THE GENESIS OF A CHRONO-CLIMO-SEQUENCE OF MOLLISOLS IN WEST-CENTRAL OKLAHOMA

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CHAPTER I

INTRODUCTION

Soils in varying stages of development occur on terraces of major rivers in central and western Oklahoma. Many of these soils were previously classified as members of the Regosol or Chernozem great soil groups in western Oklahoma and as members of the Regosol or Reddish Prairie great soil groups in central Oklahoma. These soils are currently being reclassified according to the 7th Approximation (40). Their classification according to this system is in doubt, but it is likely that most terrace soils of central and western Oklahoma will be classified as Mollisols at the order level. There are a number of important differences between soils of this area, and a number of soil forming factors have influenced the genesis of these soils. Locally, both relief and the soil parent material have been important factors in soil genesis. However, the soil forming factors climate and time likely have been dominant regionally, and this study deals with the effect of these factors on the genesis of soils developed on terraces of the South Canadian River.

The objectives of the study were as follows:

1.) One objective was to characterize the soils of the study with respect to selected morphological, physical, chemical, and mineralogical properties and to relate these properties to the soil forming variables climate and time. This information should be of value in understanding the variability between soils of the study area.

2.) A second objective was to obtain information pertinent to the classification of the soils. This information is needed if these soils are to be accurately classified according to the 7th Approximation. This applies at both the lower categorical levels, such as the subgroup and family, and at the higher categorical levels, such as the order and suborder. Ultimately the classification of these soils at the series level likely will be affected because soils that are classified into different categories of the 7th Approximation cannot be members of the same series.

A total of 13 soil pedons were studied. The soils and the sampling sites were selected in a way to allow both a comparison between soils developed under different climatic conditions and between soils which are apparently of a different age. Jenny's procedure (27) of holding all but one soil forming factor constant and comparing soils as this single factor varied was followed as closely as possible in this study. The study area extends from Roger Mills to Pontotoc County in a general west-east direction. Figure 1 shows the sampling sites and the precipitation zones[1] within which these sites are located.

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[1] U.S.D.A. Agriculture Yearbook. Climate and Men. 1941. pp.1065-1074.

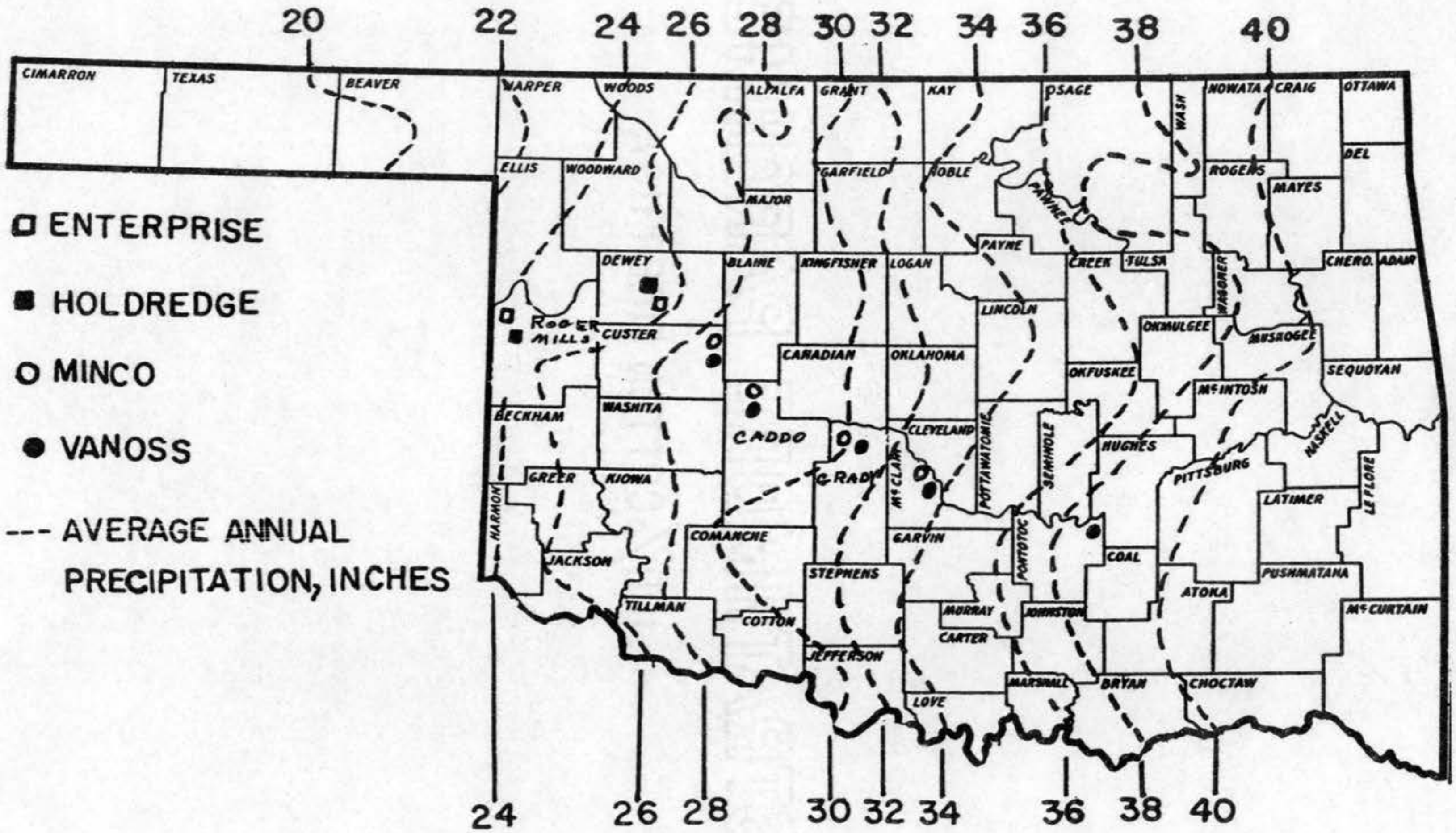

Figure 1. Soil Sampling Sites and the Precipitation Zones in Which the Sites are Located

CHAPTER II

REVIEW OF LITERATURE

The average annual precipitation of the study area increases progressively from approximately 24 inches in Roger Mills County to approximately 38 inches in Pontotoc County (44). Thornthwaite (42) classified the climate of this area as dry subhumid in the western part, Roger Mills to central Grady County, and moist subhumid in the eastern part. The mean annual temperature of this area is relatively uniform, examples being 15.7° C at Elk City in Roger Mills County and 16.7° C at Ada in Pontotoc County (30). The vegetation of the area in its native state was predominantly mixed grasses (15).

The soils sampled in Roger Mills and Dewey Counties were previously mapped as members of the Enterprise and Holdredge Series (3). The Holdredge is the more strongly developed of the two soils. According to the soil survey report of Roger Mills County both the Holdredge and Enterprise soils developed from aeolian materials. In Dewey County the survey party found that these soils formed in both wind and water deposited materials on level to sloping river terraces (41). In general, the Enterprise soils occur on low terrace positions, but there are exceptions.

The South Canadian River, the apparent source of the sediments in which the soils of this study have formed, originates in or near the mountains along the western border of the dissected highlands in northeastern New Mexico (32). The highlands consist of sandstone, but numerous other rock types occur in the area of New Mexico drained by the South Canadian. Examples of the other rock types are shales, limestone, conglomerate, coal, and basalt.

A number of studies have been done on deposits of the South Canadian River in Oklahoma. In a study in Blaine, Dewey, and Custer Counties Fay (9) detected five terrace levels of probable Pleistocene age. These terraces were 300, 270, 220, 150, and 50 feet above the present flood plain. Fay stated that the two highest of these terraces are apparently of Kansan age, the middle two terraces may be of Illinoian age, and the lowest terrace may be of Wisconsinan age. He divided the Pleistocene sediments into four main types that were deposited at different times under slightly different conditions. One of these types consists of clay and fine silt deposits, up to 20 feet thick, forming a thin veneer over cut benches in the bedrock immediately southwest of the river. This type of sediment appears to be similar in character to that from which the soils of this study have formed. In a later publication, Fay (10) stated that only three terrace levels are mapped, though five may be identified. He stated that the upper levels are mostly covered by sand dunes. Weaver (49) identified three distinct terraces of the South Canadian River in Hughes County. These terraces were 10-15, 30-40, and 65-80 feet above the present flood plain. There is general agreement that the source of the sediments deposited by the South Canadian was Cretaceous and older rocks of the Rocky Mountain area or Tertiary sediments of the High Plains (9, 19, 49).

Permian formations occur adjacent to the study area and, while they are not generally considered to be a major source of the sediments comprising the South Canadian River terraces, they cannot be disregarded. According to Fay (9), the surface rocks of the region that he studied in Blaine, Custer, and Dewey Counties belong to the Permian system and consist mainly of red beds named Cloud Chief formation, Rush Springs sandstone and Marlow formation of the Whitehorse group, and Dog Creek shale. Mankin[1] found that the clays of the Marlow, Rush Springs, and Cloud Chief formations consist primarily of montmorillonite and a 7 angstrom magnesium chamosite. He found that the clays of the Dog Creek shale and a number of other Permian formations contain illite and chlorite.

In weathering studies in soils, it is necessary to establish that the unweathered, or at least less strongly weathered, reference material and the weathered materials have similar origins and to obtain some measure of the kind and degree of changes that have occurred as a result of weathering. Studies of the sand and silt mineralogy are often utilized in this type of work.

The utilization of the sand and silt mineralogy in weathering studies is based on the fact that in general different mineral species have a different susceptibility to weathering. Goldich (12) presented the following weathering stability series:

Olivine	Calcic Plagioclase
Augite	Calcic-Alkalic Plagioclase
Hornblende	Alkalic-Calcic Plagioclase
Biotite	Alkalic Plagioclase

Potash Feldspars
Muscovite
Quartz

Beginning at the top of each branch and going down the branches towards

[1]Unpublished data presented on a clay mineral field trip in 1966.

quartz, the minerals become progressively more difficult to weather. Pettijohn (37) compiled weathering stability indices for a number of heavy minerals. Zircon, tourmaline, and garnet are examples of minerals which he considered relatively stable; epidote, the amphiboles and the pyroxenes are examples of minerals that he considered relatively susceptible to weathering. A relative weathering scale compiled by Dryden and Dryden (6) is in general agreement with that of Pettijohn, but garnet was found to be highly susceptible to weathering. This apparent discrepancy is probably related to the variability of different species of garnet. Results of work by Graham (13) on feldspar weathering are in agreement with the stability series of Goldich. In 1940, Graham published the results of work showing that hydrogen saturated clays were effective in weathering calcium feldspars but were ineffective in weathering the potassium feldspar microcline. He later weathered all members of the plagioclase series artificially and determined relative weathering rates by assigning albite, the most stable member, an index number of 1 and assigning other members a numerical value equal to the number of times faster than albite that they weathered (14). The following values were assigned to the plagioclase series:

Albite- 1.0
Oligoclase- 1.7
Andesine- 2.8
Labradorite- 6.9
Bytownite-13.9
Anorthite-16.1

Jackson and Sherman (22) noted that weathering stability series are valid to the extent that specific surface effects may be disregarded.

One would expect that comparisons would have to be made between samples having relatively narrow size limits if the specific surface effects are to be disregarded.

Both light and heavy mineral distributions are utilized in weathering studies. Buckhannon and Ham (4) identified the nonopaque heavy minerals in samples of recent riverwash, Pleistocene alluvium, the Ogallala formation, and various Permian materials. Most, but not all, of the sediments came from portions of Oklahoma drained by the South Canadian River. He found that the presence of the minerals epidote, Kyanite, augite, and basaltic hornblende in the nonpermian sediments could be used as a criteria for differentiating between Permian and Pleistocene sediments. Epidote was present in both Permian and Pleistocene sediments, but it composed 15-30% of the Pleistocene sediments whereas it usually composed $<$ 1.0% of the Permian sediments. Ruhe (39) used two weathering ratios, the ratio of (zircon + tourmaline) /(amphiboles + pyroxenes) and the ratio of quartz/feldspar, to study weathering on three groups of paleosols. The soils developed on surfaces that were of late Wisconsin, late Sangamon, and Yarmouth-Sangamon age. The times of exposure to weathering of these surfaces were respectively 6800 years, 13,000 years, and unknown but $<$ 13,000 years. In general, the weathering ratios indicated an increasing degree of weathering going from the youngest to the oldest surface. On the two oldest surfaces the weathering ratios decreased progressively from the A to the C horizons. On the youngest surface, the weathering ratios were smaller for the A horizon than for the C horizon. In his explanation of this apparent discrepancy, Ruhe stated that little destruction of minerals has occurred on soils of the younger surface and an orderly arrangement of weathering ratios has not yet been established. Vanderford (46) studied soils developed in relatively uniform loess under climatic conditions ranging from 20-55 inches of rainfall annually and found that the quartz increased relative to the other sand size minerals as the rainfall increased. Quartz was being compared to a combination of all sand size mineral species rather than to a specific mineral. Marshall and Jefferies (33) summarized the relationship between the heavy mineral distribution and the degree of weathering and parent material homogeneity as follows:

a.) Qualitative and quantitative differences in the suite of the most stable heavy minerals are characteristic of materials of different geologic origin.

b.) Qualitative similarity of the suite of stable heavy minerals but quantitative differences in mineral ratios are characteristic of differences in conditions of deposition.

c.) A combination of qualitative and quantitative similarity in the stable heavy mineral suite, qualitative similarity in the unstable mineral suite, and quantitative dissimilarity in the unstable mineral suite is characteristic of differences in the degree of weathering between the materials being compared.

Jackson, et al. (26) developed a weathering sequence of clay size minerals. The sequence is given in Table I. The stability of the minerals increases progressively from stages 1-13. In general, one or two minerals would be expected to be dominant at a particular weathering stage and other minerals of the sequence would be expected to decrease with remoteness in the sequence. Exceptions to the sequence occur. For example, minerals occasionally occur out of sequence as secondary

TABLE I

WEATHERING SEQUENCE OF CLAY-SIZE MINERALS[2]

Weathering Stage and Symbol		Clay-Size Mineral Occurring at Various Stages of the Weathering Sequences
1.	Gp	Gypsum (also halite, etc.)
2.	Ct	Calcite (also dolomite, aragonite, etc.)
3.	Hr	Olivine-Hornblende (also diopside, etc.)
4.	Bt	Biotite (also glauconite, chlorite, antigorite, nontronite, etc.)
5.	Ab	Albite (also anorthite, microcline, stilbite, etc.)
6.	Qr	Quartz (also cristobalite, etc.)
7.	Il	Illite (also muscovite, sericite, etc.)
8.	X	Hydrous mica-intermediates ("X")
9.	Mt	Montmorillonite (also beidellite, etc.)
10.	Kl	Kaolinite (also halloysite, etc.)
11.	Gb	Gibbsite (also boehmite, etc.)
12.	Hm	Hematite (also goethite, limonite, etc.)
13.	An	Anatase (also rutile, ilmenite, corundum, etc.)

[2] M. L. Jackson, et al. (26)

depositions. Gypsum and Calcite are examples of minerals commonly occurring out of sequence as secondary depositions. Also, the sequence may be reversed under conditions of decreased or excluded leaching and oxidation. In 1959, Jackson (21) noted that the secondary chlorites commonly occurring in soils are more stable than the primary ferromagnesian chlorites and are typical of weathering stage 8. He also assigned vermiculite a stability index of 8. Leith and Craig (31) studied a number of soils developed from igneous rocks in North Carolina and found that in general, the distribution of the clay mineral species conformed with Jackson's weathering sequence.

Certain aspects of loess deposition have been found to influence the character of soil profiles-degree of weathering, clay content, etc. - occurring at different points in loess mantled areas. It has been found that there is a general tendency for the loess thickness to decrease as the distance from the source becomes greater and for the clay content to increase as the loess becomes thinner (43). Foss and Rust (11) found that the clay increase with distance from the source was accompanied by an increase in the fine silt content and a decrease in the sand and coarse silt content. A number of workers have found a relationship between the distance from the source and the chemical and mineralogical characteristics of the loess and the loess derived soils. Caldwell and White (5) found that the quartz/feldspar ratios in the 2-5 micron and 5-20 micron fractions of the A2 horizons in a number of soils increased with distance from the loess source. Beavers (1) found that the CaO/ZrO_2 ratios in the 2-20 and 20-50 micron fractions of the A horizons of six soil profiles decreased with distance from the loess source. The decrease was more rapid in the 2-20 micron than in the

20-50 micron fraction. Foss and Rust (11) found that the carbonate content of the loess decreased with distance from the source. Hutton (20) postulated that the differences in the degree of profile development at different distances from the source may be due to differences in the effective time of weathering. He assumed that all loess in the study area was deposited concurrently and that the thinner, and therefore more slowly deposited, loess was in effect exposed to weathering for a longer period of time than the thicker portions of the loess deposit.

CHAPTER III

METHODS OF STUDY

Sampling Procedure

Paired sampling sites, one site representing a relatively mature soil and the other a less mature soil, on terraces of the South Canadian River were located in six counties. In a seventh county, Pontotoc, it was possible to locate a sampling site only for the relatively mature soil. The primary criterion in selecting the sampling sites was that in each county the soil profiles be typical of the soil types being studied in that county. Soil scientists of the Soil Conservation Service who had previous field experience in the counties of the study area assisted in the effort to select typical soil profiles.

As previously mentioned, profiles of the Holdredge and Enterprise Series were sampled in Roger Mills and Dewey Counties. The profiles sampled in other counties were tentatively classified as members of the Vanoss and Minco Series. Except for a greater depth to carbonates, these soils are very similar to the Holdredge and Enterprise soils and may be considered as their analogues, the Vanoss corresponding to the Holdredge and the Minco to the Enterprise soils.

Each soil was sampled by horizon from pits of 5-6 feet in depth. In some cases, samples were taken at greater depths with an auger. Prior to sampling, each soil profile was described using standard horizon nomenclature. In the soils of the less mature sequence horizonation was indistinct and, in some cases, the assignment of horizon symbols was largely arbitrary. This was done in a manner to avoid extremely thick horizons that, though appearing homogeneous in the field, might have important variations within the horizon. The samples were air dried, ground to pass a 2 mm. sieve, and stored for analysis.

Analyses of the Total Soil

Physical analysis consisted of determination of the particle size distribution and of thin section studies. The chemical analyses consisted of the determination of cation exchange capacity, extractable cations, pH, percent $CaCO_3$ equivalent, and the percent of organic matter. The percent of organic matter was determined only on the first three horizons of each soil, but the other analyses were done on all horizons.

Particle Size Distribution

The particle size distribution was determined by the pipette method of Kilmer and Alexander (29) except that the sample weight was determined by summing the weights of all soil fractions rather than by weighing an oven dried sample prior to analyses. The $<$ 0.002, 0.002-0.02, 0.02-0.05, and 0.05-2.0 mm. fractions were expressed as a percentage of organic matter-free, carbonate-free soil. The 0.05-2.0 mm. fraction was further fractionated into the five standard sand subfractions. The organic matter and the carbonates were destroyed using the H_2O_2 digestion and the treatment with HCl described by Jackson (24) except that the pH was lowered only to 5-5.5 with HCl rather than to 3.5-4.

Thin Section Studies

Thin sections were made of peds from selected horizons of the soils in Roger Mills and Caddo Counties. The sections were cut perpendicular to the vertical axis of the peds and were ground to the standard thickness of 30 microns. The primary objective of the thin section study was to obtain evidence relating to the movement or lack of movement of clay within the soil profiles. Therefore, the major effort was aimed at obtaining measurements of the amount and distribution of oriented clays within the different soil horizons. The terminology of Brewer (2) was used in describing the thin sections. Using a petrographic microscope, three predetermined transects were studied on each of the sections at a magnification of 450X. A high magnification was required because the argillans, the concentrations of oriented silicate clays, were thin. Using a calibrated eyepiece, semiquantitative measurements were made on the soil materials along the transects. The transects consisted of lines rather than areas, and the width in mm. of the materials along the lines were measured.

Cation Exchange Capacity

The samples were saturated with NH_4 by washing 2.0 gm. samples four times with 10 ml of a 1 N ammonium acetate solution. The excess NH_4 was removed by washing four times with 10 ml of 95% ethanol. The washings consisted of shaking the samples for five minutes on a reciprocating shaker and centrifuging until the soil particles were thrown out of suspension. The ammonium acetate washings were saved for further analysis and the ethanol washings were discarded. Ammonium from the samples was distilled into a 2% boric acid solution containing methyl red and brom cresol green indicators. The indicators were prepared by mixing 5 parts of a 0.1% brom cresol green solution with 1 part of a 0.1% methyl red solution, and approximately 400 ml of this indicator solution was added to 20 liters of boric acid solution. The NH_4 was determined by titrating the solution to a pink endpoint with an HCl solution. A microkjeldahl unit was used for the distillation and a 10 N KOH solution was used to provide a displacing cation for the NH_4.

Extractable Cations

The ammonium acetate solution extracts from the CEC procedure were diluted to 50 ml with a 1 N ammonium acetate solution and aliquots were taken for determination of calcium and magnesium. The calcium and magnesium were determined using the versenate titration described in USDA Handbook 60 (45). Sodium and potassium were determined with a Beckman DU flame spectrophotometer.

Soil pH Determination

The pH was determined on a soil-distilled water paste and on a 1:1 mixture of soil and 1 N KCl solution. The readings were taken on a model H2 Beckman pH meter.

$CaCO_3$ and Organic Matter Determination

An acid neutralization method was used to determine the percent $CaCO_3$ equivalent (45). The organic matter was determined with a method described by Harper (18).

Analyses of the < 0.002 mm. Fraction

The methods utilized in studying the < 0.002 mm. fraction were x-ray diffraction, CEC determination, surface area determination, and total K_2O determination. An x-ray diffraction analysis was done only on three selected horizons of each of the soils from Roger Mills, Caddo, and McClain Counties. The other analyses were done on five, or six in some cases, selected horizons from all soils.

X-ray Diffraction

The clay for this analysis was separated from soil samples which had been dispersed only by beating a soil suspension with a soil dispersion mixer for approximately five minutes. Stokes Law (29) was used to calculate the settling rate of a 0.002 mm. particle, and at the end of the time required for the particle to settle to a depth of 10 cm. the clay was removed by siphoning. Most of the samples were siphoned twice, but a few of the poorly dispersed calcareous samples were siphoned three times. Except for the addition of the minimum amount of $MgCl_2$ solution required to flocculate and allow concentration of the suspensions, the clays received no treatments prior to preparation for x-ray analysis. The clay samples were centrifuged after flocculation and the centrifugate was discarded. The samples were than suspended in the volume of water required to give approximately the desired suspension concentration. Duplicate slides of each sample were prepared for x-ray analysis by pipetting enough of the clay suspensions onto glass slides so that a thin, continuous clay film remained after air drying. The clay films were of a thickness such that it was not possible to see the glass slides through the films. One of the sets of duplicate slides was placed over $CaCl_2$ in a desiccator overnight and the samples were x-rayed the next day. The other set of the duplicate samples was placed over a pan of ethylene glycol in an aluminum desiccator and the desiccator was heated for approximately four hours over a low flame. The pan of ethylene glycol was then removed and the samples were x-rayed the next day. The glycolated samples were scanned over an angular range of approximately $2\text{-}10^0\ 2\theta$, and the other samples were scanned over an angular range of approximately $2\text{-}28^0\ 2\theta$.

Cation Exchange Capacity

The clays were separated from soil samples in which the organic matter and $CaCO_3$ had been removed by the H_2O_2 and acidified sodium acetate solution digestions of Jackson (24). After these treatments the soils were washed free of excess salts and the clay fraction was separated by repeated siphoning. After completion of the clay separation, the clays were concentrated by flocculation with a 1 N sodium acetate solution, washed free of the excess salts with 95% ethanol, and air dried in the ethanol. The dry clays were ground to pass a 60 mesh sieve and stored for CEC, surface area, and total K_2O determination. The CEC was determined by the calcium saturation method of Jackson (25).

Surface Area

The samples for this analysis were magnesium saturated by washing in a 1 N magnesium acetate solution. The samples were washed free of excess salts with 95% ethanol, air dried in the ethanol, and ground to pass a 60 mesh sieve. The surface area was determined by the ethylene glycol vapor method of Morin and Jacobs (35). The total surface area was determined on samples that had been vacuum dried over P_2O_5, and the external surface area was determined on samples which had been heated to 600° C for two hours.

Total K_2O

The samples were digested in a $HF-HClO_4$ mixture and the extracts were prepared for analysis as described by Jackson (25). The potassium was determined on a Perkin-Elmer, Model 303 atomic absorption spectrophotometer.

Mineralogical Analysis of the Sand and Silt Fractions

The heavy mineral suite of the 0.05-0.10 mm. fraction of all horizons in the soils of Roger Mills, Caddo, and McClain Counties was studied. The light minerals of the 0.02-0.05 and 0.05-0.10 mm. fractions of five, or in some cases six, selected horizons of all soils were studied.

Heavy Mineral Determination

The sand was treated for the removal of free iron oxides by the method of Kilmer (28) and the heavy minerals were separated in 1, 1, 2, 2-tetrabromoethane, a liquid of specific gravity 2.96. The liquid was poured into 15 ml. conical centrifuge tubes and a small amount of sand was added. The sand was mixed with the liquid by using a glass rod and the sample was centrifuged. Following repetition of this step, a glass rod having a small, well-rounded ball burned onto one end was slowly worked through the light minerals floating on top so as not to mix the light minerals and liquid any more than necessary. The heavy minerals resting in the tip of the conical tubes were held in place with the ball on the glass rod while the liquid and light minerals were poured onto filter paper. The heavy minerals were washed thoroughly in acetone and were air-dried. Suitable amounts of the grains were mounted in canada balsam on petrographic glass slides. The grains were identified by standard optical methods. Approximately 600 non-opaque grains per slide were identified. All mineral grains in the microscopic fields of view along predetermined transects were counted.

Light Mineral Determination

The 0.02-0.05 and 0.05-0.10 mm. fractions were mounted on gelatin coated slides using the method of Fairbairn (8). The only differentiation made was between quartz and feldspars. This was done by immersing the grains in an oil having a refractive index of 1.538 and classifying the grains as quartz if their refractive index was greater than that of the oil or feldspars if their refractive index was less than that of the oil. This method allowed some error due to overlap between feldspar and quartz refractive indices, but inspection of the grains with other criteria, primarily the cleavage and occasional twinning in the feldspars, indicated that the method allowed a good approximation. Also, studies on several of the samples with a higher refractive index oil indicated that the calcium plagioclases were almost totally absent and therefore would introduce little error into the analysis. Approximately 200 counts per sample were made for each size fraction.

CHAPTER IV

RESULTS AND DISCUSSION

The soil series designations given to some of the profiles at the time of sampling probably would no longer apply. However, the final correlation has not been made on most of the profiles and the original designations will be retained for the purpose of discussion. The important point relevant to the discussion is that the relatively mature soils are represented by the Holdredge and Vanoss Series whereas the less mature soils are represented by the Enterprise and Minco Series. In order to facilitate certain comparisons of soils in different climatic zones, the soils in Roger Mills and Dewey Counties were designated as group I soils, those in Custer and Caddo County as group II soils, and those in Grady and McClain as group III soils.

Field Studies

The data regarding the location of the soil profiles relative to the probable parent material source, the South Canadian River, is summarized in Table II. The soil profiles were sampled on the south side of the river except in Dewey County. In the sampling area in Dewey County, the river flows northward and the profiles were taken on the west side of the river.

The data in Table II show that Holdredge and Vanoss soils occur at greater distances from the river than the Enterprise and Minco soils except in Grady County. Field observations and inspection of soil maps in some of the counties indicated that in general this is the typical distributional pattern of these soils.

TABLE II

HORIZONTAL AND VERTICAL DISTANCE OF SOIL SAMPLING SITES FROM THE SOUTH CANADIAN RIVER

County	Soil	Horizontal Distance, Miles	Vertical Distance, Feet
Roger Mills	Enterprise	0.6	
Roger Mills	Holdredge	4.7	
Dewey	Enterprise	0.3	43
Dewey	Holdredge	1.4	
Custer	Minco	0.7	
Custer	Vanoss	2.4	
Caddo	Minco	0.9	153
Caddo	Vanoss	3.8	208
Grady	Minco	1.7	70
Grady	Vanoss	1.2	110
McClain	Minco	1.0	77
McClain	Vanoss	4.1	75
Pontotoc	Vanoss	0.8	100

The vertical distance of the sampling sites above the river bed was estimated from topographic maps. With the exception of one of the Enterprise soils, the sites in Roger Mills, Dewey, and Custer Counties were not covered by topographic maps. However, it was obvious in Roger Mills and Dewey Counties that the Holdredge sampling sites occurred on higher elevation terraces than the Enterprise sampling sites. The transition between the terraces on which the Minco and Vanoss soils occurred in Custer County was not sharp, but it appeared that the Vanoss soil definitely occurred at a higher elevation than the Minco soil. Considering both field observations and information obtained from topographic maps, it appears that the Holdredge and Vanoss soils definitely have formed on higher elevation terraces than the Enterprise and Minco soils. However, the sampling sites in McClain County are an exception to this generalization.

A comparison of the distance above the river bed of the different sites with values reported in the literature does not yield definite answers on the age of the terraces. However, it appears probable that the terraces on which the Enterprise and Minco soils occur are of Wisconsinan or Illinoian age whereas the terraces on which the Holdredge and Vanoss soils occur are likely of Illinoian age only. In Roger Mills, Dewey, and Custer Counties, the terraces on which the Enterprise and Minco soils were sampled occur very close to the stream channel and probably are of Wisconsinan age. Except for the sampling sites in McClain County, the Holdredge and Vanoss soils apparently occur on terraces which are of a greater age than the terraces on which the Enterprise and Minco soils occur, though the terraces were possibly deposited in the same geological period in some cases. However, the possibility exists that these terraces are loess mantled, and the age of the terraces may not be indicative of the effective time of soil formation. Assuming this is the case, the soils occurring at the greatest distance from the river, the Holdredge and Vanoss soils, still likely would have been subjected to weathering for a greater period of time than the soils occurring closer to the river.

