# THE CLAY MINERAL COMPOSITION OF REPRESENTATIVE SOILS FROM FIVE GEOLOGICAL REGIONS OF TEXAS *

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## ABSTRACT

Mineralogical studies for the <2 $\mu$ fractions are presented for seventeen soil profiles and two surface horizon samples, which represent eight soil types and five geological regions in the state. There was no evidence of clay mineral formation in the upper 6 feet or more of soil. X-ray diffraction data from the Lufkin, Ruston and Katy soils suggested some decomposition of montmorillonite and kaolinite in the upper horizon. However, the overall picture is one of little change in clay mineral composition between the soils and parent sediments.

## INTRODUCTION

A soil from the geological viewpoint may be defined as that part of the mantle which has been sufficiently decomposed and otherwise modified that it supports rooted plants. On the basis of this definition, the larger portion of the earth's surface is covered by soil which may be credited as the major contributor to recent sediments. By the nature of its position, the soil is continuously exposed to a variety of intense weathering forces, which may modify its mineral composition with relative rapidity. Knowledge of the mineral composition of soils is of importance in determining the agricultural potentials of soils. Such information is also helpful in understanding the nature of the soil forming processes. The objective of this paper is to present the clay mineralogy for some 17 soil profiles representing the dominant and more agriculturally important soils from five geological regions of Texas.

## MATERIALS AND METHODS

The five geological regions of the state are represented by 17 soil profiles and two surface samples. Soil types, numbers of profiles investigated and locations with respect to geological regions and counties are given in Table I.

The organic matter was removed from ten grams of soil with hydrogen peroxide. The sample was transferred to a 250 ml. centrifuge tube and washed twice with 50 ml. of distilled water to remove any soluble mineral matter. It was then transferred to a 250 ml. square bottle, 50 ml. of a 0.1 N solution of sodium hexametaphosphate added, the total volume

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TABLE I. — GEOLOGICAL REGION, SOIL TYPE, NUMBER OF PROFILES INVESTIGATED AND LOCATION OF PROFILES WITH RESPECT TO COUNTIES

| Geological region | Soil type | Number of profiles investi-gated | Location of profiles (county) |
|---|---|---|---|
| Southern High Plains | Amarillo fine sandy loam | 1[1] | Lynn |
| | Amarillo loam | 1 | Lynn |
| Blackland Prairies | Houston Black clay | 5 | |
| | | 1[1] | Fayette |
| | | 1 | Bell |
| | | 1[1] | McLennan |
| | | 1 | Ellis |
| | | 1[1] | Fannin |
| Forested Coastal Plain | Lufkin fine sandy loam | 2 | |
| | | 1[1] | Fayette |
| | | 1 | Brazos |
| | Ruston fine sandy loam | 2 | |
| | | 1[1] | Cass |
| | | 1 | Cherokee |
| Gulf Coast Prairie | Lake Charles clay[2] | 2 | |
| | | 1[1] | Fort Bend |
| | | 1 | Jefferson |
| | Katy sandy loam | 1[1] | Waller |
| Rio Grande Delta | Harlingen clay | 3 | |
| | | 1[1] | Hidalgo |
| | | 2 | Cameron |
| | Willacy fine sandy loam | 2 | |
| | | 1[1] | Hidalgo (Engelmann Gardens Farm) |
| | | 1 | Hidalgo (Rio Farms) |

[1] Denotes profiles for which X-ray diffraction patterns are shown in subsequent figures.
[2] Only samples for the 0–7″ depth were available.

brought up to 150 ml. and then stirred for 30 minutes with a malt-mixing machine. Following dispersion the sample was transferred to a 2,000 ml. beaker, the volume made up to approximately 1,200 ml. with distilled water and separation of the clay effected by sedimentation, using Stoke's law to determine settling rates. The material remaining in suspension to a predetermined depth was siphoned off. The clay was flocculated with magnesium acetate, transferred to a 250 ml. centrifuge tube and excess salts removed with several washings of distilled water.

