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SOIL AND LANDFORM RELATIONSHIPS ON A CAMBRIAN AND MISSISSIPPIAN GEOLOGIC SEQUENCE IN EASTERN TENNESSEE

A Thesis

Presented for the

Master of Science

Degree

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Nathan T. Hartgrove

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I dedicate this thesis to my wife, Laura Hartgrove, without whose love, support and patience its completion may not have been possible.

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ABSTRACT

Soil and landform relationships were studied on a group of soils developing from parent materials belonging to the Mississippian Grainger formation, the Cambrian Rome formation and the Cambrian Conasauga group in eastern Tennessee. The Conasauga group is made up of the Pumpkin Valley shale, Rutledge limestone, Rogersville shale, Maryville limestone, Nolichucky shale and Maynardville limestone. These are middle to late Cambrian age lithologies.

Alfisols, Inceptisols and Ultisols were the prevalent soil orders forming on this landscape. Alfisols occurred where high base parent materials were weathering and where agricultural practices were contributing bases to the soil environment. Alfisols were present on the Grainger formation, Pumpkin Valley shale, a deep alluvium overlying the Rutledge limestone, on the Maryville limestone and the Maynardville limestone. High base Inceptisols were forming on the flood plain of Richland Creek and in the Grainger formation. Low base Inceptisols were forming on the Rome formation. Ultisols developed in the residuum from the Rutledge limestone and Nolichucky shale.

This is an evolving landscape. With the exception of some deep, relatively well developed soils on more stable

landscape components, there was little indication of stability among the landforms. Field studies revealed little accumulation of colluvium, except in some larger coves associated with the Grainger formation. It seems that geologic erosion has precluded the placement of deep colluvial deposits on most of this landscape. There was evidence, however, of relatively shallow layers of colluvium overlying some of the pedons observed.

An obvious relationship between degree of soil development and relief was observed, to the extent that on all but the most gentle slopes, the effect of relief was the overriding soil forming factor, obscuring much of the contribution of the parent material. On the stable landscape components, time, climate (or paleoclimate) and parent material were dominant factors of soil formation. High base saturation was observed in the upper parts of profiles on the Rutledge limestone unit. This high content of bases was not readily attributable to a single soil forming factor. Agricultural practices are thought to play some role in the high base content of these soils, but cannot account for all of the bases present in the upper meter or so of these profiles. It would seem that the bases are somehow being laterally translocated in this part of the landscape.

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INTRODUCTION

Landforms are in a continual state of evolution. Erosion, transport and soil formation are constantly active, driven by forces acting on materials at or near the earth's surface. This research project was undertaken to investigate the results of these processes on a landscape underlain by a series of differing parent materials. The objectives of the research were to: 1) evaluate degree of soil formation relative to landscape position, relief and parent material in a series of soils developing on a sequence of geologic formations, 2) assess to some degree the influence of other soil forming factors, namely, time, climate and biotic influences, and 3) generate a set of morphological, chemical and physical soil data that would be generally applicable to mapping and classification of many soils found in the Appalachian Ridge and Valley Province in eastern Tennessee on similar landscapes and parent materials.

The study area was the Richland Valley, in Grainger County, about 20 miles northeast of Knoxville, Tennessee. The valley is a little more than a mile wide and is underlain by eight geologic formations. The valley has moderate to high relief, with a difference in elevation from lowest to highest of nearly 200 meters. Richland

Creek and its tributaries are well incised into the landscape and headward erosion has been an active contributor to the evolution of the landscape in recent periods. Slopes range from nearly level to very steep (0 to greater than 50 percent), and slope class tends to change with changes in parent material. Slope and relief are directly related to the geologic materials and reflect the resistance to weathering of the parent materials.

The geologic formations are the Mississippian Grainger formation, the Cambrian Rome formation and Cambrian Conasauga group. The Grainger formation consists of interbedded shale, siltstone and fine grained sandstone. The Rome formation in the area is made up mainly of sandy shale and soft silty sandstone. The Conasauga group is made up of six named formations ranging from middle to late Cambrian in age. They are, from oldest to youngest, (from north to south in the Richland Valley), the Pumpkin Valley shale, Rutledge limestone, Rogersville shale, Maryville limestone, Nolichucky shale and the Maynardville limestone. With the exception of the Rogersville shale, this part of the Richland Valley is a fairly complete exposure of the Conasauga group. In this part of the Valley, the Rogersville shale is largely covered by the alluvium of Richland Creek. This study area provided an excellent opportunity to investigate soil

formation on a variety of parent materials and landscape positions over a relatively short distance.

1. REVIEW OF LITERATURE

Geology

The Conasauga group derives its name from the Conasauga River in Whitfield and Murray Counties, Georgia, where the formations are dominantly shale (Rodgers, 1953). This group of formations extends northward, broadening eastward and southeastward to the Pulaski fault, passing a little west of Knoxville as it extends northeastward through Tennessee. In the eastward portion of the belt, dolomite appears in the limestone units and the corresponding rocks of the group occur in six named formations (Rodgers, 1953). All six formations are Cambrian in age and are named, from oldest to youngest, Pumpkin Valley shale, Rutledge limestone, Rogersville shale, Maryville limestone, Nolichucky shale and Maynardville limestone (Walker, 1985). At the thickest, the section is 592 meters thick. This occurs several kilometers east of this study area (Walker, 1985). In the area where this study occurs, the Conasauga group is conformably overlain by the Copper Ridge dolostone and is underlain by the Rome formation. The Rome formation is nonconformably underlain by the Mississippian Grainger formation (Walker, 1985).

The Conasauga group was deposited during alternating tidal shelf-intrashelf-basin-carbonate ramp episodes of deposition (Hasson and Haase, 1988). The eastward margin of the basin consists of shaly limestone and dolostone and these are more dominant eastward in the formations of the Conasauga. The basin sediments are limestone, shale and shaly limestone that are, on average, 40 to 50 percent limestone. The westward margins of the basin are dominantly calcareous shales and siltstone (Hasson and Haase, 1988). Conasauga shales generally weather to thin acid soils, but where limestone is present, the soils are notably deeper and free of rock fragments (Rodgers, 1953). Recent studies in Conasauga group materials, west of Knoxville indicates that residual soils formed over saprolite are generally not very well developed, whereas those of colluvial and alluvial origin possess an appreciable degree of morphologic development (Lambert, 1988). Other research on the Nolichucky and Maryville formations shows the soils to be Typic Hapludults, Typic Hapludalfs and Aquic Hapludalfs on materials associated with these formations (Phillips, 1988).

Brief descriptions of the geologic units are given in the following paragraphs. These are summarized dominantly from Walker, 1985, except where otherwise indicated.

The Pumpkin Valley shale contains no sandstone, but is occasionally interbedded with thin crossbedded limestone. The shales range from brown to variegated in color. The Pumpkin Valley shale represents a subtidal depositional environment with no evidence of subaerial exposure.

The Rutledge limestone is characterized by dominantly thick bedded limestone and dolostone, ranging from medium to fine-grained. The interbeds of limestone and dolostone are, for the most part, regular and of nearly equal thickness, but some thin bedding occurs locally. Observable fossils are virtually absent, but there is an occasional trilobite fragment. There is an abrupt, but conformable, upper contact with the overlying Rogersville shale.

The Rogersville shale consists of three distinct lithologies: an underlying shale, a limestone member and an overlying shale. The shale is gray to greenish in color and has a silty clay texture. Numerous thin beds of mottled limestone are present throughout. Fossils present in the Rogersville formation are trilobites and brachiopods. The shales contain significant amounts of iron sulfide nodules. This formation represents a relatively shallow basin environment.

The Maryville limestone is a complex of lithologies of mottled limestone interbedded with clayey dolostone and, in places, fine-grained shale. These lithologies are thought to have been deposited during a period of alternating depositional environments. Fossil remains include trilobites and echinoderms.

The Nolichucky formation contains many lithologies similar to the Maryville formation, but with a significantly higher proportion of shale. The shale is dark brown, silty and laminated in medium to thick beds. Some of the shale material in the Nolichucky has a high content of carbonates when fresh. Iron sulfide nodules are numerous in the upper part.

The Maynardville formation has two members: the Low Hollow limestone and the Chances Branch dolostone. The Low Hollow member is mostly massive, fine grained limestone. The Chances Branch member is generally fine to medium grained clayey dolostone.

The uppermost Rome formation is roughly equivalent to the lowermost Conasauga (Walker, 1985). Shale, siltstone and very fine to medium grained sandstone make up the bulk of the Rome facies, with minor inclusions of silty dolostone and limestone (Rodgers, 1953; Walker, 1985). The Rome has common glauconitic intervals containing greenish hued materials (Hasson and Haase, 1988; Walker,

1985). The sediments were deposited in a dominantly tidal environment (Walker, 1985).

The Mississippian age Grainger formation consists of basal and middle siltstone members, a silty shale member and an upper sandstone member. Fossils are not uncommon in the Grainger formation (Walker, 1985).

Soil Formation and Geomorphology

"Soils are natural bodies formed on the land surface, occupying space and having unique morphology" (Simonson, 1959). Genesis of soils occurs in two overlapping steps: 1) the accumulation of parent material, and, 2) differentiation of horizons. Horizon differentiation is brought about by additions to or removal from the parent materials and by transfer or transformation of material within the parent materials (Simonson, 1959). Some processes that act over time in soil genesis tend to promote horizon differentiation and others tend to retard it. For this reason, soil genesis is certainly a multiple process complex of activity occuring over time (Simonson, 1978).

Soil landscape systems must be viewed in terms of some minimum area of consideration. A landscape model may be thought of as consisting of the following components: 1) consolidated bedrock (skeleton), 2) potentially mobile

solids, or plasma, 3) water or liquid, 4) air and, 5) biota, or plants and animals (Hole, 1978). Soils are slowly changing systems, and therefore the separation of cause and effect in soil forming processes can be quite difficult and it has been suggested that a true model of soil formation should be based on energy relationships or energy vectors in the system (Runge, 1973). The basic organizational unit is a valley basin or drainage basin (Huggett, 1975). Soil landscapes are open systems, bounded by interfluves, the soil weathering front (or, the soil-parent material interface) and the land surface (Huggett, 1975). Other workers have proposed in great detail a nine unit landscape model which is descriptive of a three dimensional slope extending from interfluve to valley bottom and from the soil surface to the parent material, having arbitrary lateral dimensions (Conacher and Dalrymple, 1977).

Major processes that drive soil formation are additions of materials to the soil system, such as organic matter additions or deposition of sediment, losses of materials by decomposition, leaching, translocation of materials from one part of the system to another, mineral and organic transformations within the system and physical and chemical alterations (Foss and Segovia, 1984). It is interesting that many common processes of soil formation,

such as depletion of weatherable minerals by leaching, organic matter accumulations in certain soils, and clay accumulation cannot go on forever and may be thought of as self-limiting or self-terminating processes (Torrent and Nettleton, 1978). The point to which these so-called "feedback processes" have proceeded would seem to have bearing on any attempt to ascertain the degree of development of a given soil.

Processes accompanying soil formation produce unique and distinctive soil characteristics under the influence of the five basic soil forming factors, which are time, climate, relief, parent material and biotic processes (Jenny, 1941; Huggett, 1975; Birkeland, 1984). Various soil properties may be expected to reach a steady state condition in varying amounts of time. Steady state may be thought of as a near equilibrium condition in which input and output of energy and materials are nearly of equal proportion. A soil may be thought of as in steady state when at least the majority of its individual properties reach steady state (Birkeland, 1984).

Soil properties have a quantitative character that means that they may be functionally interrelated. Climate, organisms and relief act on parent material through time (Jenny, 1941). The magnitude of a given soil property varies with time and estimates of relative age

and degree of development of soils is based on differentiation of horizons that are presumed to become more obvious with time (Jenny, 1941).

Sometimes, it is difficult to know exactly the point at which parent material stops and soil begins. Parent material may be defined as "the initial state of the soil system" (Jenny, 1941). Degree of fracturing of consolidated or geologic parent material, as well as its permeabilty to water, is strongly related to mechanical weathering processes that will serve to create a soil parent material (Jenny, 1941; Birkeland, 1984). Investigators in central Virginia have found that the bedrock plays a major role in the soil characteristics of the profile developed (Plaster and Sherwood, 1971). These studies were in nonglaciated areas, where the soils were fairly well developed in a time sense and the other soil forming factors did not differ significantly. Little quantitative work has been reported on rates of bedrock weathering, but it seems that rock weathering rate is not necessarily a linear function over the long term and is certainly affected by accumulations of weathered material. Some minimum thickness of residue (or soil parent material) will accumulate to act as a buffer between parent rock and weathering agents (Colman, 1981).

Relief is a very significant factor in soil formation. Water penetration into the parent material varies with relief. Added rainfall runs off steeper slopes more readily, leading to slow formation of cambic and argillic horizons, whereas more rapid infiltration encourages subsurface weathering (Huggett, 1975). Soils on very steep slopes tend to have profile characteristics that are imperfectly developed or possibly missing in cases of extremely high relief (Jenny, 1941). Finally, high relief is associated with accelerated erosion by water. Formation of a soil profile requires that the rate of soil formation exceed the rate of soil removal by erosion (Bos and Sevink, 1975). Areas most affected by water erosion are those with a rugged relief, which brings about a concentration and acceleration of surface runoff into certain areas on a complex slope. Slope gradient and length are the major erosive factors, given that rainfall is present (Holy, 1980).

Climate as a soil forming factor is intimately related to leaching, accumulation of organic matter, particle size and mineralogy. Water from rainfall is the primary agent in leaching. Higher rainfall has the mineralogic effect of trending toward siliceous sand mineralogy and higher clay content with increasing amounts of rainfall. Temperature is a major factor in the

kinetics and speed of soil chemical processes (Jenny, 1941). Additionally, it is sometimes difficult to always know whether paleoclimate or time is responsible for many of the features observed in highly weathered soils (Birkeland, 1984). Soils that are middle or early Pleistocene in age have undergone many climatic, vegetative and stability changes. Processes of rubification are thought by some investigators to only be active when soil temperatures are in excess of 15 degrees Celsius. This means that morphologic features observed in many deep red soils that date to the Pleistocene or earlier are probably more a product of paleoclimate rather than of time (Ciolkosz, et. al., 1989).

Biotic processes as soil forming factors involve the action of soil organisms and plants. Plants provide a source of organic matter, soil microorganisms break down organic matter and other substances into various soil constituents. Density of plant cover has a direct effect on erodibility of sloping soils and on moisture relations at the soil surface and in the root zone (Jenny, 1941).

Man may also be thought of as a biotic soil forming factor (Jenny, 1941). In the last 100 to 200 years, man has greatly accelerated erosion on many soils (Hall, et. al., 1982). Man also modifies the soil forming factors through agricultural activities by irrigating,

fertilizing, liming and by changing the vegetative composition of certain areas. These practices have a direct and sometimes rather profound effect on the composition, biotic character and climate of the soils (Jenny, 1941).

The age of a soil may be thought of either as the absolute amount of time since some pedologically catastrophic event occured (chronologic age), or, as the relative stage of development compared with some arbitrary standard (pedologic age). "Time zero" may be sudden or incremental. Determination of a chronologic time zero depends on the adequacy of dating technology (Hall, et. al., 1982). Soil dating is also very difficult to apply in a practical sense because soil formation is controlled by local soil forming factors and it is difficult to establish a norm to apply in a wide range of situations (Hall, et. al., 1982).

Attempts to relate chronologic age to pedologic age in recent alluvium suggest that morphologic features are effective in distinguishing chronologic ages of soils differing by 1500 years or more. These findings are based on studies of oriented clay film volume, in situ weathering of clay minerals, fine clay to total clay ratios and distinctness of morphologic boundaries (Bilzi and Ciolkosz, 1977). Relative horizon distinctness has

also been found by investigators in California to be quite useful as a morphologic indicator of lithologic discontinuities (Meixner and Singer, 1981).

Changes can occur rapidly in young geologic materials such as recent alluvium (Foss and Segovia, 1984). Organic matter accumulation and structure development may become evident in 50 years or less, but 2000 to 3000 years are necessary in humid temperate climates to produce significant profile development (Foss and Segovia, 1984). Argillic horizon development in Alfisols takes about 10,000 years (Birkeland, 1984) although it has been suggested elsewhere that a very weak argillic horizon with thin discontinuous clay films may form in 4000 to 6000 years (Foss and Segovia, 1984). Cambic horizons can form in as little as 200 years, but commonly persist after 2000 years (Bilzi and Ciolkosz, 1977). Ultisols are often the result of paleoclimate and are associated often with pre-Wisconsinan parent materials (Birkeland, 1984). Other work with well developed soils indicates that 10,000 to 30,000 years are required to develop one to two meters of soil with thin continuous clay films and moderate structure. More than one million years is necessary to form two to five meters of a strongly developed soil whose argillic horizon contains thick clay films and strong structure (Foss and Segovia, 1984).

Soils formed in colluvium in the Ridge and Valley portion of Pennsylvania show a strong association with landform, covering the lower one half to three fourths of sideslopes and forming complex colluvial fans. Vertical textural changes and lithologic discontinuities are common. These are the result of heterogeneity of parent material and argillic horizon formation (Ciolkosz, et. al., 1979). Soils formed in colluvium derived from members of the Conasauga group in Tennessee have been shown to have fairly well developed argillic horizons and have been classified as Typic Hapludults (Lambert, 1988). Little colluvium was encountered in this study and no colluvial profiles were sampled.

Careful consideration should be given to selection of samples to represent soil landscapes. It has been suggested that the sampled unit (pedon) should be defined and identified as a specific location, not as a spatial entity (Holmgren, 1988). Satellite sampling designs would be preferable for spatial sampling. A satellite sample is a sample of a similar pedon in the same landscape (Holmgren, 1988).

All work with soils as related to landscapes employs concepts of geomorphology (Daniels, et. al., 1971). Pedology is primarily a historical science. Soils exhibit a physiographic and morphologic bias relative to landscape

position and geomorphic surfaces. Soil associations can be clearly related to geomorphic surfaces, as work in the midwest has indicated (Ruhe, 1956). Red argillic horizons are attributed to Pleistocene surfaces in New Mexico, while browner cambic horizons are found on post-Pleistocene surfaces (Daniels, et. al., 1971). Additionally, this same research shows that redder cambic horizons with clay content comparable to the browner ones are associated with older surfaces than those on which the brown cambic horizons occur (Daniels, et. al., 1971).

It is unlikely that soils on older surfaces pass through all of the same stages as soils on younger surfaces. Soils can develop the same properties through different routes and soils on old surfaces are manifestations of many episodic fluctuations in the local soil forming factors (Daniels, et. al., 1971).

Soil Morphology and Classification

The fact that soils are organized natural bodies (Simonson, 1968) covering the earth's surface makes it possible to describe the various properties of individual soil layers in either quantitative or semi-quantitative terms. The morphology of the soil will tell an investigator a great deal about the genesis and degree of development of a soil profile. Distinctness and degree of

expression of properties among horizons in a profile as compared with its presumed parent material is an excellent way of evaluating the relative pedologic age of a soil (Bilzi and Ciolkosz, 1977).

Development of soil morphology proceeds through time, beginning with organic matter accumulation in a surface layer and proceeding through clay accumulation and structure development (Hall, et. al., 1982). Extent of clay formation and accumulation in the subsoil horizons is a primary morphologic indicator of degree of soil development and is an easily observable feature of the soil profile (Hall, et. al., 1982). Soil color can also be a significant morphologic indicator of genetic processes. Slight changes in color occur as oxidation and weathering proceed in young geologic materials (Scully and Arnold, 1979). Formation and secondary accumulation of iron compounds in subsoil layers is a major contributor to soil color. Braunification or "turning brown" of soil materials occurs as iron is weathered from primary minerals in relatively young soils (Blume, 1988). The process of lessivage, or transport of soil particles vertically downward in the profile also contributes to this process (Blume, 1988). As mineral weathering proceeds, the effect of iron accumulation becomes more dramatic. Research has indicated that as little as 1.7

percent content of hematite in a soil can produce a red soil hue. This indicates that iron compounds are possibly the most effective pigmenting agents in soils low in organic matter (Torrent, et. al., 1983).

Complete morphologic description of a soil must precede sampling and characterization if an investigator is to adequately interpret the data gathered in the laboratory and relate it back to soil forming processes active in the landscape. Standard terminology has been devised for describing soils in the field (Soil Survey Staff, 1981). Investigation of the soil is made on a soil body having some observable dimensions, usually a pit or some other type of practical and suitable excavation (Soil Survey Staff, 1981). The profile to be studied or sampled should be described as completely and accurately as possible, preferably on a form devised for such a purpose so that as few as possible omissions will occur (Soil Survey Staff, 1981).

After profile descriptions have been completed, sampling has been done, and laboratory data become available, the soil profile may then be classified taxonomically. The United States Department of Agriculture has established a system of classification for soils in the United States and its territories (Soil Survey Staff, 1975; 1990). Taxonomic limits are set forth

for diagnostic features in soils that apply at the various taxonomic levels. There are six levels of taxonomy. These are: order, suborder, great group, subgroup, family and series (Soil Survey Staff, 1975; 1990).

There are many possible combinations of properties that affect the classification of soils at taxonomic levels below the soil order. These include particle size, mineralogy, soil temperature regime, moisture regime, fragment content and organic matter content, among numerous others (Soil Survey Staff, 1975). For the sake of brevity these many features and their taxonomic limits will not be discussed here.

Soil Chemical Properties Related to Soil Genesis

Inherent variability among soils may or may not be reflected when sample sites are relatively few in relation to the area of consideration. A great effort must be given to select representative sampling locations. Variability is especially notable in many soil chemical properties. For example, elemental determinations of titanium, zirconium, iron, calcium and potassium have given large degrees of variability in studies of soils forming in various parent materials (Drees and Wilding, 1973). In other studies using morphologically matched paired pedon samples, considerable variation has been

shown to exist, with chemical properties showing considerably more variability than physical properties (Mausbach, et. al., 1980). Sampling technique must be kept in mind when interpreting data and thought should be given that samples are adequate for the accuracy required by the nature of the investigation (Drees and Wilding, 1973).

