9.8	----------
5116133	48-72	1,180	9.1	10.8	----------
Cajon gravelly coarse sandy loam:					
5116138	0-16	440	8.8	7.5	----------
5116139	16-60	430	9.0	8.0	----------
Casa Grande fine sandy loam:					
511690	0-3½	240	9.4	8.9	120
511691	3½-7	880	9.9	11.3	1,260
511692	7-16	8,700	10.1	17.4	720
511693	16-36	10,020	10.2	25.6	3,600
511694	36-65	4,800	10.4	21.9	6,000
511695	65-96+	4,710	9.5	8.2	4
Gila silt loam:					
511613	0-12	730	9.0	21.9	----------
511614	12-50	570	9.0	28.0	----------
511615	50-70	1,210	9.1	27.9	----------
La Palma fine sandy loam:					
511656	0-12	1,680	10.3	9.6	----------
511657	12-24	4,090	10.5	17.6	----------
511658	24-48	5,680	10.4	30.9	----------
511659	48+	4,880	10.5	34.1	----------
Laveen silt loam:					
511683	0-14	610	9.2	19.7	----------
511684	14-44	1,670	9.9	21.1	----------
511685	44-60	2,170	9.7	21.1	----------
Mohave sandy loam:					
511608	0-8	380	8.1	8.4	11
511609	8-18	330	8.7	10.2	6
511610	18-40	510	9.3	12.5	6
511611	40-66	950	9.5	13.2	19
511612	66-96	1,060	9.8	7.2	7
Teague gravelly loam:					
511601	0-2½	510	8.5	15.5	----------
511602	2½-20	240	8.3	18.9	----------
511603	20+	630	8.8	18.9	----------
Pima clay:					
5116149	0-16	1,920	9.0	39.6	72
5116150	16-40	4,075	8.8	31.2	115
5116151	40+	5,770	8.6	19.7	28

[1] Data supplied by the Department of Agricultural Chemistry and Soils, Arizona Agricultural Experiment Station.

TABLE 9.—*Analytical data on soils of the Casa Grande area, Ariz.*—Continued

Soil type and sample No.	Depth	Total soluble salts	pH	Moisture equivalent	Percolation (time for first drop to pass through 8-inch column)
	Inches	*Parts per million*		*Percent*	*Minutes*
Pima silty clay					
541624	0–16	1,230	8.6	35.6	55
541625	16–44	760	8.8	26.9	85
541626	44–72	1,130	8.4	36.8	110
Pinal sandy loam					
5116145	0–15	440	9.3	10.1	
5116146	15+	3,020	9.1		
Sawtooth gravelly sandy loam					
511604	0–10	345	9.0	10.2	
511605	10–24	340	9.0	10.9	
511606	24–40	400	9.0	14.2	
511607	40–70	500	9.0	14.5	
Continental sandy loam:					
5116164	0–6	410	9.0	10.9	
5116165	6–14	180	8.3	16.3	
5116166	14–32	490	9.0	13.3	
5116167	32–56	640	9.3	10.7	
5116168	56+	320	9.4	4.5	
Vekol clay					
5116208	0–12	480	8.6	19.4	
5116209	12–30	440	8.9	21.2	
5116210	30–96	570	9.0	19.1	
5116211	96+	750	9.1	15.5	
Toltec loam					
511636	0–18	750	9.3	15.7	
511637	18–24	1,380	9.7	17.2	
511638	24–40	2,020	10.0	16.8	
511639	40–60	3,420	9.6	21.4	
511640	60–72	5,290	9.4	18.1	
Topaz loam:					
511672	0–10	500	9.3	14.0	
511673	10–20	1,840	10.0	22.9	
511674	20–38	4,190	10.3	31.1	
511675	38–50	10,320	10.4	40.0	
511676	50–85	12,050	10.5	32.8	
511677	85–96+	8,400	10.2	33.1	
Tubac clay loam:					
511641	0–2	275	8.6	9.0	85
511642	2–14	1,620	8.6	21.1	31
511643	14–40	2,780	9.0	20.0	16
511644	40–60	4,190	8.8	20.8	25
511645	60–72	1,000	9.8	17.3	5
511646	72–96	890	9.9	15.4	6
Mohave loam:					
5116152	0–7	260	8.1	12.3	43
5116153	7–24	285	8.6	12.1	9
5116154	24–40	720	9.0	14.8	9
5116155	40–60	420	9.3	14.7	12
5116156	60–84	505	9.4	14.5	10
5116157	84+	505	9.4	13.7	12
Infertile silt [2]		1,760	9.4	23.8	900
Infertile silt [3]		5,680	8.5	21.9	340
Fertile irrigation silt [4]		1,260	8.7	18.1	20