Free iron oxides were removed from the Amarillo and Ruston soil samples according to the procedure by Aguilera and Jackson (1953, p. 359). Samples for X-ray diffraction analyses were prepared by placing 100-150 mg. of clay in a 100 ml. centrifuge tube, 50 ml. of a 1.0 N solution of magnesium acetate added and the samples boiled gently for 10 minutes, after which they were centrifuged and the supernatant liquid decanted. Excess salt was removed by two washings with 25 ml. of distilled water and the samples mounted on glass slides while still in a moist state. The samples were allowed to air dry, after which they were placed in a small tin can, 4 inches in diameter, which contained a small amount of ethylene glycol and placed in an oven for an hour at a temperature of 65° C. Condensation of ethylene glycol vapors on the samples served to saturate them with ethylene glycol. After an hour they were removed from the can, placed in the oven at 65° C and left until the droplets of ethylene glycol adhering to the samples and glass slides evaporated. The samples had to be checked every 5 to 7 minutes to prevent excessive drying. Following drying, they were placed in a desiccator containing ethylene glycol for a period of 12-24 hours to come to equilibrium, after which they were irradiated. A duplicate set of samples was saturated with potassium, which was accomplished by the same procedure, except that a 1.0 N solution of potassium acetate was used and these samples were not saturated with ethylene glycol. The diffraction patterns for samples from a profile were all recorded at the same intensity settings. The X-ray diffraction unit used was a North American Philips high angle goniometer model equipped with a copper target tube.

## RESULTS AND DISCUSSION

Figure 1, a map of Texas, shows the rainfall belts, locations for the soil profiles investigated and the geological regions considered for this study.

Amarillo fine sandy loam, the representative of the High Plains region, dominates the soil pattern in the southern half of that area in Texas and comprises several million acres. The parent sediments throughout this area are of terrestrial origin and were deposited as a vast alluvial apron along the eastern foot of the Rocky Mountains during the Pliocene and more or less reworked by wind action during the Pleistocene. They represent sediments from relatively dry regions which have not passed through a cycle of strong weathering under a humid environment.

Figure 2 shows the X-ray diffraction patterns for the $<2\ \mu$ fractions separated from a profile of Amarillo soil. Illite, kaolinite and quartz constitute the major crystalline portion of the $<2\ \mu$ fraction. Of these illite appears as the dominating clay mineral. The relatively strong diffraction line commencing at approximately $6°\ 2\ \theta$ is indicative of the presence of poorly crystallized material, which fails to show any definite peak. This type of diffraction pattern has generally been observed for most Texas soil

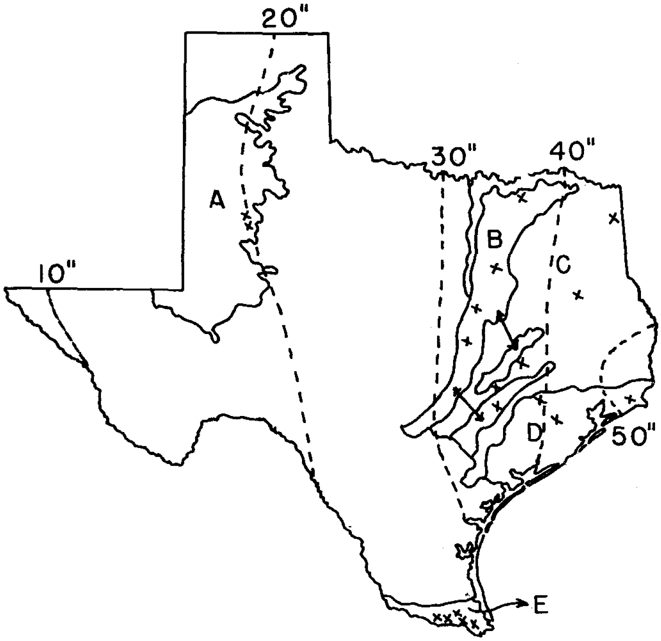


FIGURE 1. — Map of Texas showing the rainfall belts, soil profile locations and geological regions considered for this study which are as follows: (A) High Plains; (B) Blackland Prairies; (C) Forested Coastal Plain; (D) Gulf Coast Prairie; (E) Rio Grande Delta.

clay samples which contain appreciable amounts of illite. A poorly defined peak occurs at approximately 4.6° 2 $\theta$ for the 96-120" sample. No adequate explanation of this peak is offered but it is thought to be related to the mica peak at 8.8° 2 $\theta$. The X-ray diffraction patterns show essentially no change in the amount or type of clay mineral throughout the depth of the profile. The $<2\ \mu$ fractions from the other profile of Amarillo soil showed no significant variations from the one described.