There are three interpretive approaches that may be used in chemical weathering studies (Tardy, et. al., 1973). The first is to look at the distribution of secondary minerals in soil landscapes. The second is to follow the weathering of primary minerals in situ. The third is to look geochemically at ions in solution as a function of time (Tardy, et. al., 1973). It should be pointed out that chemical weathering rarely achieves its theoretical limits because short episodes of erosion can erase the effects of long periods of slow chemical weathering (Tardy, et. al., 1973).

Parent rock is the primary inorganic soil forming material. A given soil will move from its parent state toward a composition consisting entirely of oxides of silicon, aluminum and iron (Chesworth, 1973), given sufficient time. Every soil evolves at its own rate but towards a common end. Rates of formation of pedogenic oxides are controlled by many factors, but especially

important are temperature, moisture, pH and Eh (Schwertmann and Taylor, 1989). Rates of weathering could be monitored over time in soils. Research has shown that rates of decrease in pH and base saturation are similar among many soils, regardless of the nature of the parent material or climate (Bockheim, 1980).

Residual soils in a vertical rock, saprolite, soil sequence have been shown to exhibit losses of silica, calcium and sodium with increasing weathering intensity (Calvert, et. al., 1980). Close proximity to bedrock does not necessarily indicate a low intensity of weathering. Initial weathering products from this zone often influence the direction of soil formation and, ultimately, the nature of the soil formed (Calvert, et. al., 1980).

Pedogenic iron oxides are present as fine particles in one or more mineral forms. They are commonly referred to as "free iron oxides" as a means of distinguishing them from structural forms of iron bound up in other minerals. Content and form are subject to modification as the soil environment changes (Schwertmann and Taylor, 1989). Removal of pedogenic oxides of iron, aluminum and manganese from topsoil and subsequent accumulation in the subsoil produce depth functions that are valid indicators of soil development (Blume and Schwertmann, 1969) when the maximum degree of silicate weathering is in the topsoil.

This is true for most soils forming in humid temperate regions. Formation of these oxides proceeds deeper through weathering and typically reaches a maximum in the subsoil B horizon (Blume and Schwertmann, 1969).

Iron (III) oxides produce yellow and red hues that vary with various forms and concentrations of these materials present. The degree to which iron (II) in silicate mineral structures have been converted to iron (III) "free" oxides by hydrolysis and oxidation is useful for characterizing degree of soil development (Schwertmann, 1985).

Carbon content of soils as a function of depth is a taxonomic criterion for several taxonomic classes (Soil Survey Staff, 1975). The distribution of carbon, especially in organic forms, in a soil profile is a useful indicator of stratigraphy in young soils, such as those formed in recent alluvium (Scully and Arnold, 1979). Distribution of organic carbon content with depth, whether it constantly decreases, increases or fluctuates with increasing depth, can reveal much about the genesis of the soil profile.

Manganese oxides can be an indicator of the soil weathering environment (Blume and Schwertmann, 1969). Manganese oxides have also been associated with the presence and movement of water through soil profiles.

They tend to accumulate in zones where water movement is impeded (Ross, et. al., 1976) and where drainage is imperfect. Accumulations of manganese oxide precipitates in surface layers is not unusual in many soils. These higher proportions of manganese oxides in surface layers are related to the biocycle, or surface recycling of compounds by the plant cover (Blume and Schwertmann, 1969).

Soil Mineralogy

Minerals present in soils are either inherited from the soil parent material or are secondary, that is, formed in the soil profile during weathering (Cady, 1960). The complexity of soil mineralogy varies among soils with the degree of stratification of the soil parent materials and the differential resistance to weathering agents of the mineral species present. Clay movement through soil profiles may also fractionate mineral species (Cady, 1960).

Formation of secondary minerals in soils is dependent on the nature of the primary mineral, especially its elemental makeup and solubility product. The time required for formation of secondary minerals can be expressed as a function of solubility product, rate of crystallization or precipitation and the rate of removal

(leaching) of weathering products (Buol, et. al., 1980). Clay fractions of representative Ultisols in the southeast show kaolinite, gibbsite, hydroxyinterlayered vermiculite (HIV) and quartz to be dominant mineral species. There is indication of a possible equilibrium coexistence between HIV and kaolinite. Hydroxyinterlayered vermiculite persists, and probably forms, in many Ultisols and is most abundant in surface layers. Kaolinite is dominant in argillic horizons of many Ultisols studied to date (Karathanasis, et. al., 1983).

Studies of clay formation from granite have indicated that the order of appearance of secondary minerals during weathering is essentially the same, regardless of climate and landscape position, beginning with gibbsite and proceeding through kaolinite, iron oxides, manganese oxides, etc. (Tardy, et. al., 1973). This fact indicates that mineralogy of the soil is concurrent with its degree of development. Increased intensity of weathering brings about a mineralogical simplification of the clay fraction and a high proportion of oxyhydroxides and kaolinite are present as a soil reaches mineralogical maturity (Chesworth, 1973).

Kaolinite forms in an acid weathering environment where the concentrations of silica and aluminum are nearly equal and basic cations are nearly absent.

Hydroxyinterlayered vermiculite occurs where the concentration of hydrogen ions is moderate to high and aluminum and silica are present. Mica is often a precursor to this mineral. In all mineral weathering sequences, weathering proceeds toward the lowest free energy condition (Buol, et. al., 1980), that is, the least soluble mineral composition.

Goethite and hematite tend to be the most widespread of the iron oxide minerals in soil clays (Schwertmann, 1985). These materials as they occur in soils are seldom as well crystallized as when they are synthetically prepared (Schwertmann, 1985). This may be due to the fact that they form incrementally and sporadically during soil weathering, and their degree of crystallinity is an obvious reflection of the pedoenvironment (Schwertmann, 1985).

The basic structure of pedogenic iron oxides is octahedral, with an iron atom surrounded by six oxygen atoms (as in hematite) or hydroxide ions (as in goethite and lepidocrocite). The different phases vary in the arrangements of the individual octahedra. The alpha phase, that of hematite and goethite, is a hexagonal arrangement of close packed octahedra and the gamma phase, that of lepidocrocite, is a cubic arrangement of octahedra (Schwertmann and Taylor, 1989). Goethite occurs in almost

any soil type and climatic regime and is the source for yellow and brown soil colors. It is frequently associated with hematite, which, if present in high enough concentration, gives rise to red soil colors (Schwertmann and Taylor, 1989).

Lepidocrocite is often associated with vividly mottled reductomorphic soils (Schwertmann and Taylor, 1989; Fitzpatrick, et. al., 1985), but it has been identified in some freely drained soils (Fitzpatrick, et. al., 1985), on a wide range of parent materials and physiographic situations. Lepidocrocite formation requires a reducing condition to mobilize divalent iron and a subsequent oxidation at the solution interface (Fitzpatrick, et. al., 1985). Lepidocrocite is metastable, although reasonably well crystallized, relative to goethite. If kinetics are favorable lepidocrocite will form, and may persist, in many pedoenvironments. It has been known to remain stable for significant periods (Schwertmann, 1985).

Commonly used techniques for characterizing clay mineralogy in soils are not altogether quantitative, but it is possible to make good estimates of relative abundance of clay minerals if one considers some of the properties of the individual clay species. The cation exchange capacity (CEC) of kaolinite is highly pH

dependent, but is typically in the range of 1 to 10 cmol kg^{-1} clay. The CEC of vermiculites is typically about 120 to 150 cmol kg^{-1} clay. Illites typically range from 20 to 40 cmol kg^{-1} clay in CEC (Bohn, et. al., 1985). The apparent CEC of the clay can be used diagnostically to make an estimate of what the dominant clay minerals may be (Soil Survey Staff, 1983). Even though this is a calculated value and not a measured one, it provides some insight into the composition of the clay fraction. Another useful calculated value is the CEC to clay ratio (Soil Survey Staff, 1983) which has been empirically categorized into the taxonomic clay mineralogy classes, as follows: less than .2 is kaolinitic, .2 to .3 is kaolinitic or mixed, .3 to .5 is mixed, .5 to .7 is mixed or montmorillonitic and greater than .7 is montmorillonitic (Soil Survey Staff, 1983). These estimates have been shown to be applicable in most cases.

Mineralogy of soils in loamy particle size classes is determined by counting grains from representative sand fractions (Soil Survey Staff, 1975). Sand grains are often a reflection of the soil parent material and are not necessarily highly weathered although parent materials of sedimentary origin have undergone at least one cycle of weathering prior to surface exposure and may tend more toward siliceous mineralogy (Chesworth, 1973). Feldspars

are the most common constituent of the earth's crust (Fredrickson, 1951). Feldspars are anhydrous tectosilicates composed of corner sharing aluminum and silica tetrahedra in an infinite three dimensional array (Huang, 1989). Feldspars contain varying amounts of sodium, potassium, calcium and other trace cations. Sodium and calcium bearing feldspars are termed plagioclase. Varieties of potassium feldspars are sanidine, orthoclase, microcline and adularia. These have identical chemical compositions but vary in crystallographic properties (Huang, 1989).

The nature of feldspars makes them useful indicators of the nature of soil parent materials and degree of soil weathering (Huang, 1989). They are stable at high temperature and pressure, but are unstable at earth surface conditions. Their quantity in soils varies with intensity and capacity factors of the weathering environment and kaolinite may form rapidly from silt or even sand sized feldspar grains, depending on the microenvironment of weathering (Huang, 1989).

A taxonomic class of siliceous applies to soils that are more than 90 percent quartz, which is common in sedimentary materials, or other highly resistant mineral by weight (Soil Survey Staff, 1975). The mixed class of loamy soils requires that no single mineral other than

quartz or feldspar make up more than 40 percent by weight. As previously stated, the composition of minerals in these soils is determined by grain counts performed on representative sand fractions from the mineralogy control section of the soil under study (Soil Survey Staff, 1975).

2. MATERIALS AND METHODS

Nature of the Study Area

The study area is located about 20 miles northeast of Knoxville, Tennessee, in Grainger County (Figure 1). The area is in major land resource area 128, the Southern Appalachian Ridges and Valleys. The arrangement of ridges and valleys is controlled by a series of southwest to northeast trending thrust faults (Rodgers, 1953). The climate is humid and temperate (National Climatic Data Center, 1990). In winter, valleys are quite cool with occasional warm and cold spells. In summer, the valleys are warm and frequently hot. Average winter temperature is 3 degrees Celsius and the average summer temperature is 24 degrees Celsius. The coldest temperature on record is -32 degrees Celsius and the hottest is 39 degrees Celsius. The average annual precipitation is 106 centimeters, about half of which occurs between April and September. Average seasonal snowfall is 28 centimeters. The average afternoon relative humidity is about 60 percent (National Climatic Data Center, 1990).

The Richland Valley in Grainger County is a southwest to northeast trending valley that runs the entire length of the county. This valley averages about 1 mile wide and

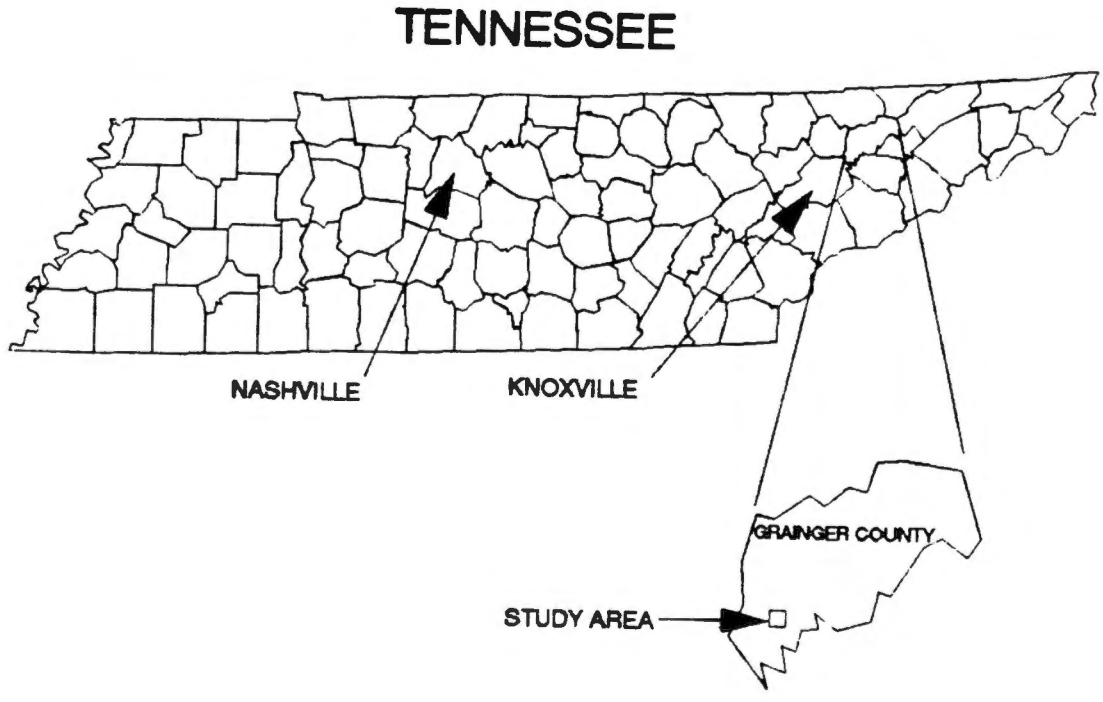


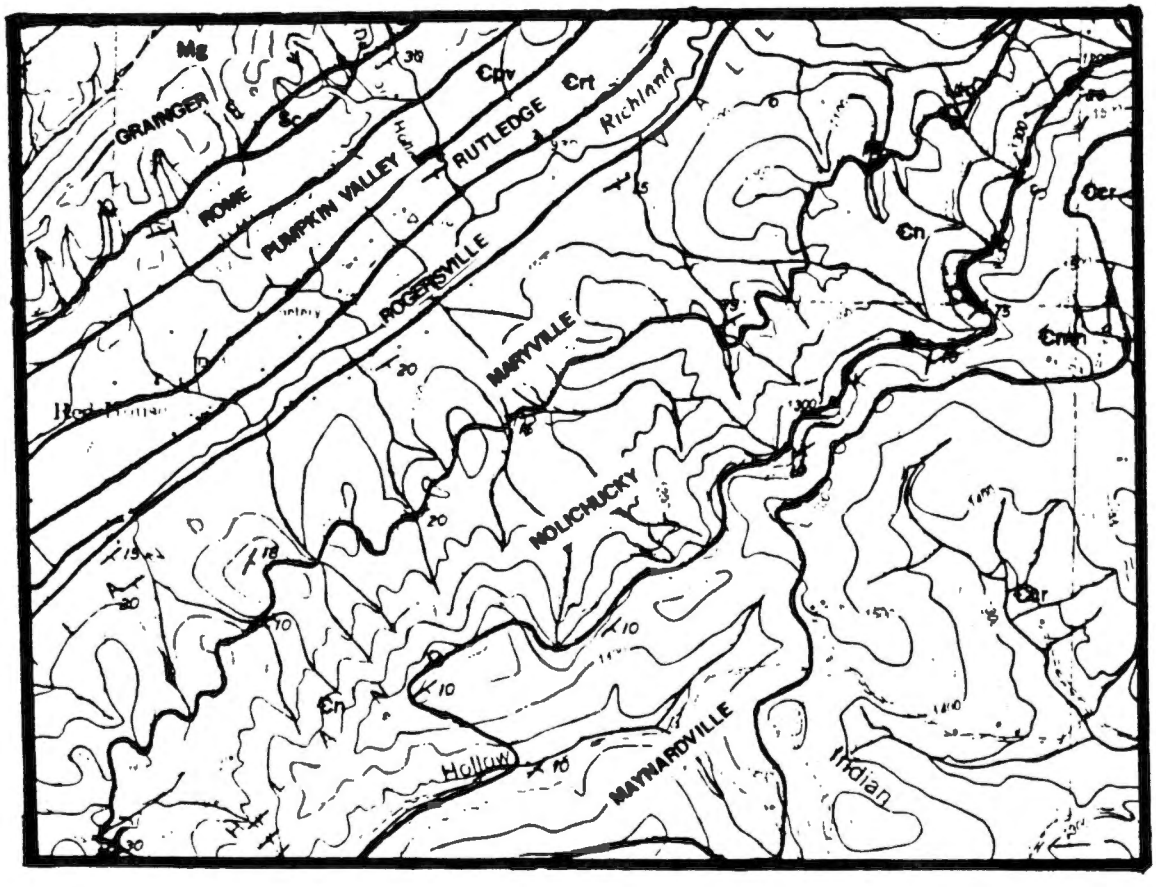
Figure 1. Map showing the general location of the study area relative to Tennessee.

is underlain by eight separate geologic formations of Cambrian and Mississippian age rocks. Relief is moderate to high, with a maximum elevation difference of nearly 200 meters.

Field methods

Two sites were chosen for landscape cross sections on the northeast part of the Luttrell, Tennessee topographic quadrangle in the Richland Valley. The sites were chosen for accessibilty and for how well they represented the landscapes associated with the various geologic formations. Figure 2 is a map showing the geology of the study area. Transects were conducted in straight lines at the two cross sections with stops occurring in each geologic unit. A total of 21 sites, consecutively numbered, were observed on the two cross sections (Figure 3). The transects crossed the valley roughly from northwest to southeast, approximately perpendicular to the strike of the rock strata. A hydraulic probe, hand auger or a suitable excavation was used to observe the soils at each stop.

Detailed morphologic descriptions of each soil layer were prepared at each stop, using standard field techniques and terminology (Soil Survey Staff, 1981). Sites were selected from each geologic unit for sampling.



Luttrell, Tennessee topographic quadrangle, northeast part.

Figure 2. Map showing the geologic units in the study area.

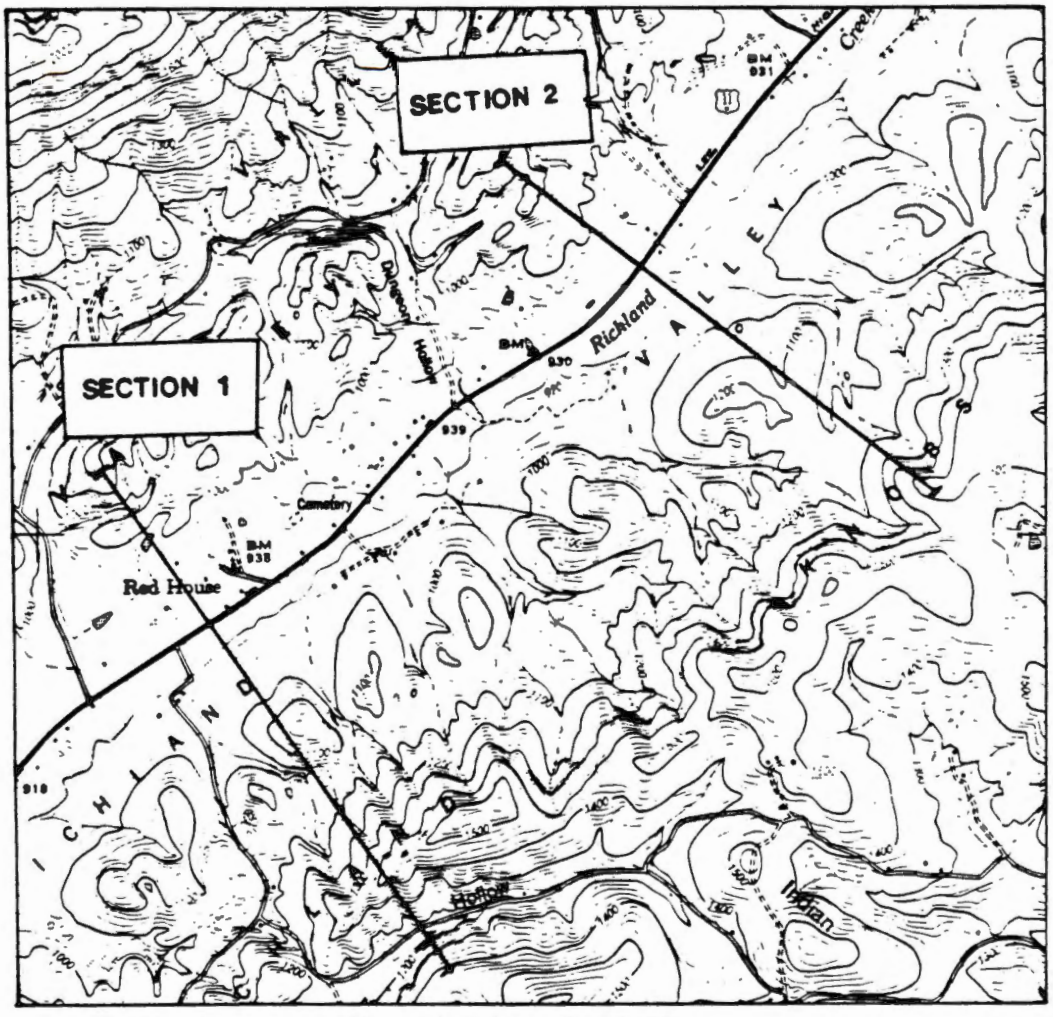


Figure 3. Topographic map showing the location of the two cross sections.

Selection of sample sites was based on the results of observations from the cross sections and on transect studies completed as part of a soil survey in progress in Grainger County. Ten pedons were sampled from the 21 observed for laboratory characterization. These ten pedons covered the soil types found on the various geologic formations. Sampling and sample preparation were carried out as prescribed for soil survey investigations. The pedons sampled and characterized in the laboratory were those numbered 1, 5, 6, 8, 9, 10, 12, 13, 14 and 16. The samples were air dried and crushed to pass a two millimeter screen (Soil Survey Staff, 1984). Subsamples were further ground as needed for individual laboratory methods.

Laboratory methods

Particle size analysis was determined on all samples using the pipette method (Kilmer and Alexander, 1949; Gee and Bauder, 1986). Particle size fractions determined were sand, silt and clay as defined by the USDA system of textural classification (Soil Survey Staff, 1981).

Soil pH was determined potentiometrically on a soil-water paste and a soil-calcium chloride paste (McLean, 1982). Manganese oxides were extracted with hydroxylamine hydrochloride (Chao, 1972; Gambrell and Patrick, 1982).

Free iron oxides were extracted with sodium citrate-sodium dithionite (Olson and Ellis, 1982). These extracts were analyzed for iron and manganese, respectively, by atomic absorption spectroscopy, on a Perkin-Elmer model 5000 spectrophotometer. Total carbon was determined on all samples by dry combustion using a Leco CR12 carbon analyzer according to the manufacturer's procedural recommendations.