The soil profiles were described as follows:

Enterprise Loam (0-1%)

Location: Roger Mills County, Oklahoma, 1.5 miles west of Highway 30 and approximately 30 yards north of a dirt road in the southwest 1/4 of the southwest 1/4 of S3, R26W, T16N.

Ap1 0-23 cm. -- Dark brown (7.5YR4/2) loam, brown (7.5YR5/4) when dry; weak fine granular; slightly hard, very friable; pH8.1; gradual smooth boundary; calcareous.

AC1 23-53 cm. -- Dark brown (7.5YR4/2) loam, brown (7.5YR5/4) when dry; weak coarse prismatic and weak medium subangular blocky; soft, very friable; pH8.1; diffuse smooth boundary; calcareous.

AC2 53-89 cm. -- Dark brown (7.5YR4/2) silt loam, brown (7.5YR5/4) when dry; weak coarse prismatic and weak medium subangular blocky; soft, very friable; pH8.4; diffuse smooth boundary; calcareous.

AC3 89-125 cm. -- Dark brown (7.5YR4/4) silt loam, brown (7.5YR5/4) when dry; weak medium prismatic and weak medium subangular blocky; slightly hard, very friable; pH8.0; diffuse smooth boundary; calcareous. 2.54

C1 125-152 cm. -- Brown (7.5YR5/2) silt loam, light brown (7.5YR6/4) when dry; slightly hard, very friable; pH8.0; very diffuse boundary; calcareous. 2.54) 8900 3 762 1380

C2 152-178 cm. -- Brown (7.5YR5/2) silt loam, brown (7.5YR5/4) when dry; slightly hard, very friable; pH8.2; very diffuse boundary; calcareous.

C3 178-203 cm. -- Reddish brown (5YR4/4) loam, brown (7.5YR5/4) when dry; slightly hard, very friable; calcareous.

Holdredge Silt Loam (0-1%)

Location: Roger Mills County, Oklahoma, approximately 0.1 miles south of the intersection of Highway 30 and a dirt road in Durham and 25 yards east of the dirt road in the northwest 1/4 of the northwest 1/4 of S25, R26W, T16N.

Ap1 0-20 cm. -- Dark brown (7.5YR3/2) silt loam, brown (7.5YR5/4) when dry; moderate medium granular; slightly hard, friable; pH7.8; clear smooth boundary.

B1 23-33 cm. -- Dark brown (10YR3/3) silt loam, dark brown (10YR4/3) when dry; moderate medium subangular block; hard, friable; pH7.7; clear smooth boundary.

B21t 33-46 cm. -- Dark brown (7.5YR4/2) silt loam, brown (7.5YR5/4) when dry; moderate coarse prismatic and moderate medium subangular blocky; hard, friable; pH7.8; gradual smooth boundary.

B22t 46-86 cm. -- Dark brown (7.5YR4/2) silt loam, brown (7.5YR5/4) when dry; moderate coarse prismatic breaking to moderate medium subangular blocky; hard, friable; pH7.9.

B3 86-107 cm. -- Dark brown (7.5YR4/4) loam, brown (7.5YR4/4) when dry; moderate coarse prismatic and moderate medium subangular blocky; hard, friable; pH7.8; clear wavy boundary; calcareous.

C1 107-130 cm. -- Reddish brown (5YR4/4) loam; yellowish red (5YR5/6) when dry; weak coarse prismatic and weak medium subangular blocky; very hard, friable; pH8.0; diffuse smooth boundary; calcareous.

C2 130-147 cm. -- Reddish brown (5YR5/4) loam; reddish yellow (5YR6/6) when dry; very hard, friable; pH8.2; gradual smooth boundary; calcareous, lower 2-3 inches transitional to the underlying horizon.

IIA1b 147-163 cm. -- Dark brown (7.5YR4/2) loam, brown (7.5YR5/4) when dry; moderate medium granular; soft, very friable; pH7.9; clear wavy boundary.

IICca 163-178 cm. -- Light brown (7.5YR6/4) when moist or dry; very hard, friable; strongly calcareous, many $CaCO_3$ concretions.

Enterprise Silt Loam (0-1%)

Location: Dewey County, Oklahoma, 330 feet east and 200 feet south of the northwest corner of S17, T17N, R17W.

Ap1 0-18 cm. -- Dark brown (7.5YR3/2) silt loam, dark brown (7.5YR4/2) when dry; weak medium granular; slightly hard, friable; pH7.5; abrupt smooth boundary; calcareous.

A12 18-33 cm. -- Dark brown (7.5YR3/2) silt loam, dark brown (7.5YR4/2) when dry; moderate medium subangular blocky; slightly hard, friable; pH8.0; gradual smooth boundary; calcareous.

AC1 33-51 cm. -- Dark brown (7.5YR3/2) silt loam, dark brown (7.5YR4/2) when dry; moderate medium subangular blocky; slightly hard, friable; pH8.0; diffuse smooth boundary; calcareous.

AC2 51-89 cm. -- Dark brown (7.5YR4/2) silt loam, brown (7.5YR5/4) when dry; moderate medium subangular block; slightly hard, friable; pH8.1; diffuse smooth boundary; calcareous.

AC3 89-102 cm. -- Dark brown (7.5YR4/4) silt loam, brown (7.5YR5/4) when dry; moderate medium subangular blocky; slightly hard, friable; pH8.1; diffuse smooth boundary; calcareous.

C1 112-137 cm. -- Brown (7.5YR5/4) silt loam, light brown (7.5YR6/4) when dry; moderate medium granular; slightly hard, friable; pH8.3; diffuse smooth boundary; strongly calcareous.

C2 137-158 cm. + -- Brown (7.5YR5/4) silt loam, light brown (7.5YR6/4) when dry; weak medium granular; slightly hard, friable; pH8.3; strongly calcareous.

Holdredge Silt Loam (0-1%)

Location: Dewey County, Oklahoma, 1000 feet south and 660 feet west of the northeast corner of the southeast quarter of S30, T18N, R17W.

Ap1 0-20 cm. -- Dark brown (7.5YR3/2) silt loam, dark brown (7.5YR4/2) when dry; moderate medium granular; hard, friable; pH6.2; abrupt smooth boundary.

A12 20-36 cm. -- Dark brown (7.5YR3/2) loam, dark brown (7.5YR4/2) when dry; moderate medium granular; hard, friable; pH6.9; diffuse smooth boundary.

B21t 36-71 cm. -- Dark brown (7.5YR3/2) loam, dark brown (7.5YR4/2) when dry; moderate medium prismatic and moderate medium subangular blocky; very hard, friable; pH7.4; diffuse smooth boundary.

B22t 71-97 cm. -- Dark brown (7.5YR4/2) loam, brown (7.5YR5/4) when dry; moderate medium prismatic and moderate medium subangular blocky; very hard, friable; pH7.6; gradual smooth boundary.

B23t 97-114 cm. -- Dark brown (7.5YR4/2) loam, brown (7.5YR5/2) when dry; moderate medium prismatic and moderate medium subangular blocky; very hard, friable; pH7.7; gradual smooth boundary.

B3 114-142 cm. -- Dark brown (7.5YR4/4) loam, brown (7.5YR5/4) when dry; moderate medium subangular block; very hard, friable; pH7.9; clear smooth boundary; few small $CaCO_3$ concretions but the soil matrix is noncalcareous.

C1 142-152 cm. + -- Brown (7.5YR5/4) loam, light brown (7.5YR6/4) when dry; weak medium subangular blocky; hard, friable; pH7.9; strongly calcareous.

Minco Silt Loam (1-3%)

Location: Custer County, Oklahoma, approximately 0.4 north of Highway 33 on a dirt road and 0.2 miles west on a private road and 100 yards north of the private road in the southwest 1/4 of the southeast 1/4 of S16, R14W, T15N.

Ap1 0-23 cm. -- Dark brown (7.5YR3/2) silt loam, brown (7.5YR5/4) when dry; weak fine granular; slightly hard, very friable; pH7.5; abrupt smooth boundary.

A12 23-33 cm. -- Dark brown (7.5YR4/2) silt loam, dark brown (7.5YR4/4) when dry; moderate medium subangular block; slightly hard, very friable; pH6.7; clear smooth boundary.

B1 33-48 cm. -- Dark brown (7.5YR4/2) silt loam, brown (7.5YR5/4) when dry; moderate medium subangular blocky; slightly hard, very friable; pH7.6; clear smooth boundary.

B21 48-61 cm. -- Dark brown (7.5YR4/4) silt loam, brown (7.5YR5/4) when dry; moderate medium subangular blocky; slightly hard, very friable; pH7.5; gradual smooth boundary; few $CaCO_3$ threads in lower part of horizon.

B22 61-81 cm. -- Dark brown (7.5YR4/4) silt loam, brown (7.5YR5/4) when dry; moderate medium subangular blocky; slightly hard, very friable; pH7.9; gradual smooth boundary; calcareous, common $CaCO_3$ threads.

B23ca 81-109 cm. -- Dark brown (7.5YR4/4) silt loam, light brown (7.5YR6/4) when dry; weak coarse prismatic and moderate medium subangular blocky; slightly hard, very friable; pH8.1; diffuse smooth boundary; strongly calcareous, many $CaCO_3$ threads.

B24ca 109-142 cm. -- Reddish brown (5YR4/4) silt loam, light brown (7.5YR6/4) when dry; weak coarse prismatic and moderate medium subangular blocky; slightly hard, very friable; pH7.9; gradual smooth boundary; strongly calcareous, many $CaCO_3$ threads decreasing in frequency in the lower part of the horizon.

C1 142-165 cm. -- Reddish brown (5YR4/4) silt loam, light brown (7.5YR4/4) when dry; weak coarse prismatic; slightly hard, very friable; pH7.9; diffuse smooth boundary; strongly calcareous, only a few $CaCO_3$ threads.

C2 165-188 cm. -- Reddish brown (5YR4/4) silt loam, pinkish gray (7.5YR6/2) when dry; slightly hard, very friable; strongly calcareous.

Vanoss Silt Loam (0-1%)

Location:	Custer County, Oklahoma, approximately 1.2 miles south of highway 33 and approximately 15 yards west of a dirt road in the northeast 1/4 of the southeast 1/4 of S28, R14W, T15N.
Ap1	0-20 cm. -- Dark brown (7.5YR4/2) silt loam, brown (7.5YR5/4) when dry; moderate medium granular; slightly hard, friable; pH6.5; abrupt smooth boundary.
A12	20-33 cm. -- Dark brown (7.5YR3/2) silt loam, dark brown (7.5YR4/2) when dry; moderate fine granular; hard, friable; pH6.6; gradual smooth boundary.
B1	33-53 cm. -- Dark brown (7.5YR3/2) silt loam, dark brown (7.5YR3/2) when dry; moderate medium subangular blocky; very hard, friable; pH6.8; gradual smooth boundary.
B21t	53-74 cm. -- Dark brown (7.5YR3/2) silt loam, dark brown (7.5YR4/2) when dry; moderate medium subangular blocky; very hard, friable; pH7.2; gradual smooth boundary.
B22t	74-102 cm. -- Dark brown (7.5YR4/2) silt loam, dark brown (7.5YR4/2) when dry; weak medium prismatic and moderate medium subangular blocky; very hard, friable; pH7.5; gradual smooth boundary.
B23t	102-117 cm. -- Dark brown (7.5YR3/2) silt loam, dark brown (7.5YR4/2) when dry; moderate medium subangular block; very hard, friable; pH7.4; gradual smooth boundary.
B24t	117-140 cm. -- Dark brown (7.5YR4/2) silt loam, brown (7.5YR5/2) when dry; moderate medium prismatic and moderate medium subangular blocky; very hard, friable; pH7.9; abrupt smooth boundary.
IIB21t	140-168 cm. -- Dark brown (7.5YR3/2) silty clay loam, brown (7.5YR5/2) when dry; moderate medium blocky; extremely hard, firm; pH7.8; diffuse smooth boundary; few threads of $CaCO_3$.
IIB22t	168-173 cm. -- Dark brown (7.5YR3/2) silty clay loam, dark brown (7.5YR4/2) when dry; moderate medium blocky; extremely hard, firm; pH7.2; few threads of $CaCO_3$.

Minco Silt Loam (0-1%)

Location: Caddo County, Oklahoma, approximately 4 miles north and 6 miles west of Hinton. SW 1/4 SE 1/4 Section 3, T12N, R12W. Located 0.55 miles east of the Bethel road and old Hwy. 66 intersection and approximately 150 feet north of the old Hwy. 66.

Ap1 0-15 cm. -- Dark brown (7.5YR3/2) silt loam, dark brown (7.5YR4/2) when dry; moderate fine granular; slightly hard, friable; pH5.8; abrupt smooth boundary.

A12 15-30 cm. -- Dark brown (7.5YR3/2) silt loam, dark brown (7.5YR4/2) when dry; moderate fine granular; slightly hard, friable; pH6.3; gradual smooth boundary.

B21 30-64 cm. -- Dark brown (7.5YR3/2) silt loam, dark brown (7.5YR4/2) when dry; moderate fine granular; slightly hard, friable; one large krotovina having a diameter of approximately 3 inches observed; pH6.8; gradual smooth boundary.

B22 64-107 cm. -- Dark brown (7.5YR4/2) silt loam, brown (7.5YR5/4) when dry; weak medium prismatic breaking to weak medium granular; hard, friable; pH6.9; gradual smooth boundary.

B23 107-147 cm. -- Dark brown (7.5YR4/2) loam, brown (7.5YR5/4) when dry; weak medium prismatic breaking to weak medium granular; hard, friable; pH6.4; gradual smooth boundary.

B3 147-165 cm. -- Dark brown (7.5YR4/2) silt loam, brown (7.5YR4/4) when dry; weak medium prismatic breaking to weak medium granular; hard, friable; pH7.0; gradual wavy boundary.

Cca 165-178 cm. -- Dark brown (7.5YR4/2) silt loam, brown (7.5YR4/4) when dry; mostly massive, but a few prisms observed; hard, friable; many fine $CaCO_3$ threads; pH7.6; gradual wavy boundary.

C2 178-216 cm. -- Dark brown (7.5YR4/4) silt loam, brown (7.5YR5/4) when dry; hard, friable; few $CaCO_3$ threads in upper part of horizon; pH7.8.

Vanoss Loam (0-1%)

Location: Caddo County, Oklahoma, approximately 2 miles north and 6 miles west of Hinton. NW 1/4 SW 1/4 Section 22, T12N, R12W. Located 0.7 miles south of the Bethel Churchhouse and approximately 100 feet east of a north-south dirt road.

Ap1 0-23 cm. -- Very dark grayish brown (10YR3/2) loam, dark grayish brown (10YR4/2) when dry; weak fine granular; slightly hard, friable; pH5.5; abrupt smooth boundary.

A12 23-33 cm. -- Very dark grayish brown (10YR3/2) loam, dark grayish brown (10YR4/2) when dry; weak fine granular; hard, friable; pH6.1; clear smooth boundary.

B1 33-51 cm. -- Very dark grayish brown (10YR3/2) loam, dark brown (10YR4/3) when dry; moderate medium subangular blocky; very hard, friable; pH6.2; gradual smooth boundary.

B21t 51-79 cm. -- Dark yellowish brown (10YR3/4) silt loam; dark brown (10YR4/3) when dry; moderate medium prismatic breaking to moderate medium blocky; very hard, friable; pH7.3; gradual smooth boundary.

B22t 79-104 cm. -- Dark brown (10YR4/3) heavy loam, dark brown (10YR4/3) when dry; moderate medium prismatic breaking to moderate medium blocky; very hard, friable; clay skins on vertical faces of peds; pH6.4; gradual smooth boundary.

B3 104-127 cm. -- Dark brown (10YR4/3) clay loam, brown (10YR5/3) when dry; weak medium prismatic breaking to weak medium blocky; very hard, friable; weakly developed clay skins on vertical faces; pH6.3; gradual smooth boundary.

C1 127-152 cm. -- Dark brown (7.5YR4/4) loam, yellowish brown (10YR5/4) when dry; very hard, friable; a few weakly developed clay skins; some intermixing in the lower part with the IIC2 horizon; pH6.4; clear wavy boundary.

IIC2 152-168 cm. -- Reddish brown (5YR4/4) very fine sandy loam, yellowish red (5YR5/6); hard, friable; pH6.5.

Minco Loam (0-1%)

Location: Grady County, Oklahoma, one mile northeast of Minco, 1230 feet east and 50 feet north of the southwest corner of S15, T10N, R7W.

Ap1 0-18 cm. -- Dark brown (7.5YR3/2) loam, dark brown (10YR4/3) when dry; moderate medium granular; slightly hard, friable; pH6.1; abrupt smooth boundary.

A12 18-36 cm. -- Dark brown (7.5YR4/2) loam, dark brown (7.5YR4/2) when dry; moderate medium granular; slightly hard, friable; pH6.2; gradual smooth boundary.

B1 36-51 cm. -- Dark brown (7.5YR3/2) loam, dark brown (7.5YR4/2) when dry; moderate medium granular; slightly hard, friable; pH6.4; gradual smooth boundary.

B21 51-76 cm. -- Dark brown (7.5YR4/4) loam, brown (7.5YR5/4) when dry; moderate medium subangular blocky; slightly hard, friable; pH6.6; diffuse smooth boundary.

B22 76-102 cm. -- Reddish brown (5YR4/4) loam, reddish brown (5YR4/4) when dry; moderate medium subangular blocky; slightly hard, friable; pH6.7; diffuse smooth boundary.

B23 102-132 cm. -- Reddish brown (5YR4/4) loam, reddish brown (5YR4/4) when dry; moderate medium subangular blocky; slightly hard, friable; pH6.8; clear smooth boundary.

C1 132-152 cm. -- Reddish brown (5YR4/4) loam, reddish brown (5YR4/4) when dry; weak medium subangular blocky; slightly hard, friable; pH8.2; gradual smooth boundary; strongly calcareous.

C2 152-173 cm. -- Reddish brown (5YR4/4) loam, reddish brown (5YR4/4) when dry; weak medium subangular blocky; slightly hard, friable; pH8.6; strongly calcareous.

Vanoss Silt Loam (0-1%)

Location: Grady County, Oklahoma, 1200 feet north and 100 feet east of the southwest corner of S18, T10N, R7W.

Ap1 0-18 cm. -- Dark brown (7.5YR3/2) silt loam, dark brown (7.5YR4/2) when dry; moderate medium granular; slightly hard, friable; pH6.1; abrupt smooth boundary.

A12 18-31 cm. -- Dark brown (7.5YR4/2) silt loam, dark brown (10YR4/3) when dry; moderate medium subangular blocky; hard, friable; pH6.5; gradual smooth boundary.

B21t 31-56 cm. -- Dark brown (7.5YR4/2) silty clay loam, dark brown (7.5YR4/2) when dry; moderate medium prismatic and moderate medium subangular block; very hard, firm; pH6.7; gradual smooth boundary; thin clay skins on ped faces.

B22t 56-76 cm. -- Dark brown (10YR4/3) silt loam, brown (10YR5/3) when dry; moderate medium prismatic and moderate medium subangular blocky; very hard, firm; pH6.5; gradual smooth boundary; thin clay skins on ped surfaces.

B23t 76-94 cm. -- Dark brown (10YR4/3) silt loam, brown (10YR5/3) when dry; moderate medium prismatic and moderate medium subangular blocky; very hard, firm; pH7.0; clear smooth boundary; thin clay skins on ped surfaces.

B3 94-114 cm. -- Brown (7.5YR5/4) loam, grayish brown (10YR5/2) when dry; moderate medium prismatic and moderate medium subangular blocky; very hard, firm; pH6.9; abrupt smooth boundary; few faint mottles, thin clay skins.

C1 114-142 cm. -- Dark brown (10YR4/3) loam, brown (7.5YR5/4) when dry; weak medium subangular blocky; very hard, firm; pH8.0; diffuse smooth boundary; many $CaCO_3$ threads.

C2 142-163 cm. -- Dark brown (10YR4/3) loam, brown (7.5YR5/4) when dry; weak medium subangular blocky; slightly hard, friable; pH7.9; many $CaCO_3$ threads.

Minco Silt Loam (0-1%)

Location: McClain County, Oklahoma, 750 feet south and 850 feet east of the northwest corner of S24, T8N, R3W.

Ap1 0-18 cm. -- Dark yellowish brown (10YR3/4) silt loam, brown (10YR5/3) when dry; moderate medium granular; slightly hard, friable; pH6.2; abrupt smooth boundary.

A12 18-33 cm. -- Dark brown (7.5YR3/2) silt loam, dark brown (10YR4/3) when dry; moderate medium granular; slightly hard, friable; pH6.5; gradual smooth boundary.

B1 33-56 cm. -- Dark brown (7.5YR3/2) loam, dark brown (7.5YR4/2) when dry; moderate medium granular; slightly hard, friable; pH6.6; gradual smooth boundary.

B21 56-91 cm. -- Dark brown (7.5YR4/4) silt loam, brown (5YR5/4) when dry; moderate medium subangular blocky; hard, friable; pH6.6; diffuse smooth boundary.

B22 91-132 cm. -- Dark brown (7.5YR4/4) silt loam, brown (7.5YR5/4) when dry; moderate medium subangular blocky; hard, friable, pH7.0; diffuse smooth boundary.

B23 132-158 cm. -- Dark brown (7.5YR4/4) silt loam, brown (7.5YR5/4) when dry; moderate medium subangular blocky; hard, friable; pH6.6; diffuse smooth boundary.

B24 158-188 cm. -- Reddish brown (5YR4/4) silt loam, reddish brown (5YR5/4) when dry; weak medium subangular blocky; hard, friable; pH6.7; diffuse smooth boundary.

B3 188-229 cm. -- Dark brown (7.5YR4/4) silt loam, brown (7.5YR5/4) when dry; weak medium subangular blocky; hard, friable; pH6.8.

C1 229-246 cm. -- Dark brown (7.5YR4/4) silt loam, brown (7.5YR5/4) when dry; weak medium granular; slightly hard, friable; pH7.9; strongly calcareous.

Vanoss Silt Loam (0-1%)

Location:	McClain County, Oklahoma, 250 feet north and 250 feet east of the southwest corner of S8, T7N, R2W.
Ap1	0-20 cm. -- Dark brown (7.5YR3/2) silt loam, dark brown (10YR4/3) when dry; weak medium granular; slightly hard, friable; pH5.5; abrupt smooth boundary.
A12	20-36 cm. -- Dark brown (10YR3/3) silt loam, dark brown (7.5YR4/2) when dry; moderate medium granular; slightly hard, friable; pH5.7; gradual smooth boundary.
B1	36-56 cm. -- Dark yellowish brown (10YR3/4) silt loam, brown (7.5YR5/4) when dry; moderate medium subangular block; hard, friable; pH5.9; gradual smooth boundary.
B21	56-81 cm. -- Dark yellowish brown (10YR3/4) silt loam, dark brown (10YR4/3) when dry; moderate medium subangular block; hard, firm; pH6.2; abrupt smooth boundary; few Fe and/or Mn concretions and a few thin clay skins.
IIB21t	81-104 cm. -- Dark grayish brown (10YR4/2) silty clay loam, grayish brown (10YR5/2) when dry; moderate medium prismatic and moderate to strong medium blocky; very hard, firm; pH6.4; diffuse smooth boundary; common Fe and/or Mn concretions, thin clay skins on ped surfaces; faint mottling.
IIB22t	104-132 cm. -- Dark grayish brown (10YR4/2) silty clay loam, grayish brown (10YR5/2) when dry; moderate medium prismatic and moderate to strong medium blocky; very hard, firm; pH6.7; diffuse smooth boundary; common Fe and/or Mn concretions, thin clay skins on ped surfaces, and common distinct mottles.
IIB23t	132-158 cm. -- Dark grayish brown (10YR4/2) silty clay loam, grayish brown (10YR5/2) when dry; moderate medium prismatic and moderate to strong blocky; hard, very firm; pH6.9; clear smooth boundary; common Fe and/or Mn concretions, thin clay skins on ped surfaces, and common distinct mottles.
IIC1ca	158-170 cm. -- Dark grayish brown (10YR4/2) silty clay loam, grayish brown (10YR5/2) when dry; weak coarse subangular blocky; very hard, firm; pH7.9; diffuse smooth boundary; common Fe and/or Mn concretions, common $CaCO_3$ concretions, few thin clay skins, and common distinct mottles.
IIC2ca	170-183 cm. -- Dark grayish brown (10YR4/2) clay loam, grayish brown (10YR5/2) when dry; common Fe and/or Mn concretions and common $CaCO_3$ concretions.

Vanoss Silt Loam (0-1%)

Location: Pontotoc County, Oklahoma, 2550 feet north and 100 feet west of the southeast corner of S23, T5N, and R8E.

Ap1 0-20 cm. -- Dark brown (7.5YR4/2) silt loam, brown (7.5YR5/4) when dry; weak medium granular; slightly hard, friable; pH6.6; abrupt smooth boundary.

B1 20-41 cm. -- Dark brown (7.5YR4/2) silt loam, brown (7.5YR5/4) when dry; moderate medium subangular blocky; hard, friable; pH7.1; gradual smooth boundary.

B21t 41-76 cm. -- Dark brown (7.5YR4/2) silt loam, brown (7.5YR5/4) when dry; moderate medium prismatic and moderate medium subangular blocky; hard, friable; pH6.6; diffuse smooth boundary.

B22t 76-114 cm. -- Dark brown (7.5YR4/4) silt loam, brown (7.5YR5/4) when dry; moderate medium prismatic and moderate medium subangular blocky; hard, friable; pH6.9; gradual smooth boundary.

B23t 114-152 cm. -- Dark brown (7.5YR4/4) silt loam, brown (7.5YR5/4) when dry; moderate medium prismatic and moderate medium subangular blocky; slightly hard, friable; pH6.4; gradual smooth boundary; many peds coated with silt grains.

B3 152-229 cm. -- Dark yellowish brown (10YR4/4) silt loam, brown (10YR5/4) when dry; moderate medium subangular blocky; hard, friable; pH5.9; gradual smooth boundary; many peds coated with silt grains.

C1 229-254 cm. -- Reddish brown (5YR4/4) loam, reddish brown (5YR5/4) when dry; weak medium subangular blocky; hard, friable; pH5.8.

The degree of horizon differentiation, while not really distinct in any of the profiles, appears to be greater in the Holdredge and Vanoss soils than in the Enterprise and Minco soils. This would be expected if the former soils have been exposed to soil forming processes longer than the latter soils. The field studies showed no consistent morphological differences between soils in the different climatic zones of the study area except that evidence of free $CaCO_3$

appeared closer to the soil surface in the drier portions than in the more humid portions of the study area.

A general tendency was observed for unconforming horizons to occur within or below the solum of the Holdredge and Vanoss soils. This conclusion is based on observations of a number of profiles in addition to those that were sampled. Such horizons were described in four of the seven Holdredge and Vanoss soils on the basis of morphological evidence. The solum of the Holdredge profile in Roger Mills County overlies a material that appears to be the A horizon of an immature soil on an older landform. The Vanoss soil in Caddo County overlies a sandy alluvial deposit. Unconformities occur within the solums of the Vanoss soils in Custer and McClain Counties. The materials comprising these unconformities were described as B horizons, but these materials could easily be clayey alluvial deposits. The observations on the distribution of unconforming horizons indicate that in general the Holdredge and Vanoss soils have developed in thinner deposits than the Enterprise and Minco soils.

Considering all aspects of the field studies, the Holdredge and Vanoss soils apparently have been exposed to weathering for a longer period of time than the Enterprise and Minco soils. The most likely exception is the Vanoss soil in McClain County. The morphological features of this soil could easily be due primarily to depositional rather than to soil forming processes.

Particle Size Distribution

The results of the particle size distribution analysis for all soil horizons is given in Appendix Tables XXV-XXXI. The particle size data for five selected horizons is shown graphically in Figures 2-8.

The graphs indicate several points regarding the $<$ 0.002 mm. fraction. First, the clay content of the Holdredge-Vanoss soils is greater than that of the Enterprise-Minco soils if the whole profiles are considered. There are exceptions if only certain horizons are considered. Another point is that in general the spread between the maximum and minimum clay contents within the profiles is greater in the Holdredge-Vanoss soils than in the Enterprise-Minco soils. The Vanoss and Minco soils of Grady County are an exception to this generalization. A third point is that in general there is a progressive clay increase with depth in the Holdredge-Vanoss soils, but there is no marked tendency for the clay maximums to occur at any particular point within the profiles. In some profiles the clay maximum occurs within the B horizon whereas in other profiles it occurs at the point of greatest sampling depth. The tendency for the progressive clay increase with depth is also apparent in the Minco soils of McClain, Grady, and Caddo Counties but not in the Enterprise and Minco soils of the counties to the west. The Enterprise and Minco soils of the latter counties are relatively homogeneous throughout the profiles with respect to the clay content.