The Houston Black clay soil, approximately 2½ million acres in extent, is the dominating soil of the Blackland Prairie region. This soil in general has developed from soft calcareous sediments, mostly marine but partly of terrestrial origin. Three different parent sediments were considered in this study; namely, the Austin chalk and Taylor marl which are of marine origin and the Lagarto clay which is thought to be a terrestrial deposit. The former two are of Cretaceous age while the latter is of Miocene age.

X-ray diffraction patterns for the Houston Black clay developed from three different parent sediments are shown in Figure 3. The patterns for each location represent the surface and the deepest samples investigated. Of the crystalline components, montmorillonite, in all cases, strongly dominates the $<2\ \mu$ fraction. Only traces to small amounts of kaolinite and quartz

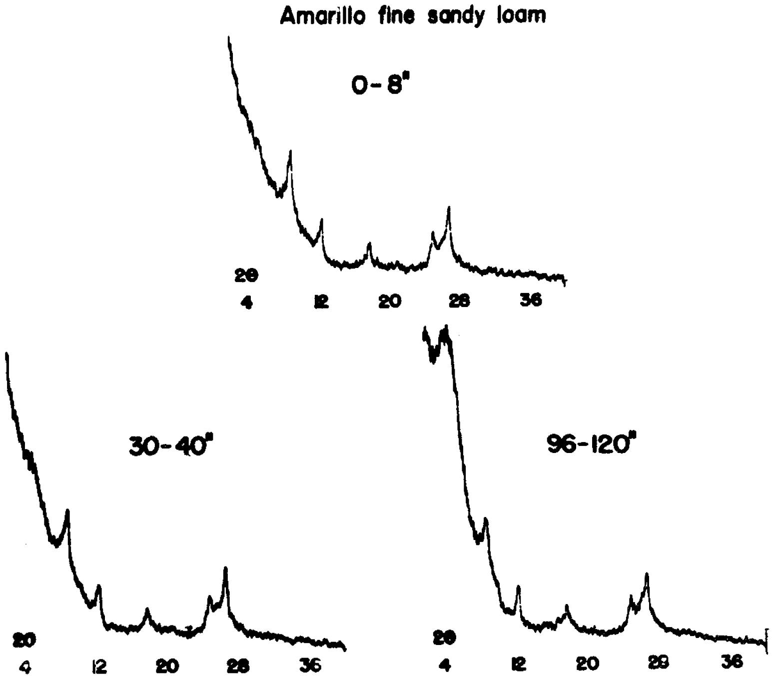


Figure 2. — X-ray diffraction patterns for the $<2\ \mu$ fractions from the Amarillo fine sandy loam soil of the southern High Plains.

occur in the $<2\ \mu$ fraction derived from the Lagarto clay and Austin chalk; in contrast, moderate amounts of kaolinite and quartz are found in the $<2\ \mu$ fraction derived from the Taylor marl. Also a trace of illite occurs in the deepest sample from the Taylor marl. X-ray diffraction results of the other two profiles, both of which are developed in the Taylor marl, do not differ in mineral composition from those shown. However, the content of kaolinite appears to be less than that shown by the Fannin County profile, which is also developed in the Taylor marl.

The clay mineral composition of the Houston Black series again shows no significant change in amount or type of clay throughout the depth of the profile, as was true for the Amarillo soil from the southern High Plains. This is interpreted as indicating a minimum amount of weathering.

The Forested Coastal Plain contains a wider variety of soils and parent sediments than the two regions already discussed. From the mineralogical viewpoint, Lufkin fine sandy loam and Ruston fine sandy loam, represent the probable extremes in the range of sediments. The Lufkin soil in Brazos county is developed in deltaic deposits of the Yegua formation while the same soil from Fayette County has formed in a littoral or shoreline deposit. Both formations are of Eocene age. The profiles of Ruston soil investi-