[2] Sample taken in SW¼ sec. 35, T. 6 S., R. 6 E.
[3] Sample taken in SE¼ sec. 36, T. 6 S., R. 8 E.
[4] Sample taken east of Kenilworth School.

Slight or shallow leaching of the Mohave soils seems to be indicated by the higher pH values and greater salt content of the lower layers, and the extent to which fine clay and colloids are accumulated in the subsoils is indicated by the moisture equivalent. The rate at which water percolates through the materials of the various horizons indicates freedom from sodium saturation in the colloidal replacement complex. Colloids, calcium carbonate, and soluble salts have accumulated in the lower horizons, but this does not prove that they have been leached and translocated from the layers above. It seems reasonable to suppose, however, that there has been some slight translocation, especially of soluble salts, and that some of the accumulation, more particularly that of the colloids, is due to hydrolysis in place.

The Cajon soils consist of almost unmodified deposits of coarse granitic materials, apparently rather recently accumulated. The soil profile is characterized by geological stratification rather than by developed soil horizons. The calcium carbonate content of these soils depends on the mineralogical origin of the materials or the topographic position with regard to overflow by water carrying calcareous materials in suspension or solution. In some places slight accumulation of calcium carbonate in the lower layers is recognizable. These soils lack the reddish-brown color of the related more mature soils, probably because they are less highly oxidized.

The Anthony soils apparently represent a somewhat more advanced stage of soil development. Their color is reddish-brown probably because of a greater degree of oxidation, and the lower horizons are somewhat more compact and contain more clay and colloids. Calcium carbonate has accumulated in the subsoil, generally in netted or veined patterns.

A soil intermediate between the Anthony and Mohave in profile development is represented by the Nunez soils, which are characterized, compared with the Anthony soils, by greater depth of the noncalcareous surface layer, higher oxidation, and a subsoil horizon of greater compaction, owing to accumulated clay and colloid. In addition to more active hydrolysis, this soil is overflowed by water that drains from higher lands and carries reddish-brown sediments high in clay and colloids.

The Continental soils, which are associated with the Mohave, appear to have reached a more advanced stage in development than those soils. The rather rusty red of the surface soil and more intense red of the subsoil seem to indicate more complete oxidation. The highly colloidal compact upper subsoil horizon overlies a horizon of high calcium carbonate concentration, which is marly in places but not indurated. Calcium carbonate is more uniformly concentrated than in the Mohave soil. This layer is predominantly gray but in places contains rusty iron stains. This profile probably represents the maximum normal concentration of lime, beyond which increased accumulation must be attributed to abnormal factors.

The Sawtooth soils represent an early stage of soil development from parent materials consisting largely of ferromagnesian minerals. The profile is similar to that of the Anthony soils, but parent rock materials from basalt, andesite, and rhyolite are recognizable and impart a darker deep reddish-brown or purplish-red color to the soil.

The Vekol soils are darker and more brown throughout than the Mohave. In stage of development they are similar to the Mohave soils, because they contain concentrations of calcium carbonate, which harden to soft nodules on exposure. It seems probable that the identity of the parent material is lost or obscured in later stages of the development of this soil and that the mature normal development is reached in the Continental soils.