Several points are evident regarding the nonclay fractions if all data are considered. The 0.002-0.02, 0.02-0.05, and 0.05-0.10 mm. fractions are by far the most abundant of the nonclay fractions in most of the pedons. In general, the 0.02-0.05 mm. silt is the most abundant single fraction, but in some horizons the 0.05-0.10 mm. sand is the most abundant. The 0.10-0.25 mm. sand is of importance in some of the pedons. Except for the Holdredge soil of Dewey County, the fractions coarser than 0.25 mm. in diameter comprise less than 5% of most of the

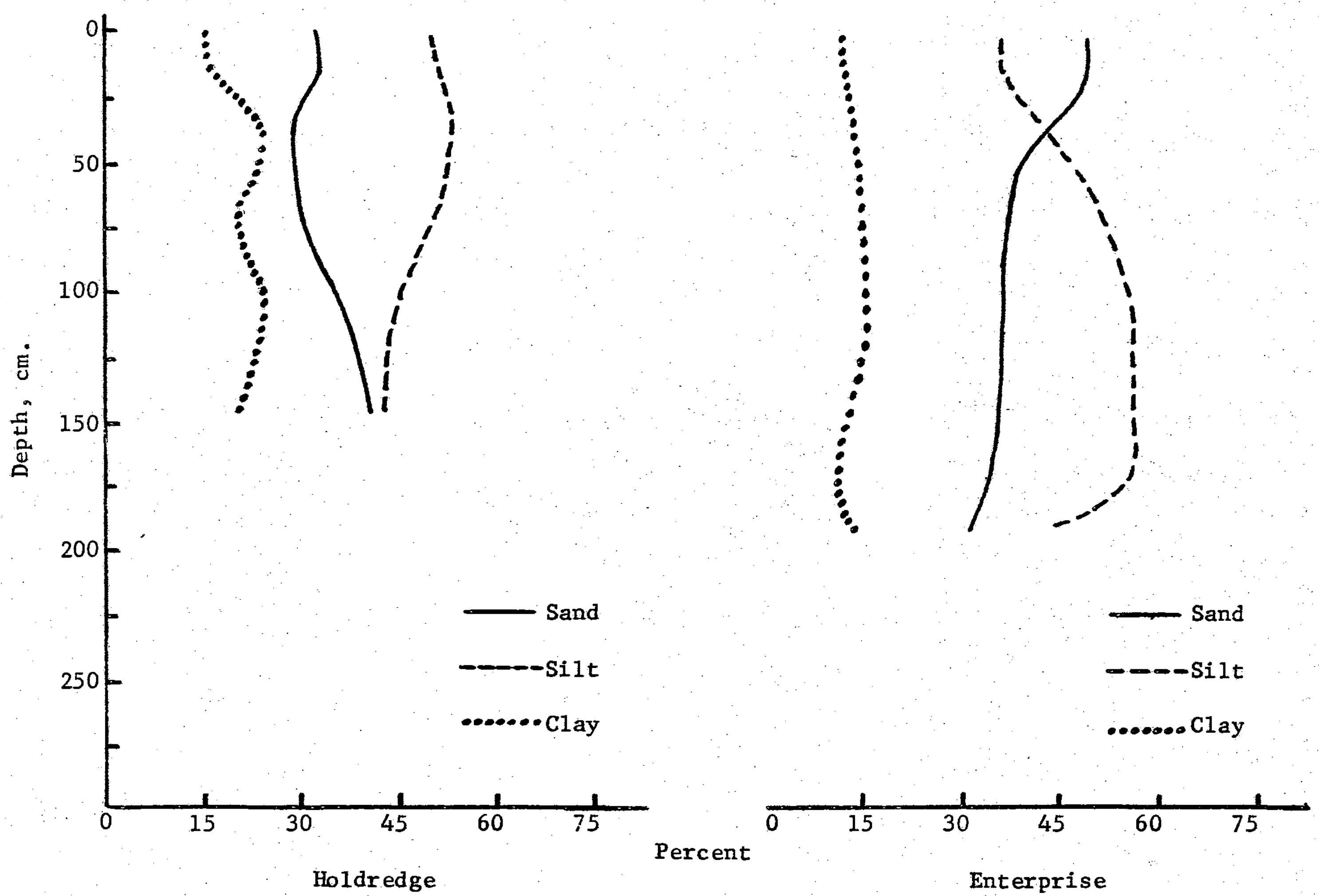

Figure 2. Particle Size Distribution of the Holdredge and Enterprise Soils of Roger Mills County

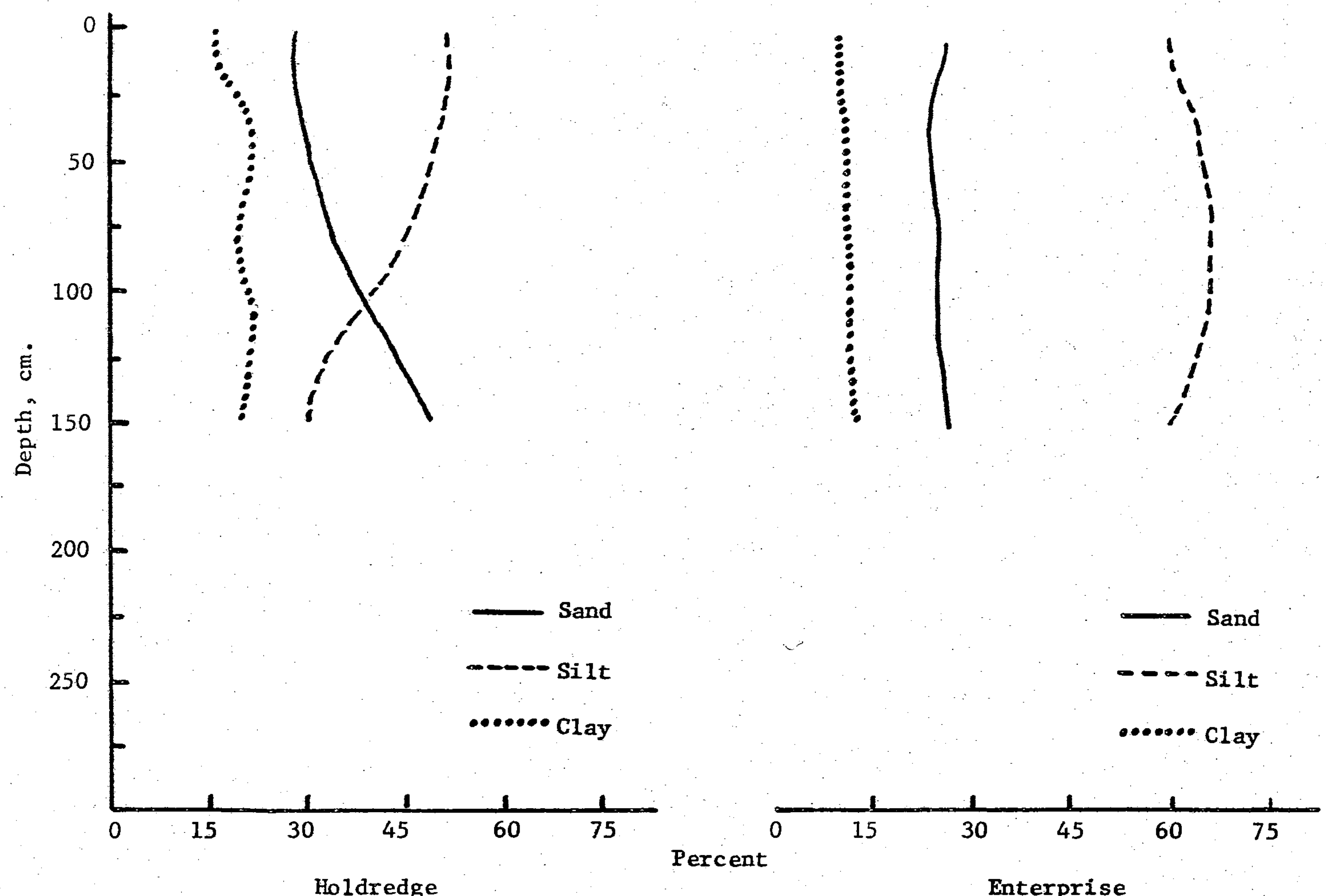

Figure 3. Particle Size Distribution of the Holdredge and Enterprise Soils of Dewey County

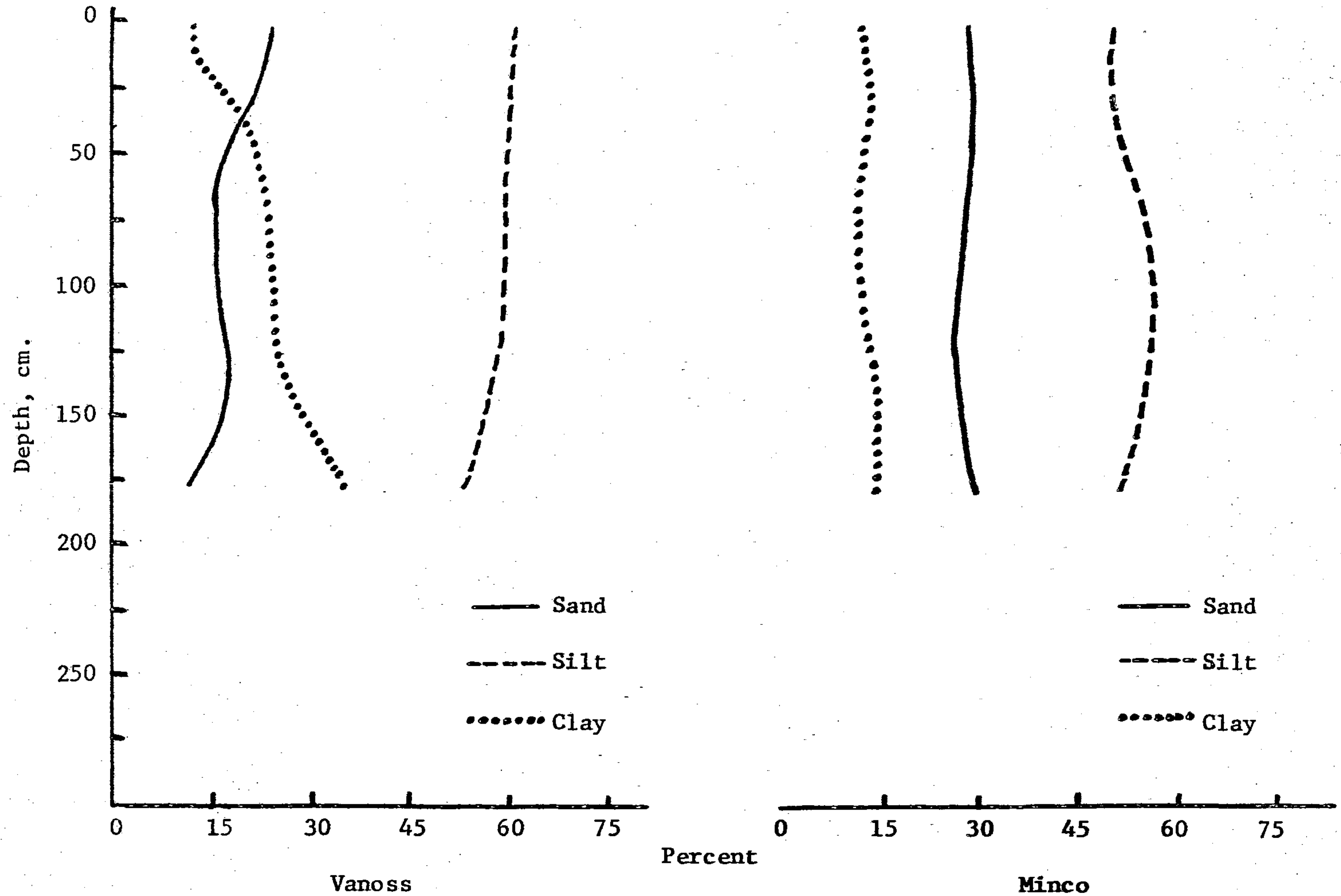

Figure 4. Particle Size Distribution of the Vanoss and Minco Soils of Custer County

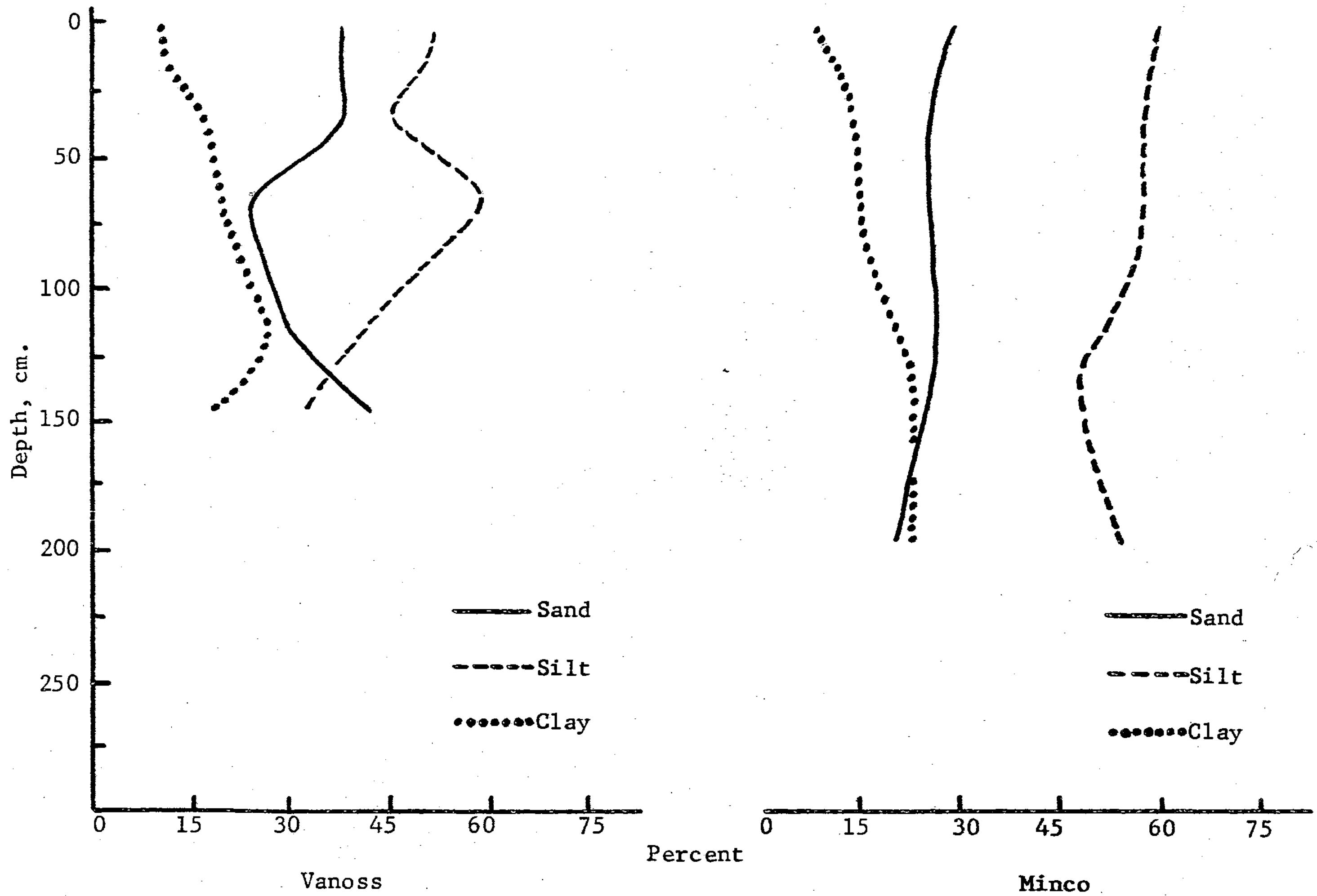

Figure 5. Particle Size Distribution of the Vanoss and Minco Soils of Caddo County

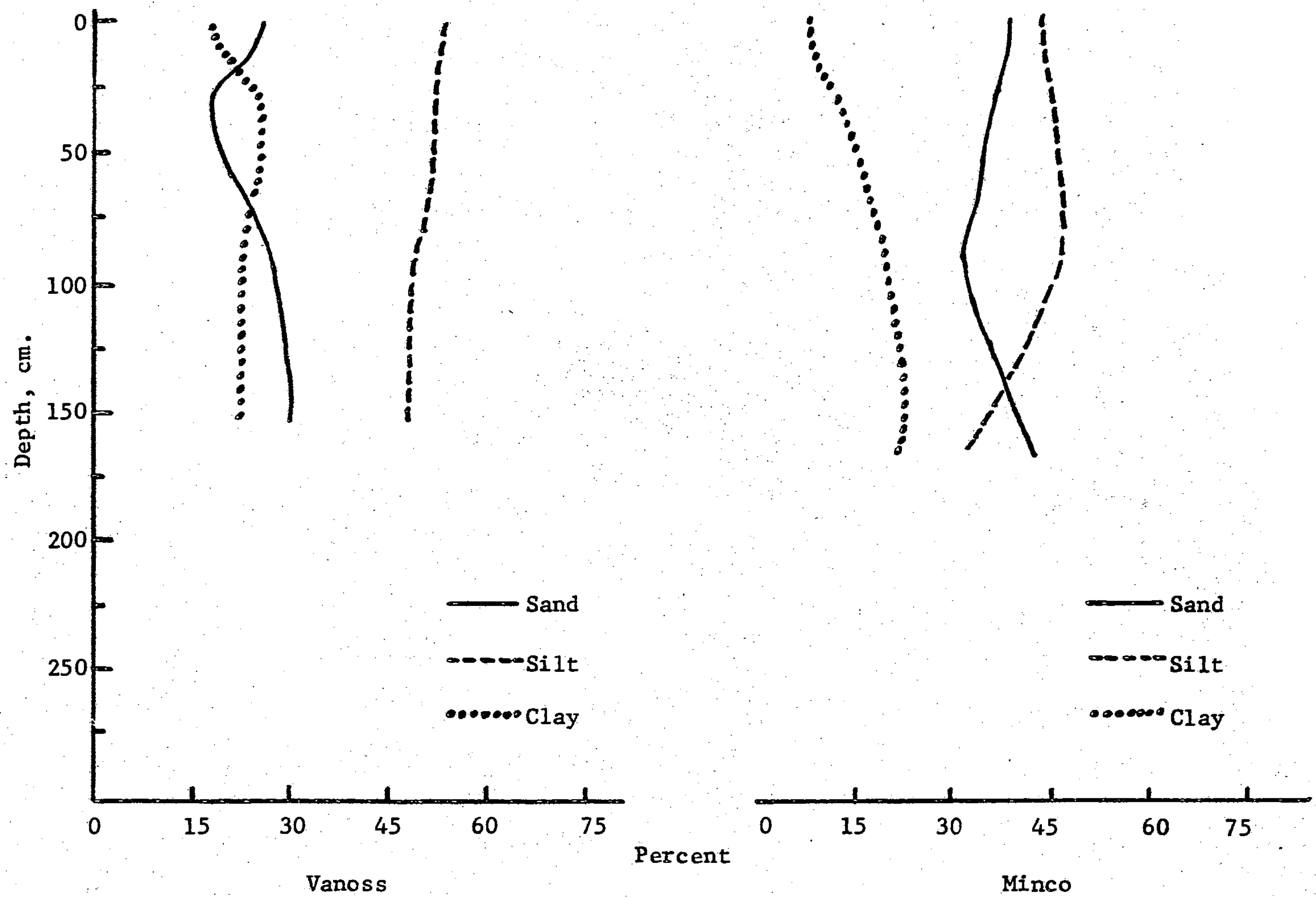

Figure 6. Particle Size Distribution of the Vanoss and Minco Soils of Grady County

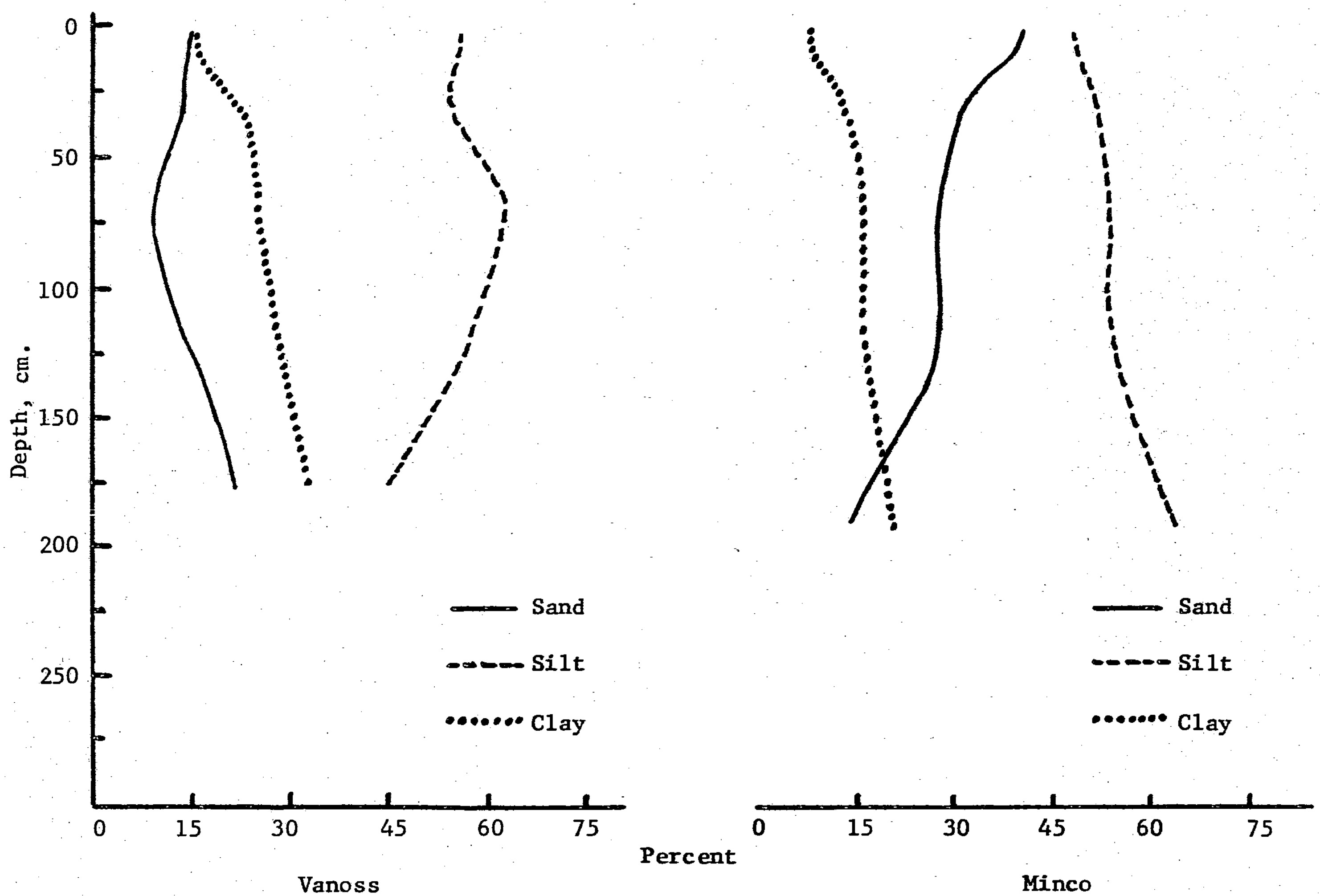

Figure 7. Particle Size Distribution of the Vanoss and Minco Soils of McClain County

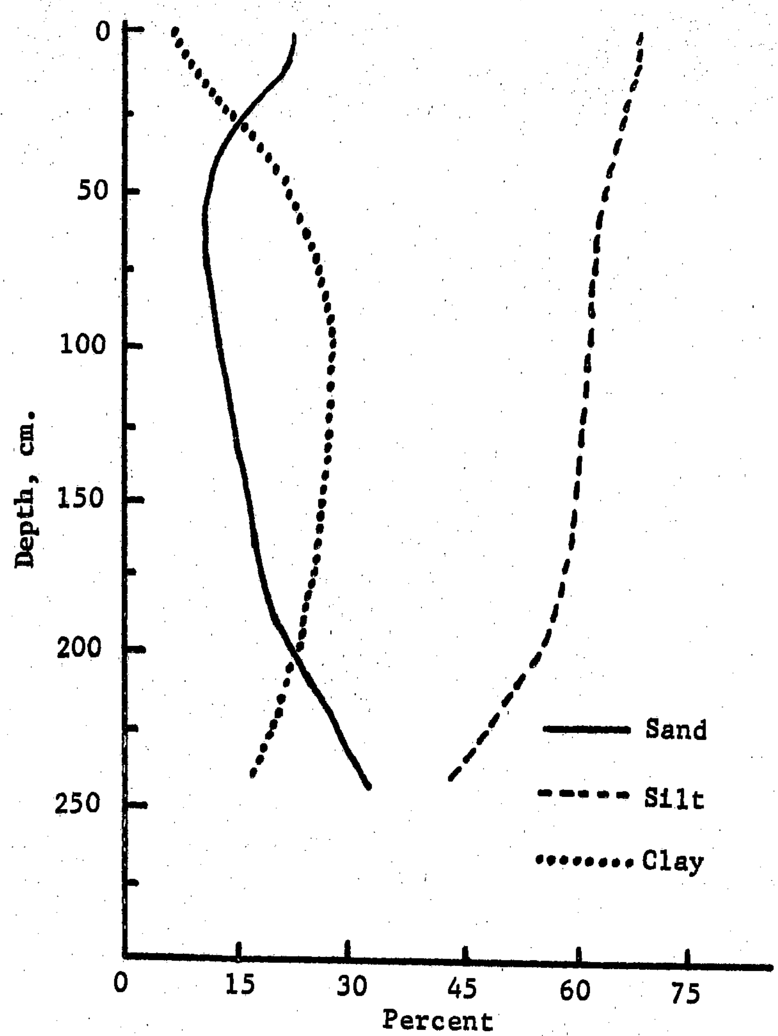

Figure 8. Particle Size Distribution of the Vanoss Soil of Pontotoc County

horizons. The 1.0-2.0 mm. fraction is absent in many of the soil horizons, and its content is very nearly negligible in the remainder of the horizons.

Close inspection of the particle size data of a number of horizons shows differences in the content of the nonclay fractions that are probably indicative of depositional differences within the pedons. However, most of these differences are relatively minor and probably are of little consequence regarding the genesis of the soils. A possible exception is the Holdredge soil of Dewey County. There is a progressive increase in the content of sand and a progressive decrease in the content of silt with depth in the pedon, thus indicating changing depositional conditions during the time the soil parent material was being deposited.

The particle size distribution, and most other properties, of the Vanoss soil of Pontotoc County will not be considered in as much detail as in other soils because this soil cannot be compared to a less mature soil. In general, its particle size distribution is similar to that of other Holdredge and Vanoss soils in the study. The data indicate that the C1 horizon of this soil was deposited under somewhat different conditions than the overlying soil material.

The particle size distribution results give little additional information beyond that available from field observations to support or reject the decision made to designate certain horizons of four of the Holdredge-Vanoss soils as unconforming horizons. The results show that the unconforming horizons of the Vanoss soils of Custer and McClain Counties have a higher clay content than the overlying horizons, but this was apparent from field observations alone. At any rate, the decision to designate the horizons as nonconforming was made more on the basis of the abruptness of the boundaries than on the increased clay content. The particle size distribution results also show that the unconforming horizon in the Vanoss soil of Caddo County is much more sandy than the overlying horizons, but again this was apparent from field observations alone. The particle size distribution of the unconforming horizons in the Holdredge soil of Roger Mills County is similar to that of the overlying horizons, but these horizons were not designated as unconformities on the basis of their particle size distribution.

The following conclusions were drawn on the basis of the particle size distribution results:

1.) The higher clay content of the Holdredge-Vanoss soils relative to the Enterprise-Minco soils is due to depositional processes rather than to soil forming processes. Soil forming processes of sufficient intensity to account for the observed difference in clay content between the two groups of soils would almost certainly have resulted in much more sharply defined textural horizons than is present in these soils.

2.) The greater spread between the maximum and minimum clay contents within the profiles and the greater tendency towards a progressive increase in the clay content with depth in the Holdredge-Vanoss soils compared to the Enterprise-Minco soils is indicative of a more advanced stage of soil formation in the former soils. The reason for this difference is likely that the effective time of soil formation has been greater for the Holdredge-Vanoss soil than for the Enterprise-Minco soils.

3.) Some depositional differences within the profiles are indicated, but in general these differences are minor and would have no major effect upon the genesis of the soils.

Thin Section Studies

The results are presented in Tables III and IV. Most, but not all, of the terminology was taken from Brewer (2). For the purposes of this study, the skeleton grains were taken as the silt and sand grains having a diameter greater than approximately 0.01 mm. in diameter. The use of the term in this manner is similar, though not identical, to Brewer's use of the term. Argillans are simply concentrations at any natural soil surface of materials composed dominantly of oriented silicate clays. The term matrix was used to include all soil materials less than approximately 0.01 mm. in diameter.

The objective of determining the percentage of voids, skeleton grains, and matrix was to gain knowledge of the general physical characteristics of the different soils. Unfortunately, the small size of many of the voids and the artificial voids created by thin section preparation made it impossible to measure the percentage of voids with any degree of accuracy. Measurements of the matrix probably are also in error because many small voids were included with the matrix. The measurements on the skeleton grains probably are considerably more accurate than the other measurements. The data are erratic and difficult to interpret, and differences between the four soils are not apparent.

