THE EFFECT OF CLIMATE ON THE GENESIS OF SOIL FORMED FROM GRANITE ACROSS OKLAHOMA

By

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CHAPTER I

INTRODUCTION

Soil is produced by the action of soil-forming processes on parent material deposited or accumulated by geologic agents (Soil Survey Staff, 1975). The characteristics of the soil at any given point in time are determined primarily by the physical and mineralogical composition of the parent material and the climate under which the soil material has accumulated and existed since accumulation.

Climate is a paramount factor in affecting chemical weathering (Loughnan, 1969). Precipitation and temperature are two major climatic parameters; the former controls the supply of water for chemical reactions and for leaching soluble constituents away from the weathering enviroment, and the latter influences the rate of these chemical reactions. Repeated leaching would hasten the weathering reactions towards completion (Jenny, 1941). The magnitude of climatic control on soil formation can best be seen by making comparisons that are global in scope (Boul et al. 1980).

The soil parent material provides the initial suite of minerals for soil clay formation. These initial minerals in turn influence soil mineralogy by their relative susceptibility to chemical weathering (Barshad, 1964).

Permeability of the parent material influences the rate of weathering by controlling the effectiveness of leaching, which in turn depends on precipitation and temperature (Birkeland, 1974; Barshad, 1964). Porous soils (for example, very sandy soils) tend to have more highly weathered clay fractions than soils of less porosity within similar enviroments (Brown and Jackson, 1958).

Primary minerals inherited from the parent rock make up the main part of the sand and silt fraction of most soils. For a given soil, the sedimentation history of the parent material determines the content of sand and the combined effect of weathering and sedimentation determines the content of silt (Barshad, 1964). The combined percentage of sand and silt in a given soil mainly governs the percentage of primary minerals in that soil. The most abundant soil minerals in the sand and silt fractions are quartz and feldspar.

According to Jackson and Sherman (1953), the tendency for specific mineral species to concentrate within specific size fractions is a function of their resistance to the intensity of weathering. Minerals which are more resistant to chemical weathering, such as members of the montmorillonite series, tend to persist in greater quantities in the finer clay fraction. Higher weathering susceptibility of less resistant minerals, such as feldspars and micas result in their extinction before they reach fine-clay dimensions.

The objectives of this study are i) to determine the secondary silicate weathering products formed under different climates and ii) to compare soil properties formed from granite rock across a range of climate.

CHAPTER II

LITERATURE REVIEW

Uniformity of Parent Material

A common test for uniformity of parent material is the constancy of a ratio of two resistant minerals in one or several size fractions (Brewer, 1964). General agreement is lacking as to what degree of departure in values constitute a definite discontinuity in parent material. The fact that some variations in ratios do occur with depth does not necessarily point to contrasting parent materials in a soil profile (Barshad, 1955). Variations may be due to the weathering of "stable" constituents (Brewer, 1968) or eluviation associated with soil formation (Barshad, 1955).

The use of resistant minerals to identify uniformity of a soil with depth is important in soil genesis studies to assess weathering potential and stratification. Resistant minerals such as zircon, anatase, and rutile do not undergo significant change during the course of soil formation, therefore, the ratio between them would remain undisturbed by weathering and leaching (Barshad, 1955; Haseman and Marshall, 1942). It is advantageous to select a particle size fraction containing the greatest quantity of the resistant minerals to be determined in order to minimize analytical error

(Chapman and Horn, 1968). It is also advantageous to select a particle-size fraction such as silt, which is suitable for examination and offers a means of confirming resistant mineral determinations by elemental analysis (i.e. Ti and Zr) (Barshad, 1955).

Another criterion for testing uniformity is the percentage sand and silt calculated on a clay free basis. This eliminates the clay distribution which is affected by soil formation (Barshad, 1955). On the basis of the percent silt, fine sand and very fine sand, it has been concluded that parent material is essentially uniform with depth and the lack of the slightest indication of a break with depth eliminates the possibility of stratified parent material (Rutledge and Horn, 1965).

The Effect of Climate on Soil Development

Climate is a paramount factor in affecting chemical weathering (Loughnan, 1969). Precipitation and air temperature are the two more important climatic factors; the former controls the supply of water for chemical reactions and for leaching soluble constituents away from the weathering zone, and the latter influences the rate of these soil chemical reactions (Jenny, 1941). The magnitude of climate control on soil formation can best be seen by making comparisons that are global in scope (Boul et al., 1980). The main soil properties that correlate with climate are organic matter content, clay content, kind of clay minerals, color, and the presence or absence of calcium carbonate (Birkeland, 1974).

Many soil properties show distinct trends with climate. These variations in the soils originate in such processes as organic matter decomposition, presence or absence of chelating agents, soil water chemistry, and the depth and rate of leaching of water through the soil. These processes are controlled by climate (Birkeland, 1974). These trends result in different types of soil orders which seem to fall within well defined climatic zones (Arkley, 1967).

Type and Formation of Clay Minerals

Determination of the kinds and relative amounts of clay minerals is essential to understand such soil physiochemical properties as shrink-swell potential, compaction, and cation exchange capacity. The knowledge of soil clay minerals is also needed for understanding the genesis and classification of soils. Soils with more than 35 percent clay content are classified into family clay mineralogy classes, according to Soil Taxonomy (Soil Survey Staff, 1975). Soils with less than 35 percent clay are classified according to their sand or total soil (<2.0 mm fraction) mineralogy.

Separation of the coarse and fine clay fractions are essential because of the tendency for specific colloidal mineral species to concentrate within specific size fractions which is a function of their resistance to weathering and intensity of weathering (Jackson and Sherman, 1953).

Minerals which are more resistant to chemical weathering such as members of the montmorillonite series, tend to persist in greater quantities in the finer clay fractions. Higher weathering susceptibility of minerals, such as the feldspars and micas, results in their extinction before they reach the fine-clay size (Jackson and Sherman, 1953).

The clay minerals in soils can orginate by different mechanisms : 1) inheritance from soil parent materials; 2) alteration and degradation of primary minerals such as biotite and feldspars; and 3) synthesis. These mechanisms, working under different enviromental conditions accompanied with the process of translocation in soils, make composition of clay minerals also a function of soil depth (Roozitalab and Gray, 1979).

In varying the climate from humid to semiarid, the soil clays are distributed from more to less kaolinitic and less to more montmorillonitic respectively (Gray et al., 1963; Roozitalab and Gray, 1979). Clay minerals of soil formed from granite tend to be highly kaolinitic in humid climates and vermiculitic, illitic and montmorillonitic in cooler or arid climates (Buol et al., 1980).

The type of clay mineral that forms in a soil solution mostly depends on the content of silica, the kind and concentration of cations present, the soil pH and the amount of leaching (Barshad, 1955).

Kaolinite is one of the most widespread clay minerals in soils. It is most abundant in soils of warm moist climates

(Dixon, 1966). Kaolinite is a 1:1 non-expanding layered silicate formed from equal concentrations of Al and Si with high hydronium concentration and essentiallly an absence of Mg and other bases (Weed, 1977). Soils containing large amounts of kaolinite are naturally acidic and infertile (Buol et al., 1980).

Illite (Hydrous mica) is a 2:1 non-expanding layered silicate, formed where mica is present in the initial material, under conditions of moderate to low hydronium concentration. Moderate to high concentration of Al and Si are required for stability (Weed, 1977).

Vermiculite is a 2:1 expanding layered silicate clay mineral found under a wide climate area, tropical, temperatures, in deserts and in areas of high rainfall (Douglas, 1965). Vermiculite is formed under moderate hydronium concentration such that K and Mg are completely removed from interlayers. Mica must be present as an initial material (Buol et al., 1980; Kittrick, 1973). Vermiculite is considered as a fast forming unstable intermediate of mica and montmorillonite (Kittrick, 1973).

Montmorillonite is a 2:1 expanding layered silicate formed from high ionic concentration of Si and Mg (Buol et al., 1980; Borchardt et al., 1968). Montmorillonite is stable in neutral, poorly drained enviroments and in soils where the leaching of Si and bases is slow (Borchardt et al., 1968).

Development of Soil Horizons

Introduction

The development of soil horizons are due to four general processes: 1) addition, 2) removal, 3) transformation, and 4) translocation (Simonson, 1959). These processes, which may offset or enhance horizon differentiation, operate in all soils, some are intensive under certain conditions and weak under others (Simonson, 1959).

Normally, the effect of soil forming processes can be recognized by studying the horizons of a soil profile (Hallsworth, 1965). The distinction between the horizons is based on properties produced by soil forming processes. These major properties include color, texture, consistence, bulk density and particle size distribution.

Difference in color

Difference in color exhibited in the soil profile may be the result of many specific pedogenic processes. Melanization, the process of darkening of soil by addition of organic matter, is considered the most pronounced means of profile differentiation during the early stages of development (Simonson, 1959). The darkening happens as a result of root extension into the soil profile. Roots which are partially decayed, produce relatively dark, stable compounds (Crompton, 1962). The dark soil material sometimes is carried deep into the profile by small living animals, or by falling of fresh organic material through cracks (Hole and Nielson, 1968).

Color differences in the soil profiles can be due to the change in the chemistry of Fe compounds. Oxidation, reduction and hydration of these compounds result in corresponding changes in color, or release of iron oxides (Brady, 1974). The red color of soils is generally related to unhydrated iron oxide and since it is relatively unstable under moist conditions, red color usually indicates good drainage and good aeration (Soil Survey Staff, 1975). The yellow colors are largely due to hydrated iron oxide and are found mainly in the B horizon. Yellow colors indicate a somewhat more moist soil climate and usually are found in deeper horizons (Soil Survey Staff, 1975).

Difference in Texture

Texture is the relative proportion of sand, silt and clay (the particle size groups smaller than 2 millimeters in diameter, based on USDA classification).

Chemical and physical weathering result in changing the nature of the parent material and therefore the texture of the soil. The products of weathering must either be synthesized to form new minerals or remain as a residue after other constituents are removed from a leaching zone (Jackson and Sherman, 1953). The sand and silt are made up of minerals released by the initial weathering or inherited from the parent material (Birkeland, 1974). The clay minerals are some of the resynthesized compounds and residues. They determine the most important physical and chemical properties of the soil (Crompton, 1962).

Considerable time is required for the soil forming factors to build up a significant amount of clay material (Jenny, 1941). The result of the soil forming factors is the difference in the amount of clay between the solum and parent material.

The clay which is formed in the solum is subject to eluviation and illuviation (Simonson, 1959). As a result, the clay is moved from one horizon within the soil profile and accumulated in another (Soil Survey Staff, 1975; Simonson, 1959).

Increased precipitation results in intensified chemical weathering and thus increased clay formation (Jenny and Leonard, 1934). An increase in clay content of the surface soil may lead to an increase in eluviation to the B horizon (Baver, 1934).

Several processes may account for higher clay content in the subsoil. One process suggests that the clay is derived from the weathering of materials in the A horizon and is precipitated in the B horizon by percolating water, this process combines transformation and translocation (Buol et al., 1980). A second process is that the clays are formed in place from minerals weathering in the B horizon; this process is called transformation (Birkeland, 1974). A third process suggests that clay accumulates by translocation into the B horizon because of flocculation and movement down small pores through which water perculates. The base of the B horizon marks the lower limit of most water movement (Birkeland, 1974; McKeague, 1969).

Texture is one of the more important characteristics of a soil profile. The variation in texture from horizon to horizon can be used to decipher the pedogenic and geologic history of the soil (Birkeland, 1974).