The Gila, Pima, and Imperial soils consist of young alluvial deposits and correspond closely in age to the Cajon soils. They are derived from mixed geological materials, largely from outside sources, deposited in first bottoms and flood plains of active streams. They are occasionally inundated and are calcareous, the calcium carbonate mainly being disseminated through the soil mass. The Pima soils are comparatively rich in organic matter, inherited mostly from the parent sediments, and they are darker than the Gila soils. The Imperial soils generally have a distinct red tinge, a heavy texture, massive structure, and, in many places, a high salt content. The Gila and Pima soils also have a comparatively high salt content, but the pH value is not abnormally high, indicating absence of sodium saturation of the colloidal complex and lack of developed lime zones.

A large number of soils in the Casa Grande area are very highly calcareous in the surface soil as well as in the subsoil. Apparently there are a number of reasons for this condition. In some places erosion has exposed limy subsoil layers; in others, overwash of calcereous materials has occurred; and in still others, lime-charged ground waters or surface waters have evaporated, leaving calcium carbonate in the soil. Normal leaching apparently has not been sufficient to cause much downward movement of the calcium carbonate, which in this area is almost wholly a product of weathering of soil materials or of soil development, as there is very little calcareous sedimentary rock. The accumulation of calcium carbonate by water is the most prolific source of its concentration. Whether precipitated from downward percolating water in normal soil development, precipitated from surface or underground waters, or produced by hydrolysis of more complex minerals in place, accumulations of calcium carbonate are constantly increasing.

The most extensive and thickest accumulations of indurated lime are at the apex of alluvial fans where alluvial accumulations in contact with the barren rock slopes of the mountains have been subjected to percolating lime-charged waters, causing cementation of cobbles, gravels, and finer interstitial materials. Layer upon layer of such indurated material, some presenting thin glazed layers or surfaces of almost pure calcium carbonate, continue to undetermined depths. Their gradient conforms to that of the alluvial fans, and they extend well out into the valleys. The conglomeratelike character and hardness generally decreases at lower elevations.

Soils developed from parent materials with an excessive content of lime or from eroded and transported highly calcareous materials have subsoils in which calcium carbonate becomes extremely concentrated, cementing the soil materials into nodules, concretions, and hardpan layers.

The Laveen soils have subsoils containing a heavy concentration of nodules. The surface soils are in general light grayish brown, pale pinkish brown, or light gray. Translocation in the profile of materials other than calcium carbonate has been limited.

In the Coolidge soils concretions of calcium carbonate are large closely packed spherical nodules of rocklike hardness, surrounded by loose or friable material. This surrounding material is somewhat cemented just above the loose stratified material that lies below the layer of calcium carbonate concentration.

The Pinal soils are similar but have a thick firmly cemented lime hardpan.

In the central parts of the valleys, series of cemented layers in the substrata indicate arrested stages of a fluctuating or subsiding water table. There are also indications of the local influence of ground water in the more elevated fan deposits. The Toltec soils have developed under the influence of a water table that fluctuated in the past. Calcium carbonate is accumulated to a great extent in these soils, either owing to inheritance from the parent materials or to saturation from a high water table. These soils have fragmental hardpan layers, one above the other separated by loose soil materials. It seems probable that calcium carbonate is the principal cementing agent in the hardpan, although iron stains do appear and iron compounds may act as cementing agents.

Another type of development is represented by the Palos Verdes soils with upper horizons that are decidedly reddish brown and that have high contents of clay and colloid in the illuvial zone above the hardpan.

The soils subjected to a high concentration of salts during their development lie at low elevations where the more youthful soils are still influenced by shallow ground water. Salinization itself does not materially alter the morphology of the soil. It is principally during the process of leaching that the adverse effects of sodium saturation and alkalization appear. Soils of the Casa Grande series represent the earliest stage at which an alkali (solonetz-like) structure is definitely developed. In this soil, a light-colored leached surface layer overlies an almost impervious plastic highly colloidal noncalcareous upper subsoil horizon, which caps material that generally is high in lime and soluble salts, deflocculated, relatively impermeable, and heavy textured. The subsoil exhibits a greater segregation of calcium carbonate than the corresponding layer of the Anthony soils but not so much as the corresponding layer of the Mohave soils, which the Casa Grande soils more nearly resemble. The dispersed red colloidal material disappears rapidly on exposure to weathering, leaving drab discolored lower subsoil layers. This highly deflocculated soil is barren of vegetation in many places and includes slick spots having a glazed bleached appearance at the immediate surface. Under this the color is more deeply reddish brown than in any other part of the profile. When dry this material resists even the penetration of a pick, and when wet it is slick and sticky.