TABLE III

MICROMORPHOLOGICAL FEATURES OF THE HOLDREDGE AND ENTERPRISE SOILS OF ROGER MILLS COUNTY

Horizon	Depth cm	% Voids	% Skeleton Grains	% Matrix	Percentage of Argillans in the Matrix	Percentage of Skeleton Grains Coated With Argillans
			----Enterprise----			
Ap1	0-23	21.3	37.1	41.6	1.9	33.3
AC1	23-53	20.9	28.5	50.6	1.4	27.4
AC3	89-125	18.8	27.0	54.2	2.4	31.0
C1	125-152	31.0	24.4	44.6	1.3	28.3
C3	178-203	24.0	34.7	41.3	1.0	14.3
			----Holdredge----			
Ap1	0-20	5.7	41.9	52.4	1.3	26.7
B1	20-33	13.2	31.7	55.1	2.2	19.2
B21t	33-46	17.3	26.7	56.0	2.3	18.5
B3	86-107	17.7	33.8	48.5	8.0	51.7
C1	107-130	13.0	38.2	48.8	5.5	55.1
C2	130-147	21.0	39.2	39.8	8.3	68.3

TABLE IV

MICROMORPHOLOGICAL FEATURES OF THE VANOSS AND MINCO SOILS OF CADDO COUNTY

Horizon	Depth cm	% Voids	% Skeleton Grains	% Matrix	Percentage of Argillans in the Matrix	Percentage of Skeleton Grains Coated With Argillans
			----Minco----			
A12	15-30	13.2	40.0	46.8	7.5	39.8
B21	30-64	12.3	45.5	42.2	9.7	41.2
B22	64-107	26.4	24.3	49.3	8.7	42.7
B3	147-165	23.9	11.5	64.6	10.4	68.0
Cca	165-178	21.1	14.0	64.9	12.5	69.6
			----Vanoss----			
A12	0-23	16.1	26.4	57.5	4.5	47.1
B1	33-51	13.2	25.9	60.9	10.3	52.2
B21t	51-79	26.7	23.9	49.4	8.3	58.2
B22t	79-104	23.5	19.0	57.5	7.1	44.1
B3	104-127	9.2	16.6	74.2	7.5	48.6
C1	127-152	2.8	27.2	70.0	5.6	48.9

The measurements of the argillans are of some interpretative value regarding genetic processes in the soils. According to Brewer (2) argillans usually form either as a result of deposition or of stress. He outlines criteria which may be used as an indication of the mode of formation of the argillans, and a high percentage of the argillans in the soils of this study, considering that most of them exhibit moderate to strong continuous orientation and have relatively sharp boundaries, appear to be depositional argillans. Most of the argillans are thin, often 4-5 microns in diameter, but this does not exclude their being depositional argillans. The content of argillans varies very little within the Enterprise profile and little clay translocation is indicated. It is likely that the results from the study of this profile can be extended to other profiles in the study having a similar particle size distribution. A general downward translocation of clay is indicated in the other profiles. Again, these results likely can be extended to other profiles having a similar particle size distribution.

Soil Chemical Properties

Calcium Carbonate Equivalent

The data are presented in Appendix Tables XXXII-XXXVIII and in Figures 9-11. All horizons were considered in plotting the data, but horizons were combined in a way to give a total of five horizons in each profile. The same method of combination was used for all profiles and the $CaCO_3$ content of different horizons was properly weighted to take into account differing horizon thicknesses. Once the combination of horizons was complete, soils were grouped as shown in Figures 10 and 11 and averages were taken of the $CaCO_3$ content in corresponding horizons

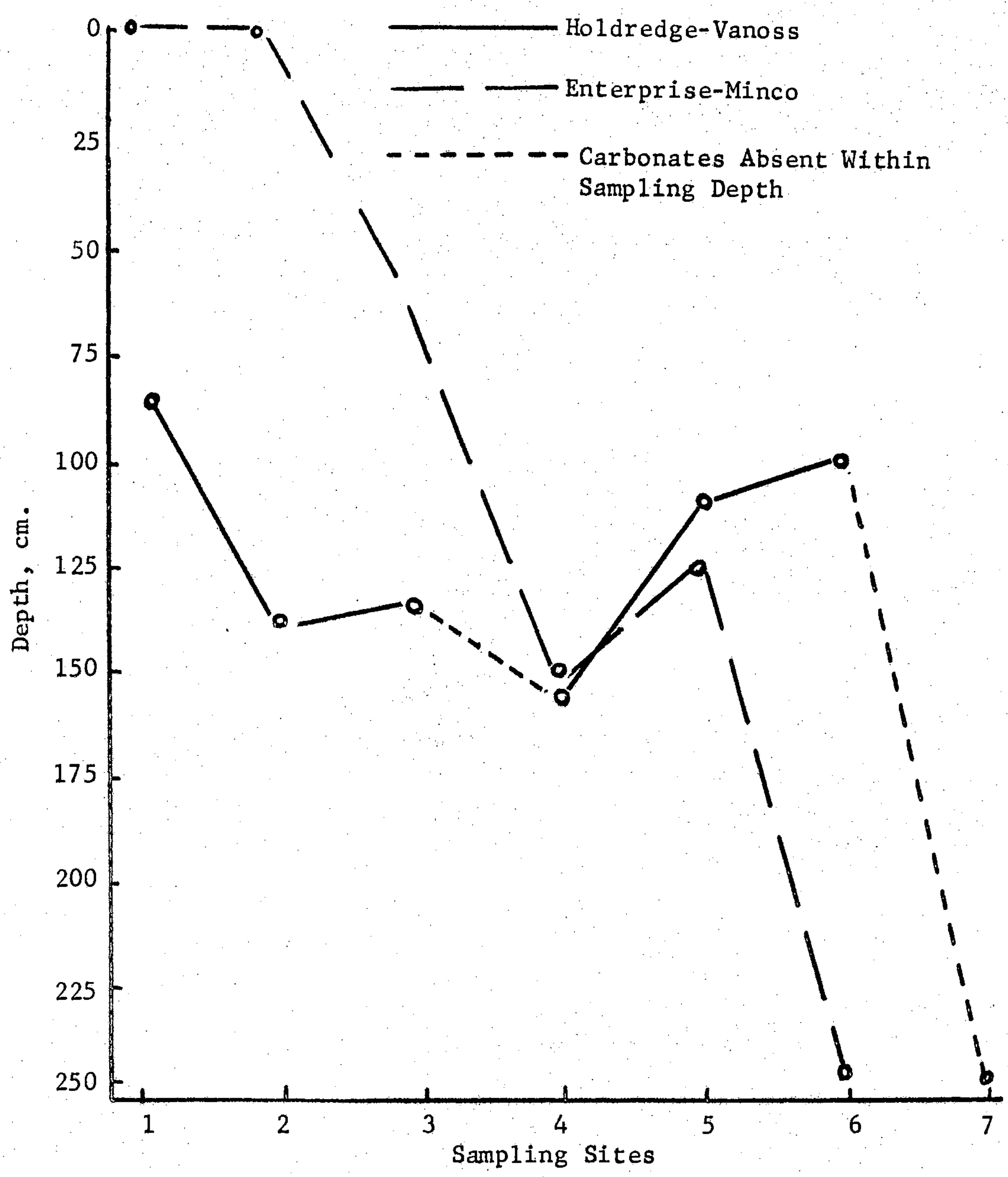

Figure 9. Depth to Carbonates as a Function of Sampling Site in a West-East Direction, Roger Mills to Pontotoc County

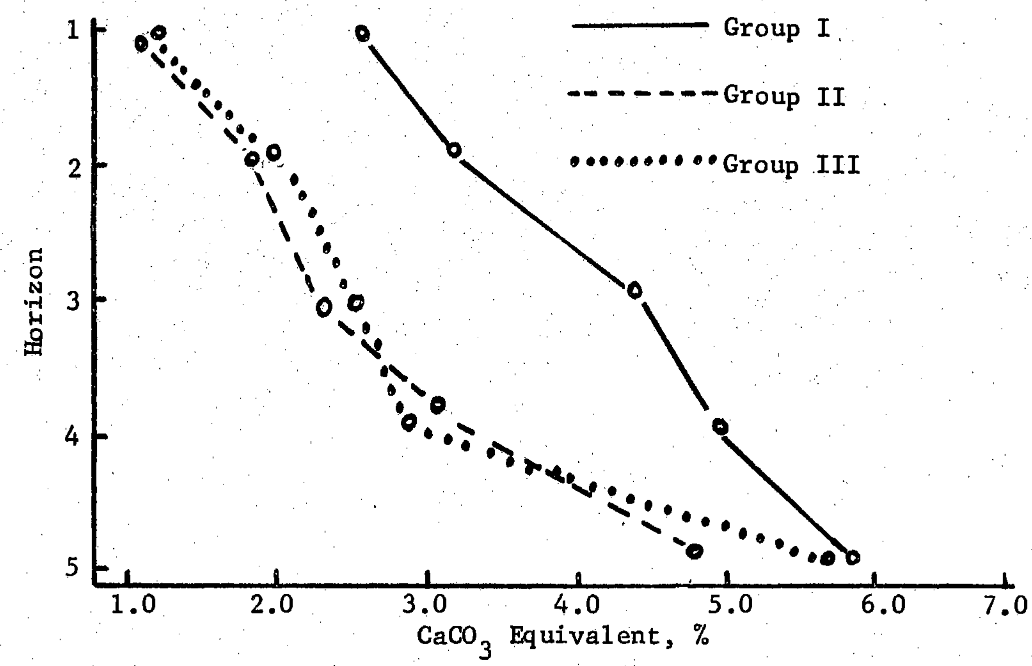

Figure 10. Distribution of Carbonates in Soils of Three Climatic Zones

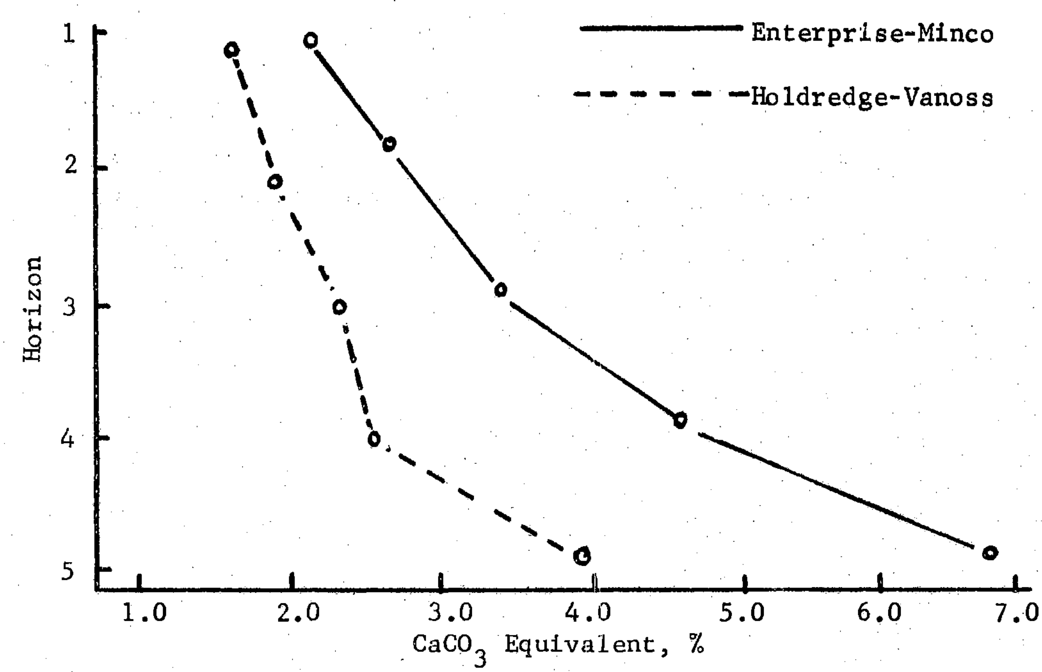

Figure 11. Distribution of Carbonates in the Enterprise-Minco and Holdredge-Vanoss Soils

of each group of soils. In general, horizon 1 represents the A horizons; horizons 2, 3, and 4 represent B or AC horizons; and horizon 5 represents C horizons. However, there are exceptions and the important point is that the numerals represent horizons occurring at progressively deeper points within the profiles. One point that must be considered in evaluating the data is that the acid neutralization method of carbonate determination that was used in this study indicates a low content of carbonate even in carbonate free samples because of neutralization by noncarbonate soil constituents. This figure appears to be close to 2% in the soils of this study.

Figure 9 illustrates the relationship between the average annual rainfall and the depth to carbonates in the soil profiles. Sampling sites rather than rainfall are plotted but the rainfall increases progressively, though not necessarily uniformly, in a west-east direction. The site numbers were assigned in a progressively increasing order beginning with site 1 in Roger Mills County and ending with site 7 in Pontotoc County. A field test with 1 N HCl was used as the criteria for determining the depth to carbonates. It is evident that there is a general increase in depth to carbonates, though there are numerous exceptions, as the rainfall increases.

Figures 10 and 11 indicate a progressive increase in carbonate content with depth in all soil groups. It is apparent that the Holdredge-Enterprise soils of Roger Mills and Dewey Counties have a higher percent $CaCO_3$ equivalent than the groupings of Vanoss-Minco soils in Custer and Caddo or in Grady and McClain Counties. Also, the Enterprise-Minco soils have a higher $CaCO_3$ equivalent than the Holdredge-Vanoss soils, particularly in the lower horizons. The difference in the percent $CaCO_3$

equivalent of the lower horizons of the latter groups of soils is exaggerated slightly by the fact that calcareous soil material was not reached within sampling depth in the Vanoss soil of Caddo County. Calcareous material was not reached within sampling depth in the Vanoss soil of Pontotoc County, but this soil was not included in the grouping of soils that is shown in Figure 11.

The following factors appear to be of particular importance regarding the genesis of soils in this study:

1.) The Enterprise-Minco soils formed from a more highly calcareous parent material than the Holdredge-Vanoss soils. There is a possibility that a greater degree of leaching in the Holdredge-Vanoss soils accounts for the observed differences, but the data in Appendix Tables XXXII-XXXVIII indicate that relatively unleached soil materials, at least with respect to the carbonate content, was reached within sampling depth in most of the profiles.

2.) The data indicate that leaching has been less intense in the western part of the study area than in the eastern part. This statement applies primarily to the Enterprise-Minco soils of Roger Mills, Dewey, and Custer Counties. The lack of leaching in these soils could be a function of their apparent short time of exposure to weathering as well as of the relatively low annual rainfall.

3.) The data indicate that leaching intensity has been greater in the Holdredge-Vanoss soils than in the Enterprise-Minco soils. The evidence for this conclusion is that the depth to carbonates is greater in the Holdredge-Vanoss soils than in the Enterprise-Minco soils in all counties except Grady. However, there is a possibility that the difference between the soils in the depth to carbonates is related to the differences in the original carbonate content in the soil parent materials.

Base Saturation

The data are given in Appendix Tables XXXII-XXXVIII. No attempt was made to differentiate between the exchangeable and extractable cations and as a result the percent base saturation is very high in the calcareous horizons. In general, the base saturation ranges from approximately 80-100% in noncalcareous horizons. The most abundant cations are calcium and magnesium. Calcium is the more abundant of these two cation species. The calcium content was found to be extremely high in the horizons containing carbonates, thus indicating that most of the carbonate consists of $CaCO_3$.

Soil pH

The data are given in Appendix Tables XXXII-XXXVIII. As would be expected, the pH values are close to 8 in the calcareous horizons. The pH values range from slightly below 6 to near neutral in the noncalcareous horizons.

Organic Matter

The results of the organic matter determinations in the upper three horizons of all profiles are presented in Appendix Tables XXXII-XXXVIII and in Figure 12. The data indicate a general increase in organic matter in a west-east direction, though there are exceptions. Based on the organic matter content, all of the Holdredge-Vanoss soils have mollic epipedons. Three of the four Minco pedons and one of the two Enterprise pedons have mollic epipedons.

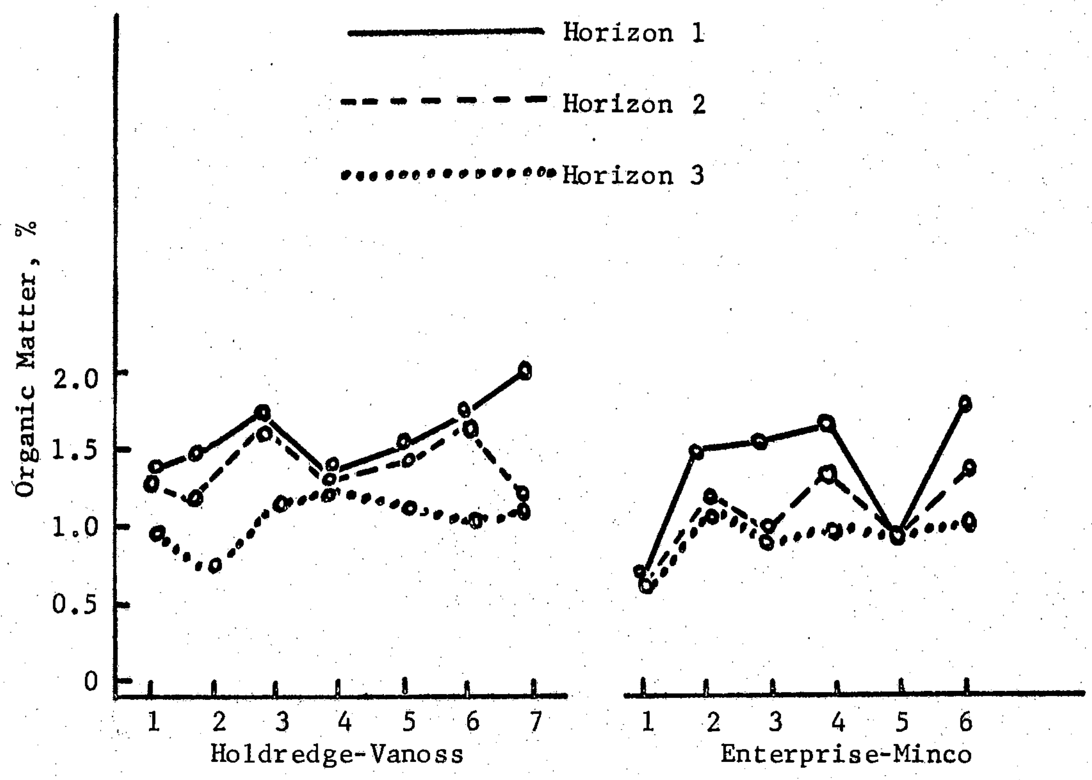

Figure 12. Organic Matter Content of the Upper Three Horizons of Each Soil Pedon in a West-East Direction, Roger Mills to Pontotoc County

Sand and Silt Mineralogy

<u>Light Minerals</u>

The light minerals, those having a specific gravity of < 2.95, were studied in the 0.02-0.05 and 0.05-0.10 mm. fractions. The objectives were to determine the degree of homogeneity of the parent material, determine the general mineralogy of the nonclay fractions, and determine whether any general weathering trends were reflected in the mineralogy. In most soils five horizons were studied, but in a few soils six horizons were studied.

A chi square analysis described by Eisenhart (7) was used to test parent material homogeneity. There is no standard way of interpreting the results of this type of analysis because a variety of factors must be considered. The probability obtained is the number of times out of 100 that one would expect to draw out of a truly homogeneous deposit a sample having a distribution of categories being measured that would give as large or larger chi square than that calculated. Even if the probability is small, one is not necessarily justified in concluding that the sample came from a different source than the reference sample. Eisenhart made the point that all factors must be considered in making a decision and he stated that everyone must choose the probability level that he is willing to accept. He stated that, in general, it is probably desirable to reject the hypothesis that two samples have similar origins if the probability is < 0.05. Eisenhart was considering geologic deposits but his guidelines should be applicable to soils. However, the effects of weathering could distort the analysis, particularly when easily weatherable minerals are being considered, and could lead to erroneous conclusions.

The results of a chi square analysis for parent material homogeneity are presented in Tables V-XI. Above the 0.05 probability level interpolation was done to the nearest value of 0.05. The C3 horizon of the Enterprise soil of Roger Mills County was used as the reference. If Eisenhart's guidelines are used, one would conclude that most, probably all, of the soil horizons have formed in materials having a similar origin. The results are quite variable within single profiles, the probability often being high for certain horizons and low for others. This variability makes definite conclusions difficult, but at least it appears likely that the parent materials of the different horizons had a reasonably similar sand and silt mineralogy.

Data on the feldspar content of five groups of soils is shown in Figures 13 and 14. The feldspar content in corresponding horizons was averaged in each of the groups. In profiles where six horizons were studied the 5th and 6th horizons were averaged. No weathering trends, for example a change in the feldspar content with depth or in an east-west direction, was evident. Such trends, if they are present in these soils, are masked by the high degree of variability. Regarding the mineralogical composition of the sand and silt fractions, it is permissible to say only that a high percentage of the soil horizons have a feldspar content of 10-15% and a quartz content of 85-90%. No attempt was made to differentiate quantitatively between the different feldspar species, but it was evident from random checks of feldspar refractive indices that the abundance of feldspars having a high content of calcium was negligible. Potassium feldspars were definitely present, but no estimate was made of the relative proportions of sodium and potassium feldspars.

TABLE V

A CHI SQUARE ANALYSIS OF SELECTED FRACTIONS IN SOILS OF ROGER MILLS COUNTY

Horizon	Depth cm	0.05-0.10 mm Chi Square	0.05-0.10 mm Probability	0.02-0.05 mm Chi Square	0.02-0.05 mm Probability
		----Enterprise----			
Ap1	0-23	3.462	0.05	1.074	0.30
Ac1	23-53	5.013	0.02	0.030	0.85
AC3	89-125	0.071	0.75	0.070	0.80
C2	152-178	0.011	0.90	0.618	0.45
		----Holdredge----			
Ap1	0-20	0.528	0.45	1.738	0.20
B1	20-33	0.095	0.75	1.416	0.20
B22t	46-86	0.166	0.65	4.746	0.02
B3	86-107	0.309	0.50	0.114	0.75
C2	130-147				

TABLE VI

A CHI SQUARE ANALYSIS OF SELECTED FRACTIONS IN SOILS OF DEWEY COUNTY

Horizon	Depth cm	0.05-0.10 mm Chi Square	0.05-0.10 mm Probability	0.02-0.05 mm Chi Square	0.02-0.05 mm Probability
		----Enterprise----			
Ap1	0-18	3.976	0.02-0.05	0.031	0.90
A12	18-33	0.392	0.55	0.239	0.65
AC2	51-89	0.020	0.90	0.088	0.80
AC3	89-112	0.132	0.70	0.015	0.90
C2	137-158	0.962	0.30	2.544	0.10
		----Holdredge----			
Ap1	0-20	3.244	0.05	0.861	0.35
A12	20-36	4.273	0.02-0.05	1.238	0.30
B22t	71-97	0.953	0.30	2.647	0.10
B23t	97-114	2.565	0.10	0.112	0.30
C1	142-152	0.562	0.45	0.015	0.90

TABLE VII

A CHI SQUARE ANALYSIS OF SELECTED FRACTIONS IN SOILS OF CUSTER COUNTY

Horizon	Depth cm	0.05-0.10 mm Chi Square	0.05-0.10 mm Probability	0.02-0.05 mm Chi Square	0.02-0.05 mm Probability
		----Minco----			
Ap1	0-23	1.781	0.20	0.010	0.90
A12	23-33	1.200	0.25	0.243	0.60
B22	61-81	2.010	0.15	0.066	0.80
B24ca	109-142	1.602	0.20	0.405	0.50
C2	165-188	4.015	0.02-0.05	0.243	0.60
		----Vanoss----			
Ap1	0-20	2.533	0.10	0.504	0.50
A12	20-33	3.558	0.05	0.108	0.75
B21t	53-74	5.837	0.02	0.180	0.65
B24t	117-140	4.353	0.02-0.05	0.071	0.80
IIB22t	168-183	4.782	0.02-0.05	0.343	0.65

TABLE VIII

A CHI SQUARE ANALYSIS OF SELECTED FRACTIONS IN SOILS OF CADDO COUNTY

Horizon	Depth cm	0.05-0.10 mm Chi Square	0.05-0.10 mm Probability	0.02-0.05 mm Chi Square	0.02-0.05 mm Probability
		----Minco----			
Ap1	0-15	1.436	0.70	2.453	0.15
A12	15-30	2.333	0.10	0.248	0.60
B22	30-64	0.718	0.40		
B23	107-147	1.461	0.20	1.364	0.25
Cca	165-178	0.112	0.30	0.459	0.50
C2	178-216	8.682	0.01	0.731	0.40
		----Vanoss----			
Ap1	0-23	0.655	0.40	4.247	0.02-0.05
A12	23-33	0.480	0.50	4.631	0.02-0.05
B21t	51-79	2.764	0.10	0.178	0.70
B3	104-127	4.079	0.02-0.05	0.024	0.90
C1	127-152	2.472	0.10	0.366	0.55

TABLE IX

A CHI SQUARE ANALYSIS OF SELECTED FRACTIONS IN SOILS OF GRADY COUNTY

Horizon	Depth cm	0.05-0.10 mm Chi Square	Probability	0.02-0.05 Chi Square	Probability
		----Minco----			
Ap1	0-18	0.224	0.65	4.656	0.02
A12	18-36	1.073	0.30	2.179	0.15
B21	51-76	0.165	0.70	0.000	1.00
B22	76-102	0.069	0.80	0.302	0.60
C2	152-173	2.500	0.10	1.047	0.30
		----Vanoss----			
Ap1	0-18	0.035	0.85	0.659	0.40
A12	18-31	2.641	0.10	2.686	0.10
B22t	56-76	4.878	0.02	1.506	0.20
B23t	76-94	1.201	0.30	0.059	0.80
C2	142-163	2.203	0.15	0.493	0.50

TABLE X

A CHI SQUARE ANALYSIS OF SELECTED FRACTIONS IN SOILS OF MCCLAIN COUNTY

Horizon	Depth cm	0.05-0.10 mm Chi Square	Probability	0.02-0.05 mm Chi Square	Probability
		----Minco----			
Ap1	0-18	4.757	0.02	0.010	0.90
A12	18-33	0.012	0.90	7.913	0.01
B21	56-91	0.641	0.80	0.368	0.50
B22	91-132	2.191	0.15	0.000	1.00
B3	188-203	0.064	0.80	3.664	0.05
C1	229-246	2.331	0.15	1.463	0.20
		----Vanoss----			
Ap1	0-20	1.783	0.20	0.289	0.10
A12	20-36	0.459	0.50	1.516	0.20
B21	56-81	0.251	0.60	0.261	0.60
IIB22t	104-132	1.268	0.25	0.843	0.40
IIB23t	132-158	0.670	0.40	4.286	0.02
IIC2ca	170-183	0.059	0.80	1.195	0.30

TABLE XI

A CHI SQUARE ANALYSIS OF SELECTED FRACTIONS IN SOILS OF PONTOTOC COUNTY

Horizon	Depth cm	0.05-0.10 mm Chi Square	0.05-0.10 mm Probability	0.02-0.05 mm Chi Square	0.02-0.05 mm Probability
			----Vanoss----		
Ap1	0-25	1.738	0.20	0.122	0.70
B22t	76-114	3.410	0.05	0.053	0.80
B3	152-175	0.747	0.40	3.011	0.10
C1	229-254	1.165	0.30	3.584	0.05

Heavy Minerals

The heavy minerals, those having a specific gravity $<$ 2.95, were studied in the 0.05-0.10 mm. fraction of all horizons in the soils of Roger Mills, Caddo, and McClain Counties. Only the nonopaque heavy minerals were studied. The objectives were to measure the degree of weathering in the different soils and to determine whether all of the soils developed in a similar parent material.