Cation exchange capacity (CEC) and exchangeable bases were determined on all samples. Cation exchange capacity was determined by the ammonium acetate method at pH 7.0 (Chapman, 1965). A Labconco rapid distillation apparatus was used for extracting the ammonium from the displaced solution. Exchangeable bases were determined on an ammonium acetate extract by atomic absorption spectroscopy on a Perkin-Elmer model 5000 spectrophotometer (Jackson, 1969).

Clay mineralogy was determined on soil clays saved from the particle size analysis. Clays were concentrated from the suspensions by centrifugation. Clay mineralogy was determined on samples from mineralogy control sections (Soil Survey Staff, 1975) of soils in clayey families and from other horizons of particular interest.

Some investigators believe that with the newer detectors being used in x-ray diffractometers, removal of

iron from the samples prior to analysis is not as critical a step as it once was (Kunze and Dixon, 1986). Two samples having high clay and free iron contents were subjected to iron removal for comparison. These were the Bt1 and Bt2 horizons of profile 16. Iron was removed using sodium citrate-sodium dithionite (Kunze and Dixon, 1986).

All of the clay samples were split into two parts which were then saturated with potassium and magnesium, respectively (Jackson, 1969). Slides for x-ray analysis were prepared using a filter membrane peel technique (Drever, 1973). The prepared slides were then scanned on a Philips x-ray diffractometer using copper radiation at 35 kilovolts and 15 milliamperes settings on the x-ray tube, with a time constant of 2 seconds and full scale at 1000 counts. Potassium saturated slides were scanned at room temperature and following heat treatments at 300 and 550 degrees Celsius. Scans were made of magnesium saturated slides at ambient relative humidity and following overnight solvation in ethylene glycol vapor (Grim, 1968; Jackson, 1969; Whittig and Allardice, 1986). Peak positions were marked and recorded for each slide and treatment and then compared with standard mineral references (Grim, 1968; Jackson, 1969; Bayliss, et. al., 1986) for identification.

Mineralogy of the soils in loamy particle size classes (Soil Survey Staff, 1975) was determined from grain counts of the dominant sand fractions. The method was modified from Jackson, 1969 and a brief summary follows. Sand fractions were saved from particle size analysis. A petrographic slide was heated on a hotplate until warm and then a small amount of Lakeside cement was melted onto the slide and allowed to liquefy. A small amount of well mixed sand was then sprinkled onto the surface of the cement. Care was taken to get the sand on the slide in a monolayer and avoid excessive piling and cluttering of the individual grains. The slide was removed from the hotplate and allowed to cool.

The cooled slide was exposed to the vapor of concentrated hydrofluoric acid for 1 to 2 minutes. This etched the grain surfaces so that stains could be applied to the grains. The slide was then rinsed and immersed in saturated aqueous sodium cobaltonitrite solution for 2 minutes. This stained any potassium feldspars present a yellowish brown color (Jackson, 1969; Bailey and Stevens, 1960). The slide was rinsed again and then immersed in a one percent aqueous solution of malachite green stain for 2 minutes. This stained any plagioclase present a greenish or bluish color (Jackson, 1969; Bailey and Stevens, 1960). The slide was rinsed and allowed to dry.

Grain counting was done using a video microscope connected to a high resolution monitor. Magnification was set so that about 75 to 150 grains were readily visible on the monitor screen, and was not changed while the count was in progress. Grains were counted and classified until a minimum of 300 grains were counted on each slide. If 300 grains was reached before a full screen was counted, the full screen was counted anyway to avoid biasing the count. Weight percentages were then averaged for each mineral identified for the sand fractions counted.

Data Analysis

Some manipulations of measured data were made in an attempt to clarify some of the morphologic and mineralogic characteristics of the soils. Ratios of fine sand to total sand and very fine sand to total sand were plotted with depth for each pedon. This type of plot has been found to be a useful method of looking for lithologic discontinuities in polygenetic soils (Cabrera-Martinez, et. al., 1989).

Interpretation of x-ray diffraction data was aided by calculating the apparent CEC of the clay (that is, expressing the CEC on a clay basis) and by calculating the CEC to clay ratios of the samples (Soil Survey Staff, 1983). Careful examination of these values along with the

x-ray diffraction patterns provided a somewhat more quantitative estimate of the relative abundances of the clay minerals present.

Soil Classification

Since the soil series is generally reserved for soil mapping application in progressive soil surveys (Soil Survey Staff, 1975), the soils in this study were classified to the family level. The following paragraphs briefly describe the soil orders that apply to this research project, and some of their diagnostic properties. Classification criteria below the order level are not discussed for the sake of brevity of presentation.

Inceptisols are genetically youthful or juvenile soils that do not possess a degree of profile development that suggests intense weathering. They typically have brownish colors throughout, with relatively little development of soil structure and little vertical translocation of materials from upper horizons to the subsoil. The major diagnostic feature of most Inceptisols is that some horizons in the subsoil show some degree of alteration when compared to the soil's presumed parent material. That is, they are obviously unlike the parent material and this dissimilarity has occurred because of the action of soil forming factors. This subsoil zone of

alteration is called a cambic horizon (Soil Survey Staff, 1975).

Alfisols are high base soils that are characterized by a subsurface horizon that is typically brown or reddish in color and shows a significant accumulation of clay in the subsoil. This accumulated clay may either be translocated vertically from overlying horizons or formed in situ from weathering of primary minerals inherited from the parent material. The accumulation of clay in this subsoil horizon must be (for most soils) 1.2 times the amount of clay in the overlying surface horizon. The horizon or horizons in which the clay accumulation occurs is cumulatively called an argillic horizon. The base saturation requirement for Alfisols is that the base saturation must be greater than 35 percent at one of the following depths, 1.25 meters below the top of the argillic horizon or 1.8 meters below the soil surface, whichever is deeper, or just above bedrock, if bedrock occurs within these depths. In a genetic sense, Alfisols are considered intermediate in their degree of development between Inceptisols and Ultisols (Soil Survey Staff, 1975).

Genetically, Ultisols are more highly developed than either Inceptisols or Alfisols. They tend to have more reddish colors, although this is not a taxonomic

requirement. Ultisols have argillic horizons with clays that tend to be more highly weathered and therefore possess a lower degree of chemical reactivity. Ultisols are distinguished from Alfisols by having low base saturation. The base saturation of Ultisols is less than 35 percent. The depth where the determination is made is the same as given above for Alfisols (Soil Survey Staff, 1975).

Entisols are soils that have not been developing long enough to develop diagnostic subsurface horizons (Soil Survey Staff, 1975). They are young soils, commonly developing in recent alluvium or where soil profiles have been drastically truncated by erosion. Entisols are permitted to have developed a diagnostic surface horizon, or epipedon (Soil Survey Staff, 1975)

3. RESULTS AND DISCUSSION

Field Characteristics, Soil Morphology and Classification

This section discusses field observations and soil morphology of the pedons sampled for the research. Soil morphology and field conditions are discussed relative to the various landscape components and parent materials. Figure 4 shows the locations of observation sites and their positions on the landscape relative to the geologic formations in the two cross sections. Brief morphologic descriptions are provided in the text for ease of discussion. Detailed narrative descriptions are provided in Appendix A for all of the 21 sites described. Refer to Appendix D for an explanation of abbreviations used in morphologic descriptions. Landscape and morphology relationships are discussed for each parent material in order, beginning with the Grainger formation and proceeding through the Rome, Pumpkin Valley, Rutledge, Rogersville, Maryville, Nolichucky and Maynardville. This order will follow from northwest to southeast across the Richland Valley and will be used throughout all discussions for the sake of order.

Soils forming on the Grainger formation were moderately deep (i.e. 50 to 100 cm deep to bedrock). All areas of soils observed in the study of the Grainger

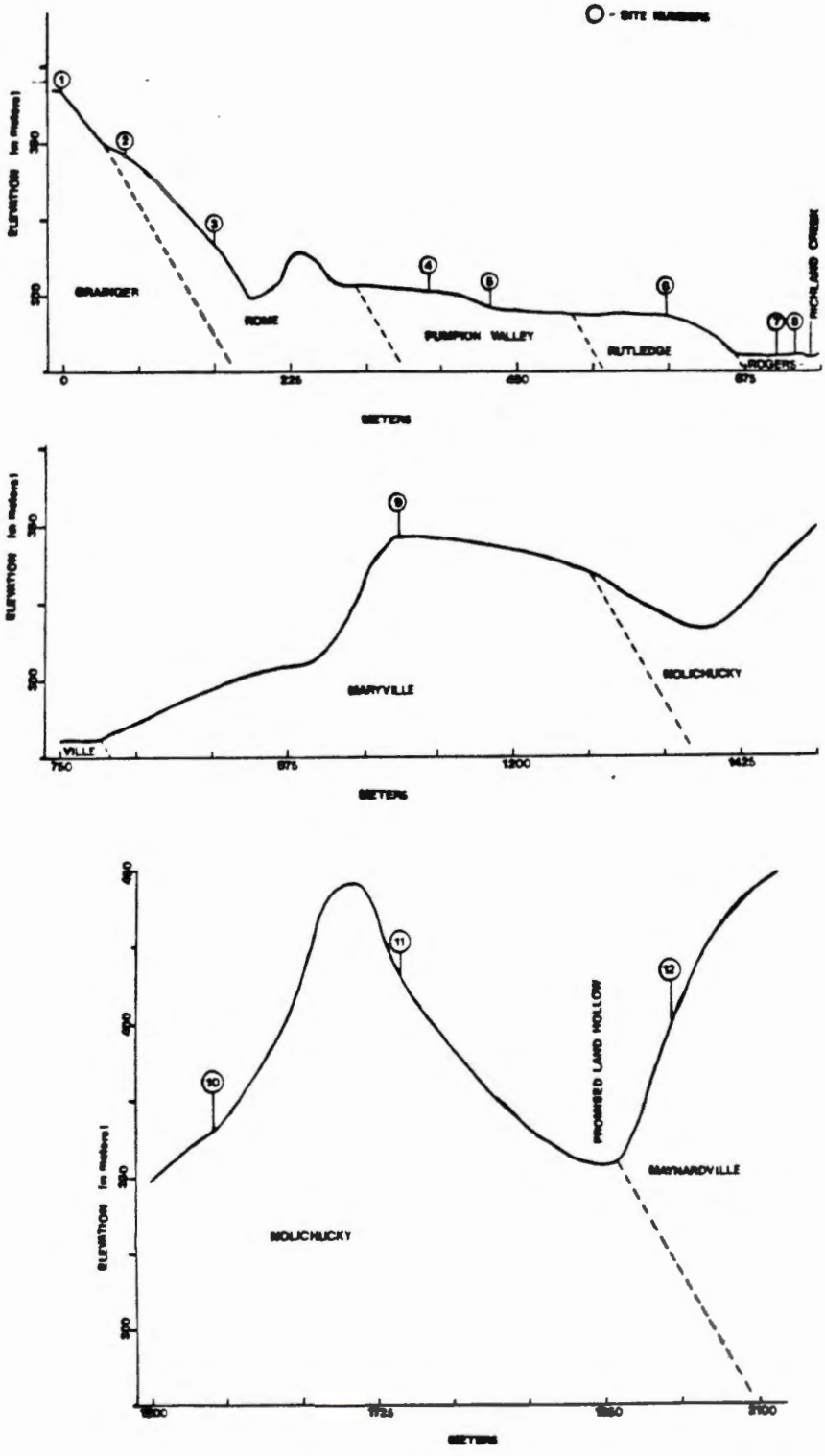


Figure 4. Location of observation sites. Cross section 1.

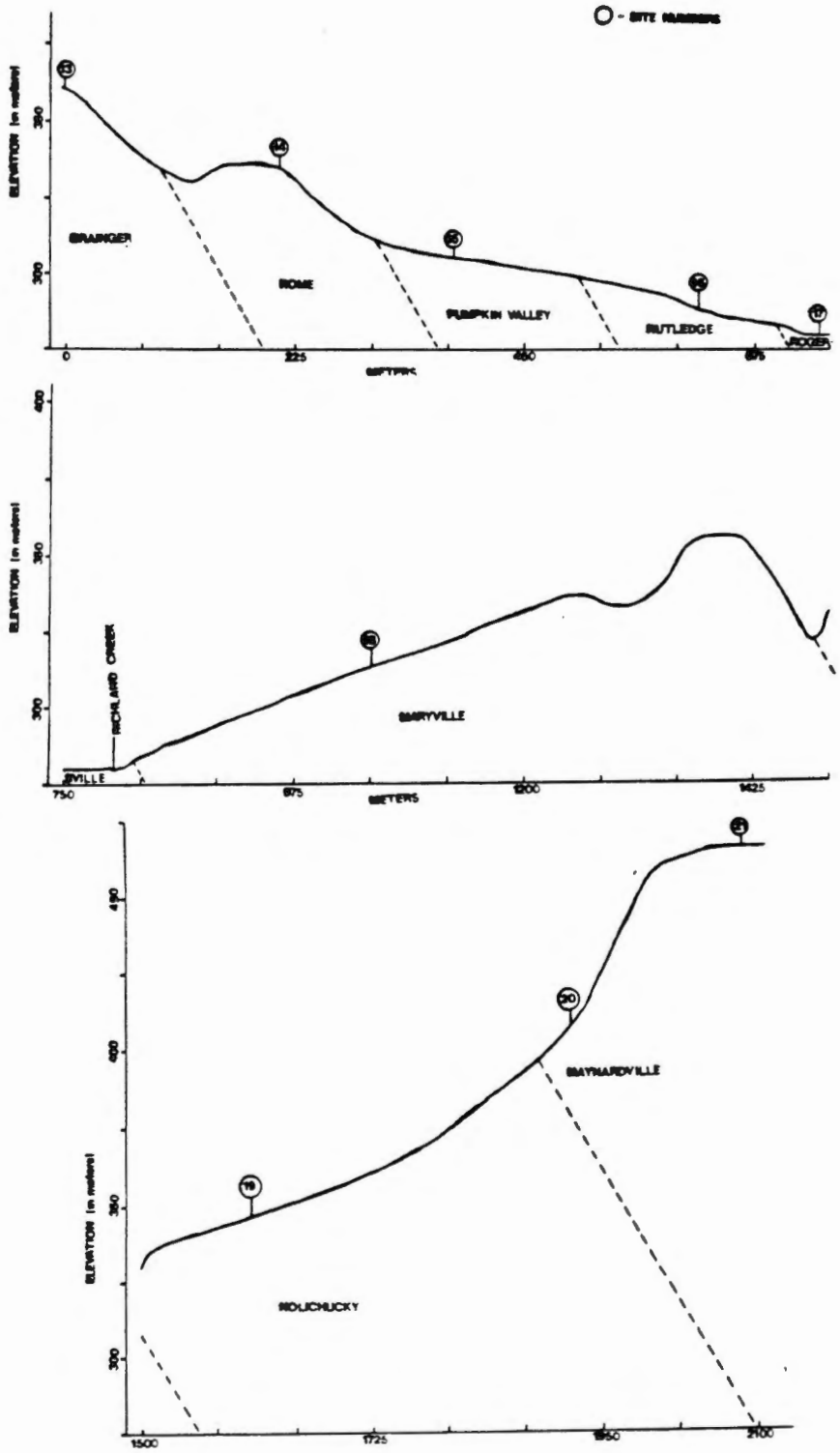


Figure 4 (continued). Cross section 2.

formation were in woodland consisting of mixed hardwoods such as oaks, maples and yellow poplars, and numerous minor species. The underlying rock was soft siltstone or shale, interbedded with a relatively hard, fine-grained sandstone. Some fossils were found in the parent material during field observations. The soils were high in silt content and had a notable content of coarse fragments weathered from the parent material. Slopes on these landscapes were often in excess of 40 percent except on narrow ridgetops and shoulders of ridges.

The pedons described in the Grainger formation were pedons 1 and 13 and both were sampled for characterization in the laboratory. The morphology of pedon 1 is given in Table 1, and that of pedon 13 in Table 2. Both of these pedons were described in the field as loamy-skeletal and as Dystrochrepts. Following laboratory characterization, these classifications were changed. Pedon 1 was found to be a loamy-skeletal, mixed, thermic Dystric Eutrochrept and pedon 13 was a coarse-loamy, mixed, thermic Typic Hapludalf.

These were weakly developed soils, low in clay content, with weak structure down through the subsoil horizons and no structure in the C horizons. The Bt horizon in pedon 13 (Table 2) was a weakly expressed argillic horizon. No morphologic evidence of clay

Table 1. Summary of the morphology of pedon 1.

Horizon	Depth cm	Color (moist)	Texture	Structure	Moist Consistence
Oi	8-0	Slightly decomposed hardwood leaf litter.			
A	0-4	10YR 4/3 (brown)	cn-l	1fgr	vfr
Bw1	4-24	10YR 5/6 (yellowish brown)	cn-sil	1fsbk	vfr
Bw2	24-41	10YR 5/8 (yellowish brown)	cnv-sil	2fsbk	fr
C	41-57	10YR 5/6 (yellowish brown)	cnv-sil	ma	vfr
Cr	57-68	Interbedded shale and fine grained sandstone of the Grainger formation.			
R	68+	Hard, fine grained Grainger sandstone.			

TAXONOMIC CLASS: loamy-skeletal, mixed, thermic Dystric Eutrochrept

Table 2. Summary of the morphology of pedon 13.

Horizon	Depth cm	Color (moist)	Texture	Structure	Moist Consistence
A	0-9	10YR 3/3 (dark brown)	gr-sil	2mgr	vfr
BE	9-15	10YR 5/3 (brown)	gr-sil	1fsbk	vfr
Bw	15-40	10YR 6/4 (light (yellowish brown)	gr-sil	1fsbk	vfr
Bt	40-68	10YR 6/6 (brownish yellow)	gr-sil	1fsbk	vfr
Cr	68-84	Weathered shale and sandstone, interbedded			
R	84+	Relatively unweathered, hard Grainger sandstone			

TAXONOMIC CLASS: coarse-loamy, mixed, thermic Typic Hapludalf

illuviation was present. There was evidence in both of these soils that the profiles may be remnants of deeper pedons that were very severely eroded during some past episode of erosion, possibly at a time when these uplands were cleared. This point will be discussed more fully in a later section.

These were high base soils, Eutrochrepts and Hapludalfs. The source of bases in these soils was feldspar weathering from the parent materials. This discussion will be developed more fully when soil mineralogy and chemical properties are discussed in later sections. Evidence will also be presented supporting the fact that soils forming in the Grainger formation are a source of transported sediment in other parts of this landscape.

Three sites were described in the Rome formation. These were pedons 2, 3 and 14. Pedon 14 was chosen as the characterization site for the Rome and a brief morphology of pedon 14 is given in Table 3. The three pedons described in the Rome formation had very similar morphology. Pedon 14 was classified as a loamy-skeletal, mixed, thermic, Lithic Dystrochrept. Pedons 2 and 3 were classified in the field as loamy-skeletal, mixed, thermic Typic Dystrochrepts, but it should be pointed out that

Table 3. Summary of the morphology of pedon 14.

Horizon	Depth cm	Color (moist)	Texture	Structure	Moist Consistence
A	0-6	10YR 5/4 (yellowish brown)	gr-l	2fgr	vfr
Bw	6-20	10YR 5/4 (yellowish brown)	gr-l	1fsbk	vfr
C	20-37	10YR 6/4 (light yellowish brown)	grx-l	ma	vfr
Cr	37-47	Variegated Rome shale, diggable with some difficulty			
R	47+	Hard, variegated sandy shale of the Rome formation			

TAXONOMIC CLASS: loamy-skeletal, mixed, thermic shallow Lithic Dystrochrept

their depths to bedrock were within a few centimeters of placing them in shallow families as well.

Rome formation landscapes were on lower lying rounded hills and ridges, lower in elevation than the Grainger formation landscapes. Slopes were quite variable, ranging from less than 10 to greater than 40 percent, with little difference noted in the soils formed on the various slopes. Pedon 14 was sampled on a ridgetop having a 9 percent slope and in an old pasture field. Some other areas of the Rome landscape were in woodland consisting of pines, oaks, poplar and beech on lower parts of some steeper sideslopes. These are extremely weakly developed soils, with weakly expressed cambic horizons and a notable content of rock fragments (Table 3).

Field notes indicated that the soils forming in the Pumpkin Valley shale ranged from shallow to moderately deep and that some areas where the soils were somewhat deeper were due to materials washing down the slopes and accumulating as thicker surface deposits. Three pedons were described in the Pumpkin Valley shale units. These were pedons 4, 5 and 15. Pedon 5 was chosen as the characterization sample because it showed some surface accumulation of colluvial materials over a subsoil higher in clay. This indicated that the material higher in clay probably represented what was weathering from the parent

material. Other areas observed on this formation were showing an effect where the soil was scoured down to rock and some shallow colluvial profiles were now developing. This site reflected the soil's relationship to its parent material, and the objective of the investigation was maintained.

The landforms underlain by the Pumpkin Valley shale were on gentle slopes, dominantly less than 12 percent. These were smooth, convex to planar slopes for the most part. Apparently, this stable geologic unit supported rather weakly developed soils. Deep weathering was being precluded by active erosion. Very few areas of this landscape component were wooded and most were being used for pasture and hay production.

The morphology of pedon 5 is given in Table 4. The upper part to a depth of 24 centimeters, was colluvial accumulation. Weak structure was observed to a depth of 34 centimeters and an argillic horizon with moderate structure (Bt) was present from 34 to 68 centimeters. The detailed description presented in Appendix A documents clay films present in the argillic horizon. The sampled pedon was classified as a fine, mixed, thermic Typic Hapludalf. The very high content of bases in this soil is thought to be man-induced as a result of agricultural

Table 4. Summary of the morphology of pedon 5.

Horizon	Depth cm	Color (moist)	Texture	Structure	Moist Consistence
Ap	0-7	10YR 4/3 (brown)	l	1fgr	vfr
BE	7-24	10YR 5/4 (yellowish brown)	l	1fsbk	vfr
2Bw	24-34	10YR 5/8 (yellowish brown)	sil	1msbk	fr
2Bt	34-68	10YR 5/8 (yellowish brown)	sicl	2msbk	fi
2Cr	68+	Moderately soft, tabular, Pumpkin Valley shale.			

