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# Soil Survey
of
# The Socorro and Rio Puerco Areas New Mexico

By
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and
E. G. FITZPATRICK

Bureau of Chemistry and Soils
In cooperation with the
New Mexico Agricultural Experiment Station

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# SOIL SURVEY OF THE SOCORRO AND RIO PUERCO AREAS, NEW MEXICO

By E. N. POULSON, in Charge, and E. G. FITZPATRICK

## AREAS SURVEYED

The Socorro and Rio Puerco areas are in Socorro County in the valleys of the Rio Grande and Rio Puerco, respectively. (Fig. 1.) The Rio Puerco is a tributary of the Rio Grande. The Socorro area extends 26 miles south and 15 miles north from Socorro, the principal town, which is 85 miles, by highway, south of Albuquerque and 220 miles north of El Paso. The Rio Puerco area extends northwest and north for 11 miles from a point about 2 miles north of the junction of the rivers. The two areas are not continuous, as the northern extremity of the Socorro area is about 8 miles south of the confluence of the streams.

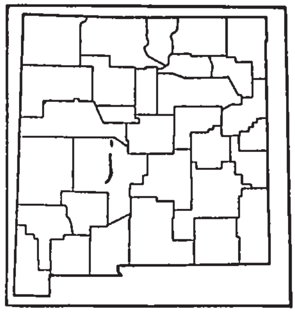

FIGURE 1.—Sketch map showing location of the Socorro and Rio Puerco areas, New Mexico

The Socorro area covers 89 square miles and the Rio Puerco area 27 square miles, making a total of 116 square miles. In both areas the survey is confined principally to the river flood plains and the bordering alluvial fans, and these valley depressions establish the general boundaries. The Socorro area varies in width from 1 mile to 3½ miles. The Rio Puerco area is more uniformly about 3 miles wide.

In a broad perspective, the early geologic and physiographic development in these areas, as along much of the Rio Grande, has been one of structure, followed by erosion and deposition, and finally by minor extrusions of basalt. The mountain ranges which lie outside the surveyed areas are remnants of the structural development of the Rio Grande Basin. The Ladron, Lemitar, Socorro, and Magdelena Mountains are on the west and the Manzano and Oscura on the east. Chupadero Mesa lies between the last two ranges. Only a few of the mountains exceed 8,000 feet in elevation, the highest being less than 10,000 feet above sea level.

Deposits many hundreds of feet thick of detrital stone, gravel, sand, silt, and clay were laid down by the Rio Grande and its tributaries in this early period. This old valley-filling material is represented by terrace plains lying above the more recent channels and valleys cut by the Rio Grande and its tributaries.

A period of comparatively recent basaltic extrusion, mainly in the form of sheets, has left conspicuous mesas which, in part, have restricted the more recent valley cutting of the Rio Grande. Chief of these are the basalt mesas at San Acacia and San Marcial.

The recent valley cutting of the Rio Grande has been most active on the west side, so that the valley now lies within about 2 miles of

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the Socorro Mountains. The general trend of the river and valley is in a southerly direction, slightly southeastward from San Acacia to San Antonio and thence gradually southwestward to San Marcial. The valley of the Rio Puerco diverges from that of the Rio Grande in a slightly northwesterly direction.

The immediate valley floors of the Rio Grande and Rio Puerco are comparatively flat flood plains consisting of materials recently deposited by the streams, and they have rather uniformly the same gradients as the rivers. Fringing the valley floors in a gradual upward rise to the terrace plains are narrow irregular belts of recent alluvial fan materials on which water and wind erosion have produced a surface broken in many places both by arroyos and hummocks. The borders of the terraces in most places define the edges of the areas surveyed by steep bluffs, roughly eroded and dissected by numerous arroyos which carry intermittently the run-off from the upland plains and mountains during the torrential summer rains. These bluffs in many places rise to heights of 100 or more feet but average much less. Arroyo erosion and deposition have obliterated these escarpments at various places, most conspicuously at the towns of Polvadera, Lemitar, Escondida, Socorro, and San Antonio. In the Rio Puerco Valley, erosion has smoothed the terrace fronts so that they merge rather smoothly with the alluvial slopes.

The Rio Grande is the master stream in the drainage of the areas, the Rio Puerco being a tributary of the former. Both rivers are muddy, silt-laden streams. The Rio Grande enters the Socorro area on the north at an elevation of about 4,660 feet above sea level and leaves at an elevation of about 4,460 feet, having a rather uniform average gradient of about 5 feet to the mile. Owing to its slight fall and its burden of silt, it flows in a meandering and aggrading manner throughout the valley, and the channel in most places is above the lower level of the bottom lands.

Diking has been resorted to since early settlement and to a certain degree has confined the flood waters within bounds except during exceptional floods. Depressions and old abandoned channels have become swamps, and most of the other bottom land is subject to a high water table which fluctuates with overflow and with the rise and fall of the water in the river channel.

During August and September, 1929, a few months after the original survey of these areas was made, two successive severe floods, caused by heavy precipitation in the watershed of tributary streams, swept through the Rio Grande Valley, and some of the soils were materially altered, necessitating a revision in the mapping of the soils, which was made in March, 1930 A deluge of silt-laden flood water spread over the entire stream bottoms throughout the total extent of the surveyed areas, depositing sediments, ranging from a few inches to 3 or more feet in depth, and partly destroying several settlements and towns. (Pl. 1, A.) The town of San Marcial became partly buried with fine sand and a number of buildings collapsed. (Pl. 1, B.) Destruction at San Acacia and San Antonio was mainly due to softening and caving in of the adobe walls. The railroad, roads, ditches, and dikes were washed out or buried in many places. These for the most part have been reconstructed. The Rio Grande cut no permanent new channels but subsided to its former extensive bed of river wash. Increased rise in the water table resulted, however, and ponded and swampy areas have in general increased, though some of the previous depressed swampy or marshy areas were filled.

The greatest deposition and therefore the greatest textural change in the soils took place between San Acacia and Pueblito, between San Antonio and San Antonito, and between a point about 4 miles south of Elmendorf and the south end of the Socorro area.

At San Acacia a deposit of 3 or more feet of Gila fine sand filled in a large area of swampy land. (Pl. 2, A and B.) This material was smoothly laid, but it may become disturbed by wind action unless control measures are taken. In the vicinities of Polvadera and Lemitar most of the fine sand deposition occurred east of the railroad tracks. This material shows the effect of swift-water deposition and is marked by channels paralleling the main stream, a condition which will add materially to the leveling problem in the reclamation of the land, especially where the deep deposition took place among tangled willows and débris. West of the railroad tracks, in the vicinity of the last-named villages, deposition was from standing water held by the railroad grade embankments, and a layer of clay about 2 feet thick was deposited over much of the land in this locality. Between Pueblito and San Antonio the soils were silted over too thinly to materially affect the texture of previously mapped areas At the narrow part of the river bottoms at San Antonio the current again became arrested, causing deposition of both light and heavy textured materials, and this affected the textures of the previously mapped soils as far down the valley as San Antonito. Heavy clay deposition from arrested waters occurred in the vicinities of La Mesa School and Val Verde; at San Marcial sand deposits were as deep as 7 feet near the river, but they decreased in depth farther from the channel and farther downstream; and in the back bottoms thick clay deposition took place.

In the Rio Puerco area the river has a gradient of 7 feet to the mile, but the channel lies well below the bottom land so that thorough drainage under present natural conditions results. This river is cutting its channel rapidly as is shown by the fact that in the southern part of the area the banks rise vertically from 10 to 15 feet to the valley floor, whereas in the northern part of the surveyed area, the banks rise in a similar manner but to extreme heights of 30 or 40 feet. Rapid and destructive erosion of the valley is evident. The high vertical banks force the stream to carry the heavy silt burden into the Rio Grande. It is estimated that 40 per cent of the silt carried by the Rio Grande below the junction of the streams comes from Rio Puerco.

The natural vegetation is necessarily sparse, except on the waterlogged river bottoms. The bottoms of the Rio Grande support dense growths of willow, tornillo, and cottonwood. The more open alkali flats are covered with salt grass, and in the permanent depressions or swamps, tules and sedges grow. The dry uplands and alluvial fans support mesquite, creosote bush, "chamiza," rabbit brush, and sparse growths of native bunch grasses. The chief vegetation of both the bottom land and alluvial slopes in the Rio Puerco area consists of a sparse growth of "chamiza" and scattered bunch grass.

When the Spanish explorers entered this region early in the sixteenth century, the valley was settled by Pueblo Indians who diverted the waters of the Rio Grande and carried on a primitive type of agriculture. The conquering Spaniards adopted the Indians' methods in the settlement of the valley. Later settlement was fostered by the Spanish and Mexican Governments. The descendants of these early settlers and of later immigrants form the greater part of the present population. Spanish is the principal language spoken.

According to preliminary reports from the 1930 Federal census[1] there are 9,611 inhabitants in Socorro County. It is estimated that about two-thirds of this population is in the Socorro area. Most of the inhabitants live in towns or community centers, probably an outgrowth of early needs of organized protection and more recently because of the impracticability of residing on the water-logged bottom lands. The Rio Puerco area is not settled.

The largest town is Socorro, the county seat of Socorro County, with a population of 2,058, possibly 75 per cent of whom are Spanish Americans. Other towns and communal villages are San Acacia, Polvadera, Lemitar, Pueblito, Escondida, Luis Lopez, San Antonio, San Pedro, San Antonito, San Marcial, and Val Verde All these towns and villages have school facilities. The New Mexico State School of Mines is located at Socorro. Electric power and telephone service are supplied where there is a demand.