Difference in Structure

Soil structure involves the aggregation of individual soil particles into compound particles called peds. Clay and organic matter accumulate by transformation and translocation, and are responsible for binding soil separates together and developing structure (Baver, 1934). Soil structure is used to distinquish the B horizon from the C horizon, and therefore, is an indicator of soil development. This B to C depth is dependent on the depth of wetting and drying cycles over time.

Organic matter not only binds, but increases soil volume the soil, and therefore increases porosity. Organic matter incorporated by grass roots helps form granular type aggregates (Brady, 1974). Plant roots sometimes extending to considerable depths within the soil profile promote granulation by the addition of organic matter (decaying roots) and by the disruptive action of the roots as they move through the soil.

Wetting and drying produces aggregation as a result of unequal strains and stresses that are set up by shrinking and swelling processes together with the disruptive action of air entrapped in pores on wetting (Baver, 1934). Drying causes a cementation of the clay particles as the soil mass shrinks.

Soil Consistence

The resistance of soil materials to forces that tend to rupture the soil aggregates is called consistence (Weir, 1956). Moist consistence properties (loose, friable, firm, and hard) are a manifestation of water cohesion and adhesion. Both these surface phenomena are largely a function of the clay content in soils, but they depend as well on the organic matter content and on the structure of the soil. Organic matter and well developed structure, especially granular or crumb, encourage low, overall cohesion and adhesion in fine textured soils, and make them easier to work, as in cultivation (Hausenbuiller, 1972). Consistence is defined in separate terms for description at three standard moisture contents (dry, moist, and wet). It is unnecessary to describe consistence at all three standard moisture conditions according to Soil Taxonomy (Soil Survey Staff, 1975). The consistence when moist is the most commonly used terms and soil description with this omitted can hardly be regarded as complete (Soil Survey Staff, 1975).

Bulk Density

Bulk density is defined as the ratio of the mass of undisturbed dried soil to its total volume. Bulk density differences may be used to detect the presence of argillic horizons and to quantify their degree of development (Buol et al., 1980) and also to locate the lower boundary of the solum (Dawud and Gray, 1979). Because bulk density varies with the type, size and degree of structure in the soil, it is often correlated to soil structure (Blake, 1965).

Relatively low bulk density measurements are found in surface soils as a result of the relatively high organic matter content and porous granular-type structure. Bulk density increases with depth due to a decrease in organic matter content, and a subsequent reduced aggregation and reduced percentage of pore spaces (Dawud and Gray, 1979). Subsoil pore spaces are reduced as a result of clay movement and the formation of pore filling precipitates (Hausenbuiller, 1972).

Generally, bulk density values beneath the solum drop from near 2.65 g/cc (quartz) to less than 2.00 g/cc with physical and chemical weathering and the subsequent development of pore spaces (Buol et al., 1980).

CHAPTER III

MATERIALS AND METHODS

Field Sampling

This study specifically concentrates on the two principle factors of soil formation, climate and parent material. Therefore, in selecting sampling sites it was necessary to control the other major factors of soil formation; relief, vegetation, and time. Relief was controlled by selecting sampling sites within a 0 to 3% slope gradient. Vegetation was controlled by selecting sampling sites with native vegetation. This included forest type for sampling sites with Spavinaw, Tishomingo # 1, and Tishomingo # 2, and grass-savannah type for sampling sites Fort Sill, Mountain Park, and Granite. Without the advantage of absolute dates, time was controlled by sampling sites on upland areas which represented the maximum intensity of weathering in that location. One site, Spavinaw, was located on a terrace position because of the limited extent of granite in that area. The selection of sampling sites was aided by geological data on granite rock made available by the State Geological Survey. The modal analyses of granite from the Wichita granite group, characterized granite as fine grained, medium grained, and coarse grained with the medium and coarse grained having similar mineralogical composition and pharentic textures. The granite rock characteristics found at each sampling site are similar to the Wichita granite group. The mineral composition of a typical granite is 52.4-65.8% orthoclase-feldspar, 30-35.3% quartz, 0.3-2.3% horblende, 0.8-3.3% biotite, 2.0-6.1% albite, 0-0.4% microline, 0.2-1.8% magnetite, and traces of ribeckite (Han et al., 1964).

The soil samples for this study were collected from six pits located across an east-west transect in Oklahoma. Samples were taken from all soil horizons. Rock fragments from within the soil profile were taken for mineralogical analysis of granite. Bulk samples were screened to pass through a 7.6 and 1.9 cm mesh seives. In addition natural clods were collected and coated with Dow Saran S310 resin for laboratory bulk density determination. Profile descriptions, percent slope gradient, vegetation and location are reported in Appendix A.

Laboratory Analyses

Bulk Sample Preparation

The bulk samples collected from each horizon of all profiles were air dried under laboratory conditions, ground by hand and screened to pass through a 2.0 mm seive. The gravel fraction (>2.0 mm to <7.6 mm diameter) was weighed. Subsamples were taken from the bulk samples for analyses. All analyses made on samples were run in duplicate and average values reported.

Physical Analyses

Bulk Density of soil was determined by the clod method using Saran resin S310 to coat the natural soil clods (Brasher et al., 1966; Blake, 1965). Particle size analysis was done by the pipette method (Kilmer and Alexander, 1949) following the removal of organic matter and dispersion with Calgon (Kunze and Rich, 1959).

Mineralogical Analyses

The silt and clay fractions from the mechanical analysis were redispersed, the silt was allowed to settle out and the clay decanted. This process was repeated several times until the clay was removed. The clay from each horizon was then separated into coarse clay (2.0-0.2 micron) and fine clay (<0.2 micron) fractions using a Sharples Super Centrifuge as described by Whittig (1965). Following the removal of free iron oxide by the dithionite-citrate-bicarbonate method of Mehra and Jackson (1960), identification of clay minerals of both the coarse and fine clays were made on orientated ceramic slides. Ni-filtered Cu K-alpha radiation generated at 35kvp and 30ma on a Electric XRD-6 X-ray diffraction unit was used for clay determination after the following treatments:- 1) Ca-saturation, 2) Ca-saturation ethylene glycol-solvated, 3) K-saturation and 4) K-saturation and heating to 350 and 500 C (Whittig,1965).

The granite rock fragments were crushed into powder and mounted in a specially designed metal wedge described by Jefferies and Jackson (1949). Identification of granite mineralogy for the parent material at each site was done using Ni-filtered Cu K-alpha radiation on a Phillips Norelco diffraction unit operated at 35kvp and 30ma.

Profile uniformity was tested by particle size analysis and the ratio of the amount of Zr to the amount of Ti in each horizon. Zr and Ti standards were prepared using known amounts of Zr and Ti from U.S.G.S.rock standards of grandiorite, andesite, granite and basalt. Concentrations of Zr and Ti were expressed on an elemental weight basis. Soil samples were finely ground to pass a 0.05 mm seive and pressed into a pellet at 4 tons per square inch (Beavers, 1960). Determinations of Zr and Ti were made on a General Electric XRD-6 X-ray spectrograph unit operated at 50kvp and 45ma. Net counts were compared to a standard curve. Zr K-alpha radiation was counted over 3 replications for 10 seconds at 22.1 for the peak and 18.0 for the background. Likewise, Ti K-alpha radiation was counted over 3 replications for 10 seconds at 85.6 for the peak and 89.0 for the background. The 10 seconds counting time was sufficient to accumulate more than 10,000 counts at the peak position.

Chemical Analyses

The pH of each soil horizon was determined from a 1-1 soil water dilution and a 1-1 soil 1N KCL mixture using a

Beckman pH meter (Fields and Parrot, 1966). Organic carbon was determined using the potassium dichromate oxidation method described by Walkey (1946) and the "Van Bemmelen factor" of 1.724 was used to calculate percentage organic matter. Total exchangeable bases and acidity was determined using a modified automatic mechanical extractor technique (Peech, 1947). Cation exchange capacity (CEC) was determined by the sum of total extractable cations. Free iron oxide was removed from samples by the sodium citrate-sodium bicarbonate buffer method and determination was made colormetrically by the Bausch and Lomb Spectrometer 20 describe by Mehra and Jackson, (1960).

CHAPTER IV

RESULTS AND DISCUSSION

Field Morphology

Soil morphological data are given in Table I and Appendix A. Climatic data indicate that the sampling sites Spavinaw, Tishomingo # 1 and Tishomingo # 2 recieves total annual precipitation of 109, 99 and 99 cm with mean annual air temperature of 16, 16 and 16 C respectively, whereas Fort Sill, Mountain Park and Granite have total annual precipitation of 76, 66 and 61 cm, with mean annual air temperature of 20, 17 and 16 C respectively. Precipitation and air temperature are the major components of climate.

Soil depth, a measure of soil formation (thickness of the A, B, and C horizons) showed Spavinaw, Tishomingo # 1, and Tishomingo # 2 with profile depth to bedrock, whereas Fort Sill, Mountain Park, and Granite showed indefinite profile depth within the lithologic discontinuity. This indicate that the colluvial deposit in these three soils has influence soil depth.

Solum thickness comprises the A and B horizons. Solum thickness within the Mountain Park and Granite soils were similar ranging from 0-121 to 0-132 cm, respectively, which suggested that these soils may be weathering at a similar rate. These two soils also recieve similar amounts of annual precipitation; 66 and 61 cm, respectively. The remaining soils Spavinaw, Tishomingo # 1, Tishomingo # 2 and Fort Sill, have solum thickness of 0-66, 0-84, 0-114, and 0-79 cm, respectively. The soil solum thickness is an important characteristic because it reflects the pedochemical weathering (Soil Survey Staff, 1975). The soils under higher total annual precipitation were expected to have thicker solum than the soils under lower total annual precipitation because of increased, oxidation, reduction, hydration, solution, and hydrolysis in these soils. Mountain Park and Granite soils have thicker solums under a lower total annual precipitation. It is possible this may be due to alternate wetting and drying in these soils. These soils have a longer drying cycle, therefore the rapid intake of water causes unequal swelling throughout the clod, and produces fractures and fragmentation along the cleavage plains.

Soil structure (Table 1, Appendix A) was similar for all soils in the A horizon except for Tishomingo # 1 which has a weak coarse granular structure as compared to a weak, moderately strong medium subangular blocky structure for the other soils. The B horizon structures of Spavinaw, Tishomingo # 2 and Granite have weak, moderately strong coarse to medium subangular blocky structure compared to moderately strong coarse to medium subangular blocky structure for Tishomingo # 1, Fort Sill, and Mountain Park soils. The C horizons tend to be similar to the B horizons

TABLE I

SELECTED MORPHOLOGICAL PROPERTIES OF THE SIX SOILS STUDIED.