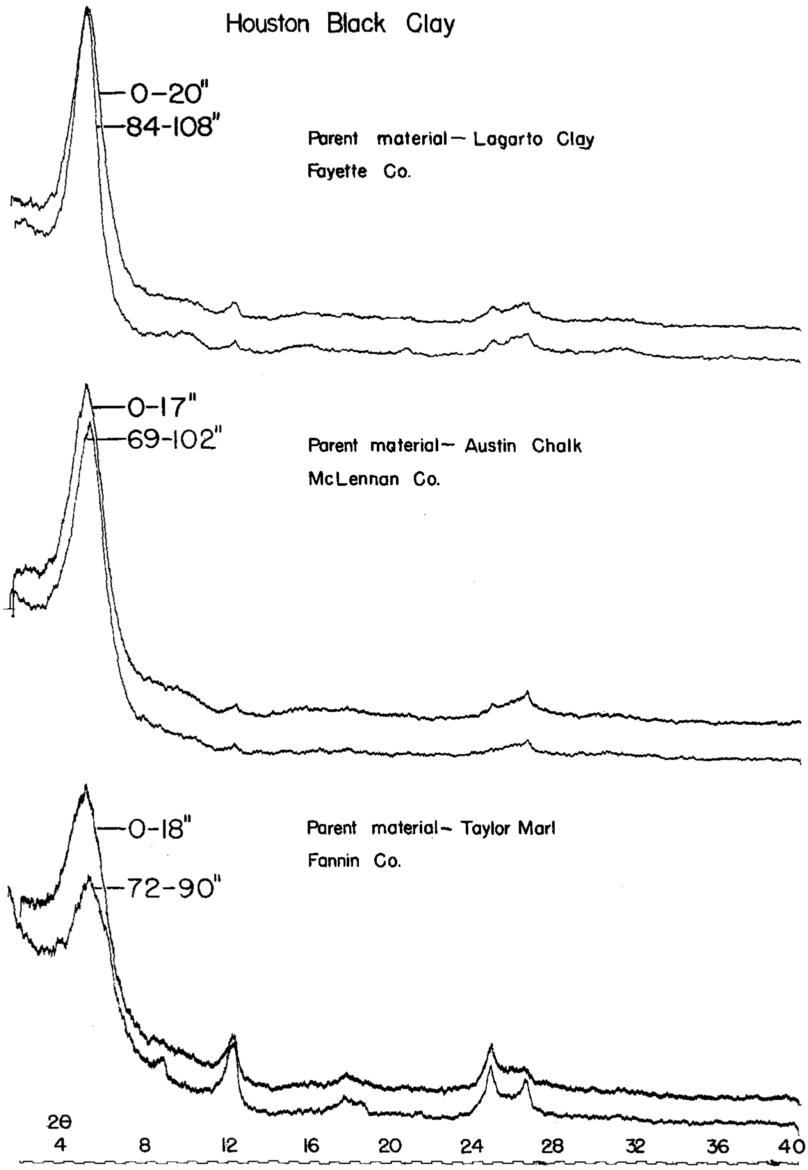


FIGURE 3. — X-ray diffraction patterns for the < 2 μ fractions from the Houston Black clay soils of the Blackland Prairies.

gated are from Cass and Cherokee counties. Both profiles were developed from marine deposits of the Claiborne (Eocene) group and may have contained minor amounts of greensand.

Figure 4 shows the X-ray diffraction patterns for the profile of Lufkin from Fayette County and the sample of Ruston from Cass County. The Lufkin soil is classified as a planosol or claypan soil. The dense underlying clay layer generally occurs at a depth of 5-10 inches and may be several