The Atchison, Topeka & Santa Fe Railway and United States Highway No. 85 follow the Rio Grande Valley, affording adequate transportation facilities. Branch railroad lines extend to surrounding mining districts and highways extending from Socorro and San Antonio parallel these lines.

Most of the agricultural products are consumed locally, but a few surplus products find market in near-by towns and mining communities. Alfalfa is shipped to Texas markets.

## CLIMATE

The Socorro and Rio Puerco areas have a climate typical of the arid Southwest, characterized by a high percentage of clear days, by light rainfall, and very little snow. The summer months are hot but not oppressive, owing to the low humidity. Extended periods of uncomfortably cold weather during winter are infrequent.

High winds, blowing chiefly from the southwest and carrying sand and dust, are of common occurrence during the spring. The winds add critically to the problem of moisture conservation in soils, and the drifting sands are a problem also.

Dry farming is not practical, and irrigation has to be resorted to for crop production.

Socorro, at an elevation of 4,600 feet above sea level, is located near the central part of the Socorro area, and climatic conditions here are probably fairly representative of the area as a whole The average annual precipitation is 10.33 inches. Extreme yearly fluctuations often occur, the most extreme being in 1905, when the precipitation was 22.40 inches, and in 1925, when it was only 4.12 inches. The heaviest rainfall normally occurs during July, August, September, and October.

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[1] Soil survey reports are dated as of the year in which the field work was completed. Later census figures are given whenever possible

The mean annual temperature is 57 6° F The highest recorded temperature is 108°, and the lowest −16°. The average frost-free season is 193 days, extending from April 8, the average date of the last killing frost, to October 20, the average date of the first. Frosts, however, have occurred as late as May 6 and as early as September 27. These early and late frosts endanger especially fruits and vegetables.

Table 1, compiled from the records of the Weather Bureau, gives the more important climatic data pertaining to Socorro.

TABLE 1.—*Normal monthly, seasonal, and annual temperature and precipitation at Socorro, N. Mex.*

[Elevation, 4,600 feet]

| Month | Temperature | | | Precipitation | | | |
|---|---|---|---|---|---|---|---|
| | Mean | Absolute maximum | Absolute minimum | Mean | Total amount for the driest year (1925) | Total amount for the wettest year (1905) | Snow, average depth |
| | °F | °F | °F | Inches | Inches | Inches | Inches |
| December | 37.7 | 81 | −16 | 0.71 | 0.50 | 1.23 | 2.0 |
| January | 37.7 | 76 | −13 | .45 | .09 | 1.05 | 1.6 |
| February | 42.9 | 80 | 1 | .40 | (1) | 1.11 | 1.8 |
| Winter | 39.4 | 81 | −16 | 1.56 | .59 | 3.39 | 5.4 |
| March | 49.7 | 91 | 10 | .61 | 0 | 1.27 | .9 |
| April | 57.5 | 94 | 15 | .73 | (1) | 2.60 | .5 |
| May | 65.7 | 102 | 28 | .43 | .16 | .07 | 0 |
| Spring | 57.6 | 102 | 10 | 1.77 | .16 | 3.94 | 1.4 |
| June | 75.0 | 108 | 35 | .54 | .45 | 1.73 | 0 |
| July | 77.3 | 108 | 42 | 1.87 | .67 | .84 | 0 |
| August | 75.6 | 106 | 45 | 1.43 | 1.54 | 1.32 | 0 |
| Summer | 76.0 | 108 | 35 | 3.84 | 2.66 | 3.89 | 0 |
| September | 68.8 | 101 | 27 | 1.48 | .32 | 7.96 | 0 |
| October | 57.9 | 95 | 6 | 1.19 | .39 | .25 | .6 |
| November | 45.9 | 85 | 5 | .40 | (1) | 2.97 | .8 |
| Fall | 57.5 | 101 | 5 | 3.16 | .71 | 11.18 | 1.4 |
| Year | 57.6 | 108 | −16 | 10.33 | 4.12 | 22.40 | 8.2 |

[1] Trace

## AGRICULTURE

Agricultural development began in the Rio Grande Valley long before the advent of the white man in North America. Early Spanish explorers and colonizers found the Indians carrying on a primitive type of irrigation agriculture which the Spaniards adopted for their own subsistence needs. This type of agriculture has more or less dominated crop production in this region during its agricultural development.

The crops have changed somewhat with the changing type of inhabitants and with minor introductions, but in the main have included alfalfa, corn, wheat, beans, chilies, vegetables, and to less degree fruits and berries. Associated industries of cattle, sheep, and goat raising have been of very minor importance except locally.

At the present time (1929) the main crops rank in importance as follows: Wheat, alfalfa, corn, beans, garden crops, chilies, melons, cantaloupes, and onions.

The variety of wheat most commonly grown is Sonora, a soft white spring variety. The yield ranges from 10 to 40 bushels an acre but averages about 20 bushels. Most of the wheat is consumed at home, the milling being done at a flour mill at Socorro.

Alfalfa, which is grown extensively, is the major cash crop. Four cuttings can be obtained when irrigation water is sufficient. The average yearly production is 3 tons an acre, but yields range from 1½ to 6 tons an acre, varying with the water supply, soil, and farming practices. The hay is baled in the field and is either shipped directly or stored. Most of it is shipped to Texas markets.

Corn is one of the subsistence crops and is nearly all consumed at home. The average yield is between 20 and 25 bushels an acre. The chief variety grown is Mexican June.

Beans are grown extensively. The Pinto variety is grown and produces from 5 to 20 bushels an acre, but average yields are low owing to poor cultural practices.

Cotton has been introduced recently, and production has been attended with a fair degree of success.

Garden crops are grown widely for home use, and truck crops such as chilies, melons, and cantaloupes find a ready market in near-by towns and in mining and sawmill communities. Other garden crops grown are onions, cabbage, lettuce, tomatoes, turnips, carrots, and cucumbers. The climate is not favorable for potato growing.

Associated with the home gardens are considerable numbers of fruit trees, berry bushes, and grapevines, and a few small orchards are in evidence. The principal orchard fruits grown are apples, pears, plums, peaches, apricots, and sour cherries. The berries are mostly gooseberries, currants, and strawberries.

Small acreages are devoted to barley and oats, most of which are cut green for hay. The native salt grass of the bottoms is used mainly for pasturage, but some is cut for hay which is of inferior quality.

Associated agricultural industries, such as the raising of cattle, sheep, goats, hogs, and poultry, are not very extensively developed. Little attention is given to the introduction of purebred animals or to breeding up the scrub livestock.

Although a few individual farmers are using modern methods and equipment, much of the farming is still done in a primitive manner.

In the growing of wheat the land is sometimes plowed before irrigating, but a common practice is to broadcast the seed, plow it under, and then irrigate. The planting is done from February 20 to March 15. Harvesting takes place late in June or early in July. The general practice is to plant beans as a second crop. The land is irrigated following the removal of the wheat crop, the beans are broadcast, and in six or eight days afterwards they are plowed under. Sometimes the beans are dropped in the furrow behind the plow. The crop receives little further attention, and very little labor is involved. The field is hoed once or twice and probably receives an irrigation or two. When the crop is mature the beans are pulled by hand and put in small piles for drying, after which they are threshed.

Corn also is very often grown in a primitive manner. The land is generally irrigated, and as soon as it is dry enough it is plowed and the seed corn is dropped about every fourth or fifth furrow behind the plow. The land is then dragged with a log or heavy drag. Corn planting takes place from about April 20 to May 20, and the crop matures in about 120 days.

Alfalfa growing is given little attention. The border and check methods of irrigation, which are used for all crops, are especially injurious to alfalfa because of the silting which covers the crowns of the plants. The flood waters during May and June contribute greatly to the deposition of silt, but the most injurious deposition occurs during July when Rio Puerco is highly silt laden.

Special attention seems to be given chilies which are grown in check plots, though this usually results in overirrigation and consequent added blight injury.

Crop rotation plays little part in the farming system. Manure is not conserved, as the livestock graze throughout the year on the salt-grass pastures and in the bosques. Commercial fertilizers have seldom been used. The only replacement of soil fertility is from the yearly irrigation silting.

There is no demand for outside laborers, as native laborers are plentiful.

Most of the farms are operated by owners. In 1930, according to the Federal census, 92.6 per cent of the farms of Socorro County were operated by owners, 6.4 per cent by tenants, and 1 per cent by managers.

Land values, according to estimates made by the State engineer, based on valuations made by the Interstate Commerce Commission, are as follows: Cultivated lands, from $50 to $125 an acre; alkali-affected and salt-grass lands, from $10 to $25; swamp lands, from $10 to $15; and timber and bosque lands, from $15 to $25.

## SOILS AND CROPS

Based both on their physiographic occurrence and their agricultural utilization, the soils of these areas are placed in three main groups as follows: First-bottom soils, alluvial-fan soils, and terrace soils. Two types of miscellaneous materials are mapped, but they have little or no agricultural significance.

These groups of soils range as named in order of their importance in the development and maintenance of the agriculture of the areas. The type of agriculture is peculiar to this section of the country, having had its origin in the early methods of irrigation and cultivation practiced by the Indians of the pueblos or villages and by the early Spanish settlers. These early practices still dominate the agriculture, and it is still in a comparatively unadvanced stage. As a result the agriculture consists mainly of growing small patches of a few staple crops, mainly wheat, corn, beans, chili peppers, and garden products for the meager needs of the rural villages which were settled and are still occupied mainly or entirely by Spanish Americans of Mexican nativity or by their descendants

It is mainly through the physiographic characteristics and relationships of the soils, as affecting the convenient diversion and distribution of water for irrigation and as related to favorable sites for villages, that the centers of rural population and the distribution of agriculture in relation to individual soil types has been determined.