Horizon	Depth (cm)	Munsell color (moist)	Texture	Structure
		Spavinaw Soil		
A	0-10	7.5YR 3/2	grl	1msbk
E	10-23	5YR 3/4	grl	1msbk
BE	23-46	5YR 4/6	grl	1fsbk
B	46-66	5YR 5/8	grsl	1csbk
BC	66-91	7.5YR 7/6	grsl	1csbk
C	91-127	7.5YR 5/4	grls	1csbk
		Tishomingo # 1 Soil		
A	0-8	10YR 3/1	grsl	1cgr
E	8-20	10YR 4/2	grsl	1msbk
EB	20-33	10YR 4/4	grsl	1msbk
Bt21	33-46	2.5YR 3/6	grcl	2csbk
Bt22	46-84	2.5YR 4/6	grsc	2csbk
BC	84-112	2.5YR 4/6	grsl	1csbk
C	112-257	7.5YR 4/4	grls	1csbk
		Tishomingo # 2		
A	0-8	10YR 4/3	grl	2msbk
E1	8-20	7.5YR 5/4	grsl	1msbk
E2	20-41	7.5YR 5/6	grsl	1msbk
EB	41-56	7.5YR 5/8	grsl	1msbk
Bt2	56-114	5YR 5/8	grsl	1csbk
BC	114-155	7.5YR 5/6	grsl	ma
C1	155-185	7.5YR 5/4	grsl	ma
C2	185-215	7.5YR 5/6	grls	sg
		Fort Sill Soil		
A	0-18	7.5YR 3/2	grsl	2msbk
E	18-28	5YR 3/4	grsl	1msbk
Bt1	28-48	2.5YR 3/6	grc	2msbk
Bt2	48-79	2.5YR 3/6	grc	2csbk
CB	79-122	2.5YR 3/6	grscl	1csbk
C	122-160	10YR 7/8	grscl	1csbk
2C	160-188+	7.5YR 6/0	-	-

TABLE I (Continued)

Horizon	Depth (cm)	Munsell color (moist)	Texture	Structure
		Mountain Park Soil		
A	0-31	7.5YR 3/2	grl	2msbk
BA	31-58	7.5YR 3/4	grsl	1msbk
Bw1	58-81	7.5YR 5/6	grsl	2msbk
Bw2	81-121	7.5YR 4/6	grl	3csbk
Cg1	121-198	7.5YR 5/2	sicl	1csbk
Cg2	198-216+	7.5YR 4/2	cl	1csbk
		Granite Soil		
A	0-23	7.5YR 3/4	grl	1msbk
AB	23-53	7.5YR 3/4	grsl	1csbk
Bw1	53-81	5YR 4/6	grl	1csbk
Bw2	81-132	2.5YR 4/6	grsl	1csbk
BC	132-188	2.5YR 4/6	grsl	ma
C	188-216	7.5YR 5/6	grscl	ma
2C	216-254+	2.5YR 5/8	grcl	ma

Textural Code: c-clay, gr-gravelly, l-loam, s-sand, si-silt

Structural Code: 1-weak, 2-moderate, 3-strong, c-coarse, m-moderate, sbk-subangular blocky, ma-massive except for Tishomingo # 2 and Granite which have massive structures. The C horizon of Tishomingo # 2 consist mainly of granite saprolite with brown clay coatings within the cracks compared to more clay in the Granite C horizon. Also both soils have over 50% gravel and rock fragments in these horizons.

The soil structures showed no trend with precipitation, suggesting that wetting and long drying cycles in the western Oklahoma, is equivalent to the long wetting and short drying cycles in eastern Oklahoma.

Soil colors were dark brown (7.5YR 3/2) within the Spavinaw, Fort Sill and Mountain Park soils to very dark gray (10YR 3/1) within the Tishomingo # 1 in the A horizon and dark red (2.5YR 3/6) within the Tishomingo # 1 and Fort Sill soils to yellowish red (5YR 4/6) within the Spavinaw and Granite soils in the B horizon using the Munsell soil color chart. The C horizons were similar in color to the B horizons. The dark brown color of the A horizons are influenced by the organic matter content. The dark red to yellowish red colors in the B horizon are due to unhydrated iron oxide and hydrated iron oxides from parent material, primarily (Brady, 1974; Soil Survey Staff, 1975). The red color usually indicates good drainage, and aeration and that the soil has entered an advance stage of weathering (Soil Survey Staff, 1975). The yellow colors in the deeper horizons usually indicate a more moist soil climate than the red colors. There was no distinct trend with soil color in these soils suggesting that precipitation differences do not play a major role in soil color. Parent material seems to be the principle factor responsible for color in the B and C horizons and organic matter in the A horizons.

A significant clay illuviation (Figure 2) were observed in Tishomingo # 1, Tishomingo # 2 and Fort Sill profiles. Spavinaw soil (Figure 1) showed the lowest increase in clay of 13% in the B horizon. Tishomingo # 1 showed an abrupt increase in clay of 33% at the 46 cm depth of the Bt21 horizon as compared to Tishomingo # 2 which showed an increase in clay to 18% at 114 cm depth of the Bt2 horizon. Fort Sill also showed an abrupt increase to 29% clay at the 48 cm depth of the Bt1 horizon. The general shape of the curve (Figure 3) showed an increase in clay in the B horizon and decrease in the C horizon except for Mountain Park and Granite. The abrupt increase in clay and the presence of clay skins in Tishomingo # 1, Tishomingo # 2 and Fort Sill suggest that clay was translocated in these soils. Comparing soils in eastern Oklahoma with soils in western Oklahoma, it is suggested that there is a definite trend of clay movement with depth west to east. This is likely due to the higher total annual precipitation in the east.

Physical Properties

Soil physical analyses data are given in Appendix B. Bulk density values were calculated including rock fragments. Bulk density values in the A horizon show Spavinaw soil with

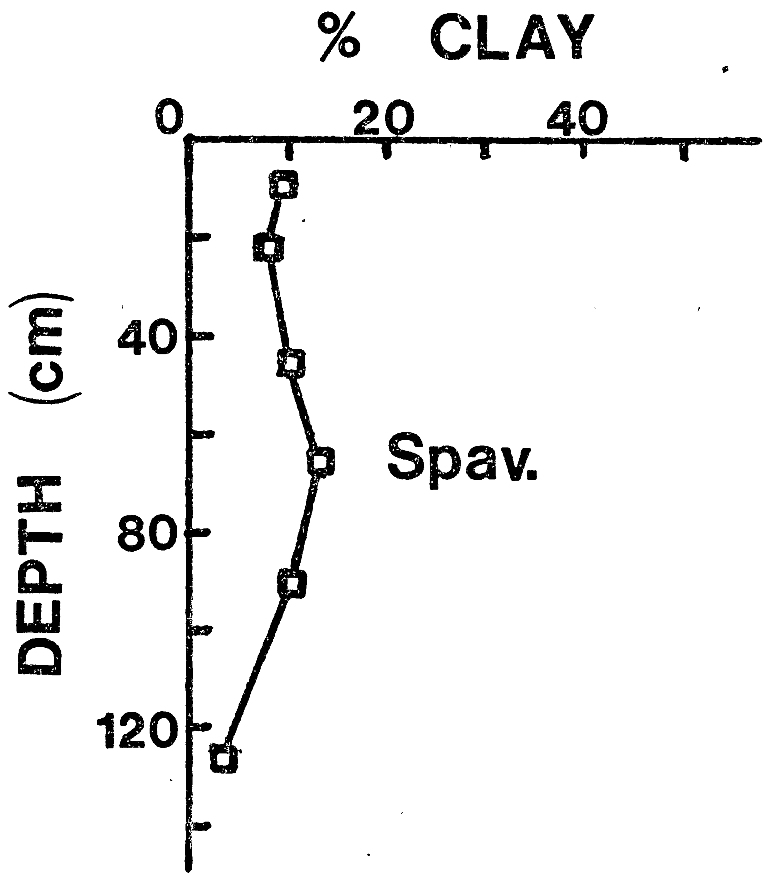

Figure 1. Percentage clay with depth for Spavinaw (Spav.) soil.

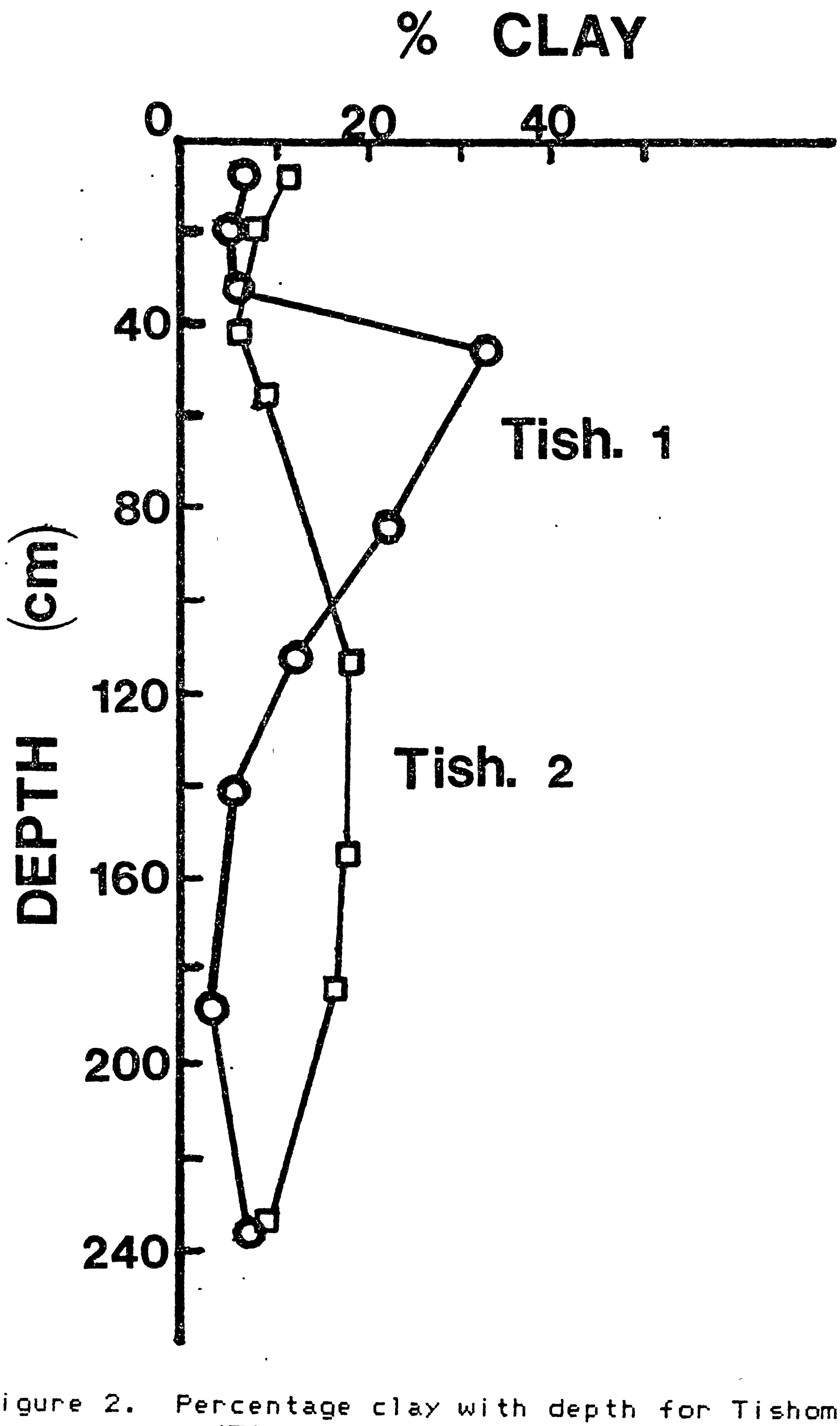

Figure 2. Percentage clay with depth for Tishomingo # 1 (Tish. 1) and Tishomingo # 2 (Tish. 2) soils.