TAXONOMIC CLASS: fine, mixed, thermic Typic Hapludalf

practices. This discussion will be developed more fully when the chemical properties are presented.

Two pedons were observed on the Rutledge limestone formation. These were pedons 6 and 16. Pedon 6 was formed in deep alluvium, deposited much earlier in the evolution of the landscape. No evidence of residuum from the Rutledge limestone was found in the sampled pedon to a depth of more than 5 meters. Morphology of pedon 6 is presented in Table 5. This pedon was well developed and represented a series of three episodes of deposition and subsequent soil formation. Discontiniuties were idendified at 281 centimeters and 435 centimeters. The genesis of this soil will be more fully discussed in later sections when the particle size distribution and chemical properties are presented. The soil is weathered deeply, as evidenced by clay formation and accumulation and red colors to considerable depth. This soil is relict and is formed on a Pleistocene stream terrace. Other observations throughout the Richland Valley indicate that terrace remnants are present on other parts of the Rutledge geologic unit. Pedon 6 was classified as a fine, kaolinitic, thermic, Typic Paleudalf. The high base nature of this soil may be influenced to some degree by agricultural practices of liming and fertilizing, but the quantity of bases present cannot be completely attributed

Table 5. Summary of the morphology of pedon 6.

Horizon	Depth cm	Color (moist)	Texture	Structure	Moist Consistence
Ap	0-20	7.5YR 4/4 (brown)	cl	1msbk	fr
AB	20-41	5YR 4/4 (reddish brown)	cl	1msbk	fr
Bt1	41-57	5YR 5/6 (yellowish red)	c	1msbk	fr
Bt2	57-92	2.5YR 4/6 (red)	c	2fsbk	fr
Bt3	92-134	2.5YR 4/6 (red)	c	2msbk	fr
Bt4	134-167	2.5YR 4/6 (red)	c	2msbk	fr
Bt5	167-190	2.5YR 4/6 (red)	c	2msbk	fr
Bt6	190-260	2.5YR 4/6 (red)	c	1msbk	fr
Bt7	260-281	2.5YR 4/6 (red)	c	1msbk	fr
2Bt8	281-302	2.5YR 4/6 (red)	c	1fsbk	fr
2Bt9	302-330	2.5YR 4/6 (red)	c	1fsbk	fr
2BC1	330-391	5YR 5/8 (yellowish red)	c	1fsbk	fr
2BC2	391-435	5YR 5/8 (yellowish red)	c	1fsbk	fr
2Cb	435-518	7.5YR 5/8 (strong brown)	c	ma	fr

TAXONOMIC CLASS: fine, kaolinitic, thermic Typic Paleudalf

to human activity. Further discussion of this phenomenon will be presented in later sections when chemical properties of this pedon are discussed.

Pedon 16 was in the Rutledge limestone residuum. The morphology of pedon 16 is given in Table 6. This pedon had a higher clay content and browner hues in the upper 150 centimeters. Only the upper 150 centimeters were sampled of this profile. This was sufficient to show the difference in classification between the alluvial profile and the residual profile. Pedon 16 was classified as a clayey, kaolinitic, thermic Typic Paleudult. A high content of bases was also present in the upper part of this profile. Again, the quantity of bases present could not be entirely attributed to agricultural management and the source of the base recharge was not specifically identified.

Most of the landscape associated with the Rutledge limestone had slopes of less than 12 percent. Although drains have cut through the Rutledge formation in places, the resistance of this parent material to geologic erosion caused it to remain stable for a significant period. The soils were very deep and intensely weathered, suggesting that geologic erosion has not been very active in removing upper layers from the developing soils. Red soils forming in these geologic materials may be more a result of some

Table 6. Summary of the morphology of pedon 16.

Horizon	Depth cm	Color (moist)	Texture	Structure	Moist Consistence
Ap	0-8	7.5YR 4/4 (brown)	cl	2mgr	fr
Bt1	8-23	5YR 4/6 (yellowish red)	sic	1msbk	fr
Bt2	23-64	5YR 5/8 (yellowish red)	c	2msbk	fr
Bt3	64-89	5YR 5/8 (yellowish red)	c	2msbk	fr
Bt4	89-109	5YR 5/8 (yellowish red)	c	1msbk	fr
Bt5	109-150	5YR 5/6 (yellowish red)	c	1msbk	fr

TAXONOMIC CLASS: clayey, kaolinitic, thermic Typic Paleudult

past climatic regime than of the present regime. If soil depth and degree of clay formation and accumulation are to be considered as representing the time factor of soil formation, then the soils on the Rutledge geologic unit are the oldest soils presently developing on this landscape.

There was not much remaining of the Rogersville shale in this part of the Richland Valley. A few small exposures of the thin bedded, fissile shale were found near the contacts with the surrounding geologies, but most of the Rogersville was removed by past erosion and the bulk of the formation is presently buried under the alluvium of Richland Creek. Apparently, of all of the formations in the Conasauga, the Rogersville shale was the most susceptible to erosion by water, either because of its mineralogical composition or because of its thin bedded and highly fractured nature. Whatever the reason, very little remains of it in this part of the Richland Valley.

The floodplain of Richland Creek was the lowest land elevation in the Richland Valley at the study site. The soil on the floodplain was observed at pedons 7, 8 and 17. Pedon 8 was sampled for laboratory characterization. This soil formed on a nearly level floodplain. The morphology of pedon 8 is presented in Table 7. This was a weakly

Table 7. Summary of the morphology of pedon 8.

Horizon	Depth cm	Color (moist)	Texture	Structure	Moist Consistence
A	0-8	10YR 4/3 (brown)	cl	1fgr	vfr
Bw1	8-21	10YR 4/4 (dark yellowish brown)	l	1fsbk to 2fgr	vfr
Bw2	21-56	10YR 4/6 (dark yellowish brown)	sil	1fsbk	fr
Bw3	56-80	10YR 4/6 (dark yellowish brown)	sil	1fsbk	fr
Bw4	80-109	10YR 4/4 (dark yellowish brown)	sil	1fsbk	fr
BC	109-150	10YR 4/4 (dark yellowish brown)	l	ma	fr

TAXONOMIC CLASS: fine-silty, mixed, thermic Fluvaquentic Eutrochrept

developed soil with a cambic horizon having weak structure throughout. The brown colors suggest that relatively little alteration has occurred from the parent material. Much of this soil profile was believed to be derived from headward erosion into the Grainger formation. Mineralogy and particle size distribution of this floodplain soil and that of the materials in the Grainger formation were remarkably similar. Theoretically, as Richland Creek incised itself into the Rogersville shale, the base level of the drainage changed. This helped to induce headward erosion into the Grainger formation and made it the source of sediment for the floodplain. Headward erosion would have been less likely into the Maryville, Nolichucky or Maynardville formations to the southeast because of the topography and their resistance to weathering. A careful study of the drainage patterns in the area indicated headward erosion to be more extensive into the Grainger formation and seemed to support this explanation of the source material for the floodplain sediments. Pedon 8 was classified as a fine-silty, mixed, thermic Fluvaquentic Eutrochrept. Pedon 7 was tentatively classified in the field as an Aeric Haplaquept and pedon 17 as a fine-loamy, mixed, thermic Fluvaquentic Eutrochrept.

The soils forming on the Maryville limestone were mostly moderately deep and deep soils (50 to 150

centimeters to limestone bedrock). Slopes ranged from 5 to 50 percent. The soils were reddish in color and high in clay content. Outcrops of Maryville limestone were common to many and occurred in bands on the landscape. The portion of the landscape underlain by the Maryville limestone was relatively stable but the soils did not weather as deeply as the residual soil in the Rutledge limestone. This was related to the nature of the parent material. The parent material apparently contained a higher proportion of dolomitic materials, and more impurities such as silica and clay.

Pedons 9 and 18 formed in the Maryville limestone. Pedon 9 was sampled for laboratory characterization and its morphology is given in Table 8. This pedon was quite high in clay content, yellowish red and red in color, with moderate structure development. Pedon 9 was classified as a fine, mixed, thermic Typic Hapludalf following laboratory characterization. Pedon 18, although shallower to rock, was given this same tentative classification in the field. Observations in other parts of the Richland Valley suggested that these two profiles were highly representative of soils forming in residuum from the Maryville limestone formation.

Soils forming on the Nolichucky shale formation were shallow and moderately deep. Slopes ranged from about 12

Table 8. Summary of the morphology of pedon 9.

Horizon	Depth cm	Color (moist)	Texture	Structure	Moist Consistence
A	0-8	10YR 3/4 (dark yellowish brown)	sicl	1mgr	fr
Bt1	8-20	5YR 4/6 (yellowish red)	sic	2fsbk	fr
Bt2	20-81	5YR 4/6 (yellowish red)	sic	2msbk	fi
Bt3	81-99	5YR 5/6 (yellowish red)	c	2msbk	fi
Bt4	99-129	2.5YR 4/8 (red)	c	2fsbk	fi
R	129+	Hard Maryville limestone			

TAXONOMIC CLASS: fine, mixed, thermic Typic Hapludalf

to greater than 50 percent. Erosion was severe on many of the areas observed. Field notes indicated numerous areas where erosion was so severe that only bedrock was exposed at the surface. Soils were observed on the Nolichucky formation at sites 10, 11 and 19. Pedon 10 was sampled for characterization in the laboratory. The soil at site 11 had a high content of shale fragments and was classified in the field as a Typic Udorthent. This site represented the most severely eroded portions of the Nolichucky. Pedon 19 was classified in the field as a clayey, mixed, thermic shallow Ochreptic Hapludult. The morphology was very weak but a thin argillic horizon was described. The morphology of pedon 10 is given in Table 9. This too was a very weakly developed soil with a relatively weak argillic horizon. Pedon 10 was classified as a fine-loamy, mixed, thermic Typic Hapludult.

The Maynardville formation at the study area contained a considerable amount of shale material, similar to the Nolichucky, along with thin-bedded, hard, fine-grained limestone. Some consideration was given during field work to the placement of the geologic boundary between the Nolichucky and Maynardville formations. This delineation may have been misplaced slightly when geologic mapping was done because the description of the Maynardville formation has little to say about the

Table 9. Summary of the morphology of pedon 10.

Horizon	Depth cm	Color (moist)	Texture	Structure	Moist Consistence
A	0-5	10YR 4/3 (brown)	sicl	2mgr	vfr
BE	5-15	10YR 5/4 (yellowish brown)	sil	1msbk	vfr
Bt1	15-26	10YR 5/6 (yellowish brown)	sicl	1msbk	fr
Bt2	26-52	7.5YR 5/6 (strong brown)	cn-sicl	1fsbk	fr
Cr	52+	Moderately soft Nolichucky shale			

TAXONOMIC CLASS: fine-loamy, mixed, thermic Typic Hapludult

presence of shale. Slopes in the Maynardville formation observed ranged from 20 to nearly 70 percent. The soils were shallow that formed in residuum from the Maynardville material. Pedons 12, 20 and 21 represented soils forming on the Maynardville formation. Pedon 12 was sampled for laboratory characterization and its morphology is given in Table 10. This pedon was weakly developed, and shallow over hard Maynardville limestone. The structure was moderate and brown colors were present throughout. Pedon 12 was classified as a fine-loamy, mixed, thermic Lithic Hapludalf. Pedon 20 was formed in colluvium over residuum and was classified in the field as a fine, mixed, thermic,Typic Hapludalf. Pedon 21 was formed in residuum from the Maynardville limestone and was classified in the field as a fine, mixed, thermic Lithic Hapludalf.

The shallow soils forming on the Maynardville limestone have been affected by accelerated erosion. Extremely steep slopes appeared to be the overriding cause of shallow depth of soil formation. Valleys cut into the Nolichucky formation provided a route of removal of sediment washing from this material and this was an additional reason why the influence of these materials was not notable on the Richland creek floodplain. Soils in the Maynardville limestone are mostly in woodland and are

Table 10. Summary of the morphology of pedon 12.

Horizon	Depth cm	Color (moist)	Texture	Structure	Moist Consistence
Oe	3-0	Hardwood litter in intermediate stages of decomposition, in a fibrous root mat.			
A	0-5	10YR 3/3 (dark brown)	sil	2mgr	vfr
BE	5-14	10YR 5/4 (yellowish brown)	sil	2fsbk	fr
Bt	14-29	7.5YR 5/6 (strong brown)	cl	2msbk	fr
R	29+	Hard Maynardville limestone			

TAXONOMIC CLASS: fine-loamy, mixed, thermic Lithic Hapludalf

high in bases, presumed to be inherited from the parent material.

Particle Size Distributions of the Soils

Particle size analysis of soils in the Grainger formation revealed that these soils were low in clay content and highest in silt content. This reflected the nature of the parent material. The shale and siltstone in the Grainger formation was very silty and also had a significant sand content in places where it was more intimately associated with the fine-grained sandstones of the formation. Clay curves indicated that these were weakly developed soils. Particle size distributions were quite regular with depth and this indicated a low intensity of pedologic weathering. The clay content was highest in the A horizon of pedon 1 (Table 11) where it was 20.3 percent, and was lower throughout the subsoil. This profile had once been deeper and erosion had been active and truncated the preexisting soil into the subsoil. A new soil is forming in the remaining material. The same was true of pedon 13 (Table 12). Clay content was 11.2 percent in the A and decreased to 8.7 in the BE. The Bt horizon in pedon 13 had only 11.3 percent clay and this placed this pedion in a coarse-loamy family. Pedon 1 was placed in a loamy-skeletal family due to the high

Table 11. Particle size distribution in pedon 1.

	percent of <2mm fraction							
Horizon	clay	silt	sand	vcos	cos	ms	fs	vfs
A	20.3	44.7	35.0	8.3	3.2	3.0	8.9	11.6
Bw1	15.7	50.7	33.6	6.7	3.3	3.5	9.4	10.7
Bw2	14.3	51.0	34.7	9.4	3.7	2.9	8.1	10.6
C	13.4	50.8	35.8	11.7	5.0	2.3	6.4	10.4

Table 12. Particle size distribution in pedon 13.

	percent of <2mm fraction							
Horizon	clay	silt	sand	vcos	cos	ms	fs	vfs
A	11.2	53.0	35.8	2.6	1.0	1.0	4.7	26.5
BE	8.7	54.1	37.2	2.0	1.0	1.1	4.6	28.5
Bw	5.4	57.7	36.9	4.9	1.7	1.3	4.5	24.5
Bt	11.3	54.6	34.1	4.6	2.1	1.0	4.5	21.9

content of rock fragments. Data on rock fragment content of the soils are presented in Appendix C.

Very fine sand was the most abundant of the sand fractions in these soils, and ranged from about 10 to 11 percent in pedon 1 and from about 22 to 26 percent in pedon 13. Silt was the primary textural component in these soils, and this reflected the contribution of the parent material. Little weathering has occurred in these soils. The soil materials were so similar to the parent materials that hardly any weathering appeared to have occurred.

Pedon 14 was sampled and characterized to represent soils forming on the Rome formation. The data from the particle size analysis of this pedon are presented in Table 13. This was a shallow, weakly developed soil, formed in the siltstone and sandy shale of the Rome formation. Clay content was highest in the surface layer, where it was 15.9 percent and lowest in the Bw horizon where it was 12.6 percent. This suggests that erosion may have truncated some portion of a preexisting deeper profile and weathering has occurred to some small degree in the remaining material. Content of rock fragments (Appendix C) was sufficient to place this soil in a loamy-skeletal particle size class. The volume percent of rock fragments was 28 percent in the A horizon, 30 percent in

Table 13. Particle size distribution in pedon 14.

	percent of <2mm fraction							
Horizon	clay	silt	sand	vcos	cos	ms	fs	vfs
A	15.9	36.0	48.1	14.6	7.7	2.5	6.5	16.8
Bw	12.6	40.8	46.6	13.3	8.4	3.0	6.4	15.5
C	15.3	40.3	44.4	15.7	8.5	2.9	5.7	11.6

the Bw horizon and 69 percent in the C horizon. Rock fragments present were channers and gravels of siltstone and sandy shale.

The primary textural component in each horizon was sand. Content of sand was 48.1 percent in the A horizon, 46.6 percent in the Bw horizon and 44.4 percent in the C horizon. The most abundant sand fractions were very coarse sand and very fine sand. Most of the very coarse sand fraction was made up of bits of Rome siltstone and shale and this was easily distinguished by observation of the individual grains. More than one mineral was present in these very coarse sand grains. Very coarse sand made up 14.6 percent of the A horizon, 13.3 percent of the Bw horizon and 15.7 percent of the C horizon. Very fine sand made up 16.8 percent of the A horizon, 15.5 percent of the Bw horizon and 11.6 percent of the C horizon.

Particle size distribution with depth was regular in this pedon, indicating that relatively little pedologic weathering had occurred and suggesting that the whole soil profile had indeed formed in residuum from the Rome parent material. The ratio of very fine sand to total sand decreased somewhat with depth (Figure 5), suggesting that the Rome formation parent material initially weathers to coarser-grained aggregates.

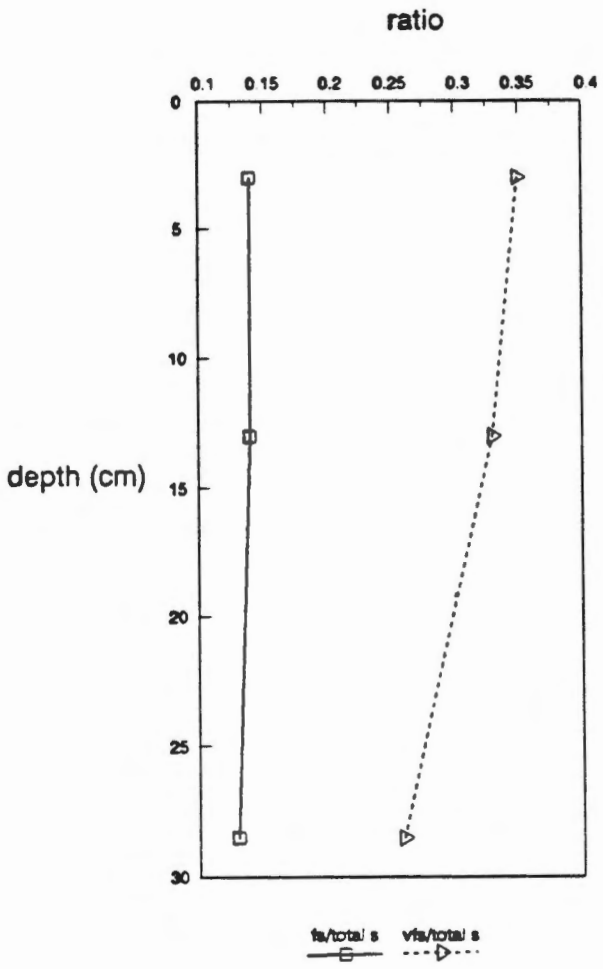


Figure 5. Plot of sand ratios with depth for pedon 14.

Soils forming on the Pumpkin Valley Shale were sampled for characterization at site 5. Particle size data for pedon 5 are presented in Table 14. With the exception of the A horizon, the content of clay increased regularly with depth in this profile. The clay content was 21.4 percent in the A, 20.7 percent in the BE, 23.7 percent in the 2Bw and 39.9 percent in the 2Bt horizon. Silt was the major component of the fine earth, ranging from 44 percent in the 2Bt to 54.1 percent in the 2Bw. The Pumpkin Valley shale is a silty shale and the silt was presumed to be derived in great part from the parent material. Since much of the very coarse sand was made up of bits of shale, it was thought likely that some of the silt present may have been due to the pedologic weathering of materials from the sand fraction.

The most abundant sand fraction was very fine sand in the 2Bw and 2Bt horizons, where it made up 9.5 and 7.7 percent. The most abundant of the sand fractions in the A and BE horizons was very coarse sand, which made up 9.8 and 11.8 percent.

The particle size distribution in this pedon indicated a lithologic discontinuity at 24 cm, just above the 2Bw horizon. A significant decrease in sand content occurred at this point (from 32 to 22.2 percent), accompanied by an increase in silt content (from 47.3 to

Table 14. Particle size distribution in pedon 5.

	percent of <2mm fraction							
Horizon	clay	silt	sand	vcos	cos	ms	fs	vfs
A	21.4	46.0	32.6	9.8	6.5	2.6	4.3	9.4
BE	20.7	47.3	32.0	11.8	5.4	2.2	3.5	9.1
2Bw	23.7	54.1	22.2	5.7	3.3	1.0	2.7	9.5
2Bt	39.9	44.0	16.1	2.7	2.4	1.0	2.3	7.7

54.1 percent). Clay content did not change significantly at this point. The ratio of very fine sand to total sand (Figure 6) showed this discontinuity quite well. The material above 24 cm (the A and BE horizons) represented a colluvial or slope wash of material downslope. The lower portion of the profile is formed in residuum from the Pumpkin Valley Shale. The preexisting profile was truncated as the new material moved in on top of the old. No evidence of an old surface layer was found.

Some degree of pedologic weathering occurred across the discontinuity. The BE and 2Bw horizons both have been influenced, and the clay distribution indicated that illuviation of clay from the BE to the 2Bw had occurred. There was a general decrease in the sand content at the discontinuity, with the exception of very fine sand, which increased. This suggested that the underlying material weathered from the Pumpkin Valley Shale, which is generally not coarse textured, but tends to be more silty. The horizons above the discontinuity were derived largely from materials weathered from the Rome formation, and the part of the Pumpkin Valley formation which is up-slope on the landscape from pedon 5.