The soils of the areas are described in detail in the following pages, and their present and potential utilization for agricultural purposes is discussed. The distribution of the soils is shown on the accompanying map, and their acreage and proportionate extent are given in Table 2.

TABLE 2.—*Acreage and proportionate extent of soils mapped in the Socorro and Rio Puerco areas, New Mexico*[1]

| Type of soil | Acres | Per cent | Type of soil | Acres | Per cent |
|---|---|---|---|---|---|
| Gila sandy clay loam | 2,176 | 2.9 | Brazito fine sand | 704 | 1.0 |
| Gila sandy clay loam, shallow-subsoil phase | 7,360 | 9.9 | Imperial clay | 3,520 | 4.7 |
| Gila clay | 6,272 | 8.4 | Imperial clay loam | 2,752 | 3.7 |
| Gila clay, shallow-subsoil phase | 2,176 | 2.9 | Anthony clay, silted phase | 2,176 | 2.9 |
| Gila fine sandy loam | 8,960 | 12.1 | Anthony loam | 1,728 | 2.3 |
| Gila very fine sandy loam | 1,472 | 2.0 | Anthony gravelly sandy loam | 8,512 | 11.5 |
| Gila very fine sandy loam, shallow-subsoil phase | 256 | .3 | Anthony sand | 8,832 | 11.9 |
| Gila very fine sandy loam, heavy-subsoil phase | 704 | 1.0 | Pinal stony sandy loam | 768 | 1.0 |
| Gila fine sand | 3,840 | 5.2 | River wash | 5,120 | 6.9 |
| Gila fine sand, heavy-subsoil phase | 1,600 | 2.2 | Rough broken land | 5,312 | 7.2 |
| | | | Total | 74,240 | ...... |

[1] The Socorro area includes 89 square miles, and the Rio Puerco area 27 square miles, a total of 116 square miles.

### FIRST-BOTTOM SOILS

The first-bottom soils include a number of individual soil types and subordinate phases which have been classified in the Gila, Imperial, and Brazito series of soils. Of these the Gila soils are the most extensive and important. It was mainly the soils of this series that were extensively modified or subjected to textural changes by deposition of sediments during the recent floods.

The Gila soils occur only in the Rio Grande flood plain. The lower-lying areas and areas adjacent to the river are subject to overflow or accumulation of surface waters which form ponds and lakes during high stages of the streams. Extensive areas formerly irrigated and cultivated have been abandoned owing to the destruction of canals, ditches, and diversion headings at times of flood, or to extension and encroachment of seeped and alkali areas. The soil areas are, however, generally smooth and favorable to irrigation and under proper irrigation and drainage are productive. These characteristics and their favorable location with respect to the diversion and distribution of irrigation water by gravity have rendered them the main agricultural soils of the surveyed areas.

The Brazito soils are closely related to the light-textured Gila soils, with which they are associated.

The soils of the Imperial series occur only in the valley of the Rio Puerco. At present they are of very little agricultural importance, but they have some potential value in connection with proposed extension of irrigation to the Rio Puerco Valley under the project of the middle Rio Grande conservancy district.

These soils crack conspicuously, forming deep crevices. In old exposures weathering gives rise to a peculiar scaling and sloughing off of materials, and to huge columnar breakage. Along the stream the soils stand in vertical banks ranging from 15 to 40 feet in height. The erosional and structural soil features will endanger the reclamation of these soils, especially if irrigation is carried on too near the banks. Surface run-off waters pour into the crevices and cracks considerable distances back from the banks, thus undermining the soil and causing rapid erosion. With increased surface run-off from irrigation and attendant increased underdrainage, or with irrigation too near the banks, more rapid destruction of the valley floor would begin.

Except in the immediate vicinity of the stream banks, the areas of Imperial soils are ideally smooth for irrigation and generally slope gently to the river. The natural vegetation is sparse and consists of scattered "chamiza" and bunch grass. However, the intractable highly impermeable character of these soils and the high salt content offer a great problem in their reclamation and cultivation. White incrustation of alkali salt does not appear at the surface, but nevertheless alkali concentration is higher than the toxic limits of crop plants.

The southeastern or lower boundary of the Rio Puerco area joins with the Middle Rio Grande Valley area surveyed in 1912.[2] The inaccessibility of this part of the Middle Rio Grande area at that time, owing to flooded and swampy areas, the subsequent changes in soil conditions due to deposition of river sediments, and the more detailed mapping in the later surveys have resulted in a conflict in the classification of the Imperial soils of the Rio Puerco area which join with Anthony sand of the earlier survey. In the earlier survey Anthony sand in this part of the Rio Grande Valley was not closely differentiated and as shown on the soil map covers the entire alluvial bottom of the Rio Puerco Valley. The soil map of the Rio Puerco area much more accurately portrays soil conditions existing at the present time.

**Gila sandy clay loam.**—Gila sandy clay loam is one of the most important agricultural soils in the Socorro area but not the most extensive. Where cultivated it has been considerably modified by agricultural and irrigation practices, principally the last, due to the high amount of suspended materials, mainly clay, carried and deposited by the irrigation waters. Through tillage and in places through wind deposition, lighter-textured materials have become incorporated in the heavier-textured surface soil, giving rise to the sandy clay loam texture. This has also slightly increased the elevation of the surface, already generally favorable, so that flooding, seepage, and accumulation of alkali have been minor disturbances. Consequently this is one of the most enduring soils of the area.

The typical soil in its virgin development in most places consists of a very heterogeneous mixture of sediments forming layers of variable texture throughout the profile The materials are calcareous throughout. The surface soil is generally of darker color than in the lighter-textured soils of the Gila series. It consists of light-brown, chocolate-brown, or dark dull grayish-brown sandy clay loam, or a series of layers of clay and clay loam, interspersed with thin bandings of sand and silt. The air-dry samples are much lighter in color than those examined under moist field conditions. At a depth of approximately 2 feet are layers of similar texture but of variable thickness, though they are generally thicker than the surface layers. The subsoil in most places is dark grayish-brown poorly oxidized material, but it includes

[2] NELSON, J W, HOLMES, L C, and ECKMANN, E C SOIL SURVEY OF THE MIDDLE RIO GRANDE VALLEY AREA, NEW MEXICO U S Dept Agr, Bur Soils, Field Oper 1912, Rpt. 14 1965-2010, illus 1915

lighter-brown materials. The darkening or dullness of color is associated with the water table which in most places lies at a slight depth during the greater part of the year. The substratum consists dominantly of a mixture of dull-gray or light-gray loose water-washed sands, generally beginning at a depth of about 4 feet and continuing to indefinite depths. This substratum underlies all the Gila soils, and to the depths determined in this survey it is not bedded with clay in most places.

The higher-lying areas of this soil, which are less frequently subjected to overflow and a high water table, contain less organic matter, and are more thoroughly and uniformly oxidized, and are therefore of lighter-brown color throughout.

The total extent of Gila sandy clay loam is 3.4 square miles. It occurs as elongated narrow areas scattered over the valley floor and also adjacent to the marginal sloping alluvial-fan soils. In the last-named situations the areas merge rather indefinitely with those soils, because of silting by irrigation. With the exception of such areas the soil is in general water-logged and affected by alkali, and more than half the land has either been abandoned because of the rising water table or encroaching alkali, or it has been allowed to remain in its virgin state.

The natural vegetation over the greater part of this soil consists of salt grass, willow, and cottonwood, but where ponded or swampy areas occur the vegetation gives place to sedges and tules. Probably about one-fourth of the land is wooded.

At the present time no special crops are grown on this soil. Staple subsistence crops are grown on the small areas which are still free from encroaching seepage and alkali accumulations, in proximity to the villages.

This soil is generally rather intractable even under the best tillage practices, though not so much so as Gila clay. When wet it is very plastic; when dry severe cracking and clodding occur, making it difficult to find a period of optimum moisture content for favorable cultivation. The principal need of the soil is organic matter, incorporation of which by use of stable manure, green manures, or the use of alfalfa in the crop rotation would alleviate the intractability as well as increase the nitrogen content of the soil. Fortunately this soil is high in calcium which is conducive to a good physical condition. A fair state of fertility is maintained by the continual silting through irrigation. However, this silting of fine-textured materials aggravates the intractability of the soil. Little or no attention is given to conservation of stable manure, and no commercial fertilizers are used.

On the water-logged and alkali-affected areas the first requisite is drainage, followed by systematic leaching for the removal of the injurious salts. This, however, is a community problem and until it is given attention as discussed elsewhere in this report, the Gila sandy clay loam areas will have little value except for pasture. The response of this soil to reclamation will, however, be slow.

**Gila sandy clay loam, shallow-subsoil phase.**—The shallow-subsoil phase of Gila sandy clay loam differs from typical Gila sandy clay loam principally in the depth to the porous sandy substratum. The differentiation is mainly arbitrary and is based on the moisture-holding capacity in relation to crop production, assuming that the more shallow surface soil, which averages less than a foot in depth and is underlain by loose porous sands, will require different irrigation and cultural practices or will respond differently from the typical soil in crop production.