The data are given in Tables XII-XIV. Mineral species other than those reported were present but only in very small amounts. Also, some grains could not be identified and were counted in an unidentified category. The mineralogy is too variable quantitatively to be of use as a measure of weathering. The ratio of (tourmaline + zircon)/(amphiboles) was calculated, but the results were erratic and are not reported. It was concluded that the parent materials of the soils in which the heavy minerals were studied had a similar origin but that there possibly was some depositional variation. This conclusion was based on the

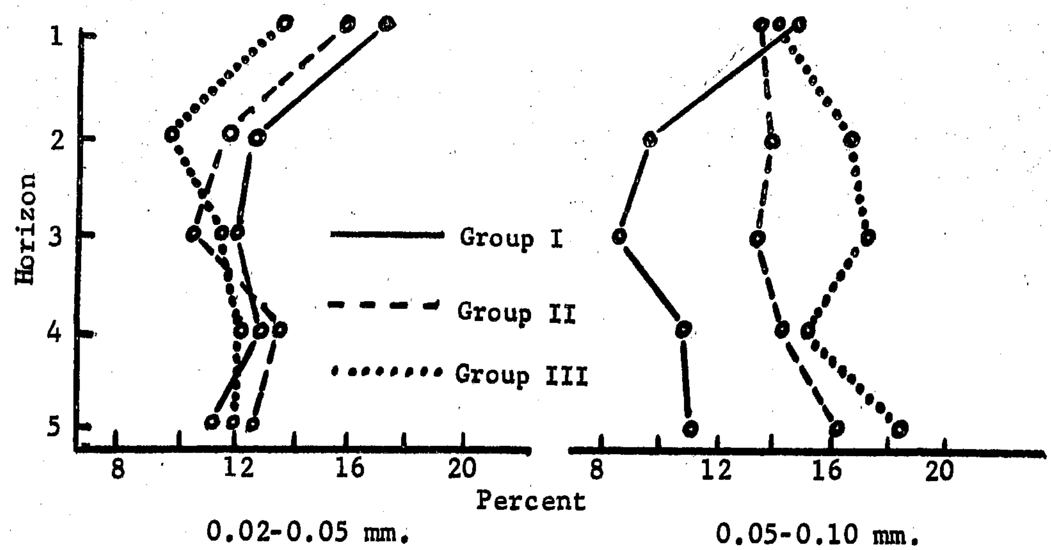

Figure 13. Feldspar Distribution in the 0.02-0.05 and 0.05-0.10 mm. Fractions of Soils of Three Climatic Zones

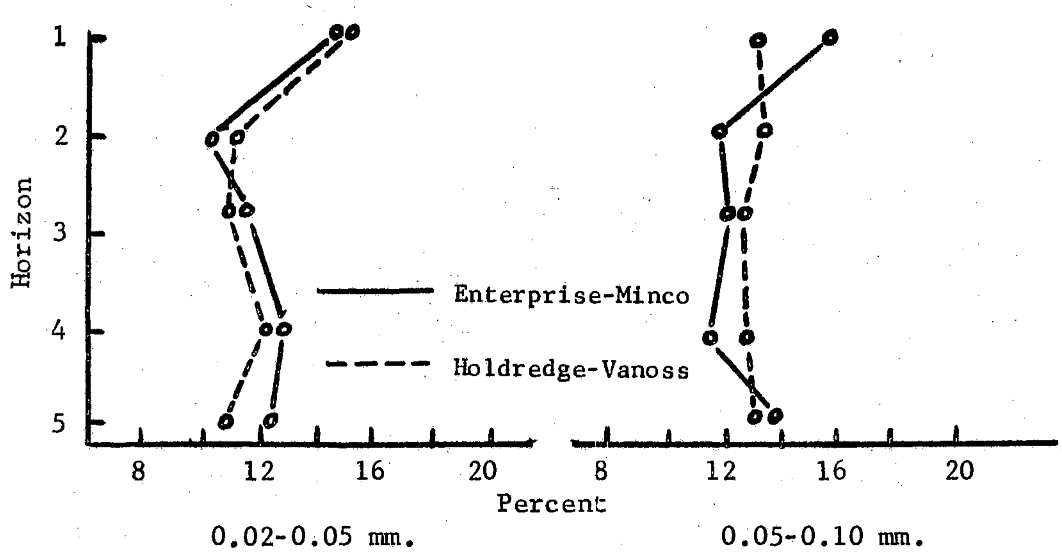

Figure 14. Feldspar Distribution in the 0.02-0.05 and 0.05-0.10 mm. Fractions of the Enterprise-Minco and Holdredge-Vanoss Soils

TABLE XII

THE PERCENTAGE OF NONOPAQUE HEAVY MINERALS IN THE VERY FINE SAND FRACTION OF THE ENTERPRISE AND HOLDREDGE SOILS OF ROGER MILLS COUNTY

Horizon	Depth cm	% Zircon	Tourmaline	Garnet	Epidote	Hornblende	Lamprobolite
			----Enterprise----				
Ap1	0-23	1.0	12.5	7.8	54.7	18.7	0.9
AC1	23-53	0.6	9.4	6.5	62.4	16.3	1.2
AC2	53-89	1.4	8.1	5.7	59.1	18.5	1.8
AC3	89-125	0.0	5.0	5.5	69.5	12.6	1.3
C1	125-152	0.5	5.6	6.5	70.9	13.3	0.0
C2	152-178	1.0	6.5	7.7	59.8	19.4	1.4
C3	178-203	1.1	8.2	8.8	57.2	20.4	1.7
			----Holdredge----				
Ap1	0-20	0.0	7.0	6.8	70.8	10.7	1.2
B1	20-33	0.2	8.5	5.0	73.6	8.1	0.8
B21t	33-46	0.9	7.3	7.0	71.2	9.9	0.9
B22t	46-86	0.6	6.0	9.3	69.9	8.6	0.9
B3	86-107	1.0	5.5	7.2	73.9	9.1	0.5
C1	107-130	1.9	3.9	13.6	70.3	5.7	0.3
C2	130-147	1.4	6.5	6.7	71.8	8.1	1.0

TABLE XIII

THE PERCENTAGE OF NONOPAQUE HEAVY MINERALS IN THE VERY FINE SAND FRACTION OF THE MINCO AND VANOSS SOILS OF CADDO COUNTY

Horizon	Depth cm	% Zircon	% Tourmaline	% Garnet	% Epidote	% Hornblende	% Lamprobolite
				----Minco----			
Ap1	0-15	1.5	11.0	5.8	58.6	16.0	2.0
A12	15-30	0.5	9.4	5.6	63.2	16.0	2.0
B21	30-64	0.8	13.1	6.3	55.6	16.5	2.3
B22	64-107	0.6	9.1	6.1	61.9	14.2	1.4
B23	107-147	1.0	6.6	6.2	65.6	15.3	1.0
B3	147-165	0.9	16.3	6.5	48.3	20.7	1.1
Cca	165-178	0.4	5.9	4.7	58.7	24.7	1.3
C2	178-216	1.2	9.2	5.5	52.4	24.1	2.5
				----Vanoss----			
Ap1	0-23	2.4	21.4	6.4	48.3	12.3	2.0
A12	23-33	1.8	36.8	3.1	44.5	7.7	1.3
B1	33-51	1.5	18.8	4.5	57.3	10.0	2.2
B21t	51-79	0.5	17.6	4.6	46.8	22.2	1.6
B22t	79-104	2.1	22.5	7.5	50.7	10.3	1.4
B3	104-127	1.3	22.0	2.5	51.4	16.3	1.7
C1	127-152	1.6	15.0	2.5	59.9	12.4	0.8
IIC2	152-168	2.6	26.4	4.5	55.5	6.2	0.4

TABLE XIV

THE PERCENTAGE OF NONOPAQUE HEAVY MINERALS IN THE VERY FINE SAND FRACTION OF THE MINCO AND VANOSS SOILS OF MCCLAIN COUNTY

Horizon	Depth cm	%					
		Zircon	Tourmaline	Garnet	Epidote	Hornblende	Lamprobolite
				----Minco----			
Ap1	0-18	1.1	14.8	5.3	62.4	11.7	0.9
A12	18-33	1.3	6.8	6.9	66.1	16.1	0.4
B1	33-56	0.9	13.9	4.5	63.9	8.5	2.2
B21	56-91	0.3	11.5	7.6	61.3	13.1	1.5
B23	132-158	0.8	12.5	6.6	57.6	17.2	1.9
B24	158-188	1.1	11.3	6.8	54.3	19.6	2.0
B3	188-203	0.5	9.3	8.8	62.9	15.2	0.5
C1	229-246	0.8	8.2	5.5	59.9	20.2	1.0
				----Vanoss----			
Ap1	0-20	2.6	16.6	9.3	53.0	10.0	1.6
A12	20-36	1.1	12.2	6.8	56.3	14.8	1.0
B1	36-56	1.5	11.6	7.0	58.7	11.2	2.3
B21	56-81	0.7	8.7	5.2	62.4	10.1	1.0
IIB21t	81-104	1.1	18.0	4.7	56.2	12.7	0.8
IIB22t	104-132	4.3	10.2	7.3	57.4	7.3	1.7
IIB23t	132-158	1.2	8.7	4.9	76.3	4.6	0.3
IIC1ca	158-170	0.3	13.9	4.1	71.7	3.8	0.3
IIC2ca	170-183	1.9	19.9	3.8	65.9	3.2	1.5

qualitative similarity of the heavy mineral suites of all horizons. Regarding the depositional differences, the expected statistical variations could account for a large part of the observed differences and on the basis of the heavy mineral data it is difficult to say whether important depositional variations are present within the profiles. Buckhannon and Ham (4) found that epidote is present only in small amounts and that lamprobolite is absent in the Permian formations adjacent to the South Canadian River. Considering their work, it appears likely that the Permian formations have not been important as a source for the sediments from which the soils of this study formed. This applies strictly, of course, only to the six soils in which the heavy mineral suites were studied. However, the other soils were sampled on similar landforms and a similar source of sediments would be expected.

Summary of Factors Relating to Parent Material Homogeneity

The results of field studies, particle size distribution determination, a mineralogical study of the light minerals in the 0.02-0.05 and 0.05-0.10 mm. fractions, and a mineralogical study of the heavy minerals of the 0.05-0.10 mm. fraction have all been used as indicators of the degree of parent material homogeneity. Taken collectively, these results indicate that all of the soils in this study have formed from sediments having a similar origin but that there have been some depositional variations. The major effect of the depositional variations probably have been to cause some changes in texture and in horizon sequences from those which would have been present in soils forming in a truly homogeneous parent material. These effects complicate to some degree but are not of a magnitude to invalidate efforts to establish a relationship between soil properties and the soil forming factors climate and time in the study area.

Clay Mineralogy

Four methods were used in studying the < 0.002 mm. fraction. These methods were x-ray diffraction, determination of the cation exchange capacity, determination of the external and internal surface area, and determination of the total K_2O content. The data obtained by all of the methods except x-ray diffraction are presented in Appendix Tables XXXIX-XXXXV. Only selected soils were studied by x-ray diffraction. The other studies were done on either five or six horizons of all of the soils. For the purposes of graphing the data, values obtained in the fifth and sixth horizons were averaged in order to have a uniform number of horizons in the soils. In the cases where soils were grouped, the values for corresponding horizons were averaged and the average values were plotted as in other analyses previously discussed.

The CEC, K_2O, and surface area determinations should allow a fairly sensitive comparison of differences between the soils and should indicate changes due to weathering because a change in any one of the parameters should, at least in general, result in a change in the other parameters. However, it is not impossible to change one of these parameters without changing the others, and it was decided to determine the degree of association between these parameters in soils of this study. The results are presented in Table XV. The correlation coefficients are not high but they do have the sign that would be expected and the association is highly significant in two of the three comparisons. The degree of association does not appear to be as great in the third comparison, K_2O content and planar surface area, as in the first two comparisons. These results, even though the degree of association between the different parameters is not high, indicate the changes that would be expected as a result of weathering in the study area. For example, if there is a tendency for potassium to be weathered out of the clay minerals as the annual precipitation increases there should be a tendency for the resulting clay minerals to show an increase in CEC and planar surface.

TABLE XV

CORRELATION COEFFICIENTS AND SIGNIFICANCE LEVELS FOR A COMPARISON OF CLAY MINERAL PROPERTIES

Parameters Being Compared	Correlation Coefficient	Significance Level
CEC and K_2O Content	-0.37	0.01
CEC and Planar Surface Area	+0.67	0.01
K_2O Content and Planar Surface Area	-0.23	0.10

X-ray Diffraction

An x-ray diffraction analysis was carried out on three horizons from each of the soils in Roger Mills, Caddo, and McClain Counties.

The results given by this method are of value primarily as a qualitative indication of the clay mineralogy because two x-ray units, a Phillips-Norelco and a Siemans, were used in the analysis and a quantitative comparison between the results obtained on the two units would be uncertain. However, it should be possible to make rough estimations of the amount of one clay mineral species relative to another within a given horizon. In addition, the x-ray unit that was used on each sample is known and by keeping this point in mind it should be possible to draw conclusions regarding quantitative trends if they are pronounced. X-ray diffractograms of the untreated samples are given in Figures 15-20. X-ray diffractograms of B and AC horizon samples that were treated with ethylene glycol are given in Figures 21 and 22. The diffractograms of the other glycolated samples were similar qualitatively to those of the B and AC horizons.

The x-ray patterns indicate that the clay mineralogy of all of the soils is similar qualitatively. The only silicate clay species of importance in these soils are montmorillonite, illite, and kaolinite. This conclusion is based primarily on the presence of the 14 Å, 10 Å, and 7.2 Å peaks in the diffractograms of untreated samples and on the observed expansion of the 14 Å mineral to 17.7 Å, or very close to this value, following treatment with ethylene glycol. The 14 Å, or more nearly 14.5 Å, and 17.7 Å peaks are broad and this lends some doubt to the conclusion that these peaks are due solely to montmorillonite. However, expansion did occur following treatment with ethylene glycol and this is the reason for the conclusion that chlorite or vermiculite are not present in significant amounts. It follows that the 7.2 Å peak must be due to a kaolinitic mineral. The presence of quartz is also indicated

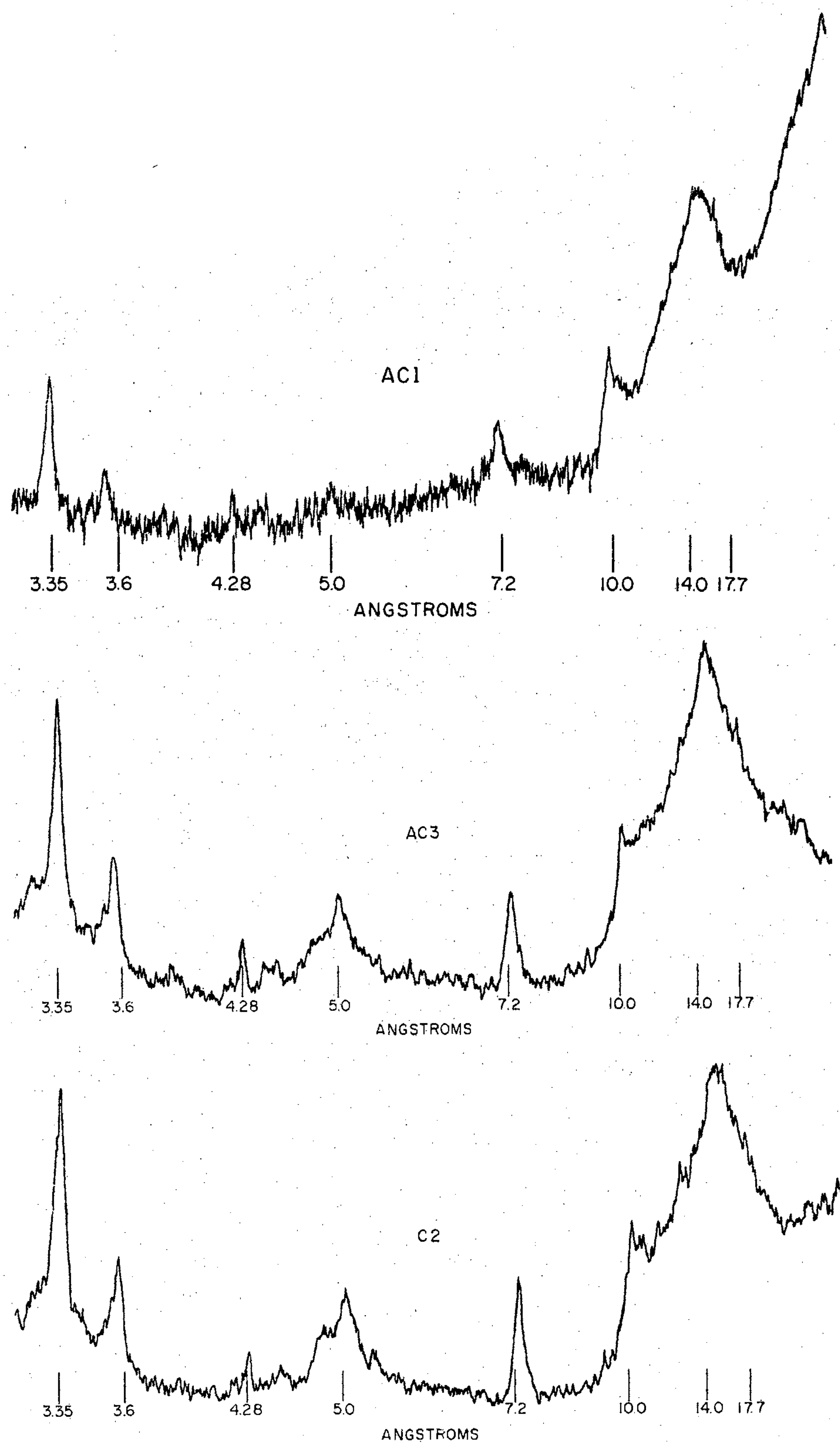

Figure 15. X-ray Diffractograms of Untreated Clay Samples From Three Horizons of the Enterprise Soil of Roger Mills County

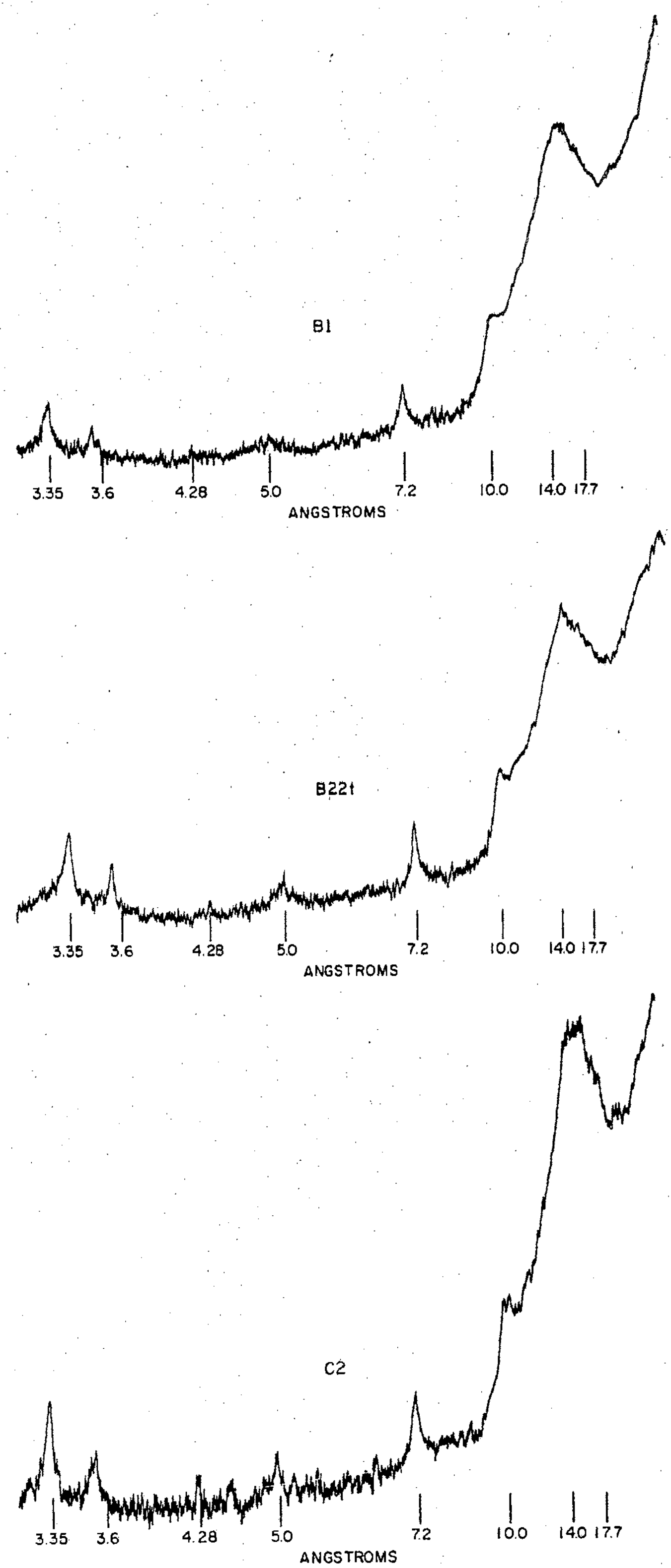

Figure 16. X-ray Diffractograms of Untreated Clay Samples From Three Horizons of the Holdredge Soil of Roger Mills County

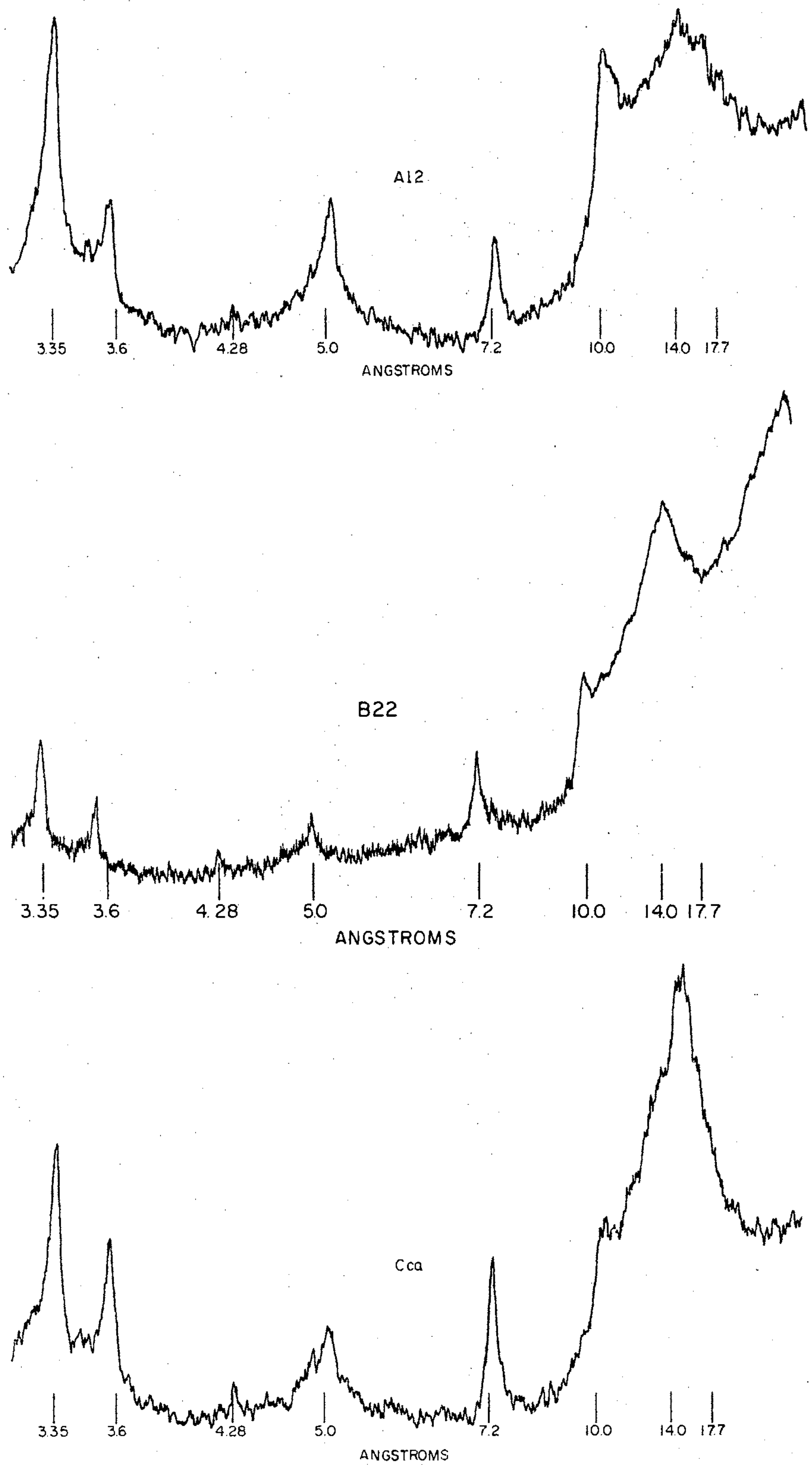

Figure 17. X-ray Diffractograms of Untreated Clay Samples From Three Horizons of the Minco Soil of Caddo County

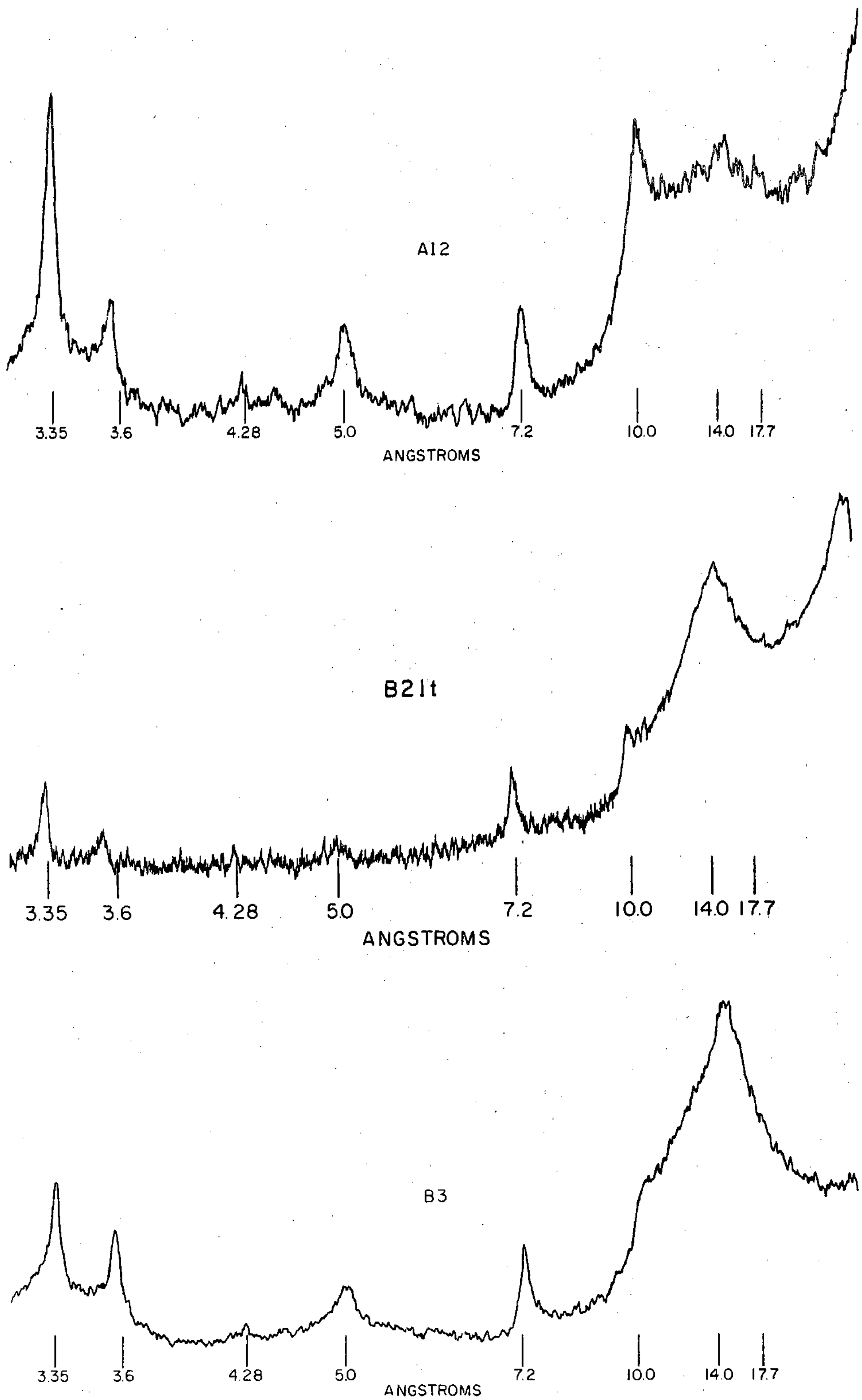

Figure 18. X-ray Diffractograms of Untreated Clay Samples From Three Horizons of the Vanoss Soil of Caddo County

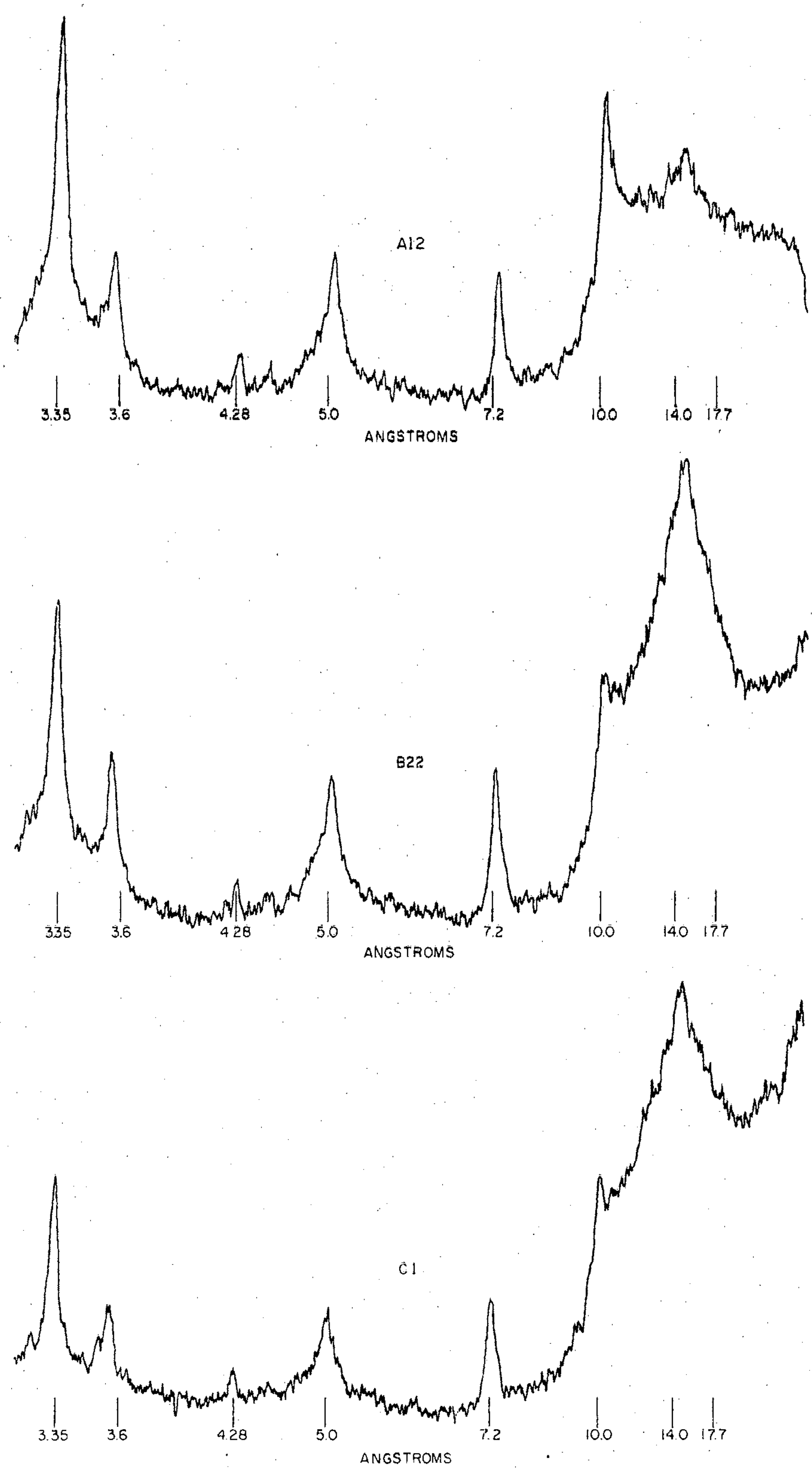

Figure 19. X-ray Diffractograms of Untreated Clay Samples From Three Horizons of the Minco Soil of McClain County