The Rutledge limestone underlies a gently sloping to sloping component of the landscape which was characterized by deep, well developed soils. There were at least two

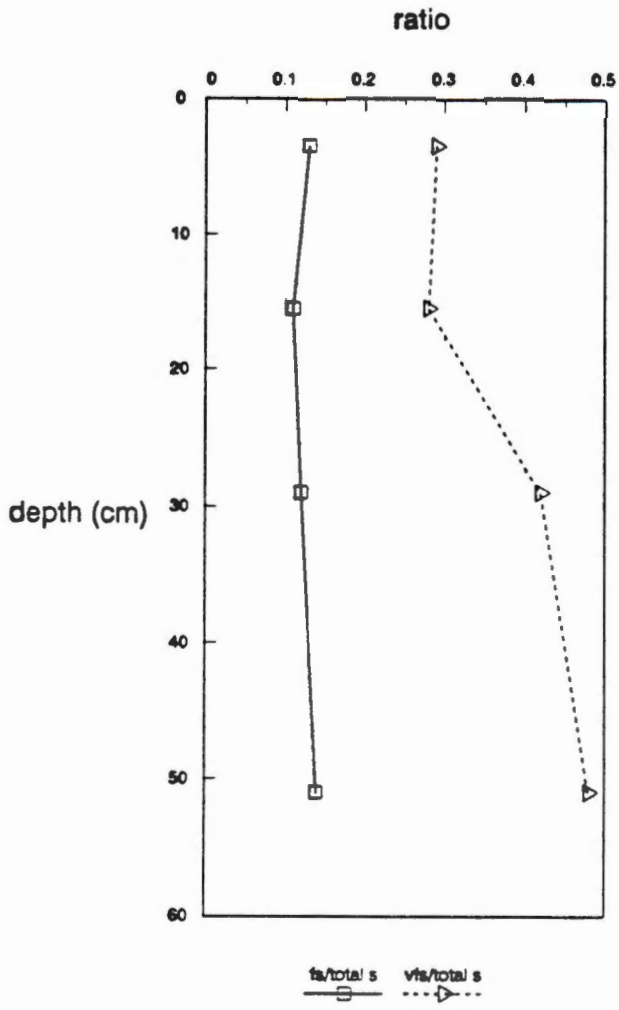


Figure 6. Plot of sand ratios with depth for pedon 5.

distinct soil types forming in association with the Rutledge limestone. Both of these were investigated on this study. Site number 6 was described in a very deep alluvial soil, forming on a Pleistocene terrace. Obviously, the transported material in the alluvial profile had already undergone at least one episode of weathering prior to its deposition here. Pedon 16 was described in a soil forming in residuum from the Rutledge limestone. This soil was also quite deep and well developed, although the colors in the subsoil were yellower than those found in the deep terrace soil. This indicated that the residual materials were not as intensely weathered as those in the alluvium at pedon 6. Despite the stage of pedologic development, pedon 16 is chronologically the oldest soil forming on this landscape. A considerable period of time was required to produce a soil profile this deep and highly developed from limestone bedrock.

The particle size distribution for pedon 6 is presented in Table 15. Two discontinuities were identified in this profile on the basis of particle size distribution. These were at 281 cm and 435 cm, and were the result of different episodes of deposition. These depths corresponded to the top of the 2Bt8 horizon and the 2Cb horizon. Ratios of fine sand to total sand and very

Table 15. Particle size distribution in pedon 6.

	percent of <2mm fraction							
Horizon	clay	silt	sand	vcos	cos	ms	fs	vfs
Ap	31.7	41.6	26.7	2.1	3.9	5.2	9.8	5.7
AB	34.2	42.7	23.1	1.8	3.3	4.4	8.7	4.9
Bt1	43.6	34.8	21.6	1.6	2.9	4.3	8.1	4.7
Bt2	43.3	34.8	21.9	1.4	3.0	4.4	8.3	4.8
Bt3	45.5	33.0	21.5	0.9	2.6	4.2	8.9	4.9
Bt4	47.6	31.6	20.8	0.8	2.3	4.3	8.5	4.9
Bt5	47.5	29.6	22.9	1.1	2.5	4.5	9.4	5.4
Bt6	49.3	30.4	20.3	0.7	2.1	3.8	8.7	5.0
Bt7	46.8	34.2	19.0	0.7	2.1	3.8	7.7	4.7
2Bt8	49.4	31.4	19.2	1.0	2.3	2.9	7.0	6.0
2Bt9	49.0	33.4	17.6	0.5	1.4	3.2	7.0	5.5
2BC1	45.6	36.6	17.8	0.5	1.0	3.2	7.5	5.6
2BC2	44.0	34.8	21.2	0.5	1.2	4.0	9.5	6.0
2Cb	61.1	16.0	22.9	1.7	2.7	5.7	9.2	3.6

fine sand to total sand (Figure 7) showed these discontinuities quite well. Figure 7 is plotted to the horizon midpoints. The 2Bt8 horizon has its midpoint at 291.5 cm and the 2Cb horizon midpoint is at 476.5 cm.

Clay content in pedon 6 ranged from 31.7 in the Ap horizon to 61.1 percent in the 2Cb horizon. With the exception of the Bt7 horizon, clay increased generally with depth. The Bt7 had 46.8 percent clay and was just above the first discontinuity and was thought to represent the pedologic weathering front active on the upper depositional sequence. This accounted for the lower clay accumulation in this horizon. Pedologic weathering had been active in the second depositional sequence (beginning in the 2Bt8 horizon) prior to deposition of the upper sequence. The 2Bt8 through the 2BC2 horizons represented a relict paleosol that had undergone approximately the same degree of weathering in the 2Bt8 and 2Bt9 horizons during transport and soil formation as had the upper sequence, based on the relative proportions of clay formation and accumulation. The top of the 2BC1 represents the front of maximum pedologic weathering that was active in the paleosol at the time it was buried. This paleosol probably dated to the early Pleistocene. The 2Cb horizon is another relict paleosol, buried under the second sequence. A yellower color (see Table 5) and

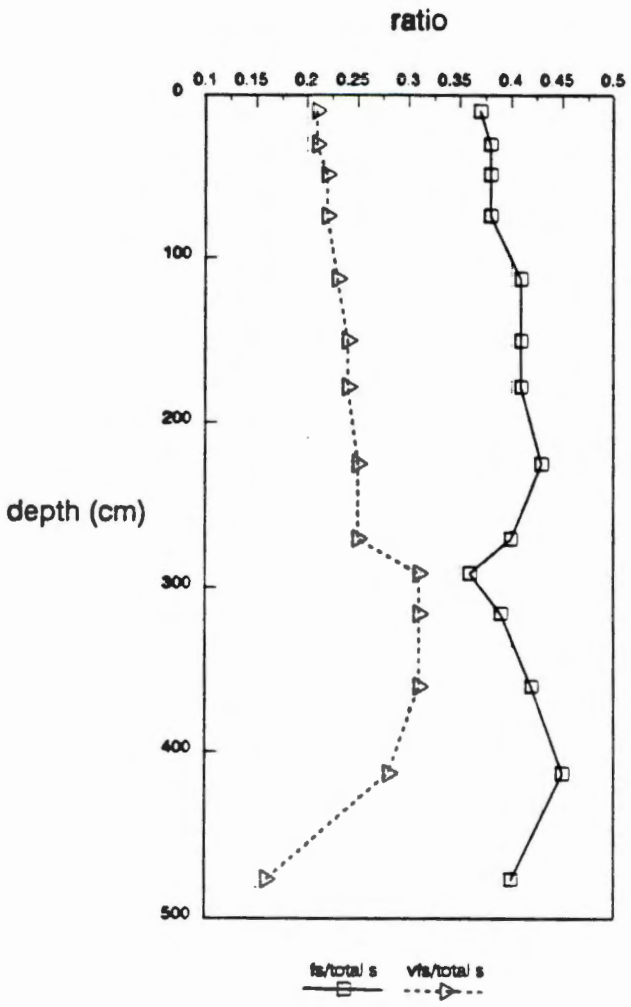


Figure 7. Plot of sand ratios with depth for pedon 6.

much higher clay content (61.1 percent, Table 15) were present. A few rounded sandstone fragments were collected from this layer during sampling. This was probably also an early Pleistocene, or possibly a pre-Pleistocene deposition.

The soil at site 16 was in residuum from the Rutledge limestone. Its particle size distribution is presented in Table 16. Figure 8 shows the sand, silt and clay distribution graphically and Figure 9 is a plot of sand fraction distribution with depth. This was a typical particle size distribution that would be expected in a soil forming in residuum from a relatively pure limestone or dolostone such as the Rutledge. Content of clay generally increased with depth, from 35.1 percent in the Ap to 81 percent in the Bt5. There was very little sand in the subsoil horizons. Higher proportions of sand and silt in the upper layers were due to migration of the fine fractions to the lower horizons. There was little evidence to suggest that any type of colluvial accumulation was present in the surface layers. This profile formed in residuum from the Rutledge parent material and has been forming on a landscape component that has been stable since pre-Pleistocene times.

Pedon 8 was sampled in the recent alluvial soil forming over the Rogersville Shale geologic unit. Table

Table 16. Particle size distribution in pedon 16.

	percent of <2mm fraction							
Horizon	clay	silt	sand	vcos	cos	ms	fs	vfs
Ap	35.1	43.8	21.1	1.2	2.5	3.7	8.5	5.2
Bt1	41.0	42.6	16.4	0.6	2.2	3.2	6.7	3.7
Bt2	70.6	24.9	4.5	0.3	0.7	0.7	1.9	0.9
Bt3	81.2	17.4	1.4	0.1	0.1	0.2	0.4	0.6
Bt4	83.7	13.2	3.1	0.0	0.4	0.6	1.2	0.9
Bt5	81.0	16.1	2.9	0.1	0.2	0.5	1.2	0.9

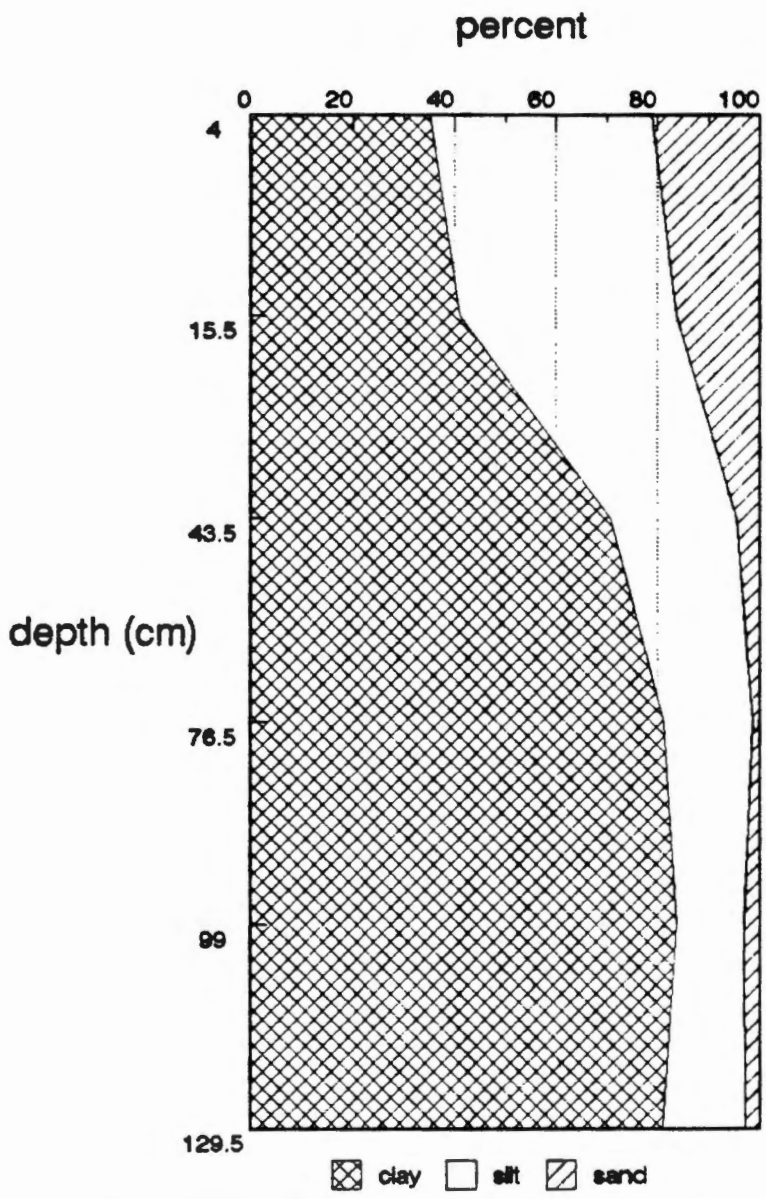


Figure 8. The distribution of sand, silt and clay in pedon 16.

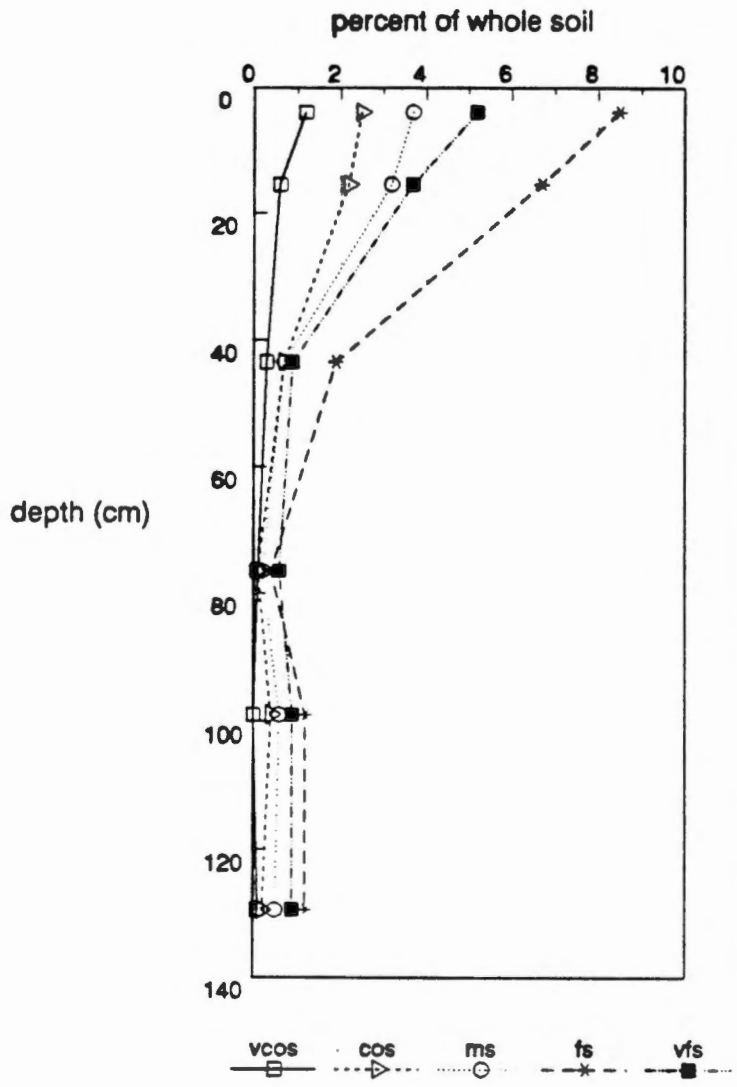


Figure 9. The distribution of sand fractions with depth in pedon 16.

17 gives the particle size distribution data and Figure 10 shows the sand ratio plots with depth for this profile. Clay content was highest in the A horizon where it was 28.7 percent and generally decreased somewhat with depth to the BC horizon where it was 19.3 percent. Silt was the major constituent of the fine earth fraction. Content of silt ranged from 39.1 percent in the Bw1 to 60.6 percent in the Bw4. The dominant sand fraction was fine sand in all horizons except the Bw4, where it was very fine sand. Fine sand ranged from 5.8 percent of the whole soil in the Bw4 to 21.2 percent of the whole soil in the BC.

Sand ratio plots (Figure 10) indicated that two or three different depositional episodes had probably occurred in this profile. Horizon nomenclature was not used to reflect this since the conventions used in assigning horizons designations stated that lithologic discontinuities were generally not indicated in recent alluvium or materials from the same source, unless they would help significantly in clarifying soil forming processes. In this weakly developed profile, there would not be much clarification by indicating lithologic discontinuities in the profile description. This soil is probably not much more than 100 or 200 years old, and probably dates to the time when the uplands were first cleared of trees and farming operations were established

Table 17. Particle size distribution in pedon 8.

	percent of <2mm fraction							
Horizon	clay	silt	sand	vcos	cos	ms	fs	vfs
A	28.7	40.0	31.3	0.4	3.8	7.9	13.3	5.9
Bw1	24.0	39.1	36.9	0.7	3.7	8.6	17.1	6.8
Bw2	24.3	51.1	24.6	0.3	2.2	4.8	10.3	7.0
Bw3	23.0	56.7	20.3	0.3	1.9	4.3	7.6	6.2
Bw4	23.7	60.6	15.7	0.0	0.1	0.8	5.8	9.0
BC	19.3	43.0	37.7	0.0	0.2	2.9	21.2	13.4

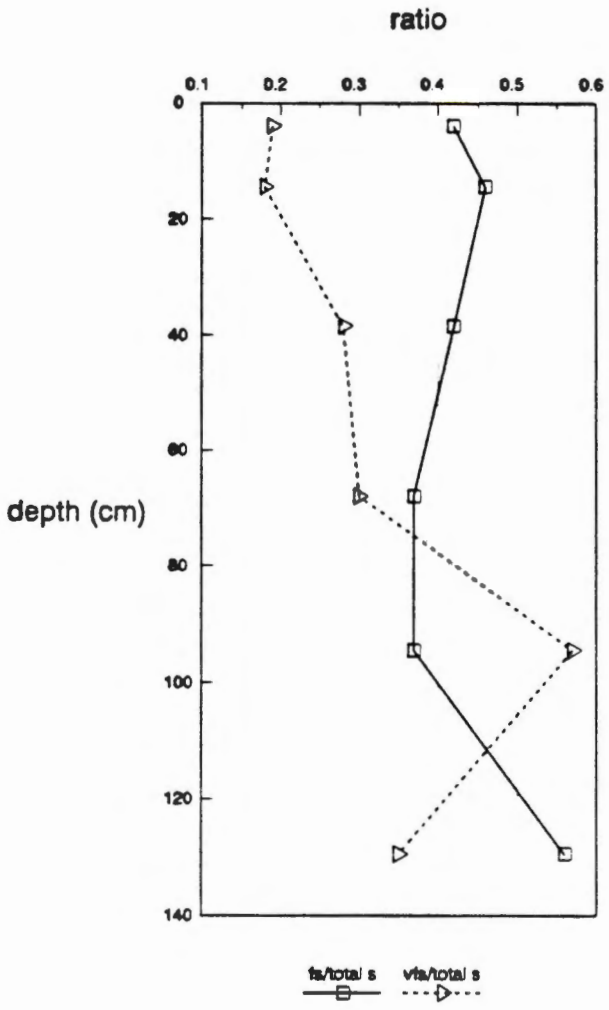


Figure 10. Plot of sand ratios with depth for pedon 8.

by settlers in the area. No significant outcrop of the Rogersville shale was found in the transect areas. No profile sample is presented of soils forming in materials directly weathered from the Rogersville formation.

The landscape underlain by the Maryville formation was relatively stable and the Maryville was apparently quite resistant to weathering by erosion and stream action. There is a distinct bluff where the Maryville outcrops along Richland Creek, indicating that the Maryville limestone is limiting southward migration of the stream channel. The landform underlain by the Maryville was a counterpart to the Rutledge limestone in this landscape and it was suspected that some old stream terraces may be found on parts of the Maryville geologic unit. Observations made during field studies revealed no such depositional features in the immediate study area and no evidence of alluvial profiles were found on the transect lines. The likelihood remains that they may exist on other parts of the unit.

Weathering of the Maryville limestone has given rise to clayey soils, as previously discussed. These soils have variable depth to rock and rock outcrops are common on the unit. This research has not attempted to ascertain exactly why this geologic unit weathers in this fashion. Scattered rock outcrops are exposed throughout the unit

and the soils range from shallow to deep to bedrock. The nature of the rock itself is probably a significant contributor to this pattern of weathering.

The soils forming on the Maryville limestone unit were represented by pedon 9. Table 18 gives the particle size distribution for pedon 9. Clay percentage increased regularly with depth and ranged from 27.4 percent in the A horizon to 83.8 percent in the Bt4, just above bedrock. Content of silt decreased regularly with depth, from 56.2 percent in the A horizon to 13.5 percent in the Bt4 horizon. Content of sand also decreased regularly with depth, from 16.4 percent in the A to 2.7 percent in the Bt4 horizon.

This profile formed in residuum from the Maryville limestone. Clay migration and formation was an obvious feature in the particle size distribution. The soil colors (Table 8) indicated that the highest degree of rubification due to weathering and oxidation of iron compounds occurred in the Bt4 horizon. The highest degree of pedologic weathering in this profile was occurring in the layer just above the bedrock. The morphology and weathering profile of this soil was probably influenced to some degree by past climatic shifts. The soil probably dates to pre-Pleistocene times, although it is not as deeply weathered as the Rutledge limestone residuum at

Table 18. Particle size distribution in pedon 9.

	percent of <2mm fraction							
Horizon	clay	silt	sand	vcos	cos	ms	fs	vfs
A	27.4	56.2	16.4	0.6	1.7	2.0	3.7	8.4
Bt1	40.7	46.8	12.5	0.7	1.0	1.4	2.5	6.9
Bt2	52.8	42.1	5.1	0.3	0.7	0.7	1.3	2.1
Bt3	69.8	26.9	3.3	0.0	0.4	0.4	0.8	1.7
Bt4	83.8	13.5	2.7	0.1	0.2	0.3	0.9	1.2

site 16. An appreciable period of time was still required to form a profile this deep from limestone bedrock.

The soil forming in residuum on the Nolichucky Shale was sampled at site 10. Particle size data for pedon 10 are presented in Table 19. This was a typical residual weathering profile, with a clay curve having 27.8 percent clay in the A horizon, 22.5 percent in the eluvial BE horizon, 30.9 percent in the Bt1 and 32.4 percent in the Bt2 horizon. The main constituent of the fine earth was the silt fraction, which ranged from 53.7 percent in the Bt2 horizon to 65 percent in the BE horizon. Very coarse sand was the dominant component of the sand fraction, ranging from 3.4 percent in the BE horizon to 6.1 percent in the Bt2 horizon. The very coarse sand fraction was largely composed of bits of shale that probably contained more that one mineral species.