In many places the surface soil is very shallow, representing a rather recent deposition of fine-textured materials from irrigation or natural flood waters. As older flood channels have been abandoned and other channels built up by the aggrading streams, the arrested waters in the back bottoms have deposited the clay materials during repeated floodings. Isolated islandlike areas of sandy materials, in many places too small to map, occur throughout areas of this soil.

In aggregate area the shollow-subsoil phase exceeds that of typical Gila sandy clay loam and covers 11.5 square miles. It is well distributed throughout the Socorro area.

Undoubtedly this soil will respond rather readily to reclamation, but the land is leachy and will require more irrigation water than typical Gila sandy clay loam. Under cultivation it is equally as refractory as the typical soil and has need of organic matter.

The principal vegetation on this soil is salt grass and tornillo, with sedges and tules in the swampy areas.

Though this is one of the most important soils as regards utilization, probably less than one-fourth of the total area is farmed, due to the swampiness and general inaccessibility of the land. The staple crops of the area are grown on it.

**Gila clay.**—The surface soil of Gila clay is dull reddish brown or dark dull grayish brown, depending on location, the lower-lying areas which have a high water table and are subject to overflow being of the darker and duller color. In the lower situations the color approaches that of the related Pima soils of previous soil surveys, which are differentiated from the Gila soils on the basis of their darker color and higher organic-matter content. The surface soil is heavy intractable clay, which when dry cracks into large blocks, the cracks opening freely and to a considerable depth. Especially in areas subject to overflow is this condition pronounced. At a depth ranging from 12 to 16 inches the material grades into slightly reddish-brown heavy plastic clay. Water from above and below does not penetrate this layer readily. At a depth ranging from about 3 to 4 feet, this material gives place to layers of sand, sandy clay, and clay, which generally merge with the sandy porous substratum within a depth of 6 feet. When freshly removed these lower materials show a dull grayish-brown deoxidized color showing the effect of a high water table.

The total area of this soil is 9.8 square miles. It has a wide distribution, but is most extensively developed between Polvadera and San Antonio and in the vicinities of San Marcial and Val Verde. Areas which do not border the alluvial-fan soils lie in the back bottoms of the older stream channels and many of them are swampy. In these positions the soil is highly deflocculated and has a high alkali-salt content even though surface accumulations are not so apparent as in the lighter-textured soils of the Gila series.

Like Gila sandy clay loam, nearly all this soil is in need of drainage and leaching to lower the water table and remove the alkali. In the reclamation of Gila clay the greatest problem will be the removal of the alkali salts, and this will be difficult owing to the general impermeability of the soil.

Approximately one-fourth of this land is cultivated at the present time, and an equal part has been abandoned, due to a rising water table and the accumulation of alkali. The remainder, which is in the virgin condition, consists of timbered and brush-covered areas of cottonwood and willow and open areas of salt grass and sedges, or it is in a baked deflocculated condition and cocklebur is obtaining a foothold.

The cultivated areas are devoted to crops similar to those grown on Gila sandy clay loam, with which this soil merges almost imperceptibly in many places. In tillage Gila clay presents even a greater problem than Gila sandy clay loam, due to its higher refractory and in many places deflocculated condition and to the greater depth of the highly impermeable clay The addition and incorporation of large amounts of stable manure or similar organic matter, together with the continued growing and turning under of green manures and alfalfa, would soon result in improved granulation and aeration, and the high lime content would further stimulate improvement. In the vicinities of Polvadera, Lemitar, San Antonio, San Marcial, and Val Verde, where deep raw clay deposition took place from the recent floods on both Gila clay and its shallow-subsoil phase, for the most part on cultivated land, soil improvement practices are especially necessary for successful crop production.

**Gila clay, shallow-subsoil phase.**—Gila clay, shallow-subsoil phase, in its immediate surface soil development is similar to typical Gila clay, but at a depth ranging from 12 to approximately 15 inches the subsoil is underlain rather abruptly by the porous substratum.

The moisture-holding capacity of the soil is lessened by the slight depth to the substratum, and in this respect this soil holds similar relationship to typical Gila clay as the shallow-subsoil phase of Gila sandy clay loam does to that soil. Its immediate reclamation will be facilitated by this feature, but it will ultimately become a more leachy soil than typical Gila clay.

Most areas of this soil, except those that have been artificially built up by irrigation sedimentation, are unfavorably located both with regard to seepage and distance from the communal villages. Staple crops are grown.

**Gila fine sandy loam.**—Gila fine sandy loam in most areas has a surface soil of dull-brown or light pinkish-brown smooth uniformly textured fine sandy loam extending to an average depth of 10 inches. Matted grass roots generally penetrate the soil to this depth and there is some darkening by organic matter, though this is more pronounced at and near the surface. The upper part of the subsoil consists dominantly of light pinkish-brown fine sand which is more or less interspersed with thin beddings of silt and clay. In the deeper part of the subsoil there is a change to coarser-textured sands such as occur in the substratum underlying all the first-bottom soils In a few places bordering areas of the heavier-textured soils, the upper subsoil layer may be dominantly clay, but this texture is nowhere so pronounced as in Gila very fine sandy loam

Most of Gila fine sandy loam lies in the aggrading part of the valley adjacent to the Rio Grande or its overflow channels, and the surface soil is continually being disturbed by deposition of fine-textured materials, the texture depending on the velocity of the streams at the time of deposition. This thin-banded sedimentation is in many places pronounced, especially in the surface soil Near the channels repeated overflows retard vegetable growth, so that the soil materials are in many places loosely organized and have a washed light-brown or light grayish-brown color. In such places the surface soil may also be disturbed by wind.

This is the most extensive soil in the areas, occupying 14 square miles, but probably not more than 1 square mile is farmed because of the general inaccessibility of the land.

Areas of this soil are less frequently under standing water than are the other Gila soils except the fine sand, but the land is subject to a comparatively high water table and associated alkali conditions. The position of the soil, the light texture, and the open structure make it less retentive of alkali salt than heavier-textured soils, and it has a lower concentration of salts throughout the profile, though surface indications in many places are to the contrary. The features mentioned should make this soil one of the most easily reclaimable.

The natural vegetation on the virgin soil is mainly willows, with associated growths of cottonwood and tornillo. A growth of salt grass is more or less general but is most pronounced in open areas.

This soil, like other first-bottom soils, is in need of drainage, in order to lower the water table, and of leaching for the removal of injurious salts. It can be reclaimed more readily than the heavier-textured soils, and since it is extensive it should become the most valuable soil in the areas for general agricultural purposes and especially for fruit growing and truck gardening. Incorporation of organic matter is very important, especially in the recently overflowed areas where loose sands have accumulated. Cultivation will loosen this sandy material, making it subject to wind action which may prove very detrimental unless precautions are taken. The deposition of silt and clay that takes place with irrigation will prove beneficial in this respect. However, after a number of years excessive silting will produce a textural change to clay loam or clay soils.

**Gila very fine sandy loam.**—Gila very fine sandy loam has a surface soil of light grayish-brown mellow smooth silty-textured very fine sandy loam, which continues to a depth ranging from 12 to 18 inches, interspersed in many places with thin laminated sedimentary layers of silt Below this and continuing to an average depth of 30 inches the layers may be thicker alternating layers of sand, silt, and clay, or the material may be predominantly sandy. The dominant color of this layer is light brown, with a pronounced pale-red color in the clay layers. The upper subsoil layer grades into a lower subsoil layer composed of dull grayish-brown poorly oxidized light-textured materials which merge with the porous substratum within a depth of 6 feet in most places.

This soil as mapped includes a few areas of Gila silt loam.

Although the total area of Gila very fine sandy loam is only 2.3 square miles, it is widely distributed Most of it occurs in narrow elongated areas in the back bottoms in conjunction with the heavier-textured soils, and it is there equally seeped and alkali impregnated. However, from the point of view of reclamation this soil should be much more readily leached of injurious salts than the heavier-textured soils.

Practically none of the land is under cultivation, owing to its inaccessibility and seeped condition. It supports a growth of cottonwood, willow, and salt grass. When reclaimed it should prove a valuable soil both on account of its ease of cultivation and its moisture-holding capacity.

**Gila very fine sandy loam, shallow-subsoil phase.**—The shallow-subsoil phase differs from typical Gila very fine sandy loam in that the light-textured substratum lies within a foot of the surface, this phase being similar in development to the shallow phases of the other Gila soils. Soil of the phase has lower water-holding capacity but is more amenable to drainage and reclamation from alkali accumulation by leaching than the thicker typical soil. The largest and most conspicuous area occurs a short distance southeast of Luis Lopez.

**Gila very fine sandy loam, heavy-subsoil phase.**—A few areas of Gila very fine sandy loam, generally bordering areas of Gila clay and Gila sandy clay loam, have been influenced in subsoil development by those soils. Where a continuous heavy clay subsoil exists, the areas have been differentiated on the map and designated as Gila very fine sandy loam, heavy-subsoil phase. The soil in these areas has a higher water-holding capacity and will become less quickly subject to drought in culture of the deeper-rooted crops, but it is less easily drained and reclaimed of alkali accumulations. The principal areas occur in the vicinity of Escondida and Socorro.

**Gila fine sand.**—The surface soil of Gila fine sand is light grayish-brown incoherent fine sand of remarkably uniform texture. This may continue to an indefinite depth but in general to an average depth of 3 feet, where it rests on light grayish-brown loose porous washed sand which grades almost imperceptibly into the sandy substratum. Owing to the loosely coherent character of the soil the surface soil in most places has been somewhat disturbed by wind and is slightly hummocky.