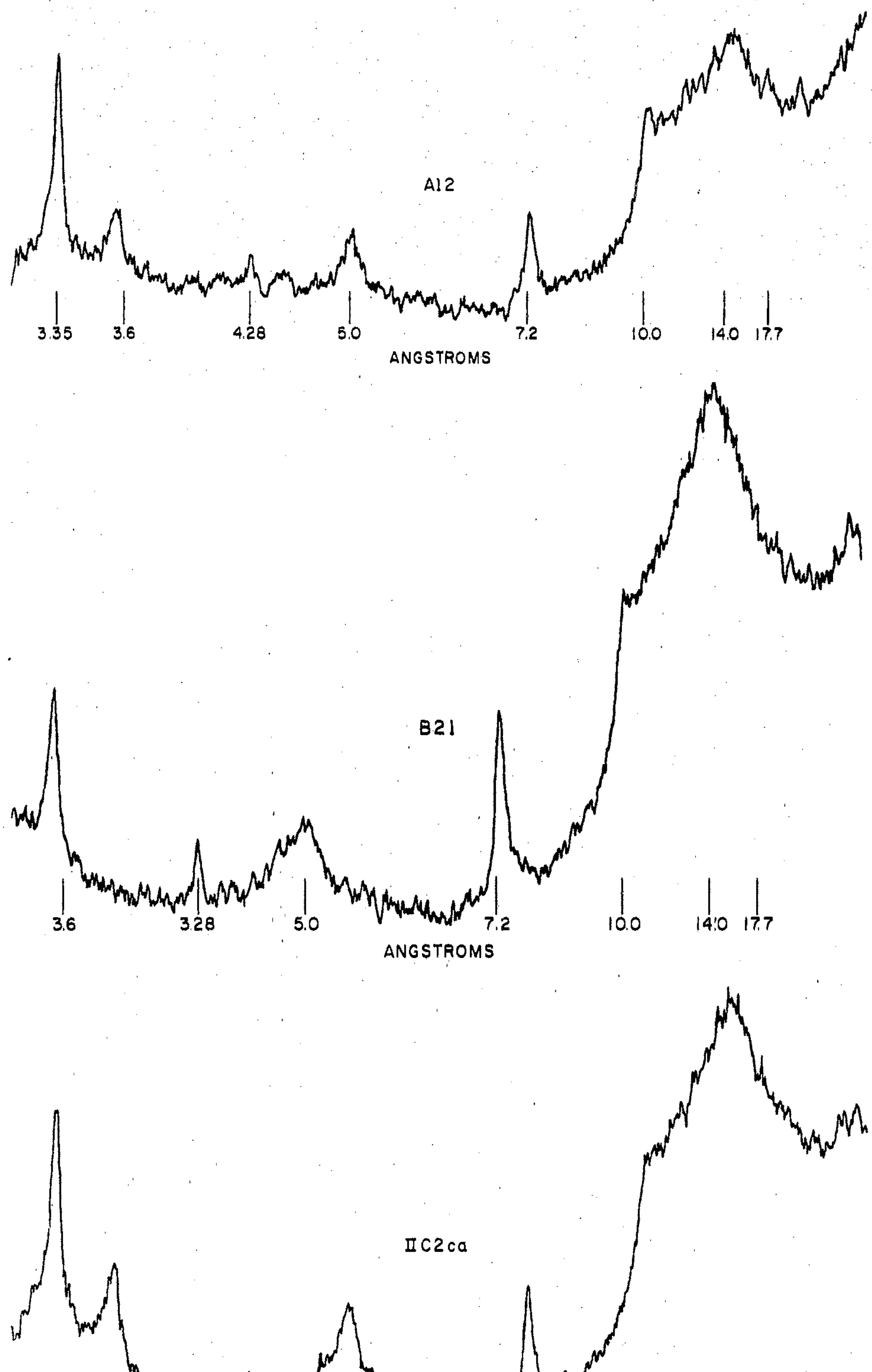

Figure 20. X-ray Diffractograms of Untreated Clay Samples From Three Horizons of the Vanoss Soil of McClain County

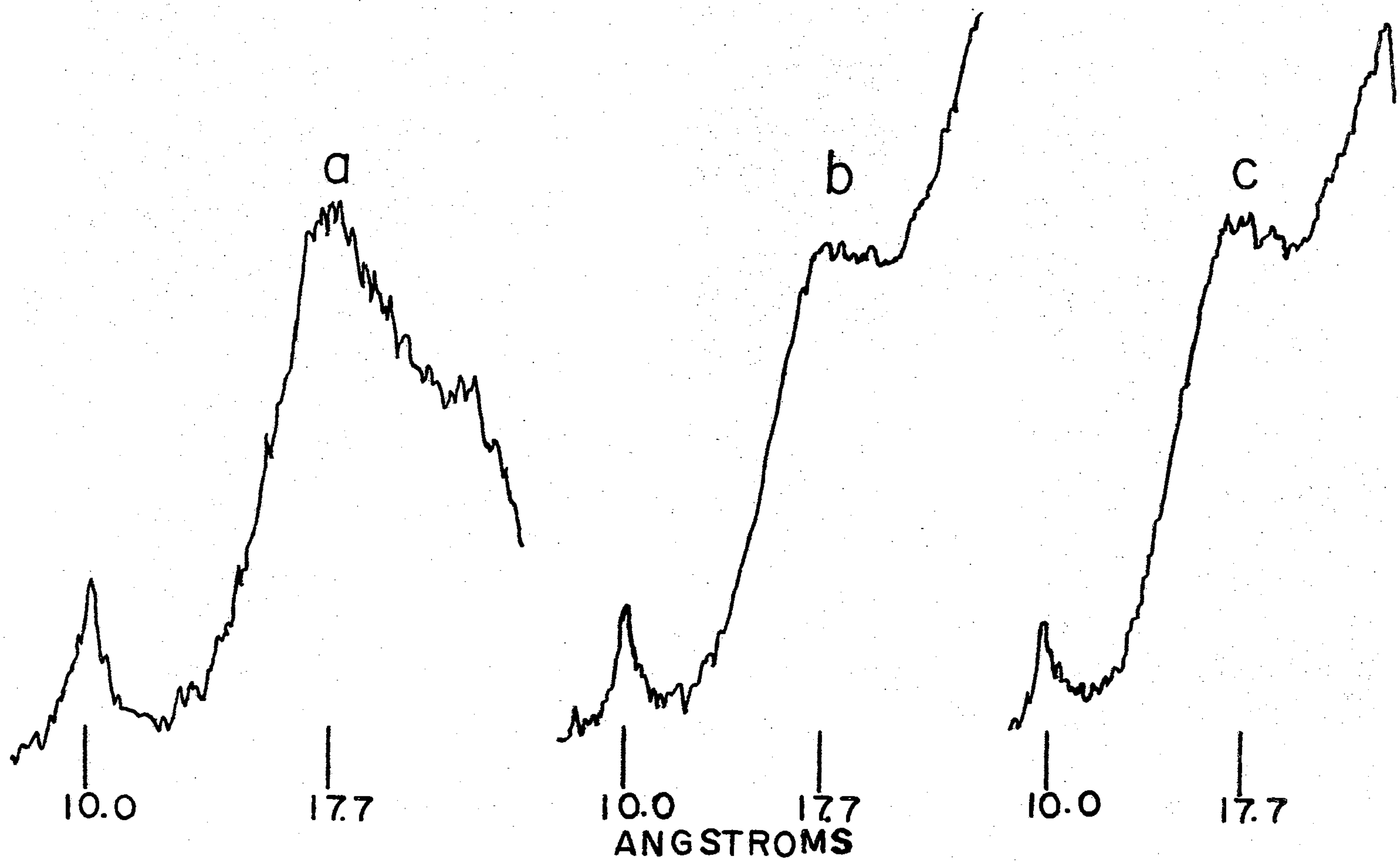

Figure 21. X-ray Diffractograms of Glycolated Clay Samples From the B or AC Horizon of the: a.) Enterprise Soil of Roger Mills County, b.) Minco Soil of Caddo County, and c.) Minco Soil of McClain County

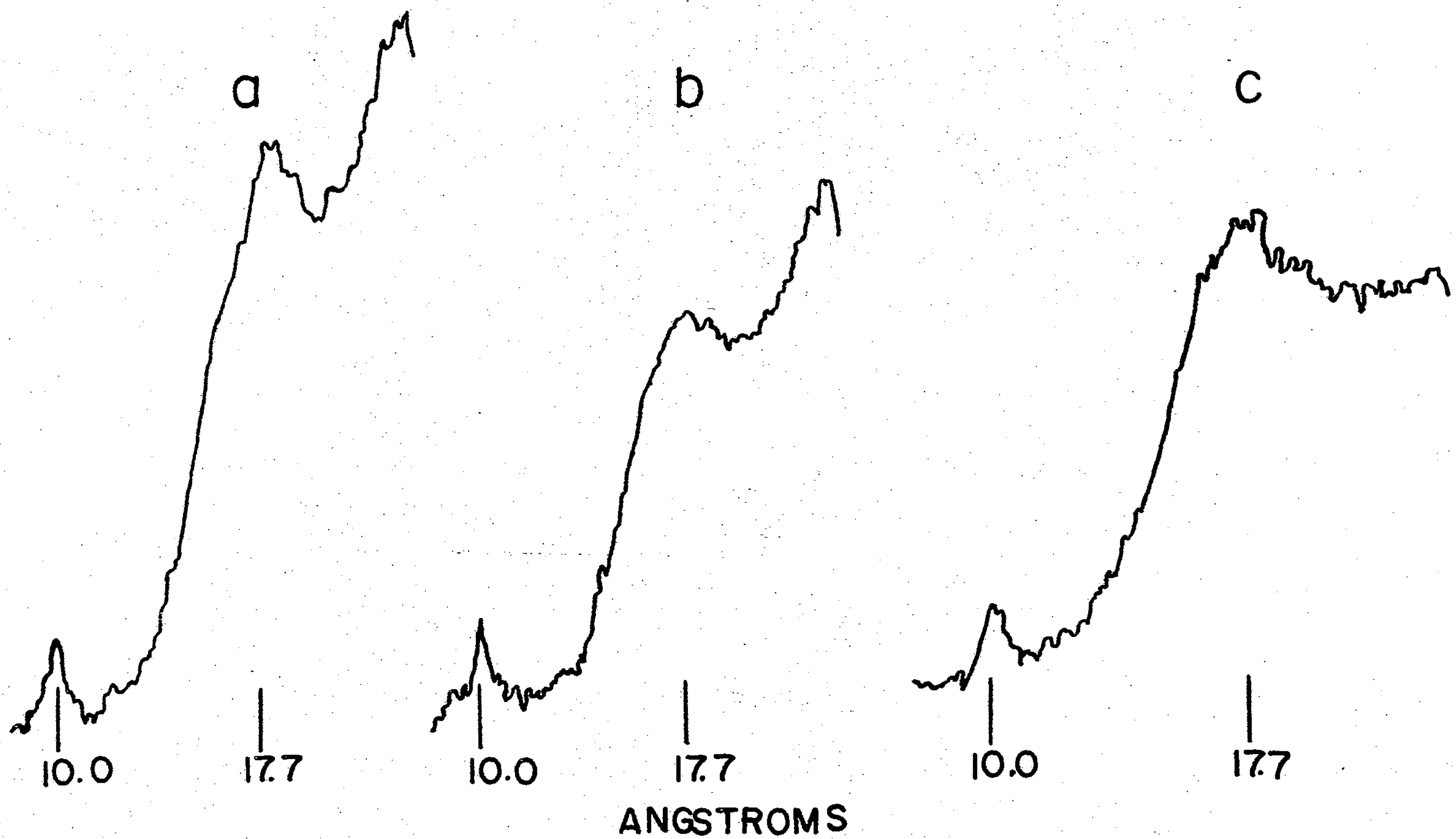

Figure 22. X-ray Diffractograms of Glycolated Clay Samples of the B Horizon of the: a.) Holdredge Soil of Roger Mills County, b.) Vanoss Soil of Caddo County, and c.) Vanoss Soil of McClain County

and the possibility that the 4.28 Å peak is due to gypsum as well as quartz cannot be absolutely eliminated.

The results permit some conclusions regarding quantitative aspects of the clay mineralogy. The content of montmorillonite, if the height of the 14 Å peak is used as a guide, appears to increase with depth in the profile. The increase appears to occur primarily from the first to the second horizons and it is difficult to say whether there is an additional increase from the second to the third horizon. In general, the 10 Å peaks are diffuse for the untreated samples but show a tendency to become sharper for the samples that were treated with ethylene glycol. No quantitative trends in the illite content within or between profiles are evident, but it appears that illite is not as abundant as montmorillonite. It is difficult to use the 5 Å peak for quantitative interpretations since it likely is due to a combination of 2nd order illite and 3rd order montmorillonite reflections. Kaolinite appears to be considerably less abundant than montmorillonite, but statements regarding the relative contents of kaolinite and illite on the basis of the x-ray data would be uncertain.

Cation Exchange Capacity

Graphs of the data and a statistical analysis of selected portions of the data are presented in Figures 23-24 and Table XVI. As in other comparisons, group I soils represent the soils of Roger Mills and Dewey Counties, group II soils represent the soils of Custer and Caddo Counties, and group III soils represent the soils of Grady and McClain Counties. The significance levels listed in Table XVI were obtained in a test of a hypothesis assuming equal mean values for the categories being compared.

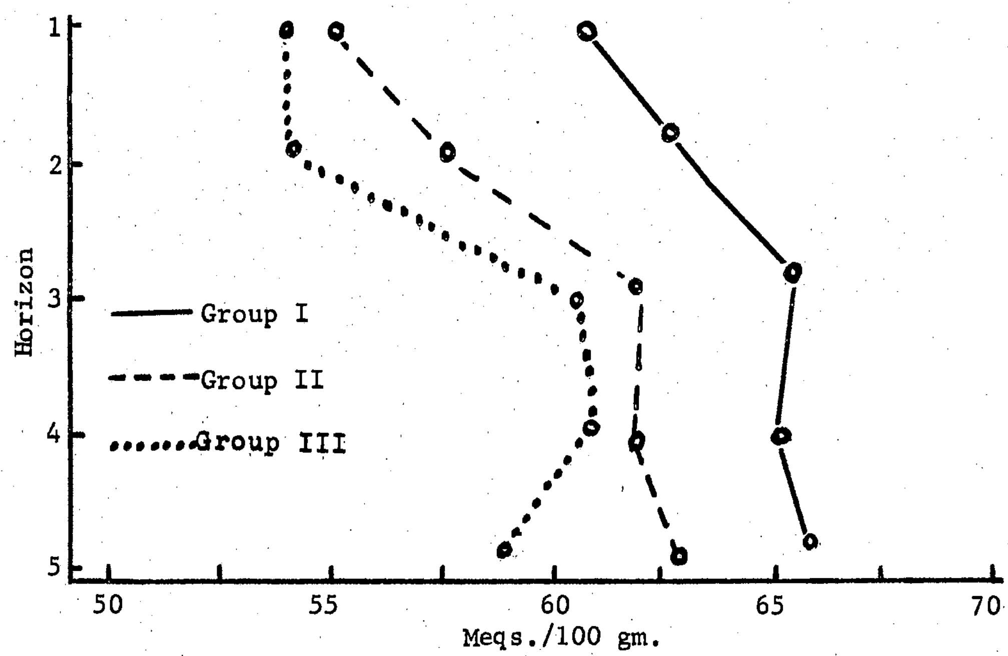

Figure 23. The CEC of the Clay Fraction of Selected Horizons in Soils of Three Climatic Zones

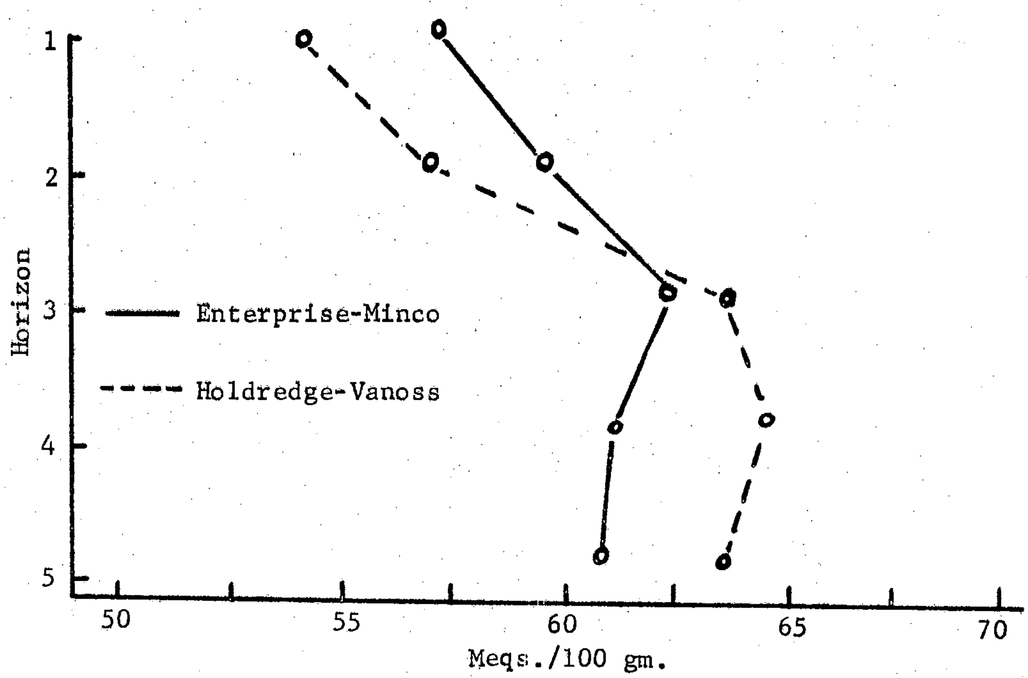

Figure 24. The CEC of the Clay Fraction of Selected Horizons in the Enterprise-Minco and Holdredge-Vanoss Soils

TABLE XVI

A STATISTICAL COMPARISON OF CLAY MINERAL PROPERTIES OF SOIL GROUPS AND OF SELECTED HORIZONS

Categories Being Compared	CEC		Planar Surface Area		Total K_2O Content	
	t Value	Significance Level	t Value	Significance Level	t Value	Significance Level
Enterprise-Minco and Holdredge-Vanoss Soils	0.27	*	0.15	*	3.02	0.01
Group I and Group II Soils	4.51	0.01	1.84	0.10	0.19	*
Group I and Group III Soils	5.10	0.01	3.74	0.01	0.82	*
Group II and Group III Soils	1.49	0.20	1.84	0.10	0.92	*
Horizons 1 and 3 (All Soils)	2.94	0.01	2.30	0.05	2.52	0.05
Horizons 1 and 5 (All Soils)	2.92	0.01	2.18	0.05	3.82	0.01
Horizons 3 and 5 (All Soils)	0.22	*	0.32	*	0.96	*
Horizon 1, Enterprise-Minco and Holdredge-Vanoss Soils	0.82	*				
Horizon 5, Enterprise-Minco and Holdredge-Vanoss Soils	0.90	*				

*Insignificant at the 0.20 level

The data shown in Figures 23-24 indicate that there is a general decrease in the CEC of the clay fraction of the three groups of soils in a west-east direction but that there is no evident difference between the Enterprise-Minco and Holdredge-Vanoss soils. There possibly may be a difference between certain horizons, for example horizon 1, in the latter soil groups. The graphs also indicate an increase in the CEC with depth in the profiles down to the third horizon. Below this point no general trend is evident.

In general, the statistical comparisons confirm the trends shown by the graphs. According to these comparisons there is no significant difference between the CEC of the clay fractions of the Enterprise-Minco and Holdredge-Vanoss soils either when all horizons are compared collectively or when single horizons from each group of soils are compared. A comparison of group I with group II and group III soils indicates a significant difference at the 0.01 level. Group II and group III soils were found to be significantly different at the 0.20 level. Horizon 1 was found to be significantly different from horizons 3 and 5 for a grouping of all soils, but no significant difference was found between horizons 3 and 5.

The relationship between the CEC of the clay fractions and the genesis of the soils will be discussed later in connection with other properties of the clay fractions.

Planar Surface Area

Graphs of the data and the results of statistical analysis are given in Figures 25-26 and in Table XVI. The trends indicated for the planar surface area in the graphs are very similar to those observed

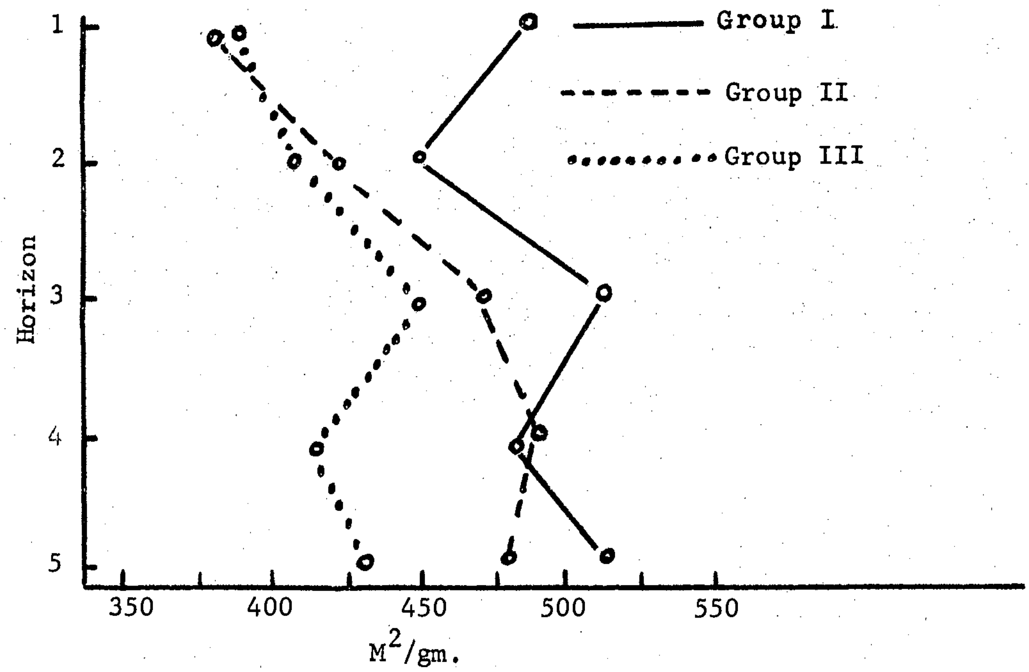

Figure 25. The Planar Surface Area of the Clay Fraction of Selected Horizons in Soils of Three Climatic Zones

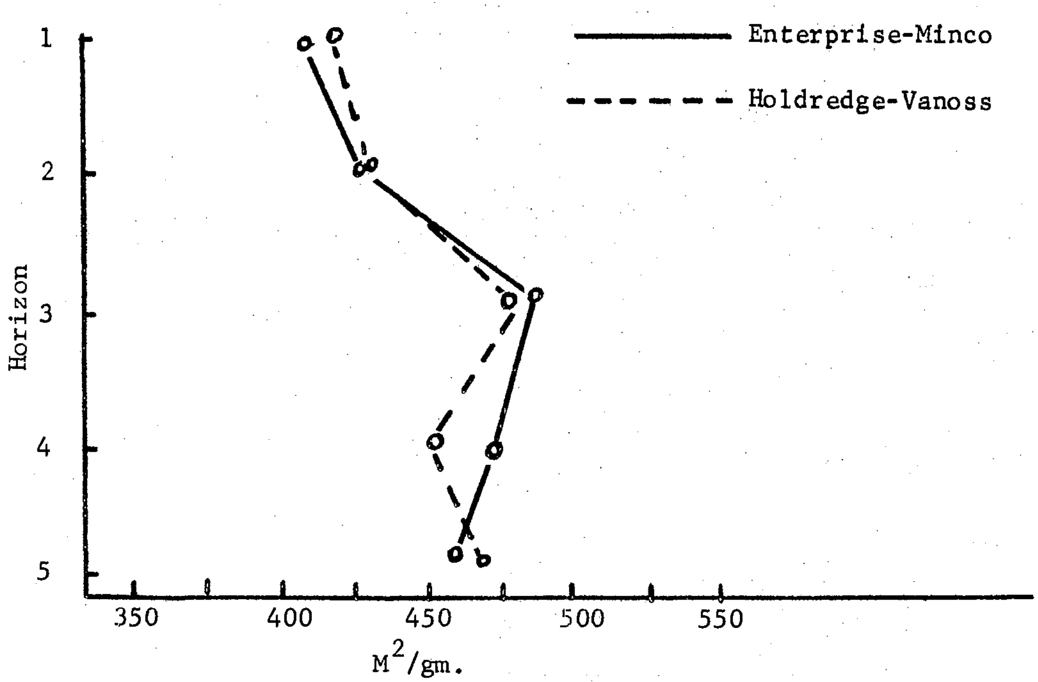

Figure 26. The Planar Surface Area of the Clay Fraction of Selected Horizons in the Enterprise-Minco and Holdredge-Vanoss Soils

for the CEC, though there are some deviations. These results are possibly slightly more erratic than those for the CEC. This is particularly evident in the results shown in Appendix Tables XXXIX-XXXXV. Statistically, the trends in the planar surface area and the CEC are identical except that there are some differences in the level of significance. This similarity is not surprising in view of the correlation between surface area and CEC.

Total K_2O

Graphs of the data and the results of statistical analysis are given in Figures 27-28 and in Table XVI. The trends in the K_2O content are different than those for the CEC and planar surface area in some respects but are similar in others. A major difference is that the K_2O content decreases with depth in the pedons whereas the other parameters show a tendency to increase with depth in the pedons. Also, in contrast to the CEC and planar surface area, there is no significant difference statistically between group I, II, and III soil, but there is a difference between the Enterprise-Minco and Holdredge-Vanoss soils. Statistically, horizon 1 is significantly different from horizons 3 and 5, but there is no significant difference between horizons 3 and 5.

Quantitative Estimation of the Clay Mineralogy

Quantitative calculations were made of the content of montmorillonite and illite. The method used in calculating the montmorillonite content will be considered first.