Following is a detailed description of Casa Grande fine sandy loam, as observed one-fourth mile north of the southwest corner of sec. 3, T. 6 S., R. 8 E.:

0 to 3½ inches, bleached light grayish-brown noncalcareous fine sandy loam that is platy at the surface and vesicular below. This material crushes when walked upon. The color becomes lighter and more nearly ash gray near and in contact with the horizon below.

3½ to 7 inches, deep reddish-brown tough clay loam that has a blocky or rather indistinctly columnar structure. The tops of the columns are covered by an ash-gray siliceous film. The material is not calcareous.

7 to 16 inches, reddish-brown calcareous gritty loam that is veined and contains red colloidal clay. This material is plastic and almost impermeable to water. Fracture planes continue from the horizon above.

16 to 36 inches, reddish-brown very tough and tight silty clay or clay, spotted with lime. This and the horizon below lose much of their red coloring on weathering in exposures, leaving drab discolored hard brittle materials.

36 to 65 inches, darker reddish-brown material that contains larger gray lime spots and is more colloidal, tough, and plastic than that above. It breaks into angular pieces with shiny colloid-coated surfaces.

65 to 96 inches +, reddish-brown loose stratified sands and gravel derived from gneiss and schist.

The analytical data indicate leaching in the upper two horizons. High alkalinity, probably owing to sodium saturation of the colloidal clay, exists in the lower horizons. The moisture equivalent indicates the high clay and colloid content of the soil material and its dispersed state. The relative impermeability of this soil is evident when its percolation rate is compared with that of Mohave sandy loam.

The Tubac soils seem to represent a more mature soil development than the Casa Grande, in soil materials which have been impregnated with sodium salts. The columnar solonetzlike structure is more definite than in the Casa Grande soils. Compared with the Casa Grande soils, the Tubac soils are noncalcareous to a greater depth, are less alkaline, and apparently the sodium saturation is reduced by replacement with calcium. A detailed description of a profile of Tubac clay loam follows:

0 to 2 inches, light-brown or light reddish-brown friable vesicular noncalcareous gritty clay loam showing white streaks with more reddish-brown materials toward the bottom of horizon, though an ash-gray or white siliceous layer lies on top of the columns below. The material is laminated with red and gray thin layers.

2 to 14 inches, very deep reddish-brown or maroon prismatic columns, from 1 to 1½ inches in diameter, of noncalcareous gritty clay loam, with rounded tops coated with grayish-white siliceous material. The surfaces of the columns are coated with darker reddish-brown colloidal material.

14 to 40 inches, angular prismatic and cubical soil aggregates of gritty clay, less than 1 inch in diameter, faintly spotted and veined with lime. This material is less red and slightly more friable than that in the layer above.

40 to 60 inches, reddish-brown silty clay loam, in which lime is more concentrated and more evenly distributed than in the layer above. The soil mass breaks into more irregular shaped clods, the surfaces of which are glazed with colloids. The material is more friable than that in the layer above.

60 to 72 inches, compact or slightly lime-cemented gritty clay loam that is grayish brown but dries to a lighter color. It is streaked with horizontal lenses of lime.

72 to 96 inches, light grayish-brown clayey sand and coarse sand containing plastic colloidal clay and some infiltrated lime. It dries to a lighter color.

In comparison with the Casa Grande soils, the Tubac soils have, according to the analytical data, a lower salt content, lower pH values, possibly the result of leaching and of replacement of sodium by calcium in the colloidal complex, and a lower moisture equivalent, indicating less dispersion of the clay even though the texture is equally as heavy or heavier. Water percolates much more rapidly through the Tubac soils than through the Casa Grande soils, indicating a more pervious structure. The slow percolation through the top horizon is characteristic of surface horizons in the dry and powdered state.