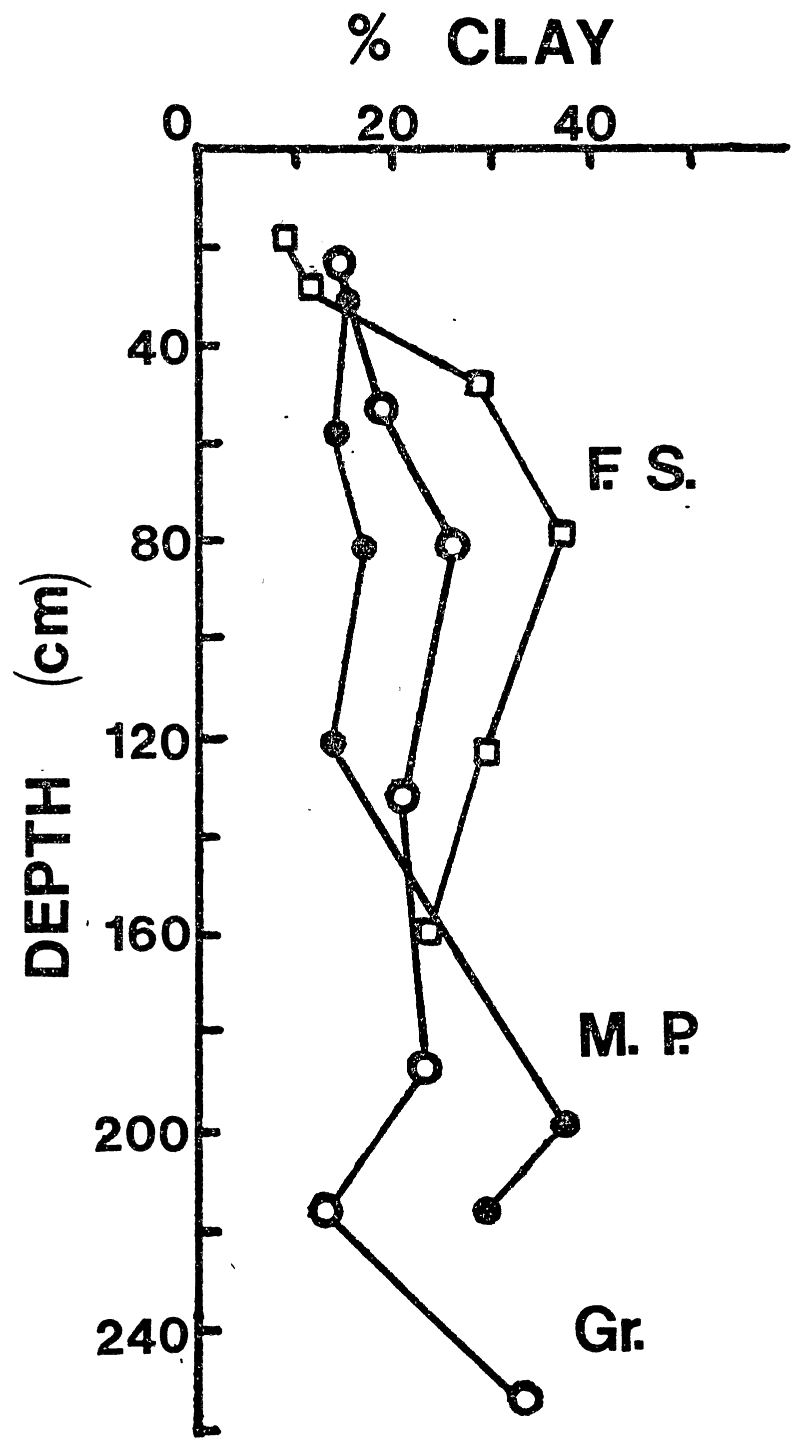

Figure 3. Percentage clay with depth for Fort Sill (F.S.), Mountain Park (M.P) and Granite (Gr.) soils.

the lowest value of 1.53 gms/cc and Mountain Park soil with the highest value of 1.70 gms/cc. These values correlate with the 4.9% organic matter in the A horizon within the Spavinaw soil as compared to 2.9% in the same horizon within the Mountain Park soil. The varying amounts of rock fragment gravel in the solum of all soils resulted in varying bulk density values in the solum while the C horizon has showed the highest bulk density value in all soils. There was no definite trend with bulk density values for the soils except depth.

Particle size distribution (Appendix B) shows an increase in the amount of total clay in the B horizon of Tishomingo # 1, Tishomingo # 2 and Fort Sill soils. This increase was mentioned in the previous section. The sand content was high in all soils with the exception of Mountain Park and Granite having only 18 to 28% in the C horizon. This is a result of the lithologic discontinuities in these profiles. The relatively high sand content, and the gravel nature of these soils are typical for granite soils (Buol et al., 1980; Goss and Allen, 1968). Soils having higher total annual precipitation have more clay movement in the B horizon and higher sand content in the A and B horizons, suggesting more weathering in these soils.

Chemical Properties

Chemical analyses data are given in Appendix C. Results indicate that the soils are more acidic in Spavinaw, Tishomingo # 1 and Tishomingo # 2 soils with total annual precipitation of more than 96 cm, and less acidic to neutral in Fort Sill, Mountain Park and Granite soils with less than 79 cm total annual precipitation. Spavinaw soil has the lowest pH value of 4.7 in the BC horizon as compared to 7.1 in the BC horizon of Granite soil. The difference of 2.4 in pH in these soils, is a result of higher leaching with the higher precipitation in the Spavinaw soil. This is an expected trend where soils become less acid with decreased precipitation.

Base saturation values (Figure 4, 5, and 6)) ranged from 18% in the E horizon of Spavinaw soil to 83 percent in the C horizon of Granite soil. The low base saturation in Spavinaw soil of 18 to 37% is a result of the leaching resulting from the coarse texture and higher precipitation (Boul et al., 1980). Likewise soils from within areas of low total annual precipitation of <71 cm have base saturation values as high as 83% as shown for the Granite soil. This result shows definite correlation between base saturation and precipitation as expected.

Calcium and magnesium were the major extractible cations from these soils (Appendix C). Extractable cations indicate that calcium is dominant in the solum of all soils, ranging from 0.82 meq/100g in the Spavinaw soil to 4.09 meq/100g in the Fort Sill soil. Magnesium and calcium were dominant in the C horizon, ranging from 0.97 meq/100g in the Fort Sill soil to 6.89 meq/100g in the Tishomingo # 2 soil. The low

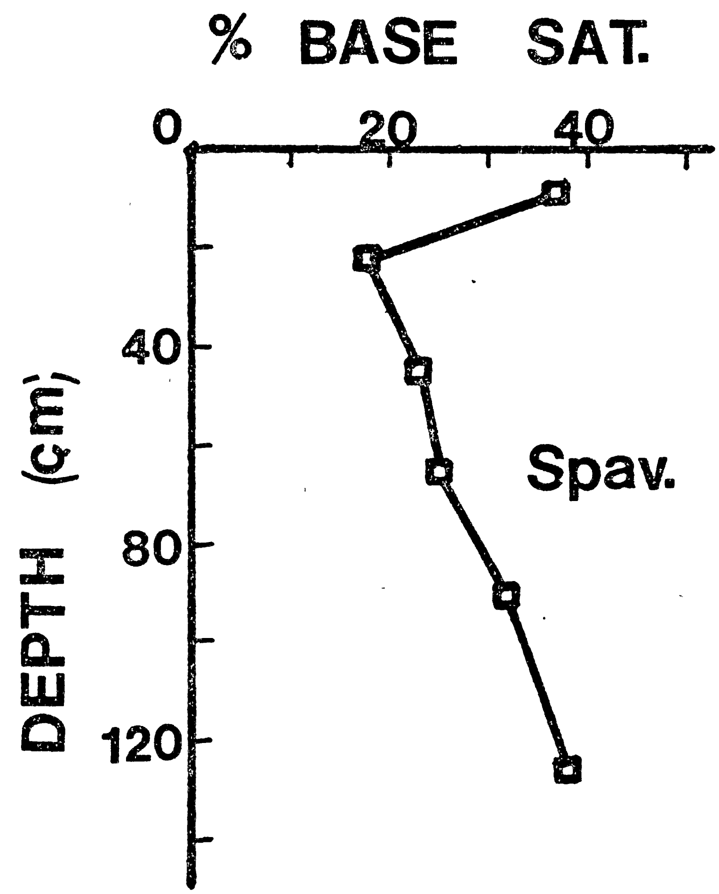

Figure 4. Percentage base saturation with depth for Spavinaw (Spav.) soil.

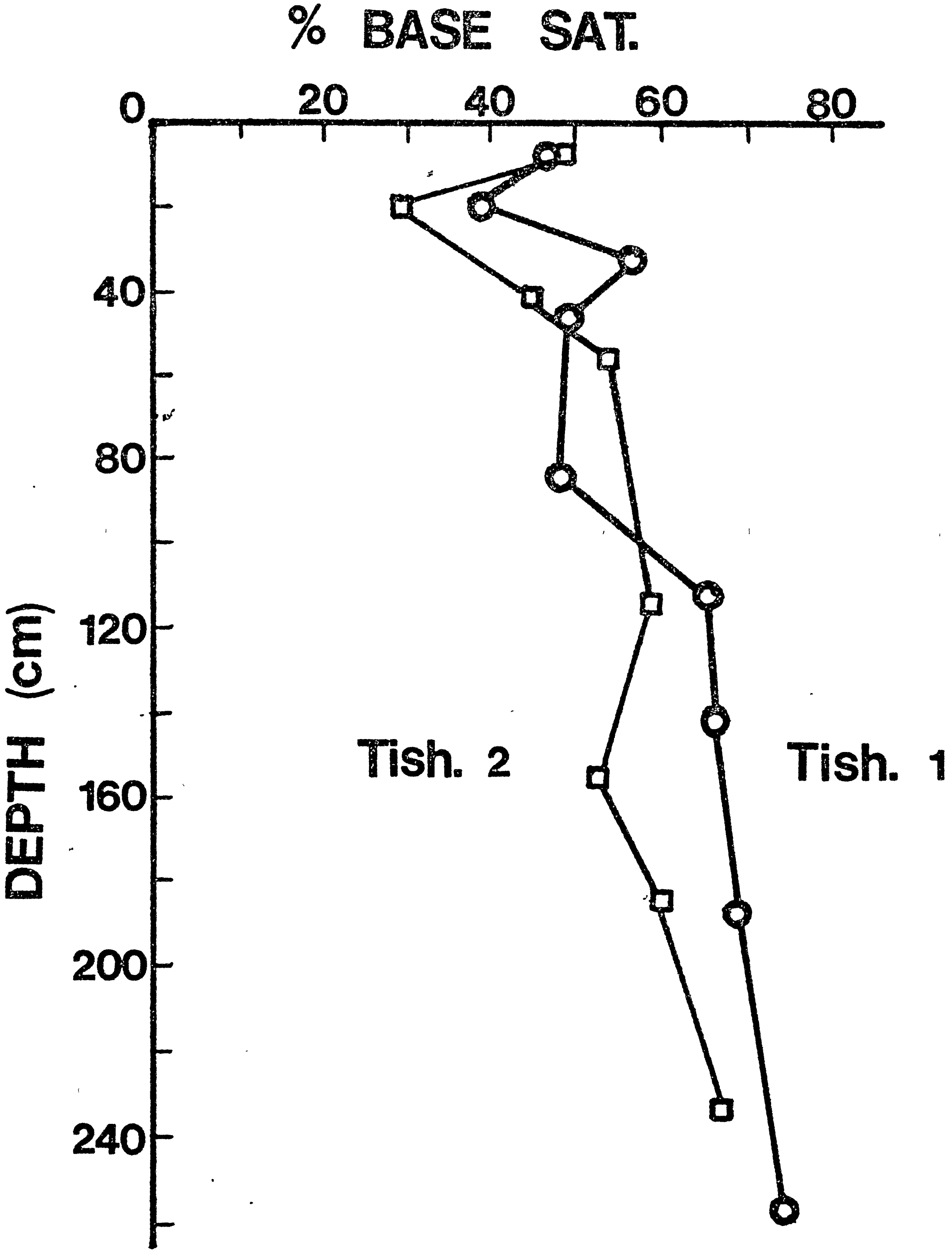

Figure 5. Percentage base saturation with depth for Tishomingo # 1 (Tish. 1) and Tishomingo # 2 (Tish. 2) soils.