The method of Mehra and Jackson (34) was used for calculating the

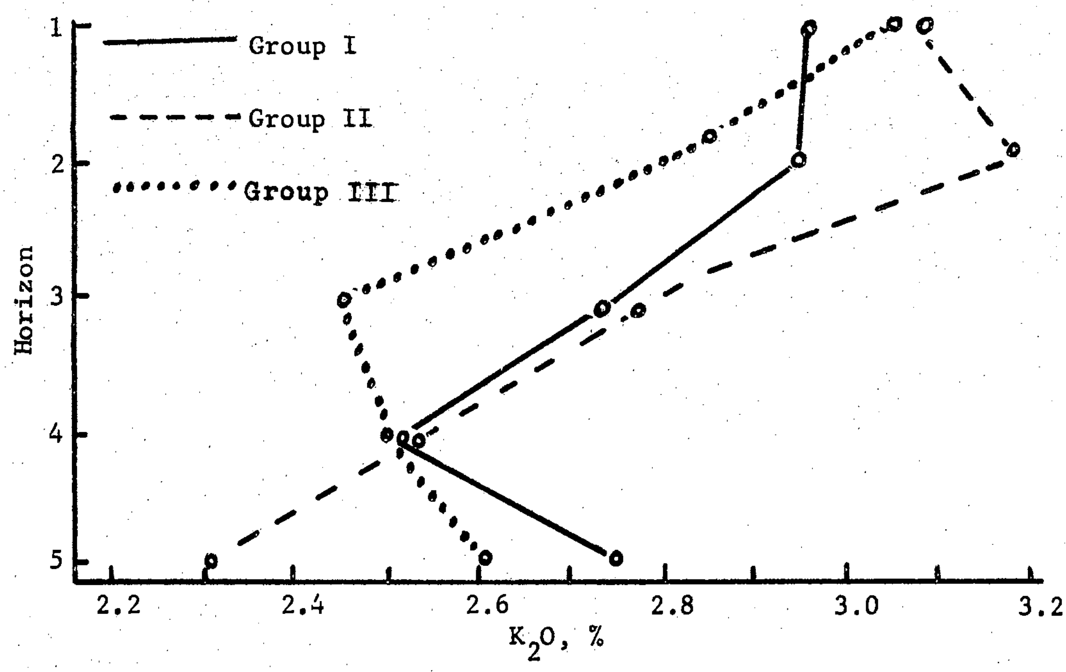

Figure 27. The Total K_2O Content of the Clay Fraction of Selected Horizons in Soils of Three Climatic Zones

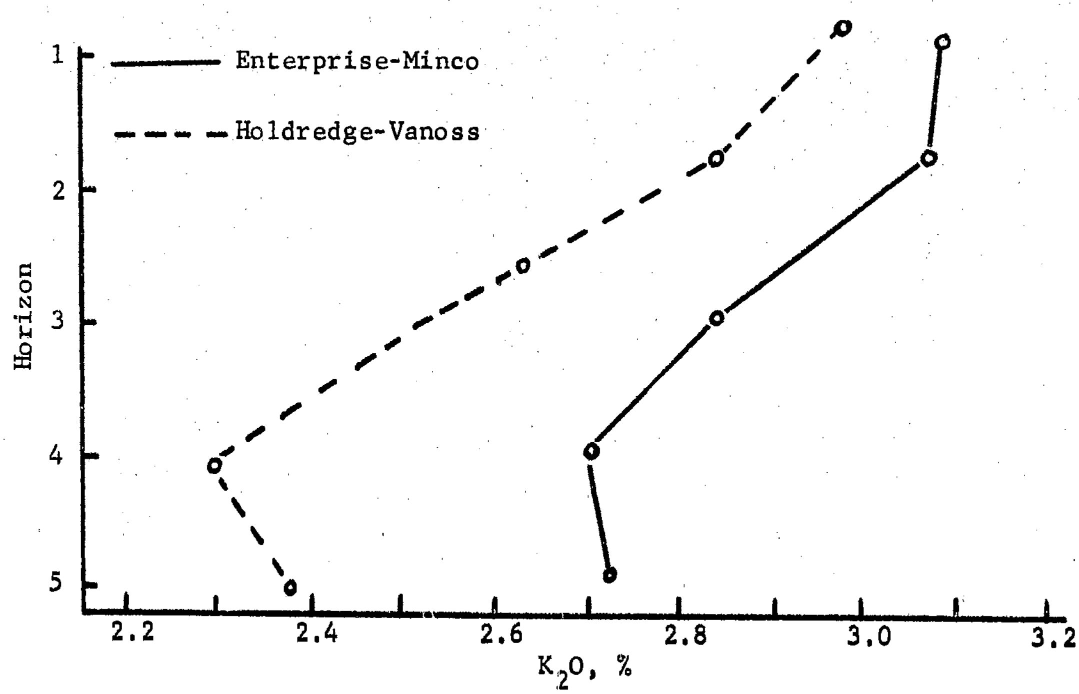

Figure 28. The Total K_2O Content of the Clay Fraction of Selected Horizons in the Enterprise-Minco and Holdredge-Vanoss Soils

content of montmorillonite. The equation is as follows:

$$\%(\text{Montmorillonite} + \text{Vermiculite}) = \frac{(\text{Planar Surface, m}^2/\text{gm.})(100)}{808\ \text{m}^2/\text{gm.}}$$

The equation holds strictly only for an aluminous montmorillonite, and the equation for other montmorillonite species would be slightly different. Also, it would be necessary to make corrections in clay fractions containing significant amounts of halloysite and amorphous materials. Small contributions to the planar surface from other sources are ignored. Since the x-ray results in this study were interpreted as indicating no vermiculite, the above equation should give the content of montmorillonite. The relatively high values for the external surface area for most of the samples, Appendix Tables XXXIX-XXXXV, lend support to the conclusion that vermiculite is not an important constituent of the clay fraction of the soils of this study. This statement is based on the assumption that a mineral such as montmorillonite having a relatively low tetrahedral charge would collapse less readily, and thus have a tendency towards an apparent higher external surface area, than a mineral such as vermiculite having a high tetrahedral charge. Many researchers have found evidence that this is definitely true when collapse due to potassium fixation is the only factor being considered. Examples are the work of Weaver (47) in which he found that expanding minerals having a high tetrahedral charge collapse much more readily when treated with a potassium containing solution than similarly treated expanding minerals having a low tetrahedral charge. Mehra and Jackson (34) obtained a higher external surface area on a montmorillonite sample than on a vermiculite sample following heating to 600° C, but they did not attempt to relate this difference to the source of charge.

The total K_2O content was used to estimate the illite content. There is no general agreement on the content of K_2O to be expected in illite. White (50) found that soil micas do not expand until the K_2O content has been reduced to 3-4%. Roberson and Jonas (38) found that other cations can substitute for potassium to some extent and produce 10 Å layers, though they are not as effective as potassium. Parry and Reeves (36) reported a glauconitic mica, free of expanding minerals, in which the K_2O content was only 3.8%. They postulated that the Na_2O content, 3.3%, in combination with the K_2O was responsible for binding the layers together. Jackson (24) stated that the "hydrous micas" actually consist of a mixture of 10 Å minerals and expandable minerals and that pure illite contains approximately 10% K_2O. He cited several reasons for this conclusion, but the best evidence was perhaps his research results showing that in 2:1 silicate clays the sum of planar sorption surface area as measured by glycerol adsorption and mica unit cell interplanar surface areas as measured by K_2O content was constant. Weaver (48) obtained results indicating that the 10% K_2O value for pure illite is perhaps slightly high but that it is more nearly correct than the values commonly reported. Much of the uncertainty regarding the K_2O content of illite is due to varying definitions of illite and it is impossible to choose a value on which there would be general agreement. However, Mehra and Jackson's results regarding constancy of the sum of the surface areas obtained by glycerol adsorption and K_2O determination indicate that "hydrous micas" are actually mixtures of illite and expanding minerals, and 10% K_2O was chosen as the standard value for illite calculations. No attempt was made to assess the potassium contribution by feldspars even though this may introduce a small error. In general, potassium feldspars have not been found to comprise a significant portion of clay-size materials (22, 31).

The estimates of the montmorillonite and illite content in the clay fractions are given in Tables XVII-XXIII. The remainder of the clay fraction is probably composed primarily of kaolinite and quartz, but no measure was obtained of their relative proportions. It is recognized that present methods do not permit really precise quantitative calculations of the clay mineraology and there is no intention to imply that the estimates are accurate to the nearest 1%. At the best, the figures are probably accurate to the nearest 10%. The CEC contributions were calculated by assuming a CEC of 100 for montmorillonite and 15 for illite. These values are within the CEC range given by Grim (16) for these minerals. Inspection of the data shows that the deviations between the actual and calculated values are quite variable but that the deviation is less than 5 in the majority of the horizons. These deviations probably are not excessive, with a few exceptions, in view of the number of factors that are involved. For example, errors in the surface area determinations would be reflected in the calculated montmorillonite content and the calculated CEC would be markedly affected. In general, the actual CEC is of approximately the magnitude that would be expected in clay samples having the composition given in Tables XVII-XXIII, and the estimates are believed to represent a good approximation of the clay mineral distribution in soils of this study. The ratio of montmorillonite:illite ranges from nearly three in some horizons to slightly more than one in others. In general, the ratio is

TABLE XVII

THE ESTIMATED MONTMORILLONITE AND ILLITE CONTENT IN THE CLAY FRACTION OF SOILS OF ROGER MILLS COUNTY

Horizon*	Depth cm	% Montmorillonite	% Illite	Actual CEC-Calculated CEC
		----Enterprise----		
Ap1	0-23	67	28	- 6.5
AC1	23-53	58	29	+ 6.1
AC3	89-125	74	27	-10.1
C2	152-178	66	28	- 3.8
C3	178-203	62	29	- 3.4
		----Holdredge----		
Ap1	0-20	54	25	+ 3.8
B1	20-33	69	27	- 7.1
B22t	46-86	73	26	- 9.7
B3	86-107	66	25	- 6.5
C2	130-147	70	27	- 7.8

TABLE XVIII

THE ESTIMATED MONTMORILLONITE AND ILLITE CONTENT IN THE CLAY FRACTION OF SOILS OF DEWEY COUNTY

Horizon	Depth cm	% Montmorillonite	% Illite	Actual CEC-Calculated CEC
		----Enterprise----		
Ap1	0-18	61	32	+ 0.5
A12	18-33	39	33	+27.1
AC2	51-89	53	30	+ 7.5
AC3	89-112	53	27	+ 9.6
C2	137-158	64	30	- 0.6
		----Holdredge----		
Ap1	0-20	56	34	- 9.4
A12	20-36	57	30	- 4.0
B22t	71-97	54	26	+ 2.1
B23t	97-114	56	21	+ 5.3
C1	142-152	58	25	+ 5.1

TABLE XIX

THE ESTIMATED MONTMORILLONITE AND ILLITE CONTENT IN THE CLAY FRACTION OF SOILS OF CUSTER COUNTY

Horizon	Depth cm	% Montmorillonite	% Illite	Actual CEC-Calculated CEC
		----Minco----		
Ap1	0-23	51	26	+ 6.6
A12	23-33	57	30	+ 2.4
B22	61-81	56	27	+ 4.0
B24ca	109-142	68	27	- 6.2
C2	165-188	56	25	+ 1.5
		----Vanoss----		
Ap1	0-20	54	33	- 4.5
A12	20-33	45	34	+ 8.1
B21t	53-74	59	31	- 3.6
B24t	117-140	55	28	+ 3.1
IIB22t	168-183	61	21	+ 3.3

TABLE XX

THE ESTIMATED MONTMORILLONITE AND ILLITE CONTENT IN THE CLAY FRACTION OF SOILS OF CADDO COUNTY

Horizon	Depth cm	% Montmorillonite	% Illite	Actual CEC-Calculated CEC
		----Minco----		
Ap1	0-15	39	34	+ 4.9
A12	15-30	64	32	-11.5
B22	30-64	66	28	- 8.1
B23	107-147	57	25	- 4.1
Cca	165-178	63	25	- 2.0
C2	178-216	66	24	- 7.7
		----Vanoss--		
Ap1	0-23	44	32	- 2.6
A12	23-33	45	31	+ 1.4
B21t	51-79	55	29	+ 4.2
B3	104-127	61	22	- 0.4
C1	127-152	57	23	- 0.8

TABLE XXI

THE ESTIMATED MONTMORILLONITE AND ILLITE CONTENT IN THE CLAY FRACTION OF SOILS OF GRADY COUNTY

Horizon	Depth cm	% Montmorillonite	% Illite	Actual CEC-Calculated CEC
		----Minco----		
Ap1	0-18	51	33	- 2.6
A12	18-36	54	32	- 5.8
B21	51-76	54	27	- 3.7
B22	76-102	50	26	+ 0.8
C2	152-173	54	27	- 4.5
		----Vanoss----		
Ap1	0-18	60	26	- 3.9
A12	18-31	53	22	- 1.2
B22t	56-76	51	19	+19.3
B23t	76-94	46	21	+23.7
C2	142-163	45	23	+13.4

TABLE XXII

THE ESTIMATED MONTMORILLONITE AND ILLITE CONTENT IN THE CLAY FRACTION OF SOILS OF MCCLAIN COUNTY

Horizon	Depth cm	% Montmorillonite	% Illite	Actual CEC-Calculated CEC
		----Minco----		
Ap1	0-18	35	34	+10.4
A12	18-33	48	32	+ 0.1
B21	56-91	56	31	- 3.8
B22	91-132	66	29	-11.4
B3	188-203	57	31	- 2.2
C1	229-246	46	31	+ 6.6
		----Vanoss----		
Ap1	0-20	45	31	- 0.5
A12	20-36	48	26	+ 3.1
B21	56-81	64	21	- 6.6
IIB22t	104-132	52	23	+ 5.5
IIB23t	132-158	62	23	- 3.5
IIC2ca	170-183	62	25	- 5.9

TABLE XXIII

THE ESTIMATED MONTMORILLONITE AND ILLITE CONTENT IN THE CLAY FRACTION OF SOILS OF PONTOTOC COUNTY

Horizon	Depth cm	% Montmorillonite	% Illite	Actual CEC-Calculated CEC
		----Vanoss----		
Ap1	0-25	38	29	+ 5.4
B1	25-41	39	30	+ 0.3
B22t	76-114	40	27	+ 2.7
B3	152-175	32	24	+13.2
C1	229-254	41	25	+ 0.8

approximately two.

Processes Determining the Clay Mineralogy

The results of four methods of study; x-ray diffraction, CEC determination, surface area determination, and total K_2O determination; indicate that the surface horizons have a somewhat different clay mineralogy than the horizons deeper in the profile. The results of the latter three methods are more conclusive than those given by x-ray diffraction. Excluding x-ray diffraction, two of the three methods indicate that there is a difference in clay mineralogy between group I, group II, and group III soils but that there is no difference between the Enterprise-Minco and Holdredge-Vanoss soils. The third method, total K_2O determination, indicates that the clay mineralogy of group I, group II, and group III soils is the same but that there is a difference between the Enterprise-Minco and Holdredge-Vanoss soils. Considering all results, it appears that certain processes have occurred to cause a mineralogical change with depth within the profiles and to cause differences, though relatively minor, in the clay mineral composition of different groups of soils in the study. The clay mineralogical trends observed in this study are probably a result of one or more of the three following general processes:

1.) Depositional Processes

2.) Clay Translocation Within the Profiles

3.) Chemical Weathering

The processes will be considered in order.

Contamination of the upper horizons with material from another source, most likely Permian formations, is the most probable means by which depositional processes could account for the observed differences in clay mineralogy within the soil pedons. The evidence, primarily the heavy mineral and particle size data, indicates that contamination from other sources has been relatively unimportant in these soils. It is impossible to say definitely that contamination has not occurred, but contamination of a magnitude to cause the consistent differences in clay mineralogy that is evident between the upper and lower horizons probably would have been reflected in other ways. Assuming that the parent materials of all horizons came primarily from the same source, there is still a possibility that there was a change with time in the mineralogical composition of the clay fraction being deposited. However, it is necessary to assume a rather abrupt change at some time if the observed differences are to be accounted for in this manner and this possibility does not appear likely.

The changes observed in the clay mineralogy in a west-east direction could be due to additions of sediments from the adjoining

Permian formations, even though such additions have apparently been minor. However, this is only a possibility and is not supported by the results of this study. This possibility appears particularly doubtful in view of the fact that in a west-east direction no consistent increases were observed in the content of any of the clay mineral species that have been reported as being dominant in the Permian formations of this area. Nevertheless, the possibility exists.

It is possible that depositional processes have accounted for the differences in the K_2O content between the Enterprise-Minco and Holdredge-Vanoss soils by concentrating the finer portion of the clay fraction in the latter group of soils. This possibility is based on the assumption that montmorillonite tends to be concentrated in the finer portion of the clay fraction.

Clay translocation, assuming that only the finer portion of the clay fraction is translocated and that montmorillonite is concentrated in the finer portion, could have caused the differences in clay mineralogy within some of the soil pedons. The clay content is presented in Figures 29-30 for the same horizons and same groups of soils in which the clay mineralogy was studied. With the exception of group I soils, there is a general increase, though it is sometimes small, in clay content down to the fourth horizon. These trends are similar, though not identical, to those that were observed of the CEC and planar surface area but are the opposite of the trends in K_2O content. Such trends would be expected if a translocation of montmorillonite into the deeper horizons and a relative concentration of illite in the upper horizons has occurred, and it appears likely that clay translocation has contributed to differences in clay mineralogy within the pedons.

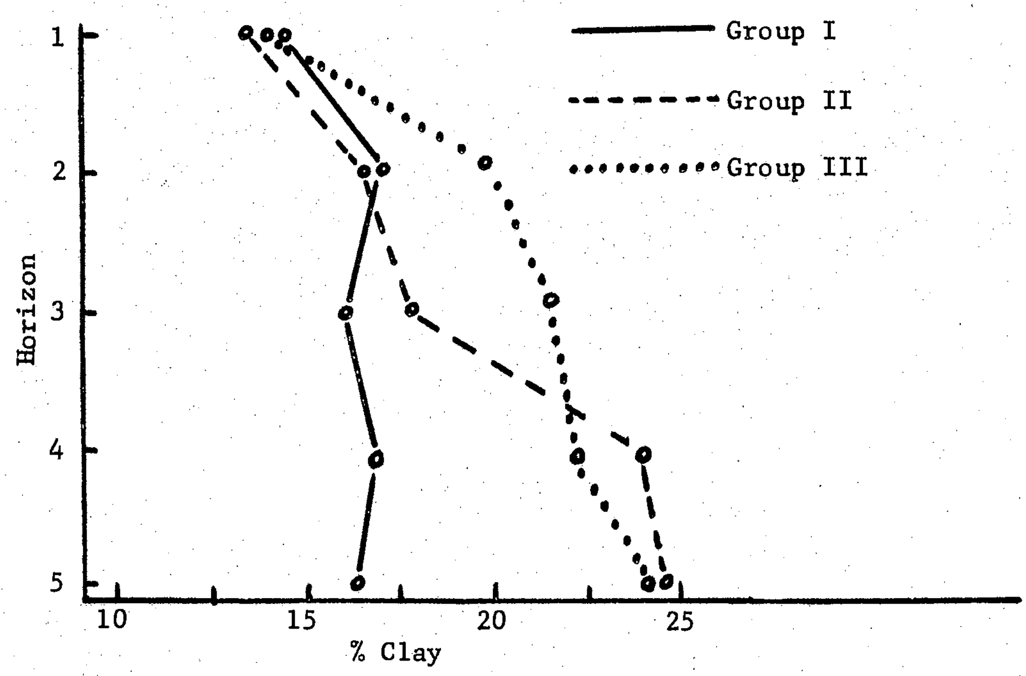

Figure 29. The Clay Content of Selected Horizons in Soils of Three Climatic Zones

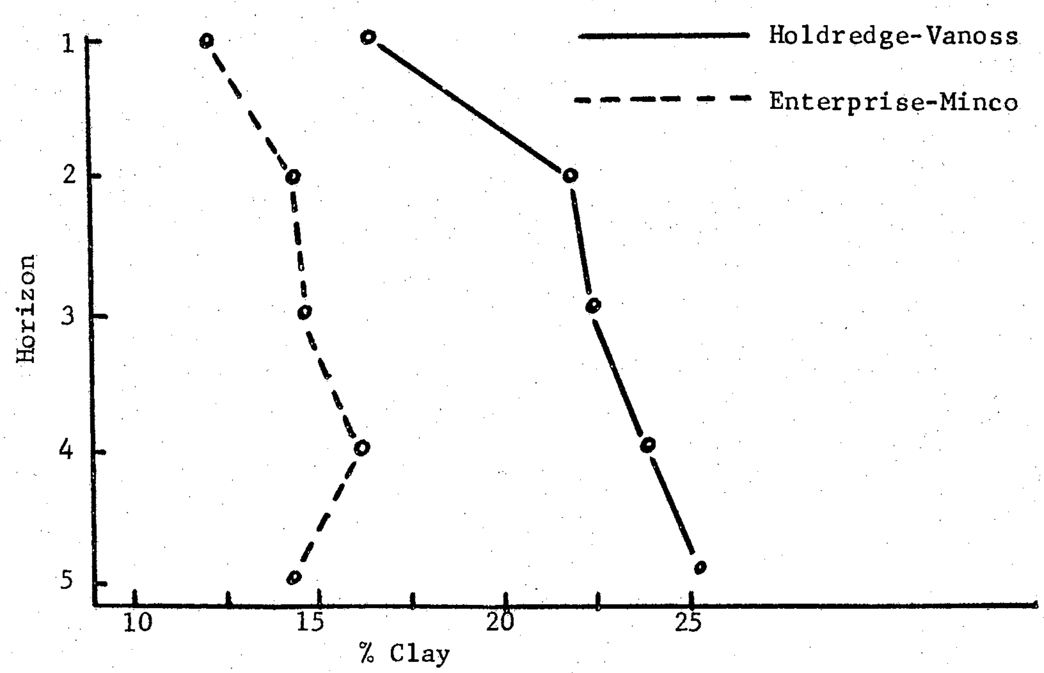

Figure 30. The Clay Content of Selected Horizons in the Enterprise-Minco and Holdredge-Vanoss Soils

A discrepancy is that, in general, the clay content shows a greater tendency than the other parameters to continue to change progressively below the third horizon and this lends serious doubt to the possibility that clay translocation is the only significant factor in causing clay mineralogical variations within the pedons.

The data indicate that chemical weathering has affected the clay mineralogy of the soils of this study. The effects of chemical weathering in causing alterations within the profiles will be considered first.

The most evident change in the clay mineral properties in the soils of this study is a general decrease in the total K_2O content with depth in the profile and an accompanying increase in the CEC and planar surface area down to the third, or sometimes fourth, horizon. The horizons referred to are those in which the clay mineralogy was studied, and data is not available to indicate the exact point in the pedons to which the K_2O decrease extends. The planar surface area and CEC would be expected to increase as potassium is weathered out of the lattice, but there is a question as to why potassium is not removed from the lattice of clays in the upper horizons more readily than from clays in the theoretically less strongly weathered lower horizons. It is postulated, though the evidence is uncertain, that the nature of the vegetation, and not the chemistry of the horizons per se, was responsible for the observed clay mineral variations with depth. Prairie grasses of the type covering the study area in its native state are very effective in recycling chemical elements and the potassium released by weathering could have been concentrated in the upper horizons by decaying vegetation. Potassium would gradually be leached out of the profile under this type of process, but a very long period of time would be required. It is unlikely that the formation of clays by weathering of the primary minerals could account for the variations within these profiles, though some clay formation has probably occurred during the time of soil formation. However, a combination of the youth of the soils and the scarcity of easily weatherable minerals in the nonclay fractions probably excludes the possibility that significant amounts of clay have formed as a result of soil forming processes.

Increasing weathering intensity has apparently caused a progressive alteration of the clay minerals in soils of this study in a west-east direction, but the data afford little evidence regarding the mechanism of alteration. The fact that no significant difference was found between the total K_2O contents of group I, group II, and group III soils places some doubt on the conclusion that there have been alterations in the clay minerals, but the data on the CEC and planar surface area strongly indicate that weathering has significantly affected the clay minerals. This conclusion is further supported by the data in Appendix Tables XXXIX-XXXXV showing that the clay minerals in the Vanoss soil of Pontotoc County have the lowest planar surface area and CEC of any soils in the study. This would be expected if the increasing precipitation and consequent increase in weathering intensity in a west-east direction has caused a progressive alteration of the clay minerals. Two possible mechanisms that could account for the observed changes are aluminum interlayering of the 2:1 silicate clays or alteration of these clays to kaolinite. These changes, assuming one or both have occurred, probably have not yet progressed to a major extent and likely would not be indicated by the limited amount of x-ray diffraction done in this study.

Soil Classification

The soils of this study were classified according to the 7th Approximation (40) and the results are given in Table XXIV. The Enterprise pedon of Roger Mills County and the Minco pedon of Grady County are exceptions to this classification. There is considerable doubt regarding the classification of these two pedons, but their properties probably fall within the limits outlined for the Inceptisol order. Some assumptions had to be made regarding the classification at categorical levels below the order, and there is therefore some doubt about the correct classification at these levels. There is some doubt about the classification of the Minco soils at the great group level because the subsurface diagnostic horizons in three of the four pedons closely approaches an argillic horizon. However, the cambic horizon criteria probably describes these horizons better than the criteria of an argillic horizon.

Considering all data, the Mollisol characteristics are less strongly expressed in the western part of the study area than in the eastern part and it appears probable that large areas of Mollisols do not occur west of Roger Mills County. However, local exceptions would be expected. The data also suggest that the Vanoss and Minco soils of the eastern portion of the area in which they are currently mapped should be classified as Udolls at the suborder level. There is a question as to whether the line between Ustolls and Udolls should be drawn as far west as was done in this study.

TABLE XXIV

A CLASSIFICATION ACCORDING TO THE SEVENTH APPROXIMATION

Soil	Order	Suborder	Great Group	Subgroup	Family Classification	
					Texture	Mineralogy
Holdredge	Mollisol	Ustoll	Argiustolls	Udic Argiustolls	Fine Loamy	Mixed
Enterprise	Mollisol	Ustoll	Haplustolls	Udic Haplustolls	Coarse Silty	Mixed
Vanoss	Mollisol	Udoll	Argiudolls	Typic Argiudolls	Fine Silty	Mixed
Minco	Mollisol	Udoll	Hapludolls	Typic Hapludolls	Coarse Silty	Mixed

CHAPTER V

SUMMARY AND CONCLUSIONS

The objectives of the study were to determine the effect of the soil forming factors climate and time on the genesis of soils developed on terraces of the South Canadian River and to obtain data pertinent to the classification of the soils. Samples were taken in seven counties of an area extending from Roger Mills County in the west to Pontotoc County in the east. The average annual precipitation in this area ranges from approximately 24 inches in Roger Mills County to 38 inches in Pontotoc County. The Holdredge-Vanoss soils occur on older landforms than the Enterprise-Minco soils, but the age of the landforms probably is not constant for either group of soils.

Field studies indicate that the degree of horizon differentiation is greater in the Holdredge-Vanoss soils than in the younger Enterprise-Minco soils, but no climatic effects are evident. A tendency was observed for unconforming layers to occur in the Holdredge-Vanoss soils, thus complicating to some degree the interpretation of the effects of soil forming processes. This tendency is probably a function of the distance of these soils from the South Canadian River.

The particle size distribution results indicate that the Holdredge-Vanoss profiles have a higher clay content than the Enterprise-Minco soils. This is almost certainly a depositional effect. A downward translocation of the clay within the profiles is indicated for the

Holdredge soils, Vanoss soils and for some of the Minco soils. However, there is no tendency for the clay maximum to occur at any particular point within the profiles. The Enterprise profiles are essentially monotextured. The amount of clay translocation has a tendency to increase with increasing soil age and possibly with increasing annual rainfall. The most abundant nonclay fractions in most of the profiles are the 0.02-0.05 and 0.05-0.10 mm. fraction. There apparently have been depositional effects within some of the pedons, but in general, these effects have been minor.

The results of thin section studies indicate that clay translocation has occurred within the Holdredge, Vanoss, and Minco profiles but not within the Enterprise profiles. However, these studies were done only on four profiles.

Chemical studies indicate that the depth to carbonates in the soils of this study has a tendency to increase both with increasing soil age and increasing annual rainfall. Also, the effects of climate are reflected in the higher carbonate content of the Holdredge-Enterprise soils compared to the Vanoss-Minco soils. Variations in the extractable cations and soil pH roughly parallel variations in the carbonate content. The organic matter content of these soils tends to increase, with exceptions, as the rainfall increases.

Results of studies on the sand and silt mineralogy indicate that all soils of this study developed in parent materials having similar origins. Depositional effects likely have influenced the genesis of these soils, but addition of sediments from other sources has not occurred to a significant degree. Results of these studies afford no evidence of weathering trends.

Studies of the clay mineralogy indicate that montmorillonite and illite are the most abundant clay minerals in these soils, commonly comprising 70% or more of the clay fraction. The content of montmorillonite is approximately twice as high as that of illite. Soil forming processes have been of sufficient intensity to alter the clay mineralogy of the upper soil horizons relative to that of the lower soil horizons. The net effect has been to increase the illite content and lower the montmorillonite content of the surface horizons relative to those horizons deeper in the profile. A tendency was also observed for the montmorillonite content to decrease as the annual rainfall increased, but none of the determinations gave evidence regarding the accompanying changes. The Enterprise-Minco soils have a slightly higher illite content than the Holdredge-Vanoss soils, this apparently being a depositional effect.

Regarding the genetic effects of climate and time, the study indicates that age differences between the soils are reflected in such apparently relatively easily affected processes as leaching of carbonates and translocation of clay but not in such processes as clay mineral alteration. Climatic differences between the soil have been of more importance in causing differences between the soils than age differences.

Differences between the soils are reflected in their classification. There is some uncertainty in the classifications in certain respects, particularly for the Enterprise Series.

The results of this study probably characterize the soils occurring on terraces of the South Canadian River reasonably well, though there would undoubtedly be numerous local variations, and reflect trends that would be expected due to varying climatic conditions and soil age differences within this area. This statement would be expected to apply only to soils which have not been significantly modified by addition of sediments from the adjacent Permian formations or from other sources. Further study of the clay mineralogy with the objective of determining the nature of the alteration accompanying increasing annual rainfall would likely be informative. A combination of differential dissolution techniques and x-ray diffraction studies would be suitable for this type of study.