This profile was not weathered very intensely. The landscape is strongly sloping and has doubtless undergone many cycles of erosion and renewed soil formation. Other observations in the Nolichucky unit revealed many severely eroded areas where soil material had essentially been removed from the underlying bedrock. This pedon, however, represented a period of soil formation long enough to have resulted in the formation of a weak argillic horizon. This profile was apparently the remains of the lower part

Table 19. Particle size distribution in pedon 10.

	percent of <2mm fraction							
Horizon	clay	silt	sand	vcos	cos	ms	fs	vfs
A	27.8	60.4	11.8	3.9	3.0	0.8	1.7	2.4
BE	22.5	65.0	12.5	3.4	3.6	1.1	1.9	2.5
Bt1	30.9	57.2	11.9	4.7	3.1	0.9	1.3	1.9
Bt2	32.4	53.7	13.9	6.1	3.7	1.0	1.6	1.5

of a preexisting deeper soil profile in which the formation of the argillic horizon has proceeded following a recent cycle of erosion.

Pedon 12 was a shallow, weakly developed profile representative of soils formed in residuum from the Maynardville limestone in the study area. Table 20 gives the results of the particle size analysis of this pedon. The A horizon had 23 percent clay. The eluvial BE horizon had a clay content of 18.1 percent and the Bt horizon had 34.5 percent clay. Silt was the dominant constituent of the fine earth, making up 53.2 percent of the A horizon, 57.4 percent of the BE and 43.8 percent of the Bt. The dominant sand fraction was fine sand, which made up 9.6 percent of the A, 10.5 percent of the BE and 9.3 percent of the Bt horizon.

Particle size distribution was regular with depth, showing development of an argillic horizon just above the contact with the underlying Maynardville limestone. This profile is the remains of a preexisting deeper soil profile. Following the truncation of the upper part, soil formation proceeded in the remaining material to form the weak argillic horizon observable in the present profile.

Table 20. Particle size distribution in pedon 12.

	percent of <2mm fraction							
Horizon	clay	silt	sand	vcos	cos	ms	fs	vfs
A	23.0	53.2	23.8	2.2	2.1	5.0	9.6	4.9
BE	18.1	57.4	24.5	1.8	2.1	5.4	10.5	4.7
Bt	34.5	43.8	21.7	1.0	1.8	6.0	9.3	3.6

Mineralogy of the Soils

Of the ten profiles sampled and characterized, four of them were in clayey families. These were pedons 5, 6, 9 and 16. Clay mineralogy was determined on the control sections of these four pedons and was also determined on the clay fraction of the Bw2 and C horizons of pedon 1 and on the Bt horizon of pedon 13. Table 21 is a summary of the findings of the x-ray analysis of the clays from these samples. X-ray diffractograms are presented in Appendix B for all samples and treatments. Appendix C has data calculated for the CEC to clay ratios and the apparent CEC of the clays. These data were used in conjunction with the diffractograms in assigning the relative abundances to the clay minerals.

Analysis of clays in pedons 1 and 13, from the Grainger formation was determined as a point of interest. Soils forming on the Grainger were found to be high in exchangeable potassium and it was found that potassium feldspar was the likely source. Potassium feldspar (microcline) was identified in both the siltstone from the Grainger formation and in the sand and silt fractions from the soils. No potassium feldspar was found in the clay fractions of these soils, but moderate amounts of kaolinite and quartz along with vermiculite, hydroxyinterlayered vermiculite (HIV) and illite were

Table 21. Mineralogy of the clays of selected samples.

Pedon-Horizon	kaolinite	vermiculite and HIV	illite	quartz	other
1 - Bw2	M	L	L	M	--
1 - C	M	L	L	M	X (goethite)
5 - 2Bt	L	L	M	X	X (lepido-crocite)
6 - Bt1	H	L	X	X	X (goethite)
6 - Bt2	H	L	L	X	X (goethite)
6 - Bt4	H	L	X	--	X (goethite)
6 - Bt6	H	X	L	X	X (goethite)
6 - 2Bt8	H	X	L	--	X (goethite)
6 - 2Cb	M	X	M	--	L (goethite)
9 - Bt1	M	M	X	X	X (goethite)
9 - Bt2	M	M	X	X	X (goethite)

(continued)

Table 21. (continued).

Pedon-Horizon	kaolinite	vermiculite and HIV	illite	quartz	other
13 - Bt	M	L	X	M	--
16 - Bt1	M-H	L	L	X	X (goethite, hematite)
16 - Bt2	H	L	L	--	X (goethite)

"X" = present, "L" = low (10-20%), "M" = moderate (20-30%), "H" = high (>30%).

found in the clays from these samples. Apparently, the weathering environment was such that the weathering of the feldspar proceeded rather rapidly towards kaolinite formation in the clay fraction. The discussion of the mineralogy of these soils will be developed further in a later section when the mineralogy of the loamy soils are discussed.

Pedon 5 was from the Pumpkin Valley shale. X-ray analysis of the clay fraction of the argillic horizon of this soil revealed that illite was the dominant clay mineral present and was present at moderate levels. Also present in low amounts were kaolinite, vermiculite, HIV, and quartz and trace amounts of lepidocrocite were found in this soil. This soil was placed in a mixed mineralogy class.

Lepidocrocite was not identified in any other clays analyzed for this study and it seemed rather interesting that it would be present here. The fact that this relatively shallow fine textured soil rests directly on top of the underlying bedrock probably caused enough water to be held in this layer to create a reducing condition sufficient for the formation and persistence of lepidocrocite in the soil material. This soil was not vividly mottled but did have some pale brown mottles in this layer above the rock. This indicated that some

reducing condition may exist. The soil was well drained according to its morphology and certainly was not a reductomorphic soil like the ones in which lepidocrocite is most often found.

Pedon 6 was from the deep alluvium covering the Rutledge limestone. As table 21 indicates, the mineralogy with depth in pedon 6 does not vary too much. Kaolinite is most abundant in all horizons studied down to the 2Cb, where is somewhat less dominant and illite is more abundant. Goethite was present in trace amounts in all horizons except the 2Cb where it was moderately abundant. The mineralogy control section for this profile is in the Bt1 and Bt2 horizons. This pedon is in a kaolinitic mineralogy class. Mineralogy of the other horizons was looked at as a possible means of locating other discontinuities in the profile. Mineralogy was not a significant indicator of discontinuities in this profile, but did support the observation that the 2Cb was derived from a different material and was apparently less highly weathered prior to its burial.

The clays in pedon 9, from the Maryville limestone, were dominated by kaolinite, HIV and vermiculite, present in moderate amounts, with trace amounts of illite, quartz and goethite. The mineralogy of this soil was mixed.

Pedon 16 was from the Rutledge limestone residuum. The Bt1 had moderate to high amounts of kaolinite, low amounts of HIV and illite and trace amounts of quartz, goethite and hematite. The Bt2 had a high content of kaolinite, low amounts of HIV and illite and trace quantities of goethite. This soil was placed in a kaolinitic mineralogy class. These horizons had appreciable contents of free iron and Appendix B shows diffractograms for samples with and without the iron removed. The most obvious difference was that somewhat better intensities were obtained in the samples from which the iron was removed. Presence or absence of the iron apparently had no significant effect on the process of identifying the minerals in the samples.

Six of the ten pedons sampled were in loamy particle size classes. These were pedons 1, 8, 10, 12, 13 and 14. Mineralogy of these soils was determined on the basis of grain counts of the dominant sand fractions (Table 22). All of the soils in loamy particle size classes were found to have mixed mineralogy. Quartz was the most abundant mineral present in the sand fractions studied, but was not present in sufficient quantities for any of the soils to have siliceous mineralogy.

Table 22. Mineralogy of the loamy soils. Data are summarized from grain counts of the sand fractions listed.

Pedon - Horizon	Sand Fractions	Quartz	Plagioclase	K-Spar	Other
		---------- % ----------			
1 - Bw2	FS, VFS	43.6	28.0	11.2	17.2
1 - C	FS, VFS	57.0	10.8	12.6	19.6
8 - Bw2	FS, VFS	54.1	9.0	9.3	27.6
8 - Bw3	FS, VFS	56.2	11.1	6.1	26.6
8 - Bw4	FS, VFS	76.4	6.0	7.1	10.5
10 - Bt1	VFS	67.9	1.7	0.3	30.1
10 - Bt2	VFS	61.7	2.4	1.0	34.9
12 - Bt	MS, FS	68.0	12.1	2.6	17.3
13 - Bt	FS, VFS	43.8	6.0	26.0	24.2
14 - C	FS, VFS	78.2	0.9	1.2	19.7

Minerals listed as "Other" include iron minerals and other accessory mineral species. "K-Spar" indicates potassium feldspars, and includes both microcline and orthoclase.

Pedons 1 and 13 are from the Grainger formation, and contained significant amounts of plagioclase and potassium feldspar in the sand fractions. Potassium feldspar and quartz were also dominant in the silt fraction of these soils (see diffractograms in Appendix B for scans of the silt fractions). Presence of these feldspars had a tremendous bearing on the classification of these soils, not only mineralogically, but chemically. Appreciable quantities of exchangeable potassium from the weathering of the feldspars placed these soils in high base families.

Pedon 8 was the recent alluvium in the Richland Creek floodplain. This soil had significant content of feldspars and had a mineralogic signature and particle size distribution quite similar to the soils formed on the Grainger formation. Plagioclase ranged from 6 percent in the Bw4 to 11.1 percent in the Bw2. Potassium feldspars ranged from 6.1 percent in the Bw3 to 9.3 percent in the Bw2. Quartz was the dominant mineral present. Content of quartz increased with depth. This indicated incremental addition to the floodplain, beginning with more siliceous material, possible derived from the limestone and shale units, with later addition of materials having higher contents of feldspars. The Grainger uplands were the source for much of the alluvium in the floodplain, especially those materials high in feldspar content.

Headward erosion in the valley, into the Grainger formation has had an impact on the soil formed in the floodplain.

Pedon 10 formed in residuum from the Nolichucky Shale. Quartz was the dominant mineral identified, with very little feldspar. There was an appreciable amount of iron oxide concretions in the sand fraction investigated and this accounted for the high content of "other" in Table 22.

Pedon 12 was from the Maynardville formation. Quartz dominated the control section, making up 68 percent of the grains counted. There was also an appreciable content of feldspar, 12.1 percent plagioclase and 2.6 percent potassium feldspars. Mineralogy of this pedon was mixed, as were all of the loamy soils studied.

Pedon 14 is from the Rome formation. Quartz made up 78.2 percent of the sands studied. There was also a significant quantity of iron concretions in the sand fractions, making up most of the 19.7 percent designated as "other" in Table 22.

Mineralogy of the soils was reflective of the nature of the various parent materials. The soils probably revealed most about their parent materials in their mineralogy than in any other measured property. This was especially true of the six pedons in loamy particle size

classes. These were relatively weakly developed soils in materials that had not been extensively weathered and the mineralogic signature of the parent materials had not been erased by physical and chemical weathering.

Chemical Properties of the Soils

The soils in the Grainger formation (pedons 1 and 13) had chemical properties indicative of their relatively low degree of weathering and reflected the nature of the parent material quite well. Pedon 1 (Table 23) had a distribution of iron that increased with depth, ranging from 14,876 mg kg^{-1} in the A horizon to 18,154 mg kg^{-1} in the C horizon. Content of manganese and carbon decreased with depth. Carbon ranged from 38,220 mg kg^{-1} in the surface to only 3,110 mg kg^{-1} in the C horizon. Manganese ranged from only 86.49 mg kg^{-1} in the C horizon to 555.26 mg kg^{-1} at the soil surface.

The cation exchange capacities (CECs) were low in this pedon ranging from 6.6 cmol kg^{-1} in the C horizon to 15.9 cmol kg^{-1} in the surface layer. Base saturations were high, ranging from 96.2 percent in the A horizon to 141.1 in the Bw2 horizon. The soil pH ranged from 4.8 in the C horizon to 5.8 in the surface layer. Potassium was the dominant exchangeable cation (see Appendix C), and was apparently coming from the weathering of the potassium

Table 23. Chemical properties of pedon 1.

Horizon	CBD-Fe	Mn NH_2OH-HCl	C Total	CEC NH_4OAc	base saturation	pH
	-------- mg kg^{-1}		-------	cmol kg^{-1}	%	
A	14 876	555.26	38 220	15.9	96.2	5.8
Bw1	15 184	411.14	11 000	8.7	44.8	5.1
Bw2	16 213	289.92	5 010	7.3	141.1	5.0
C	18 154	86.49	3 110	6.6	104.5	4.8

feldspars in the Grainger formation. The decrease in base saturation in the C horizon of this profile indicated that the intensity of weathering of feldspar is less in this zone or that primary feldspars present may have been already weathered and partially removed.

Pedon 13 was similar chemically to pedon 1, as Table 24 shows. The iron curve indicated that stripping of weathering products from the BE horizon had occurred. Iron ranged from 4,889 mg kg^{-1} in the A horizon to 14,835 mg kg^{-1} in the Bt horizon, where weathering and accumulation of illuvial materials was greatest. Manganese decreased regularly with depth, from 701.42 mg kg^{-1} in the A horizon to only 6.94 mg kg^{-1} in the Bt horizon. Carbon content also decreased regularly with depth, from 32,030 mg kg^{-1} in the surface layer to 2,480 mg kg^{-1} in the Bt horizon.

Cation exchange capacities were low, ranging from 3.5 to 10.1 cmol kg^{-1}. Base saturation values ranged from 142.8 percent in the Bw horizon to 172.5 percent in the Bt horizon. The pH values ranged from 5.0 in the Bt to 5.6 in the A horizon. High base saturation in this pedon was attributed to feldspar weathering and high exchangeable potassium, as in pedon 1.

Table 24. Chemical properties of pedon 13.

Horizon	CBD-Fe	Mn NH_2OH-HCl	C Total	CEC NH_4OAc	base saturation	pH
	-------- mg kg^{-1}		-------	cmol kg^{-1}	%	
A	4 889	701.42	32 030	10.1	153.5	5.6
BE	4 610	329.33	13 280	5.3	143.4	5.5
Bw	8 550	13.32	2 700	3.5	142.8	5.2
Bt	14 835	6.94	2 480	5.1	172.5	5.0

Chemical data for pedon 14 (Rome formation) is given in Table 25. This profile has a zone of some small degreeof weathering, as indicated by a slight increase in iron, from 12,662 in the A to 13,229 mg kg^{-1} in the Bw horizon. This small bump on the iron curve did not indicate a very high degree of weathering in this soil. Content of manganese was 45.71 mg kg^{-1} in the A horizon, 57.31 mg kg^{-1} in the Bw and 9.5 mg kg^{-1} in the C horizon. Carbon content decreased with depth, from 11,260 mg kg^{-1} in the A horizon to 3,510 mg kg^{-1} in the C horizon.

Cation exchange capacities were low, ranging from 7.6 to 8.6 cmol kg^{-1}. Base saturation was highest in the surface layer, where it was 54.6 percent and ranged to 27.6 percent in the C horizon. The pH of the soil was 4.8 in the A horizon, and was 4.7 in the Bw and C horizons.

The chemical properties of pedon 14 indicated that the soils on the Rome formation are weakly developed, and have undergone very little significant chemical weathering. The soils reflected the low base nature of the parent materials on which they are forming.

Soils forming on the Pumpkin Valley shale were sampled for characterization at site 5. The upper portion of the profile was composed of colluvium or slope wash material, overlying the residuum from the Pumpkin Valley shale. Chemical data for this pedon are presented in

Table 25. Chemical properties of pedon 14.

Horizon	CBD-Fe	Mn NH_2OH-HCl	C Total	CEC NH_4OAc	base saturation	pH
	-------- mg kg^{-1}		-------	cmol kg^{-1}	%	
A	12 662	45.71	11 260	8.6	54.6	4.8
Bw	13 229	57.31	6 570	8.2	36.6	4.7
C	10 142	9.50	3 510	7.6	27.6	4.7

Table 26. The A horizon had the lowest content of free iron oxide (17,097 mg kg^{-1}). The highest content of free iron measured was in the 2Bw horizon (25,583 mg kg^{-1}). Manganese content decreased abruptly at the discontinuity (Figure 11), from 334 mg kg^{-1} in the BE to 23.69 mg kg^{-1} in the 2Bw. This was an indication that the movement of water across the discontinuity may be restricted or that water may be held for longer periods in the lower two horizons. This might be indicative of the existence of reducing conditions necessary to form lepidocrocite, as was identified in the 2Bt horizon of this pedon. Carbon decreased with depth from 24,600 mg kg^{-1} in the A horizon to 3,540 mg kg^{-1} in the 2Bw. Carbon content increased to 4,560 mg kg^{-1} in the 2Bt horizon.

Cation exchange capacity ranged from 8.4 cmol kg^{-1} in the BE horizon to 16.6 cmol kg^{-1} in the 2Bt horizon. Base saturation was high throughout the profile, but was especially high in the upper two horizons, (103 percent in the A and 108.3 percent in the BE). In the 2Bw, the base saturation was 77.5 percent and in the 2Bt it was 64.4 percent. The soil pH ranged from 5.2 in the 2Bt to 6.7 in the BE. The base status of this soil was apparently influenced by man's activities of liming and fertilizing. This site was located in a pasture field and the high base saturation near the surface and the relatively abrupt

Table 26. Chemical properties of pedon 5.

Horizon	CBD-Fe	Mn NH_2OH-HCl	C Total	CEC NH_4OAc	base saturation	pH
	-------- mg kg^{-1}		-------	cmol kg^{-1}	%	
A	17 097	314.70	24 600	13.2	103.0	6.6
BE	18 092	334.00	9 010	8.4	108.3	6.7
2Bw	25 583	23.69	3 540	11.1	77.5	5.7
2Bt	25 218	27.25	4 560	16.6	64.4	5.2

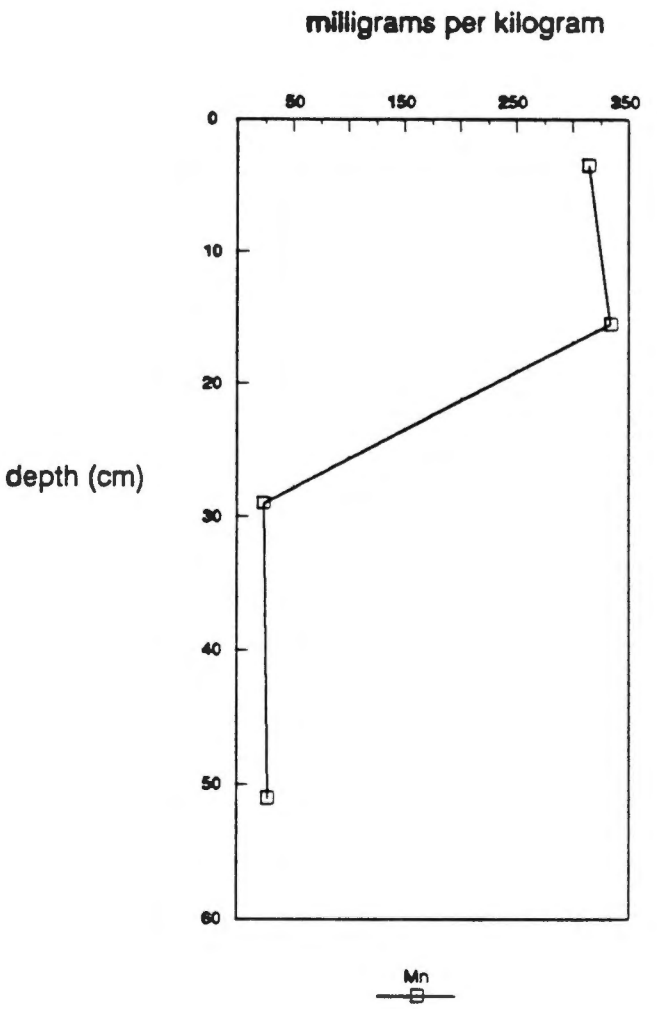


Figure 11. Manganese distribution with depth for pedon 5.

decrease below the BE horizon suggested that some recent liming or fertilizing of the pasture has occurred, and that the base saturation values measured are artificially high.

Soils on the Rutledge limestone, the alluvium at site 6 and the residuum at site 16, had chemical properties that reflected a high degree of weathering. The chemical data for pedon 6 is given in Table 27. Content of iron generally increased with depth, from 23,979 mg kg^{-1} in the Ap horizon to 44,073 mg kg^{-1} in the 2Bt9 horizon. Iron decreased in the 2BC1 to 36,025 mg kg^{-1}, and the 2BC2 had 34,202 mg kg^{-1} free iron. The iron content increased dramatically in the 2Cb horizon, to 71,160 mg kg^{-1}.

The content of manganese decreased regularly with depth to the Bt4 horizon, where it was 805.63 mg kg^{-1}. Below this, it fluctuated, sometimes significantly, especially at the top of the 2Bt8 horizon, the 2BC1 horizon, and a notable increase in the 2Cb horizon, where manganese content was 830.74 mg kg^{-1}. Manganese distribution in this profile was a good indicator of the stratigraphy of the parent material. The major fluctuations in the manganese curve corresponded to the discontinuities identified in the profile. Distribution of carbon in pedon 6 generally decreased with depth, but did fluctuate somewhat. The fluctuating carbon curve

Table 27. Chemical properties of pedon 6.

Horizon	CBD-Fe	Mn NH_2OH-HCl	C Total	CEC NH_4OAc	base saturation	pH
	-------- mg kg^{-1}		-------	cmol kg^{-1}	%	
Ap	23 979	2 350.26	12 930	11.5	153.9	6.7
AB	25 839	3 732.48	4 120	9.9	138.4	6.5
Bt1	31 124	3 052.40	2 770	8.2	179.3	6.1
Bt2	33 190	2 176.72	2 000	13.0	115.4	5.9
Bt3	36 078	1 472.71	1 670	12.1	65.3	5.3
Bt4	39 438	805.63	1 320	13.6	50.0	5.3
Bt5	40 188	974.62	1 420	12.2	53.3	5.2
Bt6	43 245	706.11	1 400	9.0	73.3	5.2
Bt7	40 781	812.88	1 740	11.9	56.3	5.3
2Bt8	41 860	184.22	1 320	11.5	60.0	5.1
2Bt9	44 073	228.20	1 360	11.2	54.5	5.6
2BC1	36 025	85.68	880	10.1	47.5	5.2
2BC2	34 202	289.25	1 020	12.8	33.6	5.0
2Cb	71 160	830.74	1 060	18.0	23.3	4.8

could be an indication of finer stratifications in the alluvial sediments that have been otherwise obliterated by soil forming processes.