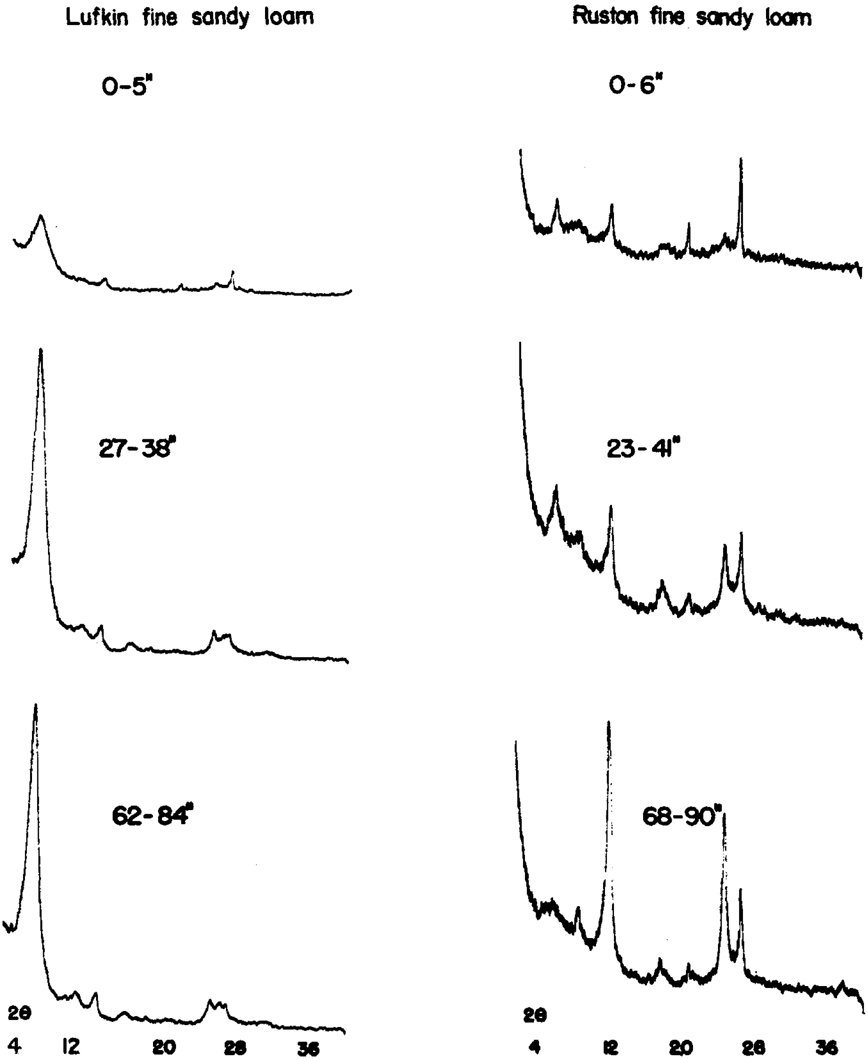


FIGURE 4.—X-ray diffraction patterns for the $< 2\ \mu$ fractions of the Lufkin and Ruston fine sandy loam soils from the Forested Coastal Plain.

feet in thickness. The lighter textured surface layer which rests abruptly on the dense clayey material underneath contains very low amounts of clay, which is attributed to movement of clay to the lower horizons as well as possible decomposition of the clay present. The latter view is supported by X-ray diffraction results of Figure 4. The montmorillonite peak for the sample from 0-5 inches is significantly weaker and more diffuse than those for the two greater depths, indicating poorer crystallinity and a greater degree of randomness. The X-ray diffraction results are, therefore, interpreted to be indicative of decomposition of montmorillonite in the surface. The mineral composition of the $<2\ \mu$ fraction for the Brazos county sample was identical, except that no montmorillonite was detectable in the clay fraction extracted from the surface soil.

The major crystalline constituents of the $<2\ \mu$ fraction for the Ruston soil are kaolinite, quartz, chlorite and illite. The amount of quartz appears to remain constant at all levels while the kaolinite content shows a pronounced increase with depth. This same general pattern for quartz and kaolinite is also shown by the sample from Cherokee County. This, as in the case of the Lufkin soil, is interpreted as being indicative of clay decomposition in the upper horizons.

The Lake Charles clay and Katy sandy loam soils were chosen to represent the heavy and light-textured soils of the Gulf Coast Prairie. The Lake Charles soil has developed from lagoonal and deltaic deposits of the Beaumont formation which is of late Pleistocene age. The Katy soil has also developed from deltaic deposits of the Lissie formation which is of early Pleistocene age.

X-ray diffraction patterns for the $<2\ \mu$ fractions of the Lake Charles and Katy soils are shown in Figure 5. The major crystalline components of the $<2\ \mu$ fraction for the Lake Charles clay are montmorillonite, illite, kaolinite and quartz; montmorillonite, however, is by far the most abundant. Montmorillonite also dominated the second sample of Lake Charles clay investigated. It differed, however, from the sample shown in that no illite was detected. Since only surface samples were studied for this particular soil, no data are available with regard to possible clay mineral variation with depth.

The Katy soil is thought to be one of the oldest soils in the United States. Its clay mineral composition therefore should be indicative of what might be expected as an end product under the existing environmental conditions. The major crystalline components of the $<2\ \mu$ fraction are kaolinite and quartz. The latter decreases with depth to the extent that it is barely detectable in the lowest horizon while the content of kaolinite shows a pronounced increase with depth. The decrease in kaolinite in the upper horizons is attributed to decomposition of the kaolinite, similar to that found in the Ruston soil.