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APPENDIX

TABLE XXV

PARTICLE SIZE DISTRIBUTION IN SOILS OF ROGER MILLS COUNTY

Horizon	Depth cm	Diameter, mm <0.002	0.002-0.02	0.02-0.05	0.05-0.10	0.10-0.25	0.25-0.50	0.50-1.0	1.0-2.0
		%	%	%	%	%	%	%	%
				----Enterprise----					
Ap1	0-23	12.5	6.0	31.1	30.4	18.3	1.7	0.2	0.0
AC1	23-53	14.0	6.3	41.4	28.2	9.4	0.6	0.1	0.0
AC2	53-89	11.3	8.4	42.6	29.6	7.5	0.5	0.1	0.0
AC3	89-125	10.9	8.9	44.1	30.4	5.3	0.4	0.1	0.0
C1	125-152	15.6	9.4	40.7	32.6	1.4	0.3	0.1	0.0
C2	152-178	10.9	9.4	45.8	28.2	5.5	0.2	0.0	0.0
C3	178-203	12.7	10.3	35.2	25.6	4.9	0.4	0.1	0.0
				----Holdredge----					
Ap1	0-23	17.6	7.2	43.4	20.0	8.9	2.0	0.9	0.1
B1	23-33	22.3	8.1	43.1	13.0	10.5	1.8	1.0	0.2
B21t	33-46	22.5	11.5	40.7	16.3	6.4	1.7	0.8	0.2
B22t	46-86	21.5	12.0	38.6	17.5	7.5	1.8	1.0	0.1
B3	86-107	22.5	12.3	32.6	18.5	10.1	2.5	1.2	0.3
C1	107-130	20.6	10.2	30.1	19.7	12.4	4.5	1.9	0.7
C2	130-147	19.3	9.7	33.3	17.5	14.2	5.0	2.5	0.5
A1	147-163	21.4	7.1	31.1	12.6	11.1	3.0	1.6	0.4
Cca	163-178	15.7	11.5	46.3					

TABLE XXVI

PARTICLE SIZE DISTRIBUTION IN SOILS OF DEWEY COUNTY

Horizon	Depth cm	Diameter, mm <0.002	0.002-0.02	0.02-0.05	0.05-0.10	0.10-0.25	0.25-0.50	0.50-1.0	1.0-2.0
		%	%	%	%	%	%	%	%
				----Enterprise----					
Ap1	0-18	10.3	9.3	52.2	30.0	3.3	1.2	0.6	0.1
A12	18-33	10.5	10.1	54.6	19.4	2.9	1.5	0.7	0.4
AC1	33-51	12.0	11.6	48.9	21.2	3.3	1.9	0.1	0.1
AC2	51-89	11.3	11.3	51.5	18.8	3.5	2.2	1.1	0.3
AC3	89-112	11.6	11.4	51.5	7.9	13.0	2.8	1.6	0.3
C1	112-137	11.8	11.6	49.3	17.3	4.9	3.4	1.3	0.3
C2	137-158	11.8	12.5	47.6	15.0	6.1	4.2	2.0	0.8
				----Holdredge----					
Ap1	0-20	17.5	14.7	39.0	13.6	6.6	5.6	2.7	0.4
A12	20-36	21.6	13.3	35.9	11.2	6.9	6.4	4.3	0.1
B21t	36-71	19.9	13.4	35.7	8.5	9.1	7.9	4.3	1.0
B22t	71-97	19.1	14.6	30.3	8.2	11.8	9.8	5.6	0.6
B23t	97-114	22.9	14.5	23.6	6.0	13.9	11.2	6.3	1.6
B3	114-142	26.8	16.1	20.7	6.1	15.9	9.5	4.4	0.7
C1	142-152	20.5	13.7	18.4	7.0	20.6	12.5	5.6	1.7

TABLE XXVII

PARTICLE SIZE DISTRIBUTION IN SOILS OF CUSTER COUNTY

Horizon	Depth cm	Diameter, mm <0.002	0.002-0.02	0.02-0.05	0.05-0.10	0.10-0.25	0.25-0.50	0.50-1.0	1.0-2.0
		%	%	%	%	%	%	%	%
				----Minco----					
Apl	0-23	16.4	6.8	46.9	24.8	3.7	1.3	0.1	0.0
A12	23-33	16.3	7.6	45.7	23.5	5.5	1.3	0.0	0.0
B1	33-48	13.9	10.8	47.4	22.0	4.7	1.2	0.0	0.0
B21	48-61	13.8	11.2	46.4	23.1	4.0	1.2	0.1	0.0
B22	61-81	13.8	11.4	45.8	20.7	6.9	1.3	0.0	0.0
B23ca	81-109	14.0	11.7	46.3	22.1	4.5	1.4	0.0	0.0
B24ca	109-142	15.2	10.4	47.9	19.5	5.2	1.7	0.1	0.0
C1	142-165	13.6	12.8	44.1	18.7	8.2	2.4	0.2	0.1
C2	165-188	14.9	11.8	43.4	18.0	9.8	2.6	0.3	0.1
				----Vanoss----					
Apl	0-20	13.9	13.7	48.9	21.0	2.4	0.1	0.1	0.0
A12	20-33	18.8	14.0	48.3	16.5	2.1	0.3	0.0	0.0
B1	33-53	21.6	14.9	45.8	15.3	2.2	0.1	0.1	0.0
B21t	53-74	22.8	15.1	46.6	13.3	2.1	0.1	0.0	0.0
B22t	74-102	23.4	17.3	43.5	13.6	2.1	0.1	0.1	0.0
B23t	102-117	25.5	18.1	40.4	13.5	2.2	1.2	0.2	0.0
B24t	117-140	25.7	20.8	38.8	12.3	2.2	0.2	0.1	0.06
IIB21t	140-168	32.9	24.7	32.0	7.2	2.1	0.4	0.4	0.2
IIB22t	168-183	36.2	23.5	30.2	5.2	2.7	0.4	1.6	0.3

TABLE XXVIII

PARTICLE SIZE DISTRIBUTION IN SOILS OF CADDO COUNTY

Horizon	Depth cm	Diameter, mm							
		<0.002	0.002-0.02	0.02-0.05	0.05-0.10	0.10-0.25	0.25-0.50	0.50-1.0	1.0-2.0
		%	%	%	%	%	%	%	%
				----Minco----					
Ap1	0-15	10.9	13.2	46.3	26.9	2.5	0.1	0.1	0.0
A12	15-30	15.4	12.1	45.8	23.8	2.8	0.1	0.1	0.0
B21	30-64	15.8	12.2	44.1	24.9	3.3	0.1	0.1	0.0
B22	64-107	16.9	13.9	42.8	22.8	3.5	0.1	0.1	0.0
B23	107-147	25.0	14.8	33.2	14.1	1.3	0.2	0.0	0.1
B3	147-165	19.1	17.1	40.3	19.1	4.2	0.1	0.1	0.0
Cca	165-178	25.0	18.1	39.6	13.8	3.4	0.1	0.0	0.0
C2	178-216	24.1	19.6	36.0	16.4	4.6	0.1	0.0	0.0
				----Vanoss----					
Ap1	0-23	13.1	12.7	36.0	27.5	10.5	0.2	0.0	0.0
A12	23-33	16.8	13.3	32.3	24.0	13.5	0.2	0.3	0.0
B1	33-51	22.2	12.8	29.5	24.5	10.6	0.2	0.1	0.0
B21t	51-79	19.0	15.5	42.2	19.5	3.5	0.1	0.1	0.0
B22t	79-104	25.4	17.2	24.1	20.7	12.2	0.0	0.3	0.0
B3	104-127	29.8	20.5	21.6	16.9	10.9	0.3	0.0	0.0
C1	127-152	21.9	12.8	22.1	24.1	18.8	0.4	0.1	0.0
IIC2	152-168	15.6	6.1	16.0	33.0	28.2	0.7	0.1	0.0

TABLE XXIX

PARTICLE SIZE DISTRIBUTION IN SOILS OF GRADY COUNTY

Horizon	Depth cm	Diameter, mm							
		<0.002	0.002-0.02	0.02-0.05	0.05-0.10	0.10-0.25	0.25-0.50	0.50-1.0	1.0-2.0
		%	%	%	%	%	%	%	%
				----Minco----					
Ap1	0-18	10.9	6.9	39.7	33.6	7.5	1.2	0.1	0.0
A12	18-36	13.4	8.2	39.5	30.3	7.2	1.2	0.2	0.0
B1	36-51	15.5	10.3	36.8	29.8	6.2	1.2	0.3	0.0
B21	51-76	17.1	10.5	39.0	25.9	6.2	1.2	0.2	0.0
B22	76-102	20.1	12.4	36.9	20.3	8.1	1.9	0.4	0.0
B23	102-132	24.0	13.1	30.1	18.4	11.6	2.4	0.4	0.0
C1	132-152	21.4	11.9	29.4	18.5	13.7	3.5	1.2	0.3
C2	152-173	21.8	7.4	28.6	20.3	15.9	4.0	1.5	0.5
				----Vanoss----					
Ap1	0-18	19.7	10.2	45.7	21.5	2.9	0.2	0.1	0.1
A12	18-31	26.4	14.3	40.7	16.0	2.1	0.2	0.2	0.1
B21t	31-56	30.0	17.2	37.1	12.8	2.2	0.2	0.3	0.2
B22t	56-76	26.6	15.7	37.8	16.2	2.8	0.3	0.3	0.2
B23t	76-94	24.1	12.7	37.6	20.0	5.0	0.3	0.2	0.0
B3	94-114	24.1	12.3	32.7	24.0	6.3	0.3	0.2	0.1
C1	114-142	21.9	11.7	32.8	26.1	6.4	0.6	0.4	0.0
C2	142-163	21.0	13.6	33.4	24.5	5.4	0.6	0.9	0.6

TABLE XXX

PARTICLE SIZE DISTRIBUTION IN SOILS OF MCCLAIN COUNTY

Horizon	Depth cm	Diameter, mm							
		$<$0.002	0.002-0.02	0.02-0.05	0.05-0.10	0.10-0.25	0.25-0.50	0.50-1.0	1.0-2.0
		%	%	%	%	%	%	%	%
				----Minco----					
Ap1	0-18	9.0	7.2	42.9	37.3	3.4	0.2	0.0	0.0
A12	18-33	14.3	10.0	41.6	31.2	2.7	0.1	0.0	0.0
B1	33-56	14.0	8.4	34.8	22.4	11.8	0.1	0.5	0.0
B21	56-91	14.5	8.9	42.2	31.6	2.7	0.1	0.0	0.0
B22	91-132	15.1	10.9	44.8	28.9	2.4	0.1	0.0	0.0
B23	132-158	15.9	12.9	48.2	21.6	1.3	0.1	0.0	0.0
B24	158-188	17.4	14.5	49.4	17.6	1.2	0.0	0.0	0.0
B3	188-203	20.2	19.2	45.4	14.6	0.5	0.0	0.0	0.0
C1	229-246	20.0	20.2	51.5	7.0	0.9	0.2	0.2	0.0
				----Vanoss----					
Ap1	0-20	17.3	14.7	51.6	14.8	1.3	0.1	0.1	0.1
A12	20-36	23.7	15.0	47.2	12.6	1.2	0.1	0.1	0.1
B1	36-56	24.1	17.3	49.8	7.6	0.8	0.2	0.2	0.1
B21	56-81	26.4	20.6	42.2	8.4	0.9	0.2	0.2	0.2
IIB21t	81-104	32.0	21.2	36.7	8.9	1.7	0.2	0.2	0.1
IIB22t	104-132	30.2	18.7	37.2	11.5	2.0	0.3	0.1	0.0
IIB23t	132-158	32.8	17.2	33.6	12.1	3.4	0.4	0.3	0.2
IIC1ca	158-170	34.1	13.8	32.5	14.6	3.0	0.5	0.7	0.8
IIC2ca	170-183	33.3	12.6	33.0	14.4	3.4	0.6	0.9	1.8

TABLE XXXI

PARTICLE SIZE DISTRIBUTION IN SOILS OF PONTOTOC COUNTY

Horizon	Depth cm	Diameter, mm							
		<0.002	0.002-0.02	0.02-0.05	0.05-0.10	0.10-0.25	0.25-0.50	0.50-1.0	1.0-2.0
		%	%	%	%	%	%	%	%
				----Vanoss----					
Ap1	0-20	10.1	23.3	44.3	15.6	4.1	1.6	1.1	0.0
B1	20-41	20.4	24.5	42.7	9.0	2.2	0.9	0.3	0.0
B21t	41-76	28.4	32.3	29.0	7.4	1.8	0.8	0.4	0.0
B22t	76-114	23.3	25.0	39.8	7.5	2.7	1.2	0.6	0.0
B23t	114-152	23.9	24.4	38.6	7.4	3.7	1.7	0.3	0.0
B3	152-229	23.8	22.2	36.3	8.8	5.3	2.4	1.1	0.2
C1	229-254	17.2	12.6	31.5	15.1	14.2	7.0	2.4	0.0

TABLE XXXII

SELECTED CHEMICAL DATA ON SOILS OF ROGER MILLS COUNTY

Horizon	Depth cm	% Organic Matter	pH H_2O	pH KCl	CEC	Meqs/100 gm Ca	Meqs/100 gm Mg	Meqs/100 gm K	Meqs/100 gm Na	% Base Saturation	% $CaCO_3$ Equivalent
					----Enterprise----						
Ap1	0-23	0.7	8.1	7.1	9.0	37.4	0.7	0.26	0.23	413	3.9
AC1	23-53	0.7	8.1	7.4	9.6	48.6	1.5	0.21	0.23	529	5.6
AC2	53-89	0.7	8.4	7.5	9.5	45.5	2.2	0.29	0.28	506	5.9
AC3	89-125		8.0	7.3	9.5	44.4	3.6	0.31	0.20	511	6.4
C1	125-152		8.0	7.1	9.2	44.5	4.1	0.21	0.23	534	7.1
C2	152-178		8.2	7.2	9.2	42.2	4.0	0.23	0.14	505	6.4
C3	178-203		8.0	7.2	9.9	42.6	3.9	0.26	0.12	474	7.2
					----Holdredge----						
Ap1	0-20	1.3	7.8	6.8	14.3	12.1	2.0	0.58		103	2.0
B1	20-33	1.3	7.7	7.1	16.6	14.2	3.4	0.61	0.28	111	2.6
B21t	33-46	1.0	7.8	7.1	16.4	13.9	3.6	0.42	0.28	110	2.6
B22t	46-86		7.9	7.1	15.7	12.7	3.7	0.32	0.22	107	2.9
B3	86-107		7.8	7.1	15.9	38.8	2.5	0.53	0.28	267	2.6
C1	107-130		8.0	7.2	13.4	33.0	5.2	0.42	0.33	290	4.4
C2	130-147		8.2	7.2	12.5	29.7	6.0	0.51	0.22	290	3.7
IIA1	147-163		7.9	7.2	12.3	17.3	6.4	0.47	0.55	200	2.9
IICca	163-178		8.2	7.4	9.2	30.2	7.7	0.42	0.55	425	21.2

TABLE XXXIII

SELECTED CHEMICAL DATA ON SOILS OF DEWEY COUNTY

Horizon	Depth cm	% Organic Matter	pH		CEC	Meqs/100 gm				% Base Saturation	% $CaCO_3$ Equivalent
			H_2O	KCl		Ca	Mg	K	Na		
					----Enterprise----						
Ap1	0-18	1.4	7.5	6.7	10.0	10.1	1.0	0.29	0.11	119	2.1
A12	18-33	1.2	8.0	7.2	10.5	17.6	1.6	0.42	0.14	188	3.3
AC1	33-51	1.2	8.0	7.2	9.5	25.5	10.3	0.06	0.14	379	3.1
AC2	51-89		8.1	7.3	8.5	35.1	2.9	0.06	0.14	453	6.3
AC3	89-112		8.1	7.3	8.6	37.1	3.8	0.06	0.11	478	7.9
C1	112-137		8.3	7.5	9.0	37.2	4.0	0.06	0.11	463	9.0
C2	137-158		8.3	7.5	9.0	35.9	5.2	0.06	0.11	461	7.5
					----Holdredge----						
Ap1	0-20	1.5	6.2	5.5	11.5	8.6	2.3	0.32	0.11	99	1.5
A12	20-36	1.2	6.9	6.3	13.7	10.5	3.2	0.06	0.11	114	1.5
B21t	36-71	0.8	7.4	6.4	13.7	10.6	3.1	0.06	0.11	102	1.6
B22t	71-97		7.6	6.5	12.5	10.4	3.2	0.06	0.14	111	2.5
B23t	97-114		7.7	6.7	15.0	11.5	4.6	0.06	0.22	110	2.3
B3	114-142		7.9	6.6	17.6	14.2	5.2	0.06	0.11	113	2.9
C1	142-152		7.9	7.1	13.6	32.2	5.0	0.06	0.11	275	4.6

TABLE XXXIV

SELECTED CHEMICAL DATA ON SOILS OF CUSTER COUNTY

Horizon	Depth cm	% Organic Matter	pH		CEC	Meqs/100 gm				% Base Saturation	% $CaCO_3$ Equivalent
			H_2O	KCl		Ca	Mg	K	Na		
					----Minco----						
Ap1	0-23	1.4	7.5	5.9	11.5	8.4	2.1	0.37	0.17	95	1.7
A12	23-33	1.0	6.7	6.4	12.0	9.0	1.9	0.32	0.20	95	1.7
B1	33-48	0.9	7.6	6.6	12.4	10.3	2.3	0.37	0.20	106	1.8
B21	48-61		7.5	7.1	11.4	17.8	2.3	0.34	0.11	180	2.3
B22	61-81		7.9	7.2	11.4	21.1	2.6	0.40	0.11	211	2.8
B23ca	81-109		8.1	7.3	10.3	32.2	3.5	0.26	0.14	349	5.9
B24ca	109-142		7.9	7.3	10.3	31.4	3.2	0.32	0.11	339	6.6
C1	142-165		7.9	7.3	10.4	31.3	4.6	0.31	0.17	350	7.8
C2	165-188		8.1	7.4	10.1	32.4	5.2	0.32		377	7.0
					----Vanoss----						
Ap1	0-20	1.7	6.5	5.8	11.7	8.6	1.9	0.70	0.22	97	1.6
A12	20-33	1.5	6.6	5.8	15.0	10.4	2.9	0.35	0.06	92	3.1
B1	33-53	1.1	6.8	6.0	16.4	11.5	3.4	0.35	0.06	93	2.1
B21t	53-74		7.2	6.4	16.0	11.6	3.7	0.34	0.11	98	2.2
B22t	74-102		7.5	6.4	16.7	12.0	3.9	0.50	0.25	100	2.2
B23t	102-117		7.4	6.5	17.2	13.0	5.0	0.50	0.09	107	2.3
B24t	117-140		7.9	6.4	19.0	13.0	5.8	0.54	0.11	102	2.0
IIB21t	140-168		7.8	7.0	23.6	36.3	8.4	0.52	0.33	194	2.2
IIB22t	168-183		7.2	6.9	24.9	34.7	9.7	0.48	0.17	181	4.6

TABLE XXXV

SELECTED CHEMICAL DATA ON SOILS OF CADDO COUNTY

Horizon	Depth cm	% Organic Matter	pH		CEC	Meqs/100 gm				% Base Saturation	% $CaCO_3$ Equivalent
			H_2O	KCl		Ca	Mg	K	Na		
					----Minco----						
Ap1	0-15	1.5	5.8	5.1	10.0	6.0	1.8	0.71	0.11	85	2.5
A12	15-30	1.3	6.3	5.5	12.9	8.9	2.4	0.64	0.28	95	3.4
B21	30-64	1.0	6.8	5.9	13.0	9.2	2.5	0.61	0.26	97	2.8
B22	64-107		6.9	6.1	13.5	10.1	2.4	0.58	0.20	99	2.9
B23	107-147		6.4	5.4	16.3	12.2	3.9	0.55	0.27	92	2.3
B3	147-165		7.0	6.4	14.5	11.5	3.5	0.61	0.28	110	2.5
Cca	165-178		7.6	7.0	15.0	47.7	5.8	0.59	0.25	365	6.2
C2	178-216		7.8	7.1	15.0	46.9	5.5	0.66	0.25	356	4.8
					----Vanoss----						
Ap1	0-23	1.3	5.5	4.9	9.5	5.8	1.8	0.58	0.14	89	1.1
A12	23-33	1.3	6.1	5.2	12.4	8.0	2.5	0.68	0.22	93	1.3
B1	33-51	1.3	6.2	5.3	14.0	9.2	3.0	0.56	0.06	92	1.5
B21t	51-79		7.3	6.3	13.7	9.1	3.2	0.50	0.17	94	2.2
B22t	79-104		6.4	5.4	14.9	10.2	4.3	0.47	0.22	102	1.9
B3	104-127		6.3	5.4	18.5	12.4	5.1	0.68	0.25	101	2.3
C1	127-152		6.4	5.7	13.4	8.6	4.0	0.55	0.09	99	2.4
IIC2	152-168		6.5	5.7	10.4	6.1	2.8	0.47	0.22	92	1.9

TABLE XXXVI

SELECTED CHEMICAL DATA ON SOILS OF GRADY COUNTY

Horizon	Depth cm	% Organic Matter	pH H_2O	pH KCl	CEC	Meqs/100 gm Ca	Mg	K	Na	% Base Saturation	% $CaCO_3$ Equivalent
					----Minco----						
Ap1	0-18	0.9	6.1	5.4	7.9	6.3	1.1	0.51	0.11	102	1.5
A12	18-36	0.9	6.2	5.5	9.4	6.7	1.5	0.26	0.09	91	1.6
B1	36-51	0.9	6.4	5.5	14.0	6.9	1.8	0.12	0.13	44	1.9
B21	51-76		6.6	5.6	10.8	8.3	3.0	0.18	0.11	107	1.9
B22	76-102		6.7	5.9	12.1	9.6	1.6	0.29	0.11	99	2.4
B23	102-132		6.8	6.2	12.6	12.3	0.9	0.19	0.12	107	3.2
C1	132-152					31.5	2.1	0.22	0.17		6.4
C2	152-173		8.6	7.2	10.5	34.6	2.1	0.24	0.12	361	5.6
					----Vanoss----						
Ap1	0-18	1.5	6.1	5.3	15.9	9.1	2.9	0.42	0.11	79	2.6
A12	18-31	1.4	6.5	5.5	17.8	13.7	4.3	0.41	0.13	105	1.9
B21t	31-56	1.5	6.7	5.6	27.5	15.0	4.3	0.21	0.11	75	2.5
B22t	56-76		6.5	6.0	19.1	13.8	4.9	0.16	0.29	98	2.6
B23t	76-94		7.0	6.0	16.0	11.8	4.1	0.08	0.14	102	2.5
B3	94-114		6.9	6.0	17.9	12.2	4.6	0.10	0.17	95	2.2
C1	114-142		8.0	7.1	15.7	32.5	6.5	0.11	0.23	251	4.3
C2	142-163		7.9	7.2	14.8	33.0	3.6	0.13	0.20	250	4.4

TABLE XXXVII

SELECTED CHEMICAL DATA ON SOILS OF MCCLAIN COUNTY

Horizon	Depth cm	% Organic Matter	pH		CEC	Meqs/100 gm				% Base Saturation	% $CaCO_3$ Equivalent
			H_2O	KCl		Ca	Mg	K	Na		
					----Minco----						
Ap1	0-18	1.8	6.2	5.7	7.7	5.1	2.0	0.64	0.09	81	2.1
A12	18-33	1.4	6.5	5.6	10.9	7.2	2.2	0.38	0.11	90	2.1
B1	33-56	1.0	6.6	5.7	10.6	7.1	2.1	0.48	0.06	94	2.0
B21	56-91		6.6	5.7	9.5	7.1	1.7	0.20	0.06	96	3.8
B22	91-132		7.0	5.7	9.5	7.4	1.2	0.20	0.06	94	1.8
B23	132-158		6.6	5.9	10.1	8.1	1.5	0.26	0.09	99	3.2
B24	158-188		6.7	5.8	11.8	7.9	0.8	0.32	0.06	81	2.5
B3	188-203		6.8	5.9	11.8	9.5	2.1	0.34	0.28	103	1.7
C1	229-246		7.9	6.9	10.4	38.0	1.7	0.38	0.22	390	7.9
					----Vanoss----						
Ap1	0-20	1.7	5.5	4.7	18.1	7.2	2.1	0.29	0.22	54	2.1
A12	20-36	1.5	5.7	5.1	15.6	8.9	2.8		0.11	76	2.3
B1	36-56	1.1	5.9	5.2	13.9	9.0	2.5	0.26	0.06	86	2.4
B21	56-81		6.2	5.4	16.7	9.9	5.7	0.32	0.12	96	3.4
IIB21t	81-104		6.4	5.4	18.8	12.8	6.7	0.26	0.11	106	2.7
IIB22t	104-132		6.7	5.8	20.1	11.9	6.9	0.45	0.12	95	4.9
IIB23t	132-158		6.9	6.1	17.9	12.4	3.6	0.45	0.20	93	3.0
IIC1ca	158-170		7.9	6.9	18.0	23.0	6.1	0.51	0.21	166	3.7
IIC2ca	170-183		7.8	7.0	17.8	26.8	7.7	0.71	0.36	199	5.4

TABLE XXXVIII

SELECTED CHEMICAL DATA ON SOILS OF PONTOTOC COUNTY

Horizon	Depth cm	% Organic Matter	pH H_2O	pH KCl	CEC	Meqs/100 gm Ca	Meqs/100 gm Mg	Meqs/100 gm K	Meqs/100 gm Na	% Base Saturation	% $CaCO_3$ Equivalent
					----Vanoss----						
Ap1	0-25	2.0	6.6	5.7	8.4	7.2	1.0	0.26	0.19	102	1.9
B1	25-41	1.1	7.1	5.9	11.7	9.3	1.5	0.32	0.28	91	2.1
B21t	41-76	1.1	6.6	5.6	13.8	9.2	3.2	0.15	0.39	97	3.1
B22t	76-114		6.9	5.7	13.3	8.5	3.0	0.48	0.39	94	2.1
B23t	114-152		6.4	5.2	12.0	7.1	3.4	0.27	0.39	93	2.5
B3	152-229		5.9	4.7	12.3	7.3	2.6	0.38	0.22	86	3.0
C1	229-254		5.8	4.5	7.9	4.5	1.8	0.32	0.33	88	2.7

TABLE XXXIX

SELECTED CHEMICAL AND PHYSICAL DATA ON THE CLAY FRACTION OF SOILS OF ROGER MILLS COUNTY

Horizon	Depth cm	CEC	% K_2O	Surface Area, m^2/gm Total	External	Planar
		----Enterprise----				
Ap1	0-23	63.5	2.84	594	293	545
AC1	23-53	68.1	2.90	528	358	468
AC3	89-125	67.9	2.72	649	309	598
C2	152-178	66.2	2.83	594	362	534
C3	178-203	62.6	2.86	549	274	503
		----Holdredge----				
Ap1	0-20	61.8	2.45	484	267	438
B1	20-33	65.9	2.69	607	284	560
B22t	46-86	67.3	2.64	639	284	591
B3	86-107	63.5	2.51	577	258	534
C2	130-147	66.2	2.69	606	258	563

TABLE XXXX

SELECTED CHEMICAL AND PHYSICAL DATA ON THE CLAY FRACTION OF SOILS OF DEWEY COUNTY

Horizon	Depth cm	CEC	% K_2O	Surface Area, m^2/gm Total	External	Planar
		----Enterprise----				
Ap1	0-18	66.5	3.21	542	312	490
A12	18-33	61.1	3.26	358	277	312
AC2	51-89	65.5	3.02	481	293	432
AC3	89-112	66.6	2.66	471	248	430
C2	137-158	68.4	2.95	562	290	514
		----Holdredge----				
Ap1	0-20	51.6	3.40	500	267	456
A12	20-36	58.0	2.98	509	274	463
B22t	71-97	60.1	2.59	487	293	438
B23t	97-114	64.3	2.07	503	316	450
C1	142-152	67.1	2.53	507	248	466

TABLE XXXXI

SELECTED CHEMICAL AND PHYSICAL DATA ON THE CLAY FRACTION OF SOILS OF CUSTER COUNTY

Horizon	Depth cm	CEC	% K_2O	Surface Area, m^2/gm Total	External	Planar
			----Minco----			
Ap1	0-23	61.6	2.64	458	255	415
A12	23-33	64.4	3.0	517	358	457
B22	61-81	64.0	2.69	500	293	451
B24ca	109-142	65.8	2.71	600	306	549
C2	165-188	61.5	2.47	491	245	450
			----Vanoss----			
Ap1	0-20	54.5	3.29	481	251	439
A12	20-33	58.1	3.43	419	319	366
B21t	53-74	60.4	3.13	523	274	477
B24t	117-140	62.1	2.77	487	264	443
IIB22t	168-183	67.3	2.12	536	242	496

TABLE XXXXII

SELECTED CHEMICAL AND PHYSICAL DATA ON THE CLAY FRACTION OF SOILS OF CADDO COUNTY

Horizon	Depth cm	CEC	% K_2O	Surface Area, m^2/gm Total	External	Planar
			----Minco----			
Ap1	0-15	48.9	3.40	355	225	318
A12	15-30	57.5	3.18	552	326	514
B22	64-107	61.9	2.80	581	264	537
B23	107-148	56.9	2.47	509	287	471
Cca	165-178	65.0	2.48	548	248	507
C2	178-216	62.3	2.38	581	261	537
			----Vanoss----			
Ap1	0-23	46.4	3.24	397	268	352
A12	23-33	51.4	3.13	416	297	367
B21t	51-79	63.2	2.85	490	271	445
B3	104-127	63.6	2.17	536	271	491
C1	127-152	59.2	2.25	510	274	464

TABLE XXXXIII

SELECTED CHEMICAL AND PHYSICAL DATA ON THE CLAY FRACTION OF SOILS OF GRADY COUNTY

Horizon	Depth cm	CEC	% K_2O	Surface Area, m^2/gm Total	External	Planar
		----Minco----				
Ap1	0-18	53.4	3.25	455	261	412
A12	18-36	53.2	3.19	475	251	433
B21	51-76	54.3	2.71	478	255	435
B22	76-102	54.8	2.62	449	267	404
C2	152-173	53.5	2.66	478	274	432
		----Vanoss----				
Ap1	0-18	61.1	2.58	519	213	483
A12	18-31	54.8	2.22	458	200	425
B22t	56-76	73.3	1.87	446	229	408
B23t	76-94	72.7	2.14	419	281	372
C2	142-163	61.4	2.27	403	229	365

TABLE XXXXIV

SELECTED CHEMICAL AND PHYSICAL DATA ON THE CLAY FRACTION OF SOILS OF MCCLAIN COUNTY

Horizon	Depth cm	CEC	% K_2O	Surface Area, m^2/gm Total	External	Planar
		----Minco----				
Ap1	0-18	50.4	3.39	319	223	282
A12	18-33	53.1	3.19	429	225	386
B21	56-91	57.2	3.14	494	232	455
B22	91-132	58.6	2.85	500	280	453
B3	188-203	59.8	3.10	507	264	463
C1	229-246	57.6	3.06	416	248	375
		----Vanoss----				
Ap1	0-20	49.5	3.08	403	248	362
A12	20-36	55.1	2.64	432	248	391
B21	56-81	60.4	2.11	555	245	514
IIB22t	104-132	60.5	2.34	462	245	421
IIB23t	132-158	61.5	2.32	546	287	498
IIC2ca	170-183	60.1	2.52	543	277	497

TABLE XXXXV

SELECTED CHEMICAL AND PHYSICAL DATA ON THE CLAY FRACTION OF SOILS OF PONTOTOC COUNTY

Horizon	Depth cm	CEC	% K_2O	Surface Area, m^2/gm		
				Total	External	Planar
		----Vanoss----				
Ap1	0-25	47.4	2.89	348	229	310
B1	25-41	44.3	2.97	348	219	312
B22t	76-114	47.7	2.68	358	197	325
B3	152-175	49.2	2.42	284	174	255
C1	229-254	45.8	2.54	371	232	332

VITA

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