The CEC in pedon 6 ranged from a low of 8.2 cmol kg^{-1} in the Bt1 horizon to a high of 18.0 cmol kg^{-1} in the 2Cb horizon. There was some fluctuation of the CEC values with depth, possibly indicating various degrees of weathering of the clays in the individual horizons. Figure 12 is a graphic presentation of base saturation with depth in this profile. There was a sharp and sudden decline in base saturation below the Bt2 horizon, where the base saturation changed from 115.4 percent to 65.3 percent. Below this, the base saturation fluctuated somewhat with increasing depth in the profile. The prevalent exchangeable cations were calcium, magnesium and potassium. This trend in base saturation was not readily attributable to the parent material or to an identifiable pedologic feature. Only a relatively small quantity of the bases present could reasonably be attributed to agricultural activity. The author suggests that lateral translocation of materials from soils and geologic materials upslope is a likely source for some of these bases, especially potassium, which was identified to be

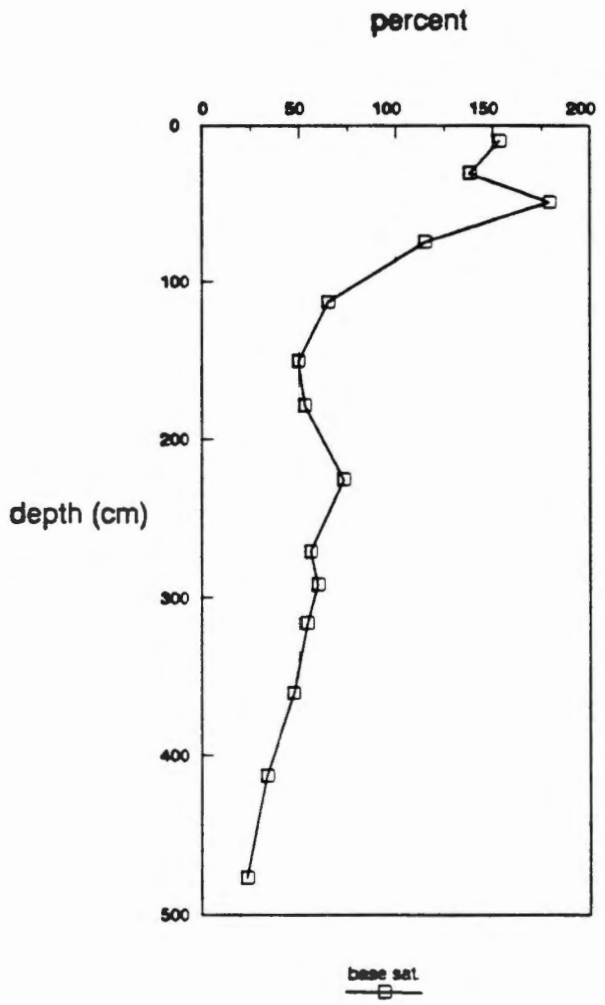


Figure 12. Plot of base saturation with depth for pedon 6.

present in significant quantity in the Grainger formation. The high concentration of bases resulted in pedon 6 being classified in the Alfisol order.

Table 28 gives the chemical data for pedon 16, sampled from the Rutledge limestone residuum. Content of free iron increased with depth from 43,703 mg kg^{-1} in the Ap to 114,067 mg kg^{-1} in the Bt3 horizon. Here, free iron decreased to 99,437 mg kg^{-1} in the Bt4 and increased again to 108,089 mg kg^{-1} in the Bt5. This indicated that the zone of maximum weathering and accumulation was in the Bt3 horizon. Content of extractable manganese decreased with depth from 1,097.11 mg kg^{-1} in the Ap to 5.53 mg kg^{-1} in the Bt4. Manganese concentration then increased to 36.83 mg kg^{-1} in the Bt5 horizon. The Bt4 horizon had the highest clay content and this manganese distribution seemed to indicate that water movement through the Bt4 horizon may be somewhat slower than through the other horizons.

Carbon content decreased uniformly with depth throughout the profile, from 27,710 mg kg^{-1} in the Ap to 2,040 mg kg^{-1} in the Bt5 horizon. Cation exchange capacity tended to increase with depth below the Bt1 and ranged from 12.6 cmol kg^{-1} in the Bt1 to 19.2 cmol kg^{-1} in the Bt5. The soil pH ranged from 7.1 in the Bt1 and Bt2

Table 28. Chemical properties of pedon 16.

Horizon	CBD-Fe	Mn NH_2OH-HCl	C Total	CEC NH_4OAc	base saturation	pH
	-------- mg kg^{-1} -------			cmol kg^{-1}	%	
Ap	43 703	1 097.11	27 710	14.3	127.3	7.0
Bt1	63 002	575.93	8 700	12.6	146.0	7.1
Bt2	108 060	51.66	4 400	15.3	155.6	7.1
Bt3	114 067	14.63	3 300	17.2	59.9	5.2
Bt4	99 437	5.53	2 270	17.5	22.3	4.9
Bt5	108 089	36.83	2 040	19.2	15.6	4.8

horizons to 4.8 in the Bt5 horizon and decreased notably (from 7.1 to 5.2) at the top of the Bt3 horizon.

Figure 13 shows the distribution of base saturation with depth in this profile. At the top of the Bt3, the base saturation decreased from 155.6 percent to 59.9 percent. This was the same situation observed at site 6 in the deep alluvium. Bases are accumulating in the upper part of this profile, probably from upslope, and possibly affected to some undetermined degree by agricultural amendments. Presence of bases in the upper part of pedon 16 has not affected the profile to a sufficient depth to alter its classification as an Ultisol.

The soil in the recent alluvium overlying the Rogersville shale was sampled at site 8 and the chemical data are presented in Table 29. With the exception of the Bw1 horizon, the content of free iron decreased with depth, from 22,159 mg kg^{-1} in the Bw1 to 12,851 mg kg^{-1} in the BC horizon. The iron curve indicated the low degree of development in this profile, showing little or no translocation and little secondary formation of iron oxides. Manganese distribution with depth (Figure 14) showed that manganese decreased in the Bw1 horizon and then bulged in the Bw2 and Bw3 horizons. This corresponded to the depth of a high water table in this soil. Morphology of the soil indicated it to be

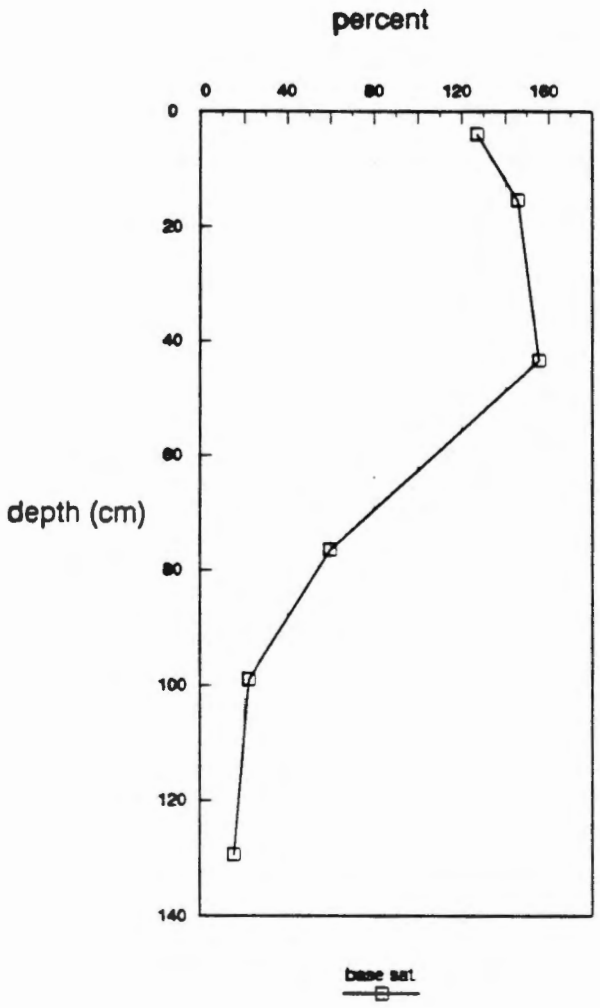


Figure 13. Plot of base saturation with depth for pedon 16.

Table 29. Chemical properties of pedon 8.

Horizon	CBD-Fe	Mn NH_2OH-HCl	C Total	CEC NH_4OAc	base saturation	pH
	-------- mg kg^{-1}	-------		cmol kg^{-1}	%	
A	21 692	1 065.56	22 920	14.5	122.8	6.5
Bw1	22 159	1 019.03	11 230	11.9	121.8	6.4
Bw2	20 896	1 070.45	8 230	13.1	145.8	6.2
Bw3	19 733	1 061.61	7 130	11.5	146.1	6.2
Bw4	15 724	1 005.94	6 580	10.2	147.0	6.3
BC	12 851	976.66	5 400	8.1	163.0	6.8

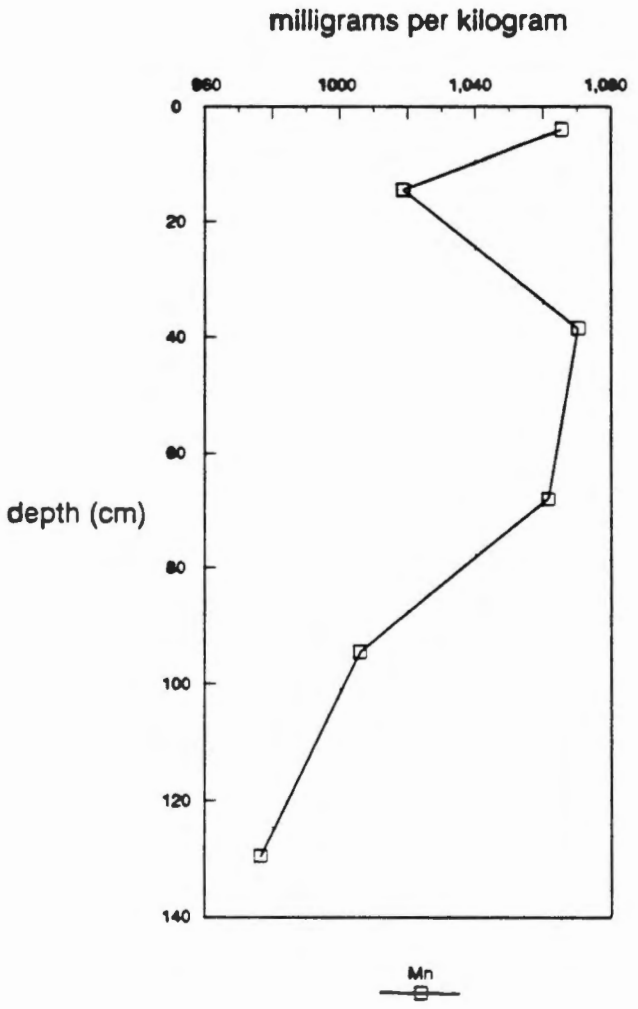


Figure 14. Plot of manganese distribution with depth for pedon 8.

moderately well drained, with a seasonal high water table in this zone. Carbon content decreased regularly with depth, from 22,920 mg kg^{-1} in the A horizon to 5,400 mg kg^{-1} in the BC horizon.

Cation exchange capacities in pedon 8 ranged from 8.1 cmol kg^{-1} in the BC to 14.5 cmol kg^{-1} in the A horizon and fluctuated somewhat with depth, possibly due to stratification of the parent material. Base saturation values were over 100 percent in all horizons, with potassium being a significant contributor to the exchangeable cations. The high base saturation was presumed due to the weathering of primary minerals (feldspars) and not to human influence. Soil pH ranged from 6.2 to 6.8. This pedon was sampled in a wooded area that was not being managed for agriculture.

Pedon 9 was sampled to represent the soils forming in residuum on the Maryville limestone. The chemical data for pedon 9 are presented in Table 30. With the exception of the Bt2 horizon, free iron content in the profile increased with depth, from 31,098 mg kg^{-1} in the A horizon to 71,997 mg kg^{-1} in the Bt4 horizon. This indicated that the zone of maximum weathering in this profile is the horizon just above the bedrock. Apparently, weathering of primary rock constituents in this zone was accompanied by rather rapid leaching of weathered materials. Base

Table 30. Chemical properties of pedon 9.

Horizon	CBD-Fe	Mn NH_2OH-HCl	C Total	CEC NH_4OAc	base saturation	pH
	-------- mg kg^{-1} -------			cmol kg^{-1}	%	
A	31 098	2 198.83	41 440	25.6	104.7	7.1
Bt1	39 203	1 653.29	18 720	19.3	104.1	7.0
Bt2	38 659	873.92	5 310	18.5	133.5	6.5
Bt3	56 742	166.64	5 240	22.5	118.7	5.8
Bt4	71 997	374.35	4 270	29.2	94.5	6.3

saturation was lowest in this horizon and seemed to support this observation. Manganese content decreased with depth, from 2,198.83 mg kg^{-1} in the A horizon to 166.64 mg kg^{-1} in the Bt3 horizon. Manganese content in the Bt4 horizon increased to 374.35 mg kg^{-1}. This indicated that some water was perching on top of the bedrock and accumulating in the Bt4 horizon. No morphologic evidence of imperfect drainage was noted during sampling. Content of carbon decreased regularly with depth, from 41,440 mg kg^{-1} in the A horizon to 4,270 mg kg^{-1} in the Bt4 horizon.

Cation exchange capacity ranged from 19.3 cmol kg^{-1} in the Bt1 horizon to 29.2 cmol kg^{-1} in the Bt4 horizon. Higher CEC values in the lower horizons were attributed to the higher content of mixed mineralogy clays in these horizons. Soil pH values ranged from 5.8 in the Bt3 to 7.1 in the A horizon. Base saturation values were high, ranging from 94.5 percent in the Bt4 horizon to 133.5 percent in the Bt2 horizon. The high content of bases in this soil was attributed to its proximity to limestone bedrock. The nature of the weathering of the rocks in the Maryville formation is such that the deeper soil profiles are situated in basins in the rock, between rock outcrops, usually on all sides. Recharge of bases into and out of

the weathering zone occurs as water moves vertically and laterally in the landscape.

The soil forming in residuum on the Nolichucky shale was sampled at pedon 10 and the chemical data is presented in Table 31. Content of free iron ranged from 12,511 mg kg^{-1} in the A horizon to 18,839 mg kg^{-1} in the Bt2 horizon, and increased regularly with depth, indicating that the zone of maximum accumulation and weathering intensity is in the layer just above rock. Content of manganese decreased from 743.48 mg kg^{-1} in the A horizon to 202.26 mg kg^{-1} in the Bt1 horizon. In the Bt2, manganese content increased to 434.43 mg kg^{-1}, indicating that some inhibition of water movement was occurring in the layer above the bedrock, or that there was a lateral flow of water in the zone above the bedrock contact. Content of carbon decreased regularly with depth, from 20,240 mg kg^{-1} in the A horizon to 2,660 mg kg^{-1} in the Bt2 horizon.

Cation exchange capacity in pedon 10 ranged from 10.9 cmol kg^{-1} in the BE horizon to 20.9 cmol kg^{-1} in the Bt2 horizon. Base saturation in the A horizon was 103.8 percent, and was presumed due to surface cycling of bases by the forest cover. Base saturation in the BE was 67.9 percent, 14.8 percent in the Bt1 and 13.4 percent in the Bt2 horizon. Soil pH ranged from 4.6 to 6.0, decreasing with depth.

Table 31. Chemical properties of pedon 10.

Horizon	CBD-Fe	Mn NH_2OH-HCl	C Total	CEC NH_4OAc	base saturation	pH
	-------- mg kg^{-1}		-------	cmol kg^{-1}	%	
A	12 511	743.48	20 240	13.2	103.8	6.0
BE	13 168	577.20	9 490	10.9	67.9	5.0
Bt1	16 616	202.26	4 240	12.8	14.8	4.6
Bt2	18 839	434.43	2 660	20.9	13.4	4.6

Table 32 presents the chemical data for pedon 12, formed in residuum on the Maynardville limestone. Free iron content increased with depth from 10,647 mg kg^{-1} in the A horizon to 19,183 mg kg^{-1} in the Bt horizon. Manganese decreased with depth, from 1,498.29 mg kg^{-1} in the A horizon to 989.32 mg kg^{-1} in the Bt horizon. Carbon content decreased with depth from 27,410 mg kg^{-1} in the A horizon to 9,520 mg kg^{-1} in the Bt horizon.

Cation exchange capacity decreased from 11.6 cmol kg^{-1} in the A horizon to 9.4 cmol kg^{-1} in the Bt horizon. Base saturation values were high, ranging from 107.4 to 186.2 percent. Soil pH ranged from 6.4 to 6.6. The high content of bases in this soil were thought to be inherited from the parent material. The soil was shallow and in close proximity to the bedrock. Woodland vegetation also contributed to the recycling of bases in the upper part of this soil profile.

Table 32. Chemical properties of pedon 12.

Horizon	CBD-Fe	Mn NH_2OH-HCl	C Total	CEC NH_4OAc	base saturation	pH
	-------- mg kg^{-1} -------			cmol kg^{-1}	%	
A	10 647	1 498.29	27 410	11.6	121.6	6.5
BE	13 553	1 332.22	16 840	9.5	107.4	6.4
Bt	19 183	989.32	9 520	9.4	186.2	6.6

4. SUMMARY AND CONCLUSIONS

The soils examined in the Richland Valley showed a strong association with landscape position and parent material. Various soil properties, both observed and measured, reflected the interaction of the geologic materials with the forces of erosion, deposition and soil formation active upon the parent materials. Lateral movement of bases in the landscape, as well as human activity was shown to have a bearing on the properties of some of the soils, and to some extent affect the classification of the soils. In the following paragraphs, major relationships among the soils, geologic units and soil forming factors active on the landscape at the study area will be summarized.

Soils investigated covered the range from weakly developed to well developed in a morphological sense. Soil profiles studied on strongly sloping and steep uplands in the Grainger formation, Rome formation, Pumpkin Valley shale, Rogersville shale, Nolichucky shale and Maynardville limestone ranged from shallow to deep. Soils studied on the Grainger formation were weakly developed. These soils had low cation exchange capacities and high base saturations due to actively weathering primary minerals. A weak argillic horizon had formed in pedon 13.

These were classified as coarse-loamy, mixed, thermic Typic Hapludalfs (pedon 13), and loamy-skeletal, mixed, thermic Dystric Eutrochrepts (pedon 1). The soils examined on the Rome formation (pedons 2, 3 and 14) were shallow and weakly developed, with high rock fragment percentages in the profile. These soils had low base saturations and were classified as loamy-skeletal, mixed, thermic Lithic Dystrochrepts.

The soils on the Nolichucky shale (profiles 10, 11 and 19) ranged from very shallow (severely eroded areas) to moderately deep. The deeper profiles contained weak argillic horizons and low base saturations. Profile 10 was classified as a fine-loamy, mixed, thermic Typic Hapludult. Pedon 11 was classified in the field as a Typic Udorthent and pedon 19 was classified in the field as an Ochreptic Hapludult. The soils examined on the Maynardville limestone (pedons 12, 20 and 21) were shallow to moderately deep, high in bases and had weak argillic horizons. Pedon 12 was classified as a fine-loamy, mixed, thermic Lithic Hapludalf. Pedon 20 was classified in the field as a Typic Hapludalf and pedon 21 as a Lithic Hapludalf. All of the soils observed on the Grainger, Rome, Nolichucky and Maynardville formations are thought to be remnants of preexisting deeper profiles that were

truncated by erosion. Soil formation has proceeded in the portion of the profile not removed by erosion.

None of the studied soils were representative of parent materials originated in the Rogersville shale. The Rogersville unit in the study area has been covered by the alluvium of Richland Creek. Soils forming on the Richland Creek floodplain (pedons 7, 8 and 17) were young alluvial soils. They were deep, weakly developed and high in bases. The particle size distributions and mineralogic characteristics were similar to the Grainger formation, which was thought to be the primary source for the upper parts of the soil profiles. The alluvial soils on the Richland Creek floodplain were classified as fine-silty and fine-loamy, mixed, thermic Fluvaquentic Eutrochrepts and Aeric Haplaquepts.

The soil characterized on the Pumpkin Valley shale (pedon 5) was moderately deep and was overlain by a mantle of colluvium from upslope. Pedon 5 had a thin, clayey argillic horizon and was high in bases. The base saturation was thought to be artificially high, presumably due to liming and fertilizing practices during farming operations. This soil was classified as a fine, mixed, thermic Typic Hapludalf.

Two distinct and unique soils were observed on the Rutledge geologic unit (Pedons 6 and 16). Pedon 6 was a

very deep, Pleistocene stream terrace that formed in three distinct episodes of alluvial deposition. This pedon had a very thick, well expressed argillic horizon. The texture was clayey and the base saturation was high. Little doubt exists that the base saturation of this soil was man influenced, although to an unknown degree. This study did not account for contribution of bases from high base parent materials higher on the slope. Base saturation remained high to a considerable depth and then decreased sharply. This showed the movement of material laterally from upslope and the possible contribution of applied soil amendments into the profile. The depth to which the soil at site 6 was affected by increased base saturation was great enough that the classification of the soil was influenced. This soil was classified as a fine, kaolinitic, thermic Typic Paleudalf.

The other soil studied on the Rutledge geologic unit (pedon 16) was formed in residuum from the Rutledge limestone. This was a deep, clayey soil with a thick, well developed argillic horizon. The upper part of the solum was high in bases. A sudden decline in base saturation occurred in this pedon, as it did at pedon 6. This soil, however, was not affected to a great enough depth to alter its classification. Pedon 16 was

classified as a clayey, kaolinitic, thermic Typic Paleudult.

The soils forming on the Maryville limestone (pedons 9 and 18) were moderately deep to deep. Shallow soils were also present in close association with rock outcrops. These soils were clayey, and had well developed morphologic features. Rock outcrops of Maryville limestone are common on this landscape component. The argillic horizons were well expressed and the base saturations were high. The soils studied on the Maryville formation were classified as fine, mixed, thermic Typic Hapludalfs.