The Rio Grande Delta is represented by the Harlingen clay and Willacy fine sandy loam. The former is developed in recent deltaic alluvium, while

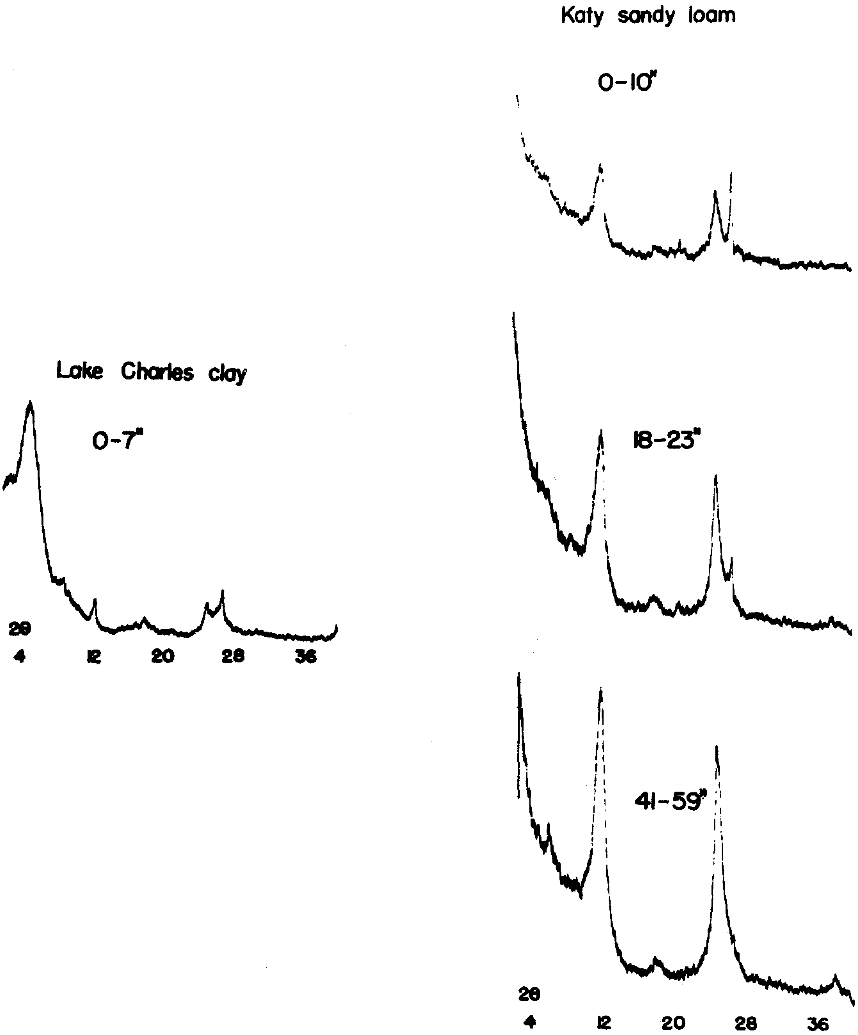


FIGURE 5.—X-ray diffraction patterns for the < 2 μ fractions of the Lake Charles clay and Katy sandy loam soils of the Gulf Coast Prairie.

the Willacy is developed in late Pleistocene deltaic sediments of the Beaumont formation.

X-ray diffraction patterns of the <2 μ fraction are shown in Figure 6. The crystalline portion of the <2 μ fractions of the Harlingen soil consists predominately of montmorillonite with minor amounts of illite, kaolinite and quartz. There is no change in the clay mineral composition throughout the profile. The same general picture holds with respect to clay mineral composition for the other two profiles studied, with the exception that the