This soil is developed principally near the Rio Grande channel. General drainage and alkali conditions are similar to those of Gila fine sandy loam although Gila fine sand, owing to its wind-modified surface, generally lies a little higher than that soil. Included with this soil in mapping are small undifferentiated areas of Gila sand and Gila sandy loam.

The total extent of this soil is at present 6 square miles, the areas from San Acacia to Pueblito and in the vicinity of San Marcial having been greatly increased during the 1929 flood The deposition left by the flood waters, except in the area adjacent to San Acacia, produced a surface much broken or corrugated by channels, due to the swift current and obstructing vegetation.

The natural vegetation is principally willow, with a scattered growth of cottonwood and tornillo. The grass covering is sparse, the more open and hummocky areas supporting growths of spiny aster and arrowweed. The recently deposited areas are either barren or have the tree or bush vegetation of the previous soil partly buried or badly entangled with the soil material

This soil will drain and leach of alkali readily but will present a problem in cultivation because its incoherent character will leave it subject to wind action. Silting by irrigation water will aid in improving the soil if this is done systematically and properly controlled. Both in the artificially silted or in its original condition the soil is very leachy and has a high water requirement.

**Gila fine sand, heavy-subsoil phase.**—Gila fine sand, heavy-subsoil phase, consists almost totally of newly deposited fine sand overlying previous Gila soils of clay and clay loam textures, and the original heavy-textured soils now constitute subsoils. This soil occurs principally east of the railroad track in the vicinities of Polvadera and Lemitar. The surface is irregular and broken, due to uneven deposition and to erosion channels. Owing to the heavy-textured subsoils, soil of this phase has a higher water-holding capacity but is less easily drained and reclaimed than typical Gila fine sand.

**Brazito fine sand.**—Brazito fine sand to a depth of 6 or more feet consists essentially of wind-blown deposits derived from Gila fine sand materials. The soil has a light grayish-brown color, with a pale-pink tint in places, and a rather uniform texture. The areas have a hummocky or well-defined dune relief, and the surface of the land is continually changing, owing to wind action.

This soil is very inextensive It occurs principally in small scattered areas in the southern part of the Socorro area south of San Antonio The vegetation is sparse, consisting mainly of spiny aster and arrowweed.

The soil materials have been blown up well above the level of other soils, consequently this soil is not affected by a high water table or by overflow. Alkali salts have not accumulated. At present the land has no agricultural value. Its future development depends on increased land value, when the cost of leveling and control of wind action may not be prohibitive. Under improved conditions the utilization of this land would be similar to that of Gila fine sand.

**Imperial clay.**—Imperial clay is the most intractable and impermeable soil of the Imperial series, and these characteristics are reflected throughout the soil. The true rich chocolate-brown color of the soil is obscured by a ½-inch baked surface crust of dull reddish-brown color. This rests on a 2 or 3 inch reddish-brown granulated mulch development of clay. Below this, rich chocolate-brown clay definitely spotted and veined with white salts continues to a depth ranging from 20 to 30 inches. The lower part of the subsoil is of similar rich chocolate-brown refractory clay but the alkali accumulation decreases with depth. In many places the material in this layer has a slightly green tinge In most places the clay extends to a depth of not less than 6 feet and in many places continues to undetermined depths. At the lower depths the clay materials generally become interspersed with seams and layers of sands and finally give place entirely to sands.

This soil occurs only in the immediate bottoms of the Rio Puerco. It occupies 5.5 square miles, lying in narrow strips along both sides of the river.

At present the land is utilized only for the scant grazing it affords.

**Imperial clay loam.**—Imperial clay loam differs from Imperial clay only in the texture of the surface soil which is clay loam to a depth ranging from 20 to 30 inches. This textural difference has been brought about chiefly from encroachment of lighter-textured wind-laid materials which have become incorporated in the surface soil. Much of this soil is developed marginal to the alluvial-fan soils and merges with them rather indefinitely.

The total extent of this soil is 4 3 square miles Most of it is in the Rio Puerco Valley, where it occurs as small scattered areas in conjunction with Imperial clay. Only one small area about one-half square mile in extent occurs in the Socorro area, east of San Acacia

### ALLUVIAL-FAN SOILS

The soils of the alluvial-fan slopes, which form more or less continuous areas marginal to the first-bottom soils, rank second in importance in the agricultural development of the areas surveyed. They are represented by soils of the Anthony series.

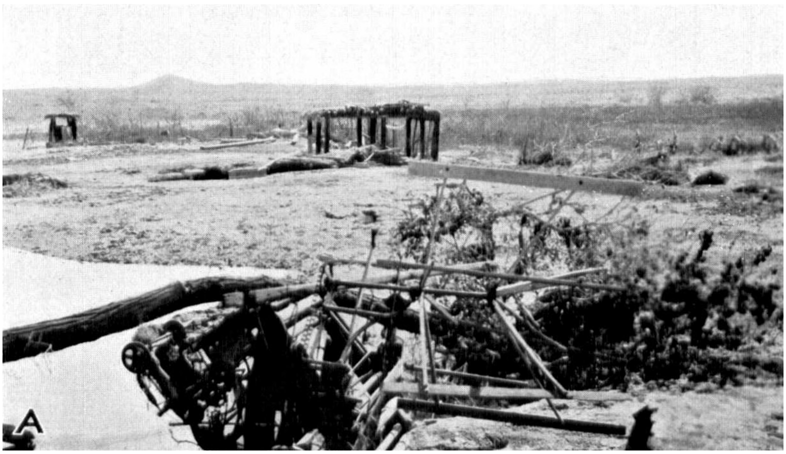
The soil materials are of geologically recent deposition, but they are older than those of the stream bottoms and have been modified to a certain extent by weathering under the arid climatic conditions and scanty vegetation Some lime and clay accumulations have resulted in the subsoil, but the sparse vegetal covering has left very little organic matter incorporated in the soil

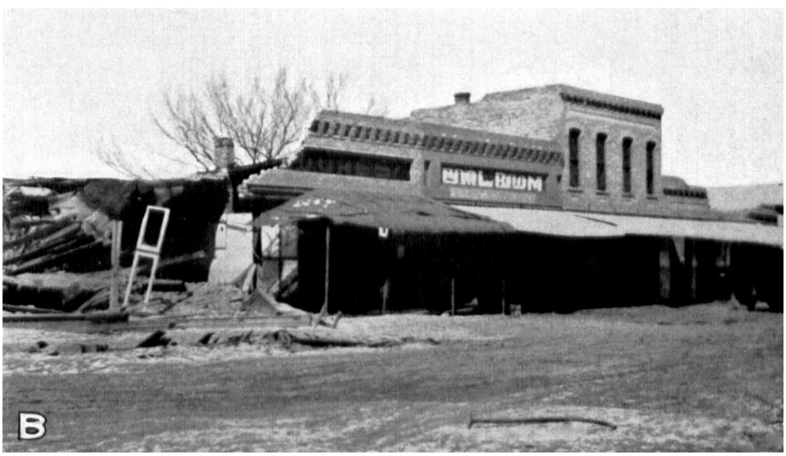
The materials have been laid down by intermittent streams, or arroyos, which carry off the surface waters of the upland plains and near-by mountains. The soils have inherited their high lime content especially from the older materials of the upland plains, which are highly calcareous. In general a deeper-red color seems to have been inherited by the soils on the east side of the Rio Grande, especially at Pueblito.

The alluvial-fan soils have a very unsymmetrical relief. The areas are rather steeply sloping and broken by numerous erosion channels which are continuing erratic deposition of materials as in the past. The surface soils are in general gravelly and in many places stony, and in the lighter-textured materials hummocks produced by wind action render these soils less favorable for irrigation and cultivation than the first-bottom soils. Furthermore, their moisture-holding capacity is reduced in proportion to the amount of porous gravelly materials in the subsoils

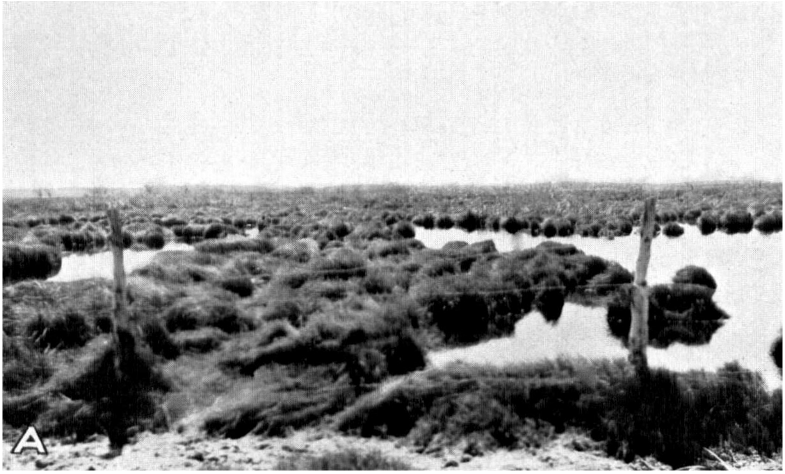
The more porous soils having the less favorable texture and relief occupy the steeper and more elevated slopes, in many places lying above water supply for irrigation. The more favorable heavy-textured Anthony soils lie marginal to the cultivated bottom soils, and wherever they are within gravity flow of irrigation water they have been brought under cultivation. Their cultivation has been further stimulated because of the encroachment of a high water table and alkali on the associated lower-lying bottom soils. The alluvial-fan soils have been subjected very little to such encroachment, owing to their higher location.