In many low areas a high water table and accumulations of lime and salts have operated to develop soils of distinct characteristics. Of comparable stage of development to the Toltec soils are the soils of the

Topaz series, which have, in addition to a fragmental hardpan apparently resulting from a fluctuating water table, a solonetzlike structure similar to that of the Casa Grande soils. The analytical data show a high concentration of salts and high alkalinity in the Topaz soils, which are similar to those properties of the Casa Grande and are in contrast to those of the Toltec. The larger clay and colloid content and high state of dispersion is indicated by the moisture equivalent.

In extensive low flat areas, such as those along the McClellan Wash, poor drainage and accumulation of salts have been more pronounced and have endured longer than elsewhere. Here a very dense indurated hardpan has developed along with a solonetzlike structure. Such conditions have given rise to the La Palma soils. Directly under and in direct contact with the massive hardpan are dense waterlogged clay and sandy strata that are mottled, owing to deoxidation. Evidently the water was under pressure before the Gila River cut to its present level and released the impounded water.

The results of mechanical analyses of two soils of the Casa Grande area are given in table 10.

TABLE 10.—*Mechanical analyses of two soils in the Casa Grande area, Ariz.*

Soil type and sample No.	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Gila fine sand:	*Inches*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
511622	0–18	0.1	8.4	20.0	50.2	8.2	6.0	7.1
511623	18–60	.1	1.7	4.9	26.2	21.6	28.5	17.0
Pima silty clay:								
511624	0–16	.2	.4	.3	1.4	1.9	56.0	39.8
511625	16–44	.1	.2	.1	.5	.6	62.6	35.9
511626	44–72	.0	.2	.2	3.7	15.1	62.1	18.7

SUMMARY

The Casa Grande area, Ariz., lies in a hot, arid section, where irrigation is necessary for the production of crops. Water is obtained by gravity flow diversion from the Gila River and by pumping from underground water-bearing strata. Water is stored in the San Carlos Reservoir impounded behind Coolidge Dam. The area of arable land greatly exceeds the area for which a supply of water is available.

The agriculture is diversified, with cotton as the main cash crop. The factors that make cotton the main crop are primarily economic and climatic. It is one of the staple commercial crops for which there generally is a ready market. If the price is not satisfactory, the crop can be stored and money can be borrowed on it. The climate is ideally suited for its growth and maturity, and a long picking season is assured. It seems to be adapted to a wider range in soil conditions than are some of the other crops commonly grown.

Alfalfa is the second most important crop and plays an important part in the crop rotation, as it helps to build up and maintain fertility. The large amount of hay and winter pasture produced by this crop has favored the development of cattle and sheep raising. Besides the beef and dairy cattle raised on the farms, cattle and sheep are brought in from the outlying ranges for fattening and feeding in winter and in times of drought. Small grains and grain sorghums are grown, largely as feed crops.

The limited supply of water for irrigation is the chief factor restricting agricultural development in this area, although considerable differences in soils influence the desirability of the land for irrigation. The soils are improved through irrigation by leaching of the toxic salts and alkali and by deposition of fertile silt and clay sediments. For this reason a rather wide range of soils may be used for growing crops in the low areas where water is most readily available.

This area lies in the region of the Red Desert soils. Organic matter and nitrogen are deficient, but the mineral elements of fertility are abundant. Lime is accumulated in excessive quantities in many of the soils, and lime-cemented hardpans occur in some of them. The high lime content limits the availability of plant nutrients, especially of phosphates, and, where hardpans are formed, the penetration of roots and water is limited. Some of the soils contain toxic salts, alkali, and sodium-saturated clays, which further limit plant growth and interfere with the penetration of moisture and roots. Except in the lower flat valley areas, drainage is good and waterlogging is infrequent. The moisture-holding capacity of most of the soils is good, but a few soils are droughty. The moisture-holding capacity and fertility of the soils are improved by deposition of sediments from irrigation waters. Heavy-textured soils and tight sodium-saturated soils absorb water slowly and have slow internal drainage.