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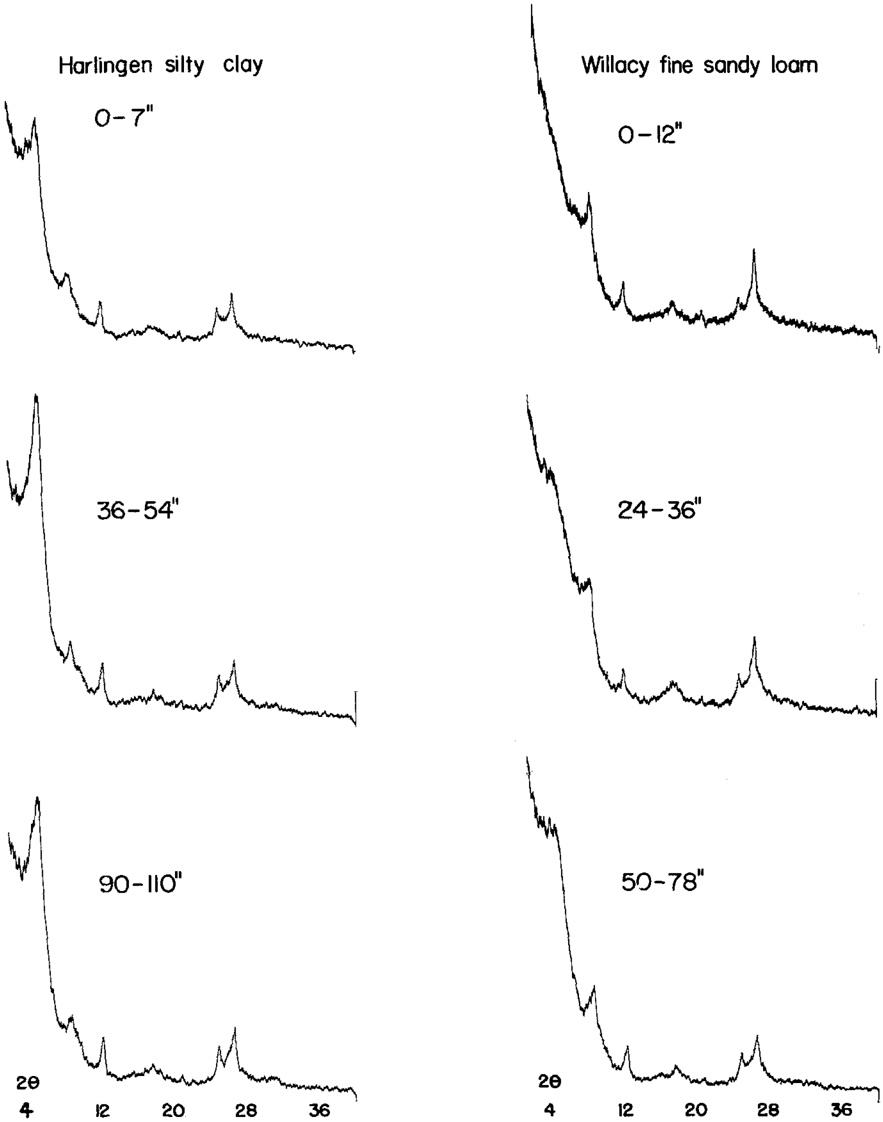


FIGURE 6. — X-ray diffraction patterns for the < 2 μ fractions of the Harlingen clay and Willacy fine sandy loam soils of the Rio Grande Delta.

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montmorillonite peaks are broader and more diffuse for the surface horizons. Since the sediments are of recent origin and considerable stratification is evident throughout the profile, the homogeneity of the clay mineral composition in the Harlingen soils is surprising. This indicates that the recent sediments deposited by the Rio Grande River were relatively homogeneous with respect to clay mineral composition.

Diffraction patterns of the $<2\ \mu$ fractions of the Willacy soil, also shown in Figure 6, show the presence of illite, kaolinite and quartz. Poorly organized material with diffraction characteristics approaching that of montmorillonite is indicated by the relatively strong diffraction line commencing at approximately $6°\ 2\ \theta$. X-ray diffraction patterns for the other profile of Willacy soil (Engelmann Gardens) were identical with the ones shown to a depth of approximately three feet. Below this depth, a broad, diffuse peak with an approximate spacing of 18 Å became descernible. The sharpness of the peaks increased for samples of increasing depth until a sharp 17.3 Å montmorillonite peak is observed for the deepest (8 ft.) sample. Diffraction data from this latter profile suggest decomposition of montmorillonite in the surface horizons. For the depths sampled, this interpretation is not supported by the data of the Willacy profile from Rio farms (Fig. 6). The latter needs to be sampled to a greater depth in order to establish whether a similar transition occurs. A further complicating factor which has to be considered is a seasonal high water table that covers much of the Rio Grande delta.

The scope of this study is too limited to permit any generalized conclusions with respect to clay mineral development or weathering in Texas soils. The data do indicate that clay mineral development within the soil profile is negligible, which, in general, is contrary to results reported from the midwestern and eastern sections of the United States. Decomposition of both kaolinite and montmorillonite was observed in the surface horizons of several profiles. The overall picture, however, shows very little change in clay mineral composition between the soils and parent sediments.

## REFERENCES

Aguilera, N. H., and Jackson, M. L. (1953) *Iron oxide removal from soils and clays:* Soil Sci. Soc. Amer. Proc., vol. 17, No. 4, pp. 359-364.