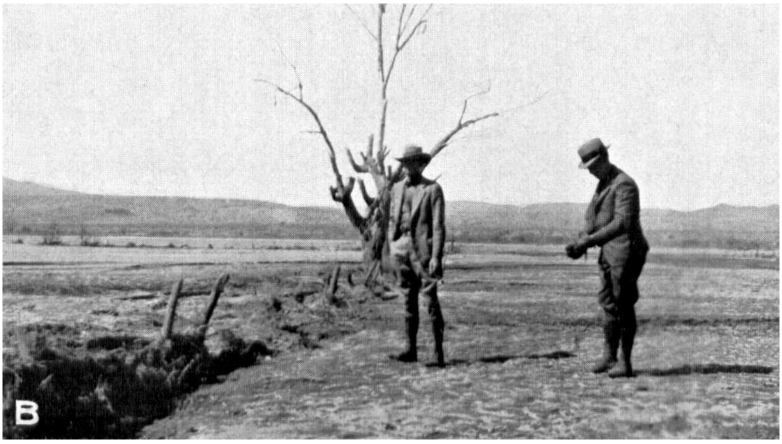
**Anthony clay, silted phase.**—Anthony clay as occurring in this survey is represented only by a silted phase which is in part an artificially built-up soil. It consists of a clay surface soil, formed by deposition from turbid irrigation waters, overlying a typical Anthony soil which in some places has become more or less obscured by infiltration of the surface clay or by tillage. An average development consists, to a depth ranging from 2 to 3 feet, of reddish-brown plastic clay which is rather intractable but, owing to constant tillage, is less refractory than the virgin bottom soils of similar texture. Below the surface soil is lighter-textured material, the texture depending on the original texture of the Anthony soil and on the degree of clay infiltration and incorporation through natural or artificial agencies





A, Site of farmstead ruined by floods in Rio Grande in 1929. B, scene on Main Street in San Marcial in March, 1930 About 3 feet of sediment was deposited here by floods in August and September, 1929, and many of the adobe buildings were destroyed





A, An area of marshland occupied by open water, cattails, and sedges on soils of the Gila series near San Acacia as appearing in March, 1929, B, filled-in areas near San Acacia in which about 3 feet of river sediment was deposited by the floods of 1929 in an area formerly occupied by marshland

These materials are generally duller or grayer in color than the material above and become coarser with depth, with included gravel and stone stratification.

This soil merges almost imperceptibly in surface soil characteristics with the heavy-textured soils of the Gila series, many areas of which have been similarly silted. In most places, however, it occupies gentle slopes above the bottom soils and has richer reddish-brown surface soils than the bottom soils which are subject to a high water table and overflow.

This soil occurs mainly in the part of the Rio Grande Valley between San Acacia and San Pedro. It occurs as narrow strips, marginal to the Gila soils, between the irrigation canals and the bottoms. The largest single areas are in the vicinities of Socorro and Lemitar. Included in these areas are marginal strips in which the silted surface layer is thin.

Its favorable location with regard to elevation above the bottoms and its generally porous subsoil make this an ideally drained soil, and it is not affected by alkali accumulations. It has been important in the agricultural development of the valley. The crops grown and yields are similar to those on the better-drained areas of the heavier-textured Gila soils. This soil, like the Gila soils, is in need of organic matter for maximum crop production and ease of tillage.

**Anthony loam.**—Anthony loam typically has a reddish-brown or dull reddish-brown loam or heavy loam surface soil, extending to a depth of about 10 inches, resting on an upper subsoil layer of heavy loam with slight clay and lime accumulation as indicated by white mottlings and general graying and compaction of the materials. The upper subsoil layer is very plastic when wet. Scattered lime-coated gravel and a few pockets of thin-bedded gravel occur in many places throughout the upper part of the soil material. Loose, coarse, porous stratified materials begin at a depth of about 3 feet, and these become more pronounced with depth.

Only a few virgin areas remain and in these there are small scattered hummocks of wind-blown materials centered around the clumps of vegetation which consist chiefly of mesquite and "chamiza." The surface is gently sloping, being suited to irrigation, and the soil under the canals has been brought under cultivation. Though at some time the greater part of the land has been under cultivation, only about one-half is now farmed, owing to seepage and alkali which have affected the low-lying areas. An extensive abandoned area along the highway north of Elmendorf, the immediate surface soil of which shows some modification from deposition of silt and very fine sand, lies almost on the same level as the first-bottom soils and has become subjected to a high water table and alkali accumulation.

The largest single area of cultivated soil is adjacent to Socorro. Here, as elsewhere, where irrigated, the surface soil is rapidly being silted with clay, and the soil will in time become similar to Anthony clay, silted phase.

This soil is used for the same staple crops as are grown on Anthony clay, silted phase, and the heavy-textured soils of the Gila series. It is, however, more friable and tractable than those soils but is in need of organic matter.

**Anthony gravelly sandy loam.**—Anthony gravelly sandy loam is extensive, including a total area of 13.3 square miles, but it is of little agricultural importance at present. It occurs chiefly in the Socorro area, for the most part lying adjacent to the canals, but generally lies too high for irrigation by gravity flow under the present or proposed canals. This soil in the Rio Puerco area will come under the proposed irrigation canal. Large favorable areas, but without water supply, lie outside of the areas surveyed, especially along the larger arroyos.

The surface soil of this soil is dull reddish-brown friable gravelly and, in places, stony sandy loam, but it has a less pronounced red cast than the heavier-textured soils of the Anthony series. The upper subsoil layer is dull grayish brown in color and gives evidence of slight lime and clay accumulation, which has resulted in a slightly heavier sandy loam texture and some compaction. The lower subsoil layer and the substratum are similar to those of the heavier-textured Anthony soils except for increased coarseness of materials and attendant lower water-holding capacity. The gravel and stone throughout the soil are more or less lime coated.

Extreme variability in the lime accumulation, as is common in the subsoils of the light-textured Anthony soils, occurs in this soil. This variability in development is associated with the age of the deposited soil materials. The arroyos are continually carrying and depositing materials, especially near the channels where the soils have not been subjected to soil-making processes very long and where the flow of water disturbs the weathering processes in the older deposits. Near the channels the materials in many places have a lighter, grittier sandy loam texture and increased gravel and stone content. Extremely stony areas are shown on the map by stone symbols.

The surface of this soil is more or less modified by wind-blown hummocks centered around the bushy mesquite and "chamiza." An extremely hummocky area, in which the surface soil is lighter textured than typical, lies north of Polvadera.

**Anthony sand.**—Anthony sand has a surface soil of light reddish-brown loose porous gritty sand, in most places sprinkled with gravel. The looseness of the material has allowed extreme wind disturbance of the surface soil, causing extensive hummocks to become centralized around the natural vegetation which is principally bushy mesquite. The subsoil is less clearly defined than in other soils of this series but in most places shows some accumulation of lime and clay, with resulting compaction, to a depth ranging from 2 to 3 feet, below which the materials are loosely stratified and porous. The only color change discernible throughout the soil occurs between depths of 1 and 3 feet, where the color is dull light reddish brown.

The total area of this soil is 13 8 square miles. Practically none of the land is cultivated, principally because it lies above the irrigation canals, but even if water were available its utility would, in general, be questionable, because of the hummocky and shifting surface soil and the porous, leachy character of the soil in general The bodies in the Rio Puerco area, however, which cover a total of about 8 square miles, have better possibilities than those in the Socorro area, especially those coming under the proposed canal. Although some of this land is rather steeply sloping and is somewhat wind disturbed and uneven, it is not so hummocky as in the Socorro area, and the cost of leveling would not be so prohibitive as in that area.

### TERRACE SOILS

The soils of the terraces, though subject to considerable variation in color and development, have in this survey been included under a single soil type recognized as Pinal stony sandy loam. This soil occurs entirely above present or probable future sources of water supply for irrigation and has no present economic value except for the scant grazing it affords.

**Pinal stony sandy loam.**—Where typically developed, Pinal stony sandy loam has a surface soil of dull reddish-brown sandy loam to an average depth of about 10 inches. This is underlain by a grayish-white marly softly cemented lime-carbonate hardpan, about 12 inches thick, which in many places is marked by considerable transitional material. Below this is an extremely hard lime-carbonate hardpan of conglomeratelike appearance, in many places containing much gravel. It is difficult to ascertain to what depth the hardpan continues, but where exposed in cuts it was found to extend to a depth of about 4 feet, ending as a lime infiltration with gravel and stone. Underlying the hardpan, the subtratum appears as unconsolidated thickly bedded strata having extremely variable textures.

The surface soil is sprinkled with gravel and stone either at the surface or at slight depth. The relief is, in general, that of an old elevated terrace broken by drainage channels, but some flat or comparatively level areas occur. The vegetation is mainly creosote bush, with some scattered bunch grass.

The chief development of this soil is directly south of Socorro, where it covers about 1 square mile.

### MISCELLANEOUS MATERIALS

The types of miscellaneous materials which do not conform to the usual classification into soil series and types, and which are of no agricultural importance except for a scant amount of grazing, consist of river wash and rough broken land.

**River wash.**—The greater part of river wash lies in or along the river bed and the overflow channels of Rio Grande and in the channel of Rio Puerco. In these places it consists of light grayish-brown or light-gray mixed sands. River wash is subject to repeated overflow and translocation of materials. It is practically barren of vegetation and is subject to severe wind action. The surface is generally flat, with occasional channels and wind-blown hummocks Small areas of river wash also occupy the larger arroyos or intermittent streams tributary to the rivers. The materials here are not so uniformly segregated, being highly mixed water-borne detritus consisting mainly of sand, gravel, and stone.