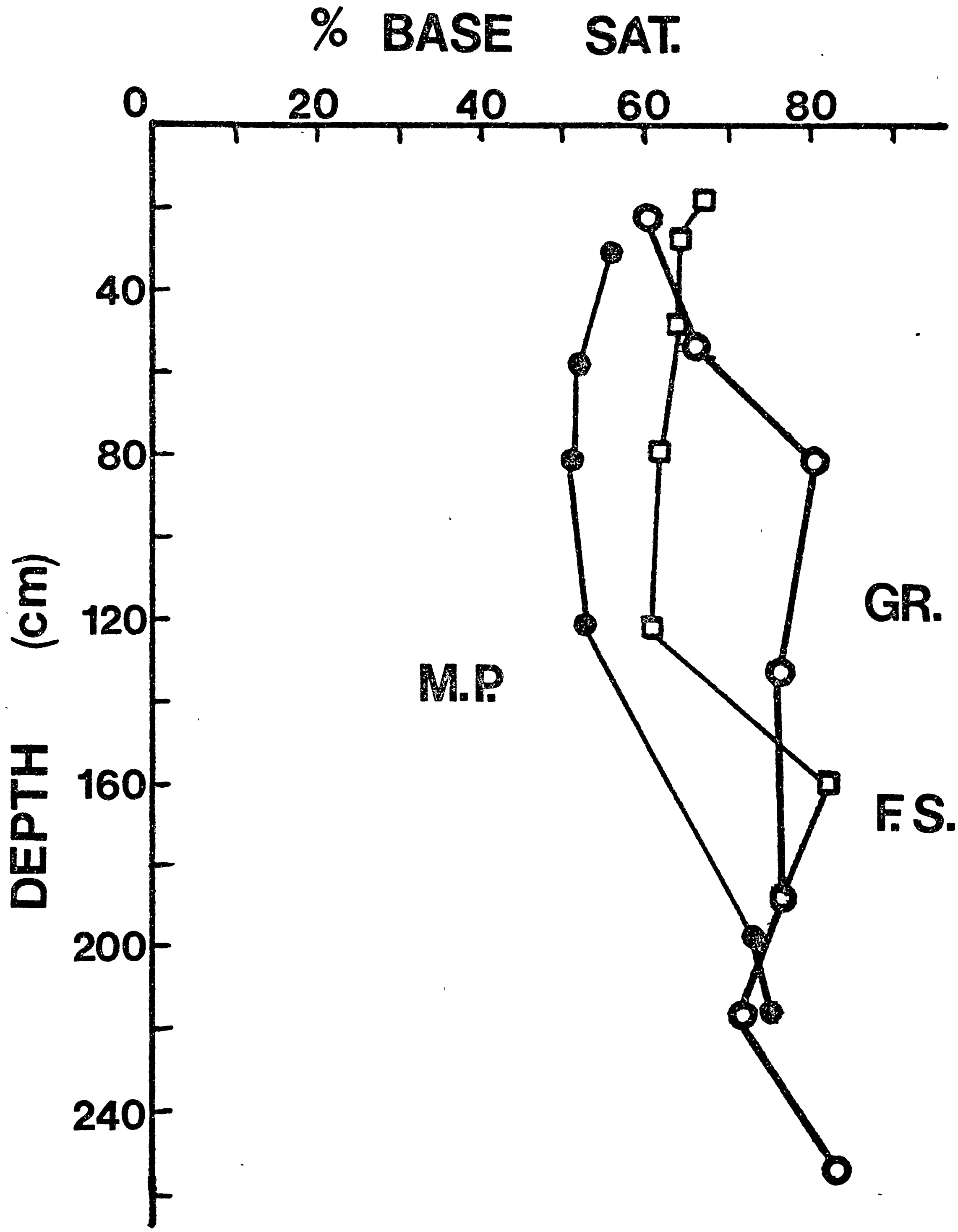

Figure 6. Percentage base saturation with depth for Fort Sill (F.S.), Mountain Park (M.P.) and Granite (Gr.) soils.

extractable cations is primarily the result of the high exchange acidity in these soils, especially soils that are subjected to high leaching.

The cation exchange capacity (CEC) ranged from 3.42 meq/100g in the 3R horizon of the Fort Sill soil to 21.13 meq/100g in Mountain Park soil. The highest values were found in the illuviated B horizons which suggested that the amount of clay and organic matter affects the CEC. Extractible cations tend to increase with depth in all profiles especially in the eastern soils, suggesting that leaching and weathering intensities are higher than for the western soils.

Organic matter content decreased with depth in all soils. Highest values ranged from 1.2 to 4.6% in the A horizon of the Fort Sill and Spavinaw soils, respectively. Soils under a forest type vegetation had more organic matter at the surface and less in the subsurface unlike soils under grass type vegetation which have a deeper organic matter incorporation. The high organic matter content in the eastern soils (4.4% in the A horizon of the Tishomingo # 1 soil and 4.6% in the A horizon of the Spavinaw soil) suggested that with an increase in total annual precipitation in these soil, organic matter is decomposing faster than that of the western soils. The western soils have organic matter values ranging from 1.2% in the A horizon of Fort Sill soil to 2.9% in the A horizon of Mountain Park soil.

Clay Mineralogy

Spavinaw Soil

The coarse clay fraction of the A horizon of the Spavinaw soil (Table II), indicates the dominance of Kaolinite with lesser amounts of illite, and montmorillonite. This trend changes in the B and C horizons with more montmorillonite and illite than Kaolinite. Interstratified Kaolinite and montmorillonite was also identified in the B horizon by a 8.0 A peak. The increase in montmorillonite in the B horizon suggested that since most of the weathering occurs in the A horizon, montmorillonite has translocate from the A horizon into the B horizon. This support the work of Roozitalab and Gray, (1979); Gray et al., (1963). The increase in montmorillonite with depth is evidence of extensive weathering in this profile and that most of the illite has weathered to montmorillonite which is more resistant (Roozitalab and Gray, 1963). In the fine clay fraction Kaolinite was the most abundant clay mineral in the A horizon, montmorillonite in the B horizon and Kaolinite in the C horizon. The dominance of illite in the fine clay of the A horizon and montmorillonite in the B horizon maybe due to the displacement of interlayer-K in illite and thus the formation of expansible clay minerals.

It is suspected that as weathering continues in the A horizon of Spavinaw soil montmorillonite formation would increase in the B and C horizon, with less illite because

TABLE II

CLAY MINERALOGY OF THE SIX SOILS FORMED FROM GRANITE

Horizon	Parent Material	X-ray Diffraction coarse clay (2-0.2u)	X-ray Diffraction fine clay (<0.2u)
		Spavinaw Soil	
E	granite/	Q(K I M)	Q(K I)
B	residium	Q(K M I)	M(Q K I)
C		Q(K M I)	Q(K)
		Tishomingo # 1 Soil	
E	granite/	K(Q I M)	Q(K M I)
B	residium	K(Q I M V)	K(Q I)
C		K(Q I M V)	Q(K I M)
		Tishomingo # 2 Soil	
E	granite/	Q(K I M)	Q(K I)
B	residium	Q(K I M V)	Q(K I M)
C		K(Q I M V)	Q(K I M)
		Fort Sill Soil	
A	granite/	Q(I K M)	Q(I)
B	colluvium	Q(K I M V)	Q(IM)
C		K(Q I M V)	Q(M K I)
		Mountain Park	
A	granite/	Q(K I M V)	Q
B	colluvium	Q(K I M V)	Q
C		M(Q K I)	Q(M)
		Granite	
A	granite/	Q(I K V M)	Q(I)
B	colluvium	Q(I K V M)	Q(I)
C		Q(I K V M)	Q(I)

*Mineral code: Q-quartz, K-kaolinite, I-illite, M-montmorillonite, V-vermiculite. Dominant minerals present are outside parentheses. Other minerals present are enclosed by parentheses and are listed in declining order.

illite will weather to montmorillonite (Roozitalab and Gray, 1979).

Tishomingo # 1 and # 2 soils

These two soils experience 99 cm total annual precipitation compared to 61 to 76 cm in Mountain Park, Granite and Fort Sill soils. This increase precipitation and relatively high base saturation resulted in Kaolinite formation as compared to illite in the other soils.

In the coarse clay fraction of these two soils (Table I), Kaolinite was the most abundant clay mineral in the A, B,and C horizons. This trend was followed by illite, montmorillonite and vermiculite, respectively. Montmorillonite increases with depth in both profiles also interstratified montmorillonite and Kaolinite were indentified in the B horizon by a 8.0 A peak of the Tishomingo # 2 soil.

In the fine clay fractions, Kaolinite was the most dominant clay mineral, followed in sequence by illite, montmorillonite and vermiculite in the A horizon. The trend with depth was similar to that of the coarse clay fraction which does not coincide with montmorillonite dominance, stated by Roozitalab and Gray (1963 and 1979).

The argillic horizon of Tishomingo # 1, Tishomingo # 2, and Fort Sill suggest that these soils are more developed than the other three soils.

Fort Sill, Mountain Park and Granite Soils

These three soils experience 61 to 76 cm total annual precipitation compared to 99 to 109 cm for the other soils. The reduction in precipitation and the increase in base saturation result in an increased in illite content.

In the coarse clay fractions of the A and B horizons, kaolinite and illite were the most dominant clay minerals with lesser amounts of montmorillonite and vermiculite. Interstratified montmorillonite and kaolinite at 8.0 peak was identified in the C horizon of Fort Sill soil.

The cambic horizons of Granite and Mountain Park suggested that these soils are younger than the other four soils. Clay illuviation is lower in these soils, most of the clay present seems to have been reprecipitated.

Uniformity of Parent Material

Titanium Zirconium Ratio

In applying the criterion of constant ratios in this attempt to determine the presence or absence of interbedded parent material in the six soils studied, it is useful to consider data obtained from the analysis of the Fort Sill, Mountain Park and Granite soils (Table III). These soils have a profile whose C horizons are believed from the data, to consist of colluvium which in turn overlies the granite. The ratios obtained should reflect this lithologic discontinuity. There is a 6.3 and 58.6 difference in the

TABLE III

TITANIUM AND ZIRCONIUM RATIOS AND DISTRIBUTION OF THE SAND, SILT AND SOIL OF THE SIX SOILS STUDIED

Horizon	Depth (cm)	Titanium/Zirconium Sand	Silt ratios	Soil
	Spavinaw Soil			
A	0-10	25.1	9.6	14.1
E	10-23	26.1	10.1	14.3
BE	23-46	29.7	9.4	14.8
B	46-66	23.5	9.4	15.2
BC	66-91	27.5	13.1	18.4
C	91-121	29.3	9.1	16.9
	Tishomingo # 1 Soil			
A	0-8	12.6	7.6	10.5
E	8-20	12.0	7.9	11.2
EB	20-33	13.0	7.3	10.8
Bt21	33-46	18.3	12.2	27.2
Bt22	46-84	30.5	27.3	38.2
BC	84-112	50.7	52.4	39.4
C1	112-142	52.9	54.3	37.1
C2	142-188	50.6	50.5	43.3
C3	188-257	57.1	-	43.3
	Tishomingo # 2 Soil			
A	0-8	8.9	4.5	6.4
E1	8-20	7.1	5.2	6.9
E2	20-41	10.2	6.3	8.8
EB	41-56	8.7	7.2	10.0
Bt2	56-114	18.4	24.6	18.1
BC	114-155	20.3	17.4	18.5
C1	155-185	38.1	9.7	18.9
C2	185-234	33.2	-	20.5
	Fort Sill Soil			
A	0-18	3.8	3.4	4.2
E	18-28	2.7	2.3	4.9
Bt1	28-48	3.6	5.7	8.1
Bt2	48-79	3.1	2.3	9.0
CB	79-122	3.0	3.8	8.5
C	122-160+	2.3	4.5	8.3

TABLE III (Continued)

Horizon	Depth (cm)	Titanium/Zerconium Sand	Silt ratios	Soil
		Mountain Park Soil		
A	0-31	28.1	3.9	10.3
BA	31-58	14.3	5.0	8.4
Bw1	58-81	14.5	4.7	10.3
Bw2	81-121	25.4	4.9	10.7
Cg1	121-198	83.6	11.2	14.6
Cg2	198-216+	66.9	13.5	15.8
		Granite Soil		
A	0-23	2.2	3.5	4.9
AB	23-53	1.8	3.8	5.6
Bw1	53-81	2.6	3.8	7.5
Bw2	81-132	3.1	4.5	6.4
BC	132-188	2.1	4.3	6.0
C	188-216	0.5	5.3	6.1
2C	216-254+	0.7	-	10.8

ratio of the silt and sand fractions, respectively, between the Bw2 and the Cg1 horizon of Mountain Park soil.