On the sloping and steep landscape components, releif was the dominant soil forming factor. Erosion of the landscape had obliterated deeper profiles that existed previously on several of the geologic units, as described above. Soils on these landscape components were forming in the remains of the older deep soil profiles. Parent material and time seem to have had an overriding influence on the formation of soils on the more stable parts of the landscape, namely the Rutledge limestone and Maryville limestone units. These are well developed soilscapes that have formed over a long time period and through many paleoclimatic shifts. Accumulation of bases in the soil profiles has substantially altered the pedologic nature of

some of these soils. By clearing the uplands when settling the area, and accelerating erosion on the landscape, man has changed the nature of the plant cover. Agricultural practices of liming and fertilization have introduced bases to the soil system during liming and fertilizing. High base parent materials higher on the slope have apparently been significant contributors of bases to soils on the Rutledge limestone units.

This research has shown the variety of soils that may be produced by interactions of various soil forming processes acting upon geologic materials. A close interaction of the various landforms is evident when the soil properties are studied across a series of varying geologic units and slope gradients. Relief is the dominant soil forming factor on this landscape. Relief has obliterated to large degree effects of other soil forming factors on several of these landscape units, but the mineralogy and various physical and chemical properties of these soils are still closely related to the parent materials and stages of development of the soils studied.

LIST OF REFERENCES

LIST OF REFERENCES

Bailey, E.H. and R.E. Stevens. 1960. Selective staining of K-feldspar and plagioclase on rock slabs and thin sections. Amer. Mineral. 65:1020-1025.

Bayliss, P., D.C. Erd, M.E. Mrose, A.P. Sabina, and D.K. Smith (eds). 1986. Mineral powder diffraction file data book. JCPDS International Centre for Diffraction Data, Swarthmore, PA.

Bilzi, A.F. and E.J. Ciolkosz. 1977. A field morphology rating scale for evaluating pedological development. Soil Sci. 124:45-48.

Bilzi, A.F. and E.J. Ciolkosz. 1977. Time as a factor in the genesis of four soils developed in recent alluvium in Pennsylvania. Soil Sci. Soc. Am. J. 41:122-127.

Birkeland, P.W. 1984. Soils and geomorphology. Oxford Univ. Press, New York.

Blume, H.P. 1988. The fate of iron during soil formation in humid-temperate environments. In J.W. Stucki, et. al. (eds). Iron in soils and clay minerals. D. Reidel Publ. Co.

Blume, H.P. and U. Schwertmann. 1969. Genetic evaluation of profile distribution of aluminum, iron and manganese oxides. Soil Sci. Soc. Am. Proc. 33:438-444.

Bockheim, J.G. 1980. Solution and use of chronofunctions in studying soil development. Geoderma 24:71-85.

Bohn, H.L., B.L. McNeal and G.A. O'Connor. 1985. Soil chemistry. 2nd ed. John Wiley and Sons, Inc., New York.

Bos, R.H.G., and J. Sevink. 1975. Introduction of gradational and pedomorphic features in descriptions of soils. J. Soil Sci. Vol 26. No. 3.

Buol, S.W., F.D. Hole and R.J. McCracken. 1980. Soil genesis and classification. 2nd ed. Iowa State Univ. Press, Ames, IA.

Cabrera-Martinez, F., W.G. Harris, V.W. Carlisle and M.E. Collins. 1989. Evidence for clay translocation in coastal plain soils with sandy/loamy boundaries. Soil Sci. Soc. Am. J. 53:1108-1114.

Cady, J.G. 1960. Mineral occurrence in relation to soil profile differentiation. 7th Int. Congress of Soil Sci. Madison, WI. 59:418-424.

Calvert, C.S., S.W. Buol and S.B. Weed. 1980. Mineralogical characteristics and transformations of a vertical rock-saprolite-soil sequence in the North Carolina piedmont: I. Profile morphology, chemical composition and mineralogy. Soil Sci. Soc. Am. J. 44:1096-1103.

Chao, T.T. 1972. Selecive dissolution of manganese oxides from soils and sediments. Soil Sci. Soc. Am. Proc. 36:764-768.

Chapman, H.D. 1965. Cation exchange capacity. In C.A. Black (ed). Methods of soil analysis, Part 2. 1st ed. Agronomy 9:891-901.

Chesworth, W. 1973. The parent rock effect in the genesis of soil. Geoderma 10:215-225.

Ciolkosz, E.J., G.W. Petersen, R.L. Cunningham and R.P. Matelski. 1979. Soils developed in colluvium in the ridge and valley area of Pennsylvania. Soil Sci. 28:153-162

Ciolkosz, E.J., W.J. Waltman, T.W. Simpson and R.R. Dobos. 1989. Distribution and genesis of soils of the north-eastern United States. Geomorphology 2:285-302.

Colman, S.M. 1981. Rock weathering rates as functions of time. Quaternary Research 15:250-264.

Conacher, A.J. and J.B. Dalrymple. 1977. The nine unit landscape surface model: an approach to pedomorphic research. Geoderma 18:1-154.

Daniels, R.B., E.E. Gamble and J.B. Cady. 1971. The relation between geomorphology and soil morphology and genesis. Adv. Agron. 23:51-88.

Drees, L.R. and L.P. Wilding. 1973. Elemental variability within a sampling unit. Soil Sci. Soc. Am. Proc. 37:82-87.

Drever, J.I. 1973. The preparation of oriented clay mineral specimens for x-ray diffraction analysis by a filter-membrane peel technique. Am. Mineral. 58:553-554.

Fitzpatrick, R.W., R.M. Taylor, U. Schwertmann and C.W. Childs. 1985. Occurrence and properties of lepidocrocite in some soils of New Zealand, South Africa and Australia. Aust. J. Soil Res. 23:543-567.

Foss, J.E. and A.V. Segovia. 1984. Rates of soil formation. In R.G. LaFleur (ed) Groundwater as a geomorphic agent. Binghampton Symposia Geomorphology. International Series No. 13. Allen and Unwin, Inc., Boston.

Frederickson, A.F. 1951. Mechanisms of weathering. Bull. Geol. Soc. Am. 62:221-232.

Gambrell, R.P. and W.H. Patrick. 1982. Manganese. In A.L. Page, et. al. (eds). Methods of soil analysis, Part 2. 2nd ed. Agronomy 9:313-322.

Gee, G.W. and J.W. Bauder. 1986. Particle size analysis. In A. Klute (ed). Methods of soil analysis, Part 1. 2nd ed. Agronomy 9:383-412.

Grim, R.E. 1968. Clay mineralogy. 2nd ed. McGraw Hill, New York.

Hall, G.F., R.B. Daniels and J.E. Foss. 1982. Rate of soil formation and renewal in the U.S.A. In Determinants of soil loss tolerance. ASA, CSSA, Madison, WI.

Hasson, K. and C.S. Hasse. 1988. Lithofacies and paleogeography of the Conasauga Group (middle and late Cambrian) in the valley and ridge province of east Tennessee. Geol. Soc. Am. Bull. 100:234-246.

Hole, F.D. 1978. An approach to landscape analysis with an emphasis on soils. Geoderma 21:1-23.

Holmgren, G.S. 1988. The point representation of soil. Soil Sci. Soc. Am. J. 52:712-716.

Holy, M. 1980. Erosion and environment. Pergamon Press, Oxford, England.

Huang, P.M. 1989. Feldspars, olivines, pyroxenes and amphiboles. In Dixon, J.B. and S.B. Weed (eds). Minerals in soil environments. 2nd ed. Soil Sci. Soc. Am., Madison, WI.

Huggett, R.J. 1975. Soil landscape systems: a model of soil genesis. Geoderma 13:1-22.

Jackson, M.L. 1969. Soil chemical analysis- advanced course. Published by the author. Madison, WI.

Jenny, H. 1941. Factors of soil formation. McGraw Hill, New York.

Karathanasis, A.D., F. Adams, and B.F. Hajek. 1983. Stability relationships in kaolinite, gibbsite and Al-hydroxyinterlayered vermiculite soil systems. Soil Sci. Soc. Am. J. 47:1247-1251.

Kilmer, V.J. and L.T. Alexander. 1949. Methods of making mechanical analysis of soils. Soil Sci. 68:15-24.

Kunze, G.W. and J.B. Dixon. 1986. Pretreatments for mineralogical analysis. In A. Klute (ed). Methods of soil analysis, Part 1. 2nd ed. Agronomy 9. American Society of Agronomy, Madison, WI.

Lambert, R.E. 1988. Landform and soil development on the Conasauga group of the Low Level Waste Disposal Site at Bear Creek Valley, Tennessee. Master's Thesis, University of Tennessee.

Mausbach, M.J., B.R. Brasher, R.D., Yeck and W.D. Nettleton. 1980. Variability of measured properties in morphologically matched pedons. Soil Sci. Soc. Am. J. 44:358-363.

McLean, E.O. 1982. Soil pH and lime requirement. In A.L. Page, et. al. (eds). Methods of soil analysis, Part 2. 2nd ed. Agronomy 9:199-223.

Meixner, R.E. and M.J. Singer. 1981. Use of a field morphology rating system to evaluate soil formation and discontinuities. Soil Sci. 131:114-123.

National Climatic Data Center. 1990. Climate of Grainger County, Tennessee. Prepared for the USDA Soil Conservation Service. NCDC, Asheville, NC. unpublished.

Olson, R.V. and R. Ellis. 1982. Free iron oxides. In A.L. Page, et. al. (eds). Methods of soil analysis, Part 2. 2nd ed. Agronomy 9:311-312.

Phillips, D.H. 1988. Genesis of soils from ancient alluvïum, Maryville limestone and Nolichucky shale in east Tennessee. Master's Thesis. University of Tennessee.

Plaster, R.W. and W.C. Sherwood. 1971. Bedrock weathering rates and residual soil formation in central Virginia. Geol. Soc. Am. Bull. 82:2813-2826.

Rodgers, J. 1953. Geologic map of east Tennessee with explanatory text. Tenn. Div. of Geology. Bull. 58, Part 2.

Ross, Jr., S.J., D.P. Franzmier and C.B. Roth. 1976. Mineralogy and chemistry of manganese oxides in some Indiana soils. Soil Sci. Soc. Am. J. 40:137-143.

Ruhe, R.V. 1956. Geomorphic surfaces and the nature of soils. Soil Sci. 82:441-455.

Runge, E.C.A. 1973. Soil development sequences and energy models. Soil Sci. 115:183-193.

Schwertmann, U. 1985. The effect of pedogenic environments on iron oxide minerals. In Stewart, B.A. (ed.). Advances in soil science. Vol. 1. Springer Verlag, New York, Inc.

Schwertmann, U. and R.M. Taylor. 1989. Iron oxides. In J.B. Dixon and S.B. Weed (eds). Minerals in soil environments. 2nd ed. Soil Sci. Soc. Am. Madison, WI.

Scully, R.W. and R.W. Arnold. 1979. Soil-geomorphic relationships in postglacial alluvium in New York. Soil Sci. Soc. Am. J. 43:1014-1019.

Simonson, R.W. 1959. Outline of a generalized theory of soil genesis. Soil Sci. Soc. Am. Proc. 23:152-156.

Simonson, R.W. 1968. The concept of soil. Adv. Agron. 20:1-47.

Simonson, R.W. 1978. A multiple process model of soil genesis. In W.C. Mahaney (ed). Quaternary soils. Geo Abstracts. Univ. of East Anglia. Norwich, England.

Soil Survey Staff. 1975. Soil taxonomy: a basic system of soil classification for making and interpreting soil surveys. USDA-SCS. Agric. Hdbk. 436. U.S. Government Printing Office, Washington, DC.

Soil Survey Staff. 1981. Soil survey manual. Chapter 4. USDA Hdbk. 18. U.S. Government Printing Office, Washington, DC.

Soil Survey Staff. 1983. Principles and procedures for using soil survey laboratory data. Unpublished document. National Soil Survey Laboratory, Lincoln, NE.

Soil Survey Staff. 1984. Soil survey investigations report number 1. USDA-SCS. U.S. Government Printing Office, Washington, DC.

Soil Survey Staff. 1990. Keys to soil taxonomy. 4th ed. SMSS technical monograph no. 6. Blacksburg, VA.

Tardy, Y., G. Bocquier, H. Pacquet and G. Millot. 1973. Formation of clay from granite and its distribution in relation to climate and topography. Geoderma 10:271-284.

Torrent, J., and W.D. Nettleton. 1978. Feedback processes in soil genesis. Geoderma 20:281-287.

Torrent, J., U. Schwertmann, H. Fetcher and F. Alferez. 1983. Quantitative relationships between soil color and hematite content. Soil Sci. 136:354-358.

Walker, K.R. (ed). 1985. The geologic history of the Thorn Hill paleozoic section (Cambrian-Mississippian), eastern Tennessee. SE-GSA. Univ. of Tennessee. Dept. of Geologic Sciences. Studies in geology 10.

Whittig, L.D. and W.R. Allardice. 1986. X-ray diffraction techniques. In A. Klute (ed). Methods of soil analysis. 2nd ed. Agronomy 9:331-362.

APPENDICES

APPENDIX A

DESCRIPTIONS OF THE PEDONS

Pedon number: 1 Geologic Formation: Grainger formation

Date: 10 Jan 1990 Vegetation: mixed hardwoods

Site Position: convex ridge shoulder
Slope: 43 percent
Elevation: 366 meters
Aspect: northwest
Erosion: severe
Drainage Class: well drained to somewhat excessively drained
Taxonomic Class: loamy-skeletal, mixed, thermic Dystric Eutrochrept

Colors are for moist soil.

Oi -- 8 to 0 cm; slightly decomposed leaves and forest litter

A -- 0 to 4 cm; brown (10YR 4/3) channery loam; common fine faint dark yellowish brown (10YR 4/4) mottles; weak fine granular structure; very friable; many fine and medium roots; 26 percent channers of shale up to 5 cm across; abrupt smooth boundary.

Bw1 -- 4 to 24 cm; yellowish brown (10YR 5/6) channery silt loam; weak fine subangular blocky structure; very friable; many fine, medium and coarse roots; few fine pores; 21 percent channers of shale up to 5 cm across; clear smooth boundary.

Bw2 -- 24 to 41 cm; yellowish brown (10YR 5/8) very channery silt loam; common fine faint yellowish brown (10YR 5/6) and pale brown (10YR 6/3) mottles; moderate fine subangular blocky structure; friable; common fine and many medium and coarse roots; common fine pores; 45 percent channers of shale up to 7 cm across; abrupt smooth boundary.

C -- 41 to 57 cm; yellowish brown (10YR 5/6) very channery silt loam; massive; very friable; few very fine and fine roots; 52 percent channers of shale up to 10 cm across; clear irregular boundary.

Cr -- 57 to 68 cm; moderately soft Grainger shale.

R -- 68 cm; hard Grainger sandstone.

Additional comments: a few fossils were found in the Grainger shale in the Cr.

Pedon number: 2 Geologic Formation: Rome formation

Date: 10 Jan 1990 Vegetation: virginia pine, mixed hardwood

Site Position: convex nose slope
Slope: 48 percent
Elevation: 347 meters
Aspect: southeast
Erosion: severe
Drainage Class: somewhat excessively drained
Taxonomic Class: loamy-skeletal, mixed, thermic, Typic Dystrochrept (this is a field classification)

Colors are for moist soil.

Oe -- 5 to 0 cm; leaves and forest debris in various stages of decomposition.

A -- 0 to 4 cm; brown (10YR 4/3) loam; weak fine granular structure; very friable; many fine and medium roots; 10 percent channers of shale; abrupt smooth boundary.

BE -- 4 to 27 cm; yellowish brown (10YR 5/4) channery loam; weak fine subangular blocky structure; very friable; many fine and common medium roots; 20 percent channers of shale; abrupt smooth boundary.

Bw -- 27 to 44 cm; yellowish brown (10YR 5/6) very channery loam; common medium distinct strong brown (7.5YR 5/6) and light olive brown (2.5Y 5/4) mottles; weak fine subangular blocky structure; very friable; common medium and few coarse roots; few fine pores; 35 percent channers of shale up to 7 cm across; clear smooth boundary.

C -- 44 to 52 cm; yellowish brown (10YR 5/6) extremely channery loam; common medium distinct light olive brown (2.5Y 5/4) mottles; massive; very friable; few fine and medium roots; 65 percent channers and flagstones up to 16 cm across; abrupt irregular boundary.

Cr -- 52 cm; moderately hard Rome shale.

Additional comments: The Rome formation seems to go a little higher on this slope than indicated on the geology map.

Pedon number: 3 Geologic Formation: Rome formation

Date: 10 Jan 1990 Vegetation: virginia pine, mixed hardwood

Site Position: convex nose slope
Slope: 45 percent
Elevation: 317 meters
Aspect: southeast
Erosion: severe
Drainage Class: somewhat excessively drained
Taxonomic Class: loamy-skeletal, mixed, thermic Typic Dystrochrept (this is a field classification)

Colors are for moist soil.

Oe -- 8 to 0 cm; leaf litter and forest debris in various stages of decomposition.

A -- 0 to 5 cm; brown (10YR 4/3) channery loam; weak fine granular structure; very friable; common fine and medium roots; 15 percent channers of shale; abrupt smooth boundary.

BE -- 5 to 14 cm; yellowish brown (10YR 5/4) channery loam; moderate medium granular structure; very friable; common medium and few coarse roots; 20 percent channers of shale; clear smooth boundary.

Bw -- 14 to 27 cm; yellowish brown (10YR 5/6) channery loam; weak fine subangular blocky structure; friable; common medium and coarse roots; few fine pores; 30 percent channers of shale up to 5 cm across; clear smooth boundary.

C -- 27 to 54 cm; yellowish brown (10YR 5/6) very channery loam; common medium distinct light olive brown (2.5Y 5/4) and strong brown (7.5YR 5/8) mottles; massive; friable; few medium roots; 50 percent channers and flagstones up to 15 cm across; clear smooth boundary.

Cr -- 54 cm; moderately hard Rome shale.

Pedon number: 4 Geologic Formation: Pumpkin Valley shale

Date: 10 Jan 1990 Vegetation: pasture

Site Position: narrow convex ridgetop
Slope: 4 percent
Elevation: 302 meters
Aspect: none apparent
Erosion: severe
Drainage Class: well drained
Taxonomic Class: loamy-skeletal, mixed, thermic, shallow Typic Dystrochrept (this is a field classification)

Colors are for moist soil.

Ap -- 0 to 3 cm; brown (10YR 4/3) channery loam; weak fine granular structure; very friable; many fine roots; 20 percent channers of shale up to 3 cm across; abrupt smooth boundary.

BE -- 3 to 17 cm; yellowish brown (10YR 5/4) very channery loam; weak fine subangular blocky structure; very friable; common fine and medium roots; few fine pores; 35 percent channers of shale up to 3 cm across; clear smooth boundary.

Bw -- 17 to 36 cm; yellowish brown (10YR 5/6); very channery loam; weak fine subangular blocky structure; very friable; few fine and medium roots; few fine pores; 45 percent channers of shale up to 3 cm across; abrupt irregular boundary.

Cr -- 36 cm; relatively soft, tabular, yellow to dark purplish Pumpkin Valley shale.

Additional comments: This little ridgetop is eroded and is not really a high ridge but more of the upper part of a roll. The eroded sediment accumulates further down this relatively gentle slope as colluvium.

Pedon number: 5 Geologic Formation: Pumpkin Valley shale

Date: 10 Jan 1990 Vegetation: Pasture

Site Position: convex to planar sideslope
Slope: 10 percent
Elevation: 296 meters
Aspect: south
Erosion: moderate
Drainage Class: well drained
Taxonomic Class: fine, mixed, thermic Typic Hapludalf

Colors are for moist soil.

Ap -- 0 to 7 cm; brown (10YR 4/3) loam; common fine faint yellowish brown (10YR 5/6) mottles; weak fine granular structure; very friable; many fine roots; 4 percent channers of shale; abrupt smooth boundary.

BE -- 7 to 24 cm; yellowish brown (10YR 5/4) loam; common medium faint yellowish brown (10YR 5/8), dark yellowish brown (10YR 4/4) and pale brown (10YR 6/3) mottles; weak fine subangular blocky structure; very friable; common fine and medium roots; few fine pores; 12 percent channers of shale; abrupt smooth boundary.

2Bw -- 24 to 34 cm; yellowish brown (10YR 5/8) silt loam; common medium distinct strong brown (7.5YR 5/8) mottles; weak medium subangular blocky structure; friable; few fine and medium roots; few fine pores; few faint clay films lining faces of peds; 7 percent channers of shale up to 2 cm across; clear smooth boundary.

2Bt -- 34 to 68 cm; yellowish brown (10YR 5/8) silty clay loam; common medium faint yellowish brown (10YR 5/4) and pale brown (10YR 6/3) and few fine distinct light olive brown (2.5Y 5/4) mottles; moderate medium subangular blocky structure; firm; common fine and medium pores; common distinct clay films lining faces of peds; 2 percent channers of shale up to 2 cm across; abrupt irregular boundary.

2Cr -- 68 cm; yellow to dark purplish Pumpkin Valley shale.

Additional comments: Coarse fragment content was described higher in the field than recorded here. The values recorded here are based on laboratory analysis. Mottle color and pattern indicate some slow permeability or perching of water in the 2Bt.

Pedon number: 6 Geologic Formation: Rutledge limestone

Date: 12 Jan 1990 Vegetation: Pasture adjacent to tobacco field

Site Position: stream terrace
Slope: 10 percent
Elevation: 293 meters
Aspect: southeast
Erosion: none to slight
Drainage Class: well drained
Taxonomic Class: fine, kaolinitic, thermic Typic Paleudalf

Colors are for moist soil.

Ap -- 0 to 20 cm; brown (7.5YR 4/4) clay loam; weak medium subangular blocky structure; friable; common fine and medium roots; few medium black concretions; clear smooth boundary.

AB -- 20 to 41 cm; reddish brown (5YR 4/4) clay loam; many coarse distinct red (2.5YR 4/6) mottles; weak medium subangular blocky structure; friable; common fine roots; few very fine and fine pores; common faint clay films; few medium black concretions; abrupt smooth boundary.

Bt1 -- 41 to 57 cm; yellowish red (5YR 5/6) clay; common medium distinct brown (7.5YR 4/4) and common fine prominent yellowish brown (10YR 5/8) mottles; weak medium subangular blocky structure; friable; few very fine and fine roots; few fine pores; common distinct clay films; many medium black concretions; clear smooth boundary.

Bt2 -- 57 to 92 cm; red (2.5YR 4/6) clay; common medium prominent strong brown (7.5YR 5/6) and yellowish brown (10YR 5/8) mottles; moderate