The total area of river wash is 8 square miles, the greater part of which is in the Socorro area

**Rough broken land.**—Rough broken land is, in general, unsuited for agriculture and includes badly eroded and dissected areas, steep slopes, and bluffs. It occurs only on those parts of the terraces which are marginal to the valley depressions, and as mapped it includes minor small areas of smooth relief which might be utilized for agriculture were rainfall sufficient for dry farming or were water available for irrigation. The smoother areas occur mainly in the Rio Puerco area where the margin of the terraces is marked by a less abrupt break, in places being smoothly rolling.

The total extent of rough broken land is 8.3 square miles.

## RECOMMENDATIONS FOR THE IMPROVEMENT OF THE SOILS OF THE SOCORRO AND RIO PUERCO AREAS

Even with the present poor equipment and lack of capital a better system of agriculture could be carried on in these areas. More attention should be given to deeper plowing and more thorough seed-bed preparation The heavy types of soil used almost exclusively for farming, such as Gila clay, Gila sandy clay loam and its shallow phase, and Anthony clay, silted phase, require improvement in their physical condition to increase aeration and retention of moisture. Thorough tillage, adding stable manure and green manures to the soil, and using alfalfa in a systematic rotation with the other crops would increase crop yields materially. Fortunately calcium, which is essential for the good physical condition of the soil is plentiful in all the soils of these areas.

For general farm crops, with the exception of alfalfa, the soil at present seems to contain sufficient plant food. Alfalfa responds markedly to phosphatic fertilizer. Indications are that the yield of truck crops would be materially increased by the application of nitrogenous fertilizers. The nitrogen supply would be increased with the incorporation of organic matter or by a rotation of crops. A rotation system in which alfalfa would occupy the land for at least three years might well be used.

It is probable that with reclamation of the extensive seeped and poorly drained areas having alkali accumulation new cash crops will be introduced, with stimulated agricultural development. Considering reclamation in relation to the present crops, alfalfa and wheat should prove to be the best crops for the heavy-textured soils such as the Gila soils, from the clay to the very fine sandy loam, Imperial clay loam, Anthony clay, silted phase, and Anthony loam. Corn would probably do well on Gila very fine sandy loam, Gila fine sandy loam, Anthony loam, and Anthony gravelly sandy loam. The lighter of these soils, such as the loams and sandy loams, are most suitable for garden and truck crops. Such light-textured soils as Gila fine sand and Anthony sand, where leveling and protection from blowing would be practical and the cost not prohibitive, should be suitable for early truck crops. With the control of floods and river channels, some of the more favorable areas of river wash might become suitable for truck crops. Likewise, with increased land value, so that the cost of leveling Brazito fine sand would not be prohibitive, this soil might find similar utilization

## IRRIGATION, DRAINAGE, AND ALKALI

Under the arid conditions of these areas irrigation is necessary for crop production At present irrigation is practiced only in the Socorro area Here the irrigation system, which is a development of the primitive irrigation practiced by the Indians and early Spanish settlers, consists of small community ditches with convenient gravity diversion and distribution Owing to river overflow and destruction of diversion headings and ditches and to silting up or aggrading of the river bed resulting in a rising water table and alkali accumulation, older irrigated areas have been abandoned and ditch alignments changed, limiting irrigation to the higher-lying lands of the bottoms and the bordering alluvial fans.

It is estimated that at present only 11 or 12 square miles of land is being irrigated in the Socorro area. This includes mainly narrow areas along the edge of the stream bottoms, with only minor developments on the valley floor in the vincinities of Polvadera, Lemitar, Socorro, San Antonio, San Antonito, and Val Verde Most of the irrigated land is artificially silted with clay sediments from turbid irrigation waters, and this silting has given rise to uniformly heavy-textured surface soils Much of the original soil, especially in the vicinities named, could not be farmed at present were it not for this silting, which in many places has raised low-lying areas out of immediate danger of the rising water table and encroaching alkali and has also built up a productive surface soil over generally unfavorable open porous subsoils. The surface configuration as related to distribution and use of irrigation water has also been improved by silting, and though this practice has in places been unfavorable to a friable physical condition, the fertility of the soils has been maintained.

During the period of irrigation development much unnecessary duplication of ditches and diversion headings resulted, which could readily be decreased, thereby economizing in cost of maintenance, in the amount of land occupied by the ditches, and in water. The numerous diversion points along the Rio Grande are merely ditch headings which lack permanence and capacity for sufficient water diversion. The expense of maintaining or replacing these numerous headings is great, and the consequent loss of water critically endangers crop production which already is hazardous, owing to the intermittent flow of the river during the growing season. Further loss of water results from seepage and evaporation from the numerous ditches. The yearly cleaning of the ditches to remove the sediment deposited from silting, which constantly builds them up and reduces the grade, is in itself expensive.

The border and check methods of irrigation are used. A comparatively even surface distribution of water is favored by the generally smooth relief, and in most places no attempt is made to level the land. No measurement of water is made, this being allowed to distribute itself over the surface and soak into the soil as the slope and the character of the soil allow.

The source of the water supply is the Rio Grande. The flow during the summer is intermittent, resulting in frequent shortage or lack of water during the growing season. Records at San Marcial show that for the 12-year period preceding 1927 the river was dry for an average of 39 days a year. Adequate water-storage facilities are needed to make crop production less hazardous.

The heavy silt burden and the insufficient fall of the river have caused a continual aggrading and widening of the river bed, so that in most places it is above the adjacent bottom lands. The extreme of this condition occurs at San Marcial, where the river bed has been built up 12 feet since 1880. Throughout the valley increased water logging and alkali accumulation on the first-bottom soils have resulted from the rising water table. Approximately 75 per cent of the irrigable land within the surveyed areas is thus affected. The encroaching seepage and alkali accumulation have caused abandonment of extensive areas and curtailed agricultural expansion. Much of the area now farmed is so affected or is in immediate danger of increasing encroachment.

Under the proposed project of the middle Rio Grande conservancy district extensive improvements in irrigation, drainage, and river-channel rectification are contemplated. It is proposed to store water on the Rio Chama, a tributary of the Rio Grande, and a proportionate part of this water will be alloted to the areas in this survey to insure an adequate supply of water during the growing season. The plans further include a diversion dam at the narrows at San Acacia, which will divert water into a main canal that will run the length of the valley in the Socorro area and, together with its laterals, will supplant the duplication of small ditches in the present inadequate and inefficient irrigation system. The area to be served here is about 26,000 acres. The proposed canal for the Rio Puerco Valley will head outside of the area at Isleta. An adequate drainage system is to be provided, and levees to define and control the river channel will be built.

Nearly all the first-bottom soils and in some places a small part of the alluvial-fan soils immediately marginal to the bottom soils are affected by alkali accumulations. In the Rio Grande Valley this condition is associated with a high water table. Either of these conditions alone is unfavorable to, or prohibitive of, the normal growth of crops, and when combined the deleterious effect is aggravated.

In the areas surveyed free ground water is reached within a depth ranging from 3 to 4 feet, and marshy or swampy areas occur in which surface water stands more or less continuously. The high ground-water level interferes with adequate root development, as the roots grow laterally above the water-logged zone, and when alkali concentration occurs in the surface soil the root development is in a very toxic zone. With aggravated conditions of high water table, the accumulation and toxicity of the alkali salts has increased due to the stimulated capillary movement of water from a water-logged subsoil under the excessive evaporation of the climate.

Both "white" and "black" alkali are found in this region. The black alkali is commonly thought of as sodium carbonate, and the white alkali is a mixture of various salts, the dominant salts being sodium chloride and sodium sulphate.

Fortunately there is very little black alkali in the areas surveyed. These salts, besides being corrosive to plant tissues, cause a deflocculated condition of the soil, making it very intractable and impermeable so that it resists reclamation stubbornly. White alkali causes physiological disturbance to the plant rather than a physical effect on the soil. Soils affected by white alkali are more readily reclaimed than those affected by black alkali. Toxicity and unfavorable physical soil conditions increase noticeably when only minor amounts of black alkali are associated with the white. With leaching out of white alkali, the black alkali increases in many places, especially in clay soils. It is not anticipated that this will occur to a great extent in these areas, owing to the high calcium content of the soils, although some increase may result in the very heavy-textured soils of the Gila series and possibly more noticeably in the Imperial soils, as at present these soils contain a small amount of black alkali.

Many crop plants are not radically affected by concentrations of white alkali of less than 0.2 per cent, and others have a tolerance greater than this but generally not greatly in excess of an 0.5 per cent concentration of salts in the air-dry soil. The type of plant, the chemical character of the salt, and the texture of the soil are the governing factors in the remunerative value of the soil. Sodium chloride is more toxic than sodium sulphate. Sodium sulphate predominates in most parts of these areas.

During the progress of the survey, areas of evident alkali accumulation were delineated and the concentration of the salts in terms of percentage of total salts in the air-dry soil in selected localities was determined by the electrolytic bridge and recorded. These determinations are shown on the soil map. The percentage of salt concentration is indicated in the form of a fraction, in which the numerator indicates the salt concentration in the surface foot of soil, and the denominator the average concentration to a depth of 6 feet.

Alkali in harmful concentrations occurs chiefly in the Gila and Imperial soils. It will be noticed that, with few exceptions, concentration in the surface soil is greater than in the subsoil. In the Gila soils, for the most part, the comparatively free-moving ground water in the porous substratum keeps the concentration low and more evenly distributed than in the surface soil. This characteristic will facilitate reclamation when drainage is provided.