In applying this criterion to the other three soils in this study, it was apparent that variations do occur between horizons, especially in the Tishomingo soils (Table III) between the B and C, (however these variations maybe due to a difference in mineralogy of the parent materials prior to inception of soil formation and eluviation and illuviation processes or the weathering of Ti minerals).

Clay Free Sand and Silt Percentages

Clay free silt (Table IV), indicates that the six soil profiles are uniform with depth, however, silt content is low due to the the sandy nature of soils, typical of soils formed from granite (Boul et al. 1980).

Sand (medium, fine, and coarse) calculated on a clay free basis was also used as a test for uniformity. This indicated a trend similar to that of clay-free silt.

The results obtained from these data suggested that during the early stage of development of Fort Sill, Mountain Park and Granite soils, some material originating from higher locations have moved downslope on these soils.

Mineralogy of Parent Rock

Mineralogical studies on granite in Oklahoma reported by Han et al.(1964) include contents of orthoclase feldspar, quartz, iron oxides, biotite, hornblende, microcline, and

TABLE IV

PARTICLE SIZE DISTRIBUTION ON A CLAY FREE BASIS AS TESTS FOR UNIFORMITY OF PARENT MATERIALS

Horizon	Depth (cm)	Percent (clay-free basis) Sand	Silt
	Spavinaw Soil		
A	0-10	54	46
E	10-23	52	48
BE	23-46	47	53
B	46-66	63	37
BC	66-91	73	27
C	91-121	86	14
	Tishomingo # 1 Soil		
A	0-8	66	34
E	8-20	76	24
EB	20-33	79	21
Bt21	33-46	66	34
Bt22	46-84	66	34
BC	84-112	83	17
C1	112-142	82	18
C2	142-188	80	20
C3	188-257	88	12
	Tishomingo # 2 Soil		
A	0-8	56	44
E1	8-20	64	36
E2	20-41	58	42
EB	41-56	61	39
Bt2	56-114	69	31
BC	114-155	64	36
C1	155-185	80	20
C2	185-234	90	10
	Fort Sill Soil		
A	0-18	64	36
E	18-28	69	31
Bt1	28-48	59	41
Bt2	48-79	61	39
CB	79-122	83	17
C	122-160+	79	21

TABLE IV (Continued)

Horizon	Depth (cm)	Percent (clay-free basis) Sand	Silt
		Mountain Park Soil	
A	0-31	50	50
BA	31-58	72	28
Bw1	58-81	69	31
Bw2	81-121	56	44
Cg1	121-198	29	71
Cg2	198-216+	39	61
		Granite Soil	
A	0-23	63	37
AB	23-53	67	33
Bw1	53-81	61	39
Bw2	81-132	71	29
BC	132-188	67	33
C	188-216	71	29
2C	216-254+	34	66

albite.

X-ray analysis was use to test wheather or not all the unweathered rock samples taken from within the soil profile was of similar mineral content, particularly primary minerals. The results seen in Table V indicated a high quartz and orthoclase feldspar content for each rock. Other identifiable minerals included microcline, albite, hornblende, calcite and siderite. It is therefore concluded that all the parent materials have similar minerals.

TABLE V

X-RAY MINERALOGY OF THE SIX GRANITE ROCKS

Rock	Minerals
Spavinaw	Q (M, Of, A, H, C, S)
Tishomingo # 1	Q (Of, M, A, H, C,)
Tishomingo # 2	Q (Of, A, M, C, H)
Fort Sill	Q (Of, M, A, C, H)
Mountain Park	Q (Of, M, A, C, H)
Granite	Q (Of, M, A, C, H)

*Mineral Code: Q-quartz, M-microcline, Of-orthoclase Feldspar, C-calcite, H-hornblende, S-siderite. Dominant minerals present are outside parentheses. Other minerals present are enclosed by parentheses and are listed in declining order.

CHAPTER V

SUMMARY AND CONCLUSION

In reviewing the morphological, chemical, physical and mineralogical data obtained from the six soils derived from granite, it was evident that climate has a significant influence on soil development. Field evidence indicated soils formed from granite are extremely gravelly regardless of the annual precipitation, because of the high weather resistant quartz content (>40%) of the parent material.

Clay illuviation was prominent in Tishomingo # 1, Tishomingo # 2 and Fort Sill soils with Mountain Park and Granite having a cambic B horizon. The presence of an argillic horizon in Tishomingo # 1, Tishomingo # 2, and Fort Sill soils suggested that these soils are further developed than the other soils. This is accompanied by a higher total annual precipitation for these sites. Spavinaw soil, although having 109 cm total annual precipitation, did not have an argillic horizon but did show signs of clay illuviation. In addition this soil was located on a high upland terrace. Therefore, it was concluded that the Spavinaw soil did not reflect maximum weathering as in the other sites.

Percentage base saturation was higher for soils located in western Oklahoma compared to soils located in eastern Oklahoma. Total annual precipitation in western Oklahoma ranges from 79 cm in Fort Sill soil to 66 cm in Granite soil compared with 107 cm in Spavinaw soil to 96 cm in the Tishomingo soils. As a result of the difference in precipitation, soils in eastern Oklahoma have a higher rate of leaching, are more acid and have lower base saturation. Soils located in western Oklahoma, due to less precipitation, are slightly acidic to neutral and have higher base saturation. It was concluded that differences in precipitation have an effect on the chemical properties of the soils within the transect.

In varying the climate from humid to subhumid, the soil clay distribution changes from more kaolinite in the alfisols to illite and montmorillonite in the inceptisols. The Spavinaw soil did not show this trend because of the terrace position of this sampling site, suggesting that this soil does not represent the maximum intensity of weathering in that location. Kaolinite was dominant in both the fine and coarse clay fractions of the alfisols with increase montmorillonite with depth. This was an expected trend since these soils have a high total annual precipitation and a relatively high base saturation which are conditions suitable for kaolinite formation. Montmorillonite seemed to be unstable in these alfisols because of the high precipitation and high leaching that these soils experience. In the inceptisols illite was dominant in the coarse clay fraction with lesser amounts of Kaolinite and montmorillonite. The high base saturation, lower precipitation and reduced leaching seem to favor the formation of illite in these soils.

Heavy mineral studies, established the overall homogeneity of the minerals from which the soils have developed; however, it is possible that during the early stage of development that some material originating from higher locations has moved downslope on the Fort Sill, Mountain Park and Granite soils.

X-ray diffraction showed that all the parent materials have similar minerals. This included, quartz and feldspars as primary mineral dominance. Therefore it was concluded that variations between the eastern and western sites is primarily due to precipitation and not parent material.

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APPENDIXES

APPENDIX A

PROFILE DISCRIPTIONS

Profile Discriptions

Soil: Spavinaw

Location: Mayes County

Slope: 0-3 percent

Parent Material: Granite/Residium

Climate: Humid with mean annual precipitation of 109 cm and mean annual temperature of 16 C

Vegetation: Forest with an understory of grasses

Soil Classification: Coarse, mixed, thermic Typic Ustochrepts

Soil Profile:

Horizon	Depth (cm)	Description (colors are for moist soil)
A	0-10	Dark brown (7.5YR 3/2) gravelly loam; weak coarse granular to weak medium subangular blocky structure; friable; many fine and medium roots; more than 15 percent gravel by volume; 30 percent rock fragments; pH 5.8; clear smooth boundary.
E	10-23	Dark reddish brown (5YR 3/4) gravelly loam; weak to moderately strong subangular blocky structure; very friable many fine and medium roots; 10 percent gravel by volume; 35 percent rock fragments; pH 4.9; clear smooth boundary.
BE	23-46	Yellowish red (5YR 4/6) gravelly loam; weak fine subangular blocky structure; friable; many fine and medium roots; 15 percent gravel by volume; 30 percent rock fragments; pH 4.9; clear smooth boundary.
B	46-66	Yellowish red (5YR 5/8) gravelly sandy loam; weak coarse subangular blocky structure; friable to firm; many fine roots; 20 percent gravel by volume; 20 percent rock fragments; pH 4.8; abrupt smooth boundary.

BC	66-91	Reddish yellow (7.5YR 7/6) gravelly sandy loam; weak coarse subangular blocky structure; friable to firm; few roots; 20 percent gravel by volume; 35 percent rock fragments; pH 4.7; clear smooth boundary.
C	91-127	Red (2.5YR 4/6) gravelly loamy sand; weak coarse subangular blocky structure; friable; few roots; 25 percent gravel by volume; 65 percent rock fragments; pH 5.1.

Soil: Tishomingo # 1

Location: Johnson County

Slope: 1-3 percent

Parent Material: Granite/Residium

Climate: Dry subhumid with mean annual precipitation of 99 cm and mean annual temperature of 16 C

Vegetation: Forest with an understory of grasses

Soil Classification: Fine, mixed, thermic Udic Paleustalfs

Soil Profile

Horizon	Depth (cm)	Description (colors are for moist soil)
A	0-8	Very dark gray (10YR 3/1) gravelly sandy loam; weak coarse granular structure; loose; many fine and medium root; 10 percent gravel by volume; 15 percent rock fragments; pH 5.8; clear smooth boundary.
E	8-20	Dark brown (10YR 4/2) gravelly sandy loam; weak medium subangular blocky structure; very friable; many fine and medium roots; 10 percent gravel by volume; 20 percent rock fragments; pH 5.7; gradual smooth boundary.
EB	20-33	Dark brown (10YR 4/4)gravelly sandy loam; weak medium subangular blocky structure; very friable; roots are common; 15 percent gravel by volume; 20 percent rock fragments; pH 6.1; abrupt smooth boundary.
Bt21	33-46	Dark red (2.5YR 3/6) gravelly clay loam; moderately coarse subangular blocky structure; very firm; clay films on surfaces of peds; few roots; 10 percent gravel by volume; 10 percent rock fragments; pH 5.8; clear smooth boundary.
Bt22	46-84	Red (2.5YR 4.6) gravelly sandy clay loam; moderately coarse subangular blocky structure; very firm; thick clay films on surfaces of peds; 10 percent

		gravel by volume; 10 percent rock fragments; pH 5.7; diffuse smooth boundary.
BC	84-112	Red (2.5YR 4/6) gravelly sandy loam; weak coarse subangular blocky structure; firm; 15 percent gravel by volume; 10 percent rock fragments; pH 5.9; diffuse smooth boundary.
C	112-257	Dark brown (7.5YR 4/4) gravelly loamy sand; weak coarse subangular blocky structure; friable; matrix ped faces; 15 percent rock fragments; pH 6.1.