The soils of the area are classified in eight groups based on chemical and physical characteristics: (1) Soils without lime accumulation; (2) soils with slight lime accumulation; (3) soils with moderate lime accumulation; (4) soils with high lime accumulation; (5) soils with lime hardpans; (6) solonetzlike ("alkali") soils with moderate lime accumulation; (7) solonetzlike soils with lime hardpans; and (8) miscellaneous land types. The extent and distribution of the soils and the areas having toxic salt concentrations are shown on the accompanying soil map.

Of the recent alluvial soils without lime concentration, the Pima and Gila soils are important in the agriculture of the area in the production of cotton, grain, and truck crops. The Pima soils have a relatively high organic-matter content and are similar to the sediments deposited on the other soils of the area by irrigation waters. The Imperial soils are tough heavy soils containing considerable quantities of salts, and they are much less desirable than the Pima and Gila for farming.

The Anthony, Papago, Sawtooth, and Nunez soils are somewhat coarser textured, are less fertile, and have a lower water-holding capacity than the Gila and Pima soils. Where sufficiently supplied with water they produce good crop yields.

The Mohave soils are the most important soils with noncalcareous surface soils and moderate lime accumulation in the subsoil. These soils include important naturally and artificially modified and silted phases. They are important in the production of cotton and alfalfa. The Tubac and Vekol soils have heavier less pervious subsoils and are less used for farming than the Mohave.

The Laveen soils are the most extensive soils with high lime accumulation and friable subsoils. The high lime content limits the availability of plant nutrients, especially phosphates. Alfalfa particularly is affected by this high lime concentration. The permeability and water-holding capacity of the Laveen soils are superior to those of the other soils with an excessive content of lime.

In the group of hardpan soils only the deep and silted phases of the Toltec soils and the silted phases of the Coolidge soils have much value for farming. The former are extensive north of Eloy. They are characterized by fragmental hardpans. The silted Coolidge soils cover an important cultivated acreage near Coolidge. They have a high lime content and nodular hardpans.

The Palos Verdes and Pinal soils are very shallow over dense firmly cemented hardpans and have very low agricultural value.

The Casa Grande soils are the principal soils of solonetzlike (alkali) structure, on which reclamation has been attempted. They cover a large total acreage under the gravity canal and in the shallower ground-water belt. Some of the lighter-textured members of the series are not difficult to reclaim and, once they become silted, are fairly productive. The heavier types are less pervious and very hard to reclaim satisfactorily.

The Topaz and La Palma soils are very inferior shallow solonetzlike soils with lime hardpans, have a very high salt content, and are strongly alkaline. Practically none of them is farmed, and they are not recommended for agricultural development.

Miscellaneous land types include rough stony land, riverwash, and dune sand, all of which are nonarable.

Irrigation is essential to agricultural development in this area, and the water supply is limited. Water from the Gila River is of good quality and contains fertile sediments, which are beneficial to the land. The same is true of the waters of the Santa Cruz River, but these are available only during exceptional flood stages. Much of the land can be irrigated only by pumping from wells, which is expensive, and in places the water is too salty to be desirable. Drainage is adequate in most places and probably will remain so. Small areas may become affected by seepage from irrigation. Intercepting drains and drainage wells probably will be effective in preventing drainage troubles or correcting those which may arise.

Many of the soils in the lower flatter areas are more or less affected by accumulations of salts and alkali and are relatively unsuitable for cultivation. Some of the more strongly alkaline soils, such as the Casa Grande, Topaz, and La Palma, have tight heavy slowly pervious subsoils and are, for this reason, hard to reclaim by irrigation and leaching. Some of the more open pervious soils may be fairly easily reclaimed even though they may contain large quantities of salts.

The soils have been grouped as to their desirability under the prevailing system of irrigation farming. This grouping is shown both in a table in the section on Land Uses and Soil Management and on the soil map. The principal factors considered in this grouping are productivity, ease of working the land, and efficiency in the use of irrigation water. Erosion also is considered, although most of the land is too nearly level to be seriously affected by accelerated erosion if cultivated. Soil management practices suitable for each soil type also are set forth in the table.

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