A great deal of variability in salt content exists from place to place, owing to differences in texture and thickness of the surface soils and subsoils, in depth to the water table, and in drainage and relief. The field determinations, therefore, are indicative of only the more general conditions. They do, however, indicate the need of reducing the salt content by leaching and of lowering the water table by drainage before extensive tracts in these areas can become permanently productive or even capable of producing crops

Drainage and leaching of the soils is the only practical method of permanent alkali reclamation. In these areas reclamation is wholly a community problem No degree of permanent success can be obtained by local individual effort as the water table must be lowered through thorough drainage, and in addition systematic and comprehensive removal of the salts by flooding and leaching must be effected. Individual local effort would result in only temporary improvement and in moving the salts to lower-lying closely adjacent areas.

The drainage system proposed in connection with the middle Rio Grande conservancy project should provide the needed drainage. If this project is carried out successfully and is followed by systematic reclamation by leaching out the salts, most of the alkali-impregnated Gila soils, which are at present almost valueless, should become productive, although it may take several years of leaching and the growing of alkali-resistant crops to accomplish this. Most of the Gila soils are readily permeable, owing to their loose porous subsoils and substrata. However, the clay and sandy clay loam members, especially where underlain by heavy subsoils and where highly impregnated, may be very difficult to reclaim, and in many places the cost of placing drains close enough for proper reclamation will be prohibitive

In the Imperial soils, which occur chiefly in the Rio Puerco area, it will probably be very difficult if not impossible to remove the salts, because of the impermeability and the great depth of the heavy-textured subsoils.

Experience of farmers on Gila soils in the Mesilla Valley, where somewhat identical conditions have existed, has shown that reclamation of these soils can for the most part be accomplished. Where the surface soil and subsoil are heavy and impervious, reclamation has been very slow and expensive, and in many places this type of soil is still unproductive.

## SOILS AND THEIR INTERPRETATION

The soils of these areas have developed under the environmental conditions of the arid Southwest. Climatic conditions to which the soil materials have been subjected during their period of development are dominated by high mean annual temperature, with long, hot summer seasons; excessive wind movement, frequently of high velocity; and low relative humidity and high rate of evaporation; together with an average annual precipitation of about 10 inches. The precipitation occurs principally as torrential rains during summer and early fall, and much of it is lost by rapid run-off, causing sheet and gully erosion. The precipitation for the remainder of the year is of minor importance from the viewpoint of soil penetration and moisture supply.

The natural vegetation, except that on the wet bottom lands, is sparse and consists chiefly of creosote bush, scrubby mesquite, "chamiza," rabbit brush, and a sparse scattering of bunch grass. On the bottom lands willow, cottonwood, tornillo, salt grass, sedges, and tules grow

The period of time during which the agencies of soil formation have acted on the soil materials has had a direct correlation with the physiographic development of the soils. The oldest-developed soils are on the terraces, the materials of which have been transported and laid down by huge streams now represented by the abated, sluggish, slowly aggrading Rio Grande and its tributary, Rio Puerco. In the stages of recession these rivers have cut their immediate valleys, which are hemmed in between steep escarpments, deep into the older-deposited detritus More or less simultaneously with the valley cutting the escarpments have become eroded and in places obliterated by erosion or by erosion products such as outwash or alluvial-fan materials deposited by the intermittent arroyos. From these materials, which to greater or less extent occupy marginal alluvial-fan slopes along the valley edges, have been developed soils intermediate in age between the elevated old terrace soils and the youngest unweathered soils of the recent flood plains. The materials of the alluvial-fan soils and to some extent of the first-bottom soils, are erosional products of the older terrace materials.

The recent bottom-land soils are dominated by parent geologic materials. In the Gila soils the materials are unweathered and the profile is geological and dominated by stratification. The soils are poorly drained, the water table being at the surface or at a very slight depth, and they have a high alkali-salt content The soil materials are highly calcareous throughout. This characteristic has been inherited from the parent materials as has also the dominant red cast, or tinge, of the soils. The relation is readily seen in comparing the color of the deposited materials and the red color of the sediment-burdened waters of the river. This is, of course, less pronounced in the lighter-textured soils of high quartz content, or where obscured by organic-matter incorporation or by deoxidized coloration from the high water table The texture ranges from clay to fine sand, the materials having been laid down in distinct variably textured stratified layers The physical effect of the natural vegetation of willow, cottonwood, tornillo, salt grass, and sedges has not been appreciable.

In the related Imperial soils a slight modification, accompanied by an accumulation of salts other than calcium carbonate, appears to have taken place, but weathering has not been sufficient to cause a B horizon of calcium carbonate accumulation even though the soil materials are highly calcareous throughout. They have a very high alkali-salt content, although the salts have not become concentrated in the surface soil, possibly due to insufficient moisture, as the soils lie well above the present water table and capillary movement is extremely slow.

The surface soil is characterized by a surface crust and mulch structure. Typically it consists of a bleached and baked vesicular crust, about one-half inch thick, which cracks into a geometric pattern of roughly pentagonal segments about 2 inches in diameter. This material rests on a rich reddish-brown finely granular loose and crumbly mulchlike material, about 2 inches thick, resembling ground coffee. Below this and continuing to a depth ranging from 20 to 30 inches the material is very compact, of rich reddish-brown or chocolate-brown color, and is veined or netted and seamed with salts and gypsum. This is the zone of maximum salt accumulation. Below this the veined salt accumulation becomes less pronounced, generally disappearing within a depth of 6 feet, at which depth the reddish-brown color of the soil is subdued by a green tinge or mottling Where a profile of the soil is exposed the lower soil material rests on a sandy substratum, in places interstratified with heavier-textured materials.

The soil throughout is of very heavy, refractory, plastic material which has a certain degree of vertical or columnar cleavage Where undermined by erosion, huge columnar masses, which break into irregular angular clods, are exposed.

The Anthony soils, which are developed from the alluvial-fan and outwash materials bordering and below the terrace escarpments, are older than the bottom-land soils and have developed appreciable compaction and accumulated lime in the subsoil. In this respect they represent an earlier stage in the development of the more mature terrace soils, with a trend in that direction. To a greater or less degree they are still dominated by the original geologic textural deposition or sedimentation.

Owing to erratic deposition of the outwash-fan materials by local arroyos or transitory streams, there is considerable difference in the age of the deposited materials, with consequent variation in extent of leaching and translocation of materials in the soil profile. In average development the surface soil to a depth of about 12 inches is dull reddish brown or grayish brown tinged with red and is loose and friable. Between depths of 12 and 36 inches occurs the zone of lime accumulation. This layer is slightly compacted and of duller or grayer color than the weathered surface soil. In many places white specks of accumulated lime are discernible. Below this lies the unweathered material, which is loosely organized, noticeably stratified, and of but slightly duller color than the surface soil. The soil materials throughout are calcareous, and most of the gravel in the upper two layers are lime coated, especially on their lower surfaces.

The Pinal soil is the most maturely developed soil in these areas. Typically it has a friable weathered surface soil extending to a depth of about 10 inches, the materials still remaining unleached and calcareous, however. The color is grayish brown, somewhat tinged with red, except at the immediate surface where a bleached ¼-inch vesicular crust occurs. Gravel and stone exposed on the surface of the soil have dark oxidized upper surfaces but are lime coated on the undersides. The surface soil is underlain at a depth ranging from 10 to 20 inches by a layer of lime accumulation consisting of a soft nodular grayish-white lime-carbonate hardpan, the upper part of which has a slight reddish-brown color and represents a transition from the surface soil. Beneath the layer of lime accumulation lies an indurated grayish-white lime-carbonate hardpan which in most places contains gravel and resembles conglomerate. The upper part of this layer is very hard and impenetrable, but with depth the material becomes less consolidated, giving the appearance of lime infiltration into formerly loose gravelly and stony strata. This layer continues with such transitional features for about 3 feet, where it rests on thickly stratified, unconsolidated materials. As seen in deep exposures the stratified material may vary extremely in thickness, and in texture from clay to stone.

Considerable variation occurs in the color and in the degree of lime accumulation and cementation in this soil, even within the small area occurring in this survey.

## SUMMARY

The Socorro and Rio Puerco areas are in the west-central part of New Mexico. They include parts of the Rio Grande and Rio Puerco Valleys and comprise chiefly first-bottom and alluvial-fan soils. The valleys are narrow, and most of them are flanked by steep, corrugated terrace escarpments. The valley floors are flat, with narrow marginal areas of alluvial fans.

The bottom lands of the Socorro area for the most part are subject to overflow, and water logging and alkali accumulations are prevalent. The bottom lands of the Rio Puerco area lie well above the present water table but are impregnated with alkali, and internal drainage under irrigation would be extremely slow.

The climate is distinctly arid. The average annual precipitation of about 10 inches occurs mainly as summer rains, and irrigation is necessary for crop production.

Only the Socorro area is settled. The inhabitants are chiefly of Spanish-American nativity. Staple crops for home consumption are grown, and near-by markets are available for surplus products. Adequate transportation facilities are available both by railroads and highways.

The unweathered soils of the Gila series, occurring on the stream bottoms, have contributed chiefly to the agricultural development.

The alluvial fans marginal to the stream bottoms are occupied by the Anthony soils which are of intermediate age and second in importance in the areas.

The most mature soils, which are developed on the old terraces, are those of the Pinal series. Only a small acreage of these soils is included in the survey, and they have no agricultural value.

The areas also include soils of the Imperial and Brazito series, of little present economic importance, and the miscellaneous materials, river wash and rough broken land.

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