Soil: Tishomingo # 2

Location: Johnson County

Slope: 1-3 percent

Parent Material: Granite/Residium

Climate: Dry subhumid with mean annual precipitation of 99 cm and mean annual temperature of 16 C

Vegetation: Forest with an understory of grasses

Soil Classification: Coarse, mixed, thermic Udic Paleustalfs

Soil Profile

Horizon	Depth (cm)	Description (colors are for moist soil)
A	0-8	Dark brown (10YR 4/3) gravelly loam; moderately medium subangular blocky structure; friable; many fine and medium roots; 10 percent gravel by volume; 5 percent rock fragments; pH 6.3; abrupt smooth boundary.
E1	8-20	Brown (7.5YR 5/4) gravelly sandy loam; weak medium subangular blocky structure; very friable to loose; many fine and medium roots; 5 percent gravel by volume; 20 percent rock fragments; pH 5.1; diffuse smooth boundary.
E2	20-41	Strong brown to reddish yellow (7.5YR 5/6 to 7.5YR 6/6) gravelly sandy loam; weak medium subangular blocky structure; friable; few roots; 10 percent gravel by volume; 25 percent rock fragments; pH 5.4; diffuse smooth boundary.
EB	41-56	Strong brown (7.5YR 5/8) gravelly sandy loam; weak medium subangular blocky structure; very friable; few fine roots; 10 percent gravel by volume; 10 percent rock fragments; pH 5.7; abrupt smooth boundary.
Bt2	56-114	Yellowish red (5YR 5/8) gravelly sandy loam; common distinct reddish yellow (7.5YR 6/8) mottles; weak coarse subangular blocky structure; very firm; clay films on surfaces of peds; 5

		percent gravel by volume; pH 5.2; diffuse smooth boundary.
BC	114-155	Strong brown (7.5YR 5/6) gravelly sandy loam; common fine faint distinct reddish yellow (7.5YR 6/8) mottles; massive structure; very firm; 25 percent gravel by volume; pH 5.2; clear wavy boundary.
C1	155-185	Brown to strong brown (7.5YR 5/4 to 7.5YR 5/6) gravelly sandy loam; common fine faint and distinct reddish yellow (7.5YR 7/6) mottles; massive structure; very firm; 20 percent gravel by volume; 25 percent rock fragments; pH5.3; clear smooth boundary.
C2	185-215+	Strong brown (7.5YR 5/6) gravelly loamy sand; common medium distinct light brown (7.5YR 6/4) and dark brown (7.5YR 3/2) mottles; single grain structure; loose; 25 percent gravel by volume; 60 percent rock fragments; pH 5.7.

Soil: Fort Sill

Location: Commanche County

Slope: 0-3 percent

Parent Material: Granite/Colluvium

Climate: Dry humid with mean annual precipitation of 76 cm and mean annual temperature of 20 C

Vegetation: Oaks with an understory of mid and tall prairie grasses

Soil classification: Coarse, mixed, thermic, typic Haplustalfs

Soil Profile

Horizon	Depth (cm)	Description (colors are for moist soil)
A	0-18	Dark brown (7.5YR 3/2) gravelly sandy loam; moderate to medium subangular structure; friable; many fine and medium roots; 15 percent gravel by volume; 10 percent rock fragments; pH 6.1; clear smooth boundary.
E	18-28	Dark rddish brown (5YR 3/4) gravelly sandy loam; weak medium subangular blocky structure; friable; many fine and medium roots; about 15 percent gravel by volume; 10 percent rock fragments; pH 6.o; clear smooth boundary.
Bt1	28-48	Dark red (2.5YR 3/6) gravelly clay; moderately medium subangular blocky structure; friable to firm; roots are common; clay films on surfaces of peds; about 10 percent gravel by volume; 10 percent rock fragments; pH 5.9; gradual smooth boundary.
Bt2	48-79	Dark yellowish brown (10YR 3/6) gravelly clay; moderately coarse subangular blocky structure; firm; roots are common; thick clay films on surfaces of peds; about 10 percent gravel by volume; 10 percent rock fragments; pH 5.9; clear smooth boundary.
CB	79-122	Dark red (2.5YR 3/6) gravelly sandy loam

		clay loam; coarse subangular blocky structure; friable; few fine roots; about 25 percent gravel by volume; 25 percent rock fragments; pH 6.2; gradual wavy boundary.
C	122-160	Yellow (10YR 7/8) gravelly sandy clay loam; common fine faint and distinct grayish (7.5YR 6/0) mottles; about 10 percent gravel by volume; 60 percent rock fragments; strong effervescence with HCl; pH 6.7. clear smooth boundary.
2C	160-188+	Gray (7.5YR 6/0) with distinct brownish yellow (10YR 6/6) mottles. 25 percent sandstone fragments imbedded within the granite.

Soil: Mountain Park

Location: Kiowa County

Slope: 0-3 percent

Parent Material: Granite/Colluvium

Climate: Subhumid with mean annual precipitation of 66 cm and mean annual temperature of 17 C

Vegetation: Mesquite grass savannah

Soil Classification: loamy, mixed, thermic typic Ustochrepts

Soil profile

Horizon	Depth (cm)	Description (colors are for moist soil)
A	0-31	Dark brown (7.5YR 3/2) gravelly loam; moderately medium subangular blocky structure; friable; many fine roots; 15 percent gravel by volume; 10 percent rock fragments; pH 6.2; clear smooth boundary.
BA	31-58	Dark brown (7.5YR 3/4) gravelly sandy loam; moderately weak subangular blocky structure; friable; many fine roots; 30 percent gravel by volume; 20 percent rock fragments; pH 6.1; clear smooth boundary.
Bw1	58-81	Strong brown (7.5YR 5/6) gravelly sandy loam; moderately weak to medium subangular blocky structure; friable; many fine roots; 20 percent gravel by volume; 40 percent rock fragments; pH 6.0; clear smooth boundary.
Bw2	81-121	Strong brown to yellow red (7.5YR 4/6 to 5YR 5/8) gravelly loam; strong coarse parting to medium subangular blocky structure; friable; few fine roots; 20 percent gravel by volume; 40 percent rock fragments; gravel by volume; pH 6.0; abrupt smooth boundary.
Cg1	121-198	Brown (7.5YR 5/2) silty clay loam; common fine faint and distinct gray (7.5YR 6/0) mottles; weak coarse subangular blocky structure; very firm;

		few fine roots; pH 6.1; abrupt smooth boundary.
Cg2	198-216+	Dark brown (7.5YR 4/2) clay loam; weak coarse subangular blocky structure; very firm; few fine roots; small amount of manganese concretion; pH 6.5.

Soil: Granite

Location: Greer County

Slope: 0-3 percent

Parent Material: Granite/Colluvium

Climate: Dry humid with mean annual precipitation of 61 cm and mean annual temperature of 16 C

Vegetation: Mid and tall prairie grasses

Soil Classification: Sandy, mixed, thermic typic Ustochrepts

Soil Profile

Horizon	Depth (cm)	Description (Colors are for moist soil)
A	0-23	Dark brown (7.5YR 3/4) gravelly loam; weak medium subangular blocky structure; very friable; many fine and medium roots; 15 percent gravel by volume; 15 percent rock fragments; pH 6.4; clear smooth boundary.
P AB	23-53	Dark brown (7.5YR 3/4) gravelly sandy loam; weak coarse subangular blocky structure; frible; many fine and medium roots; 15 percent gravel by volume; 30 percent rock fragments; pH 6.4; clear irregular boundary.
Bw1	53-81	Yellowish red (5YR 4/6) gravelly loam; weak coarse subangular blocky structure; firm; roots are common; 10 percent gravel by volume; 35 percent rock fragments; pH 7.0; clear smooth boundary.
Bw2	81-132	Red (2.5YR 4/6) gravelly sandy loam; weak coarse subangular blocky structure; friable; roots are common; 10 percent gravel by volume; 40 percent rock fragments; pH 6.9; diffuse smooth boundary.
BC	132-188	Red (2.5YR 4/6) gravelly sandy clay loam; massive structure; friable; few roots; 15 percent gravel by volume; 45 percent rock fragments; pH 7.1; abrupt smooth boundary.

C	188-216	Strong brown (7.5YR 5/6)gravelly sandy clay loam; massive structure; friable; few roots; 20 percent gravel by volume; 60 percent rock fragments; pH 6.8; abrupt smooth boundary.
2C	216-254	Red (2.5YR 5/8) gravelly clay loam; common faint and distinct reddish yellow (7.5YR 6/6) mottles; massive structure; very firm. 15 percent gravel by volume; 10 percent rock fragments.

APPENDIX B

PARTICLE SIZE ANALYSES

TABLE VI

PARTICLE SIZE DISTRIBUTION AND BULK DENSITY FOR SPAVINAW SOIL

Horizon	Depth cm	Very Coarse Sand 2-1 mm	Coarse Sand 1-.5 mm	Medium Sand .5-.25 mm	Fine Sand .25-.1 mm	Very Fine Sand .1-.05 mm	Silt 0.05-.002 mm	Clay .002 mm	Bulk Density gms/cc
					%				
A	0-10	20.97	12.59	6.42	5.53	2.86	41.76	9.87	1.53
E	10-23	19.40	10.04	8.38	6.47	2.99	44.49	8.23	1.74
BE	23-46	12.23	9.47	8.65	7.87	4.30	47.11	10.37	1.74
B	46-66	18.35	13.29	9.55	8.91	4.39	32.12	13.39	1.63
BC	66-91	18.91	15.77	12.73	11.73	6.14	24.14	10.58	1.81
C	91-127	38.57	19.34	13.14	8.54	3.45	13.56	3.40	

TABLE VII

PARTICLE SIZE DISTRIBUTION AND BULK DENSITY FOR TISHOMINGO # 1 SOIL

Horizon	Depth cm	Very Coarse Sand 2-1 mm	Coarse Sand 1-.5 mm	Medium Sand .5-.25 mm	Fine Sand .25-.1 mm	Very Fine Sand .1-.05 mm	Silt 0.05-.002 mm	Clay .002 mm	Bulk Density gms/cc
		%							
A	0-8	27.94	14.79	12.62	14.37	6.94	31.94	6.59	1.64
E	8-20	23.68	13.39	14.04	14.89	6.64	22.36	5.00	1.85
EB	20-33	20.78	14.92	14.04	16.91	7.81	19.61	5.93	1.73
Bt21	33-46	12.49	9.97	8.33	8.87	4.61	22.61	33.12	1.75
Bt22	46-84	10.89	10.64	11.04	12.08	6.86	26.22	22.27	1.72
BC	84-112	12.27	17.24	16.95	17.98	8.60	14.84	12.12	1.91
C1	112-142	21.99	20.65	15.19	14.10	5.91	16.60	5.56	2.08
C2	142-188	14.38	18.46	16.27	19.80	8.46	18.85	3.78	2.08
C3	188-257	31.81	20.32	14.23	11.53	4.09	11.03	6.99	2.08

TABLE VIII

PARTICLE SIZE DISTRIBUTION AND BULK DENSITY FOR TISHOMINGO # 2 SOIL

Horizon	Depth cm	Very Coarse Sand 2-1 mm	Coarse Sand 1-.5 mm	Medium Sand .5-.25 mm	Fine Sand .25-.1 mm	Very Fine Sand .1-.05 mm	Silt 0.05-.002 mm	Clay .002 mm	Bulk Density gms/cc
		%							
A	0-8	11.47	13.85	9.52	8.12	6.43	38.83	11.76	1.56
E1	8-20	20.36	13.86	9.12	8.57	7.18	32.59	8.32	1.92
E2	20-41	14.62	12.22	8.18	9.48	9.93	39.58	5.99	1.96
E13	41-56	18.24	13.33	8.25	7.51	7.80	35.92	8.95	1.68
Bt2	56-114	21.27	12.74	7.64	8.04	6.34	25.39	18.58	1.82
BC	114-155	10.38	10.48	11.18	12.42	8.08	29.48	17.98	1.83
C1	155-185	25.25	15.27	11.28	9.93	5.39	16.31	6.57	2.05
C2	185-234	33.39	22.23	13.91	8.82	3.14	9.04	8.97	2.24

TABLE IX

PARTICLE SIZE DISTRIBUTION AND BULK DENSITY FOR FORT SILL SOIL

Horizon	Depth cm	Very Coarse Sand 2-1 mm	Coarse Sand 1-.5 mm	Medium Sand .5-.25 mm	Fine Sand .25-.1 mm	Very Fine Sand .1-.05 mm	Silt 0.05-.002 mm	Clay .002 mm	Bulk Density gms/cc
		----------	----------	----------	----%	----------	----------	----------	
A	0-18	5.14	9.78	16.08	15.93	11.13	32.56	9.38	1.69
E	18-28	7.22	9.06	16.62	15.93	12.15	27.27	11.75	1.75
Bt1	28-48	5.43	11.16	11.11	8.77	5.38	28.86	29.29	1.84
Bt2	48-79	5.34	10.23	10.93	7.23	4.64	24.12	37.51	1.80
CB	79-122	21.14	18.50	8.78	6.28	3.64	12.15	29.51	1.88
2Cr	122-160	15.17	19.05	11.99	9.45	4.82	15.85	23.67	1.93
3R	160-188+								

TABLE X

PARTICLE SIZE DISTRIBUTION AND BULK DENSITY FOR MOUNTAIN PARK SOIL

Horizon	Depth cm	Very Coarse Sand 2-1 mm	Coarse Sand 1-.5 mm	Medium Sand .5-.25 mm	Fine Sand .25-.1 mm	Very Fine Sand .1-.05 mm	Silt 0.05-.002 mm	Clay .002 mm	Bulk Density gms/cc
		-----------------------	-----------------------	-----------------------	-----------%-----------	-----------------------	-----------------------	-----------------------	
A	0-31	8.40	6.36	6.81	6.36	14.51	42.16	15.70	1.70
BA	31-58	27.82	19.89	5.83	3.09	5.09	23.72	14.56	1.88
BW1	58-81	26.88	13.36	5.78	3.89	6.68	25.66	17.75	1.85
BW2	81-121	20.78	8.37	4.84	4.74	9.92	38.59	13.56	1.85
Cg1	121-198	4.48	2.94	2.79	3.09	4.93	44.15	37.62	2.02
Cg2	198-216+	4.37	3.88	4.72	5.57	9.30	43.13	29.03	2.02

TABLE XI

PARTICLE SIZE DISTRIBUTION AND BULK DENSITY FOR GRANITE SOIL

Horizon	Depth cm	Very Coarse Sand 2-1 mm	Coarse Sand 1-.5 mm	Medium Sand .5-.25 mm	Fine Sand .25-.1 mm	Very Fine Sand .1-.05 mm	Silt 0.05-.002 mm	Clay .002 mm	Bulk Density gms/cc
		%							
A	0-23	5.29	2.69	8.63	14.41	23.08	31.14	14.76	1.60
AB	23-53	4.78	4.08	9.06	14.94	21.72	27.09	18.33	1.63
Bw1	53-81	7.65	5.30	5.85	9.44	16.94	28.64	26.18	1.76
Bw2	81-132	27.72	7.34	3.10	4.75	13.09	23.22	20.78	1.67
BC	132-188	18.51	7.38	4.24	5.74	15.77	25.41	22.95	2.17
C	188-216	29.47	16.30	6.58	4.49	5.64	24.95	12.57	2.17
2C	216-254+	7.14	7.39	3.89	7.40	1.85	44.54	32.74	1.79

APPENDIX C

CHEMICAL ANALYSES

TABLE XII

CHEMICAL PROPERTIES OF SPAVINAW SOIL

Horizon	Depth cm	pH 1:1	pH KCl.	O.M.	Extractable Cations H	Ca	Mg	K	Na	CEC Sum	BS	Free Iron Fe_2O_3	EC 25°C mmhos
				%	------------- meq./100 gms.					------------	%	%	
A	0-10	5.8	4.9	4.6	9.1	3.4	1.32	0.65	0.76	14.55	37	0.62	0.3
E	10-23	4.9	3.7	2.2	9.5	0.82	0.79	0.25	0.19	11.55	18	0.75	0.2
BE	23-46	4.9	3.7	0.9	7.5	1.2	0.59	0.27	0.18	9.74	23	0.42	0.1
B	46-66	4.8	3.6	0.7	9.6	1.32	1.40	0.31	0.17	12.8	25	0.80	0.1
BC	66-91	4.7	3.5	0.7	10.2	1.50	2.72	0.29	0.24	14.95	32	1.15	0.1
C	91-127	5.1	3.5	0.3	8.1	1.59	2.89	0.18	0.20	12.96	28	0.8	0.7

TABLE XIII

CHEMICAL PROPERTIES OF TISHOMINGO # 1 SOIL

Horizon	Depth	pH		O.M.	Extractable Cations					CEC	BS	Free Iron	EC 25°C
	cm	1:1	KCl.		H	Ca	Mg	K	Na	Sum		Fe_2O_3	mmhos
				%	-------------- meq./100 gms. -----------						%	%	
A	0-8	5.8	5.0	4.36	6.6	3.15	2.45	0.27	0.10	12.57	47	0.21	0.2
E	8-20	5.7	4.6	2.27	5.0	1.65	1.21	0.16	0.16	8.18	39	0.15	0.3
EB	20-33	6.1	4.6	0.62	2.3	1.77	1.05	0.13	0.13	5.38	57	0.21	0.1
Bt21	33-46	5.8	4.5	1.05	7.8	3.34	3.64	0.28	0.19	15.25	49	0.59	0.08
Bt22	46-84	5.7	4.3	0.58	9.0	3.04	4.90	0.21	0.23	17.38	48	0.54	0.05
BC	84-112	5.9	3.85	0.37	6.0	4.21	6.32	0.16	0.26	16.95	65	0.39	0.08
C1	112-142	6.1	3.9	0.29	5.7	4.71	5.90	0.13	0.31	16.75	66	0.27	0.1
C2	142-188	6.3	3.85	0.16	3.6	3.34	4.16	0.11	0.32	11.53	69	0.21	0.1
C3	188-257	6.4	3.75	0.16	3.7	4.66	5.19	0.06	0.38	13.99	74	0.19	0.1

TABLE XIV

CHEMICAL PROPERTIES OF TISHOMINGO # 2 SOIL

Horizon	Depth cm	pH 1:1	pH KCl.	O.M.	Extractable Cations H	Ca	Mg	K	Na	CEC Sum	BS	Free Iron Fe_2O_3	EC 25°C mmhos
				%	meq./100.gms.						%	%	
A	0-8	6.3	5.4	4.59	5.2	3.31	1.25	0.30	0.07	10.13	49	0.23	0.3
E1	8-20	5.1	3.7	0.84	3.1	0.88	0.26	0.10	0.04	4.38	29	0.19	0.1
E2	20-41	5.4	3.9	0.40	2.6	1.33	0.64	0.10	0.04	4.71	45	0.38	0.08
EB	41-56	5.7	4.2	0.56	3.0	1.99	1.38	0.10	0.05	6.52	54	0.47	0.2
Bt2	56-114	5.2	3.6	0.75	7.5	3.47	7.04	0.27	0.20	18.48	59	0.98	0.08
BC	114-155	5.2	3.45	0.45	9.7	3.42	6.99	0.31	0.33	20.75	53	1.15	0.05
C1	155-185	5.3	3.65	0.41	7.8	4.22	6.83	0.27	0.35	19.47	60	1.31	0.07
C2	185-234	5.7	3.55	0.33	6.7	5.92	6.89	0.21	0.35	20.07	67	1.03	0.08

TABLE XV

CHEMICAL PROPERTIES OF FORT SILL SOIL

Horizon	Depth cm	pH 1:1	pH KCl.	O.M.	Extractable Cations H	Ca	Mg	K	Na	CEC Sum	BS	Free Iron Fe_2O_3	EC 25°C mmhos
				%	---------- meq./100 gms. ----------						%	%	
A	0-18	6.1	4.8	1.22	2.4	2.74	1.72	0.29	0.05	7.2	67	0.33	0.2
E	18-28	6.0	4.8	0.71	2.2	2.68	0.96	0.27	0.07	6.18	64	0.42	0.09
Bt1	28-48	5.9	4.6	1.21	4.5	3.71	3.70	0.26	0.10	12.63	64	1.09	0.1
Bt2	48-79	5.9	4.7	1.02	5.7	4.09	4.67	0.60	0.13	15.19	62	1.15	0.1
CB	79-122	6.2	4.7	0.78	4.7	2.87	3.77	0.43	0.29	12.06	61	0.80	0.8
2 Cr	122-160	6.7	5.3	0.22	2.10	3.86	4.45	0.22	0.85	11.48	82	0.67	0.2
3 R	160-188+				0.8	1.12	0.97	0.09	0.44	3.42	76	0.09	

TABLE XVI

CHEMICAL PROPERTIES OF MOUNTAIN PARK SOIL

Horizon	Depth cm	pH 1:1	pH KCl.	O.M.	Extractable Cations H	Ca	Mg	K	Na	CEC Sum	BS	Free Iron Fe_2O_3	EC 25°C mmhos
				%	meq./100 gms.						%	%	
A	0-31	6.2	5.0	2.87	4.4	3.26	2.08	0.22	0.13	10.09	56	0.23	0.2
BA	31-58	6.1	4.8	1.51	4.3	2.30	2.05	0.17	0.13	8.95	52	0.42	0.1
Bw1	58-81	6.0	4.6	0.79	3.9	1.87	1.83	0.14	0.14	7.88	51	0.57	0.1
Bw2	81-121	6.0	4.5	0.27	3.5	1.79	1.74	0.13	0.21	7.37	53	0.38	0.2
Cg1	121-198	6.1	4.8	0.24	5.6	7.96	6.17	0.18	1.22	21.13	73	0.06	0.2
Cg2	198-216+	6.5	5.0	0.17	4.0	5.88	4.73	0.16	0.98	15.75	75	0.19	0.1

TABLE XVII

CHEMICAL PROPERTIES OF GRANITE SOIL

Horizon	Depth cm	pH 1:1	pH KCl.	O.M.	Extractable Cations H	Ca	Mg	K	Na	CEC Sum	BS	Free Iron Fe_2O_3	EC 25°C mmhos
				%	meq./100 gms.						%	%	
A	0-23	6.4	5.2	1.76	3.7	2.06	1.95	0.80	0.28	9.33	60	0.42	0.2
AB	23-53	6.4	5.4	1.54	3.4	3.42	2.58	0.61	0.05	10.06	66	0.57	0.1
Bw1	53-81	7.0	5.6	1.33	2.05	4.21	3.61	0.47	0.12	10.46	80	0.67	0.2
Bw2	81-132	6.9	5.6	0.82	2.3	3.78	2.95	0.38	0.09	9.5	76	0.80	0.2
BC	132-188	7.1	5.6	0.57	2.10	3.36	2.79	0.33	0.12	8.7	76	0.67	0.2
C	188-216	6.8	5.3	0.22	1.8	2.78	1.4	0.16	0.10	6.24	71	0.52	0.2
2C	216-254+	6.4	4.9	0.12	2.05	4.85	4.79	0.30	0.24	12.23	83	1.14	0.08

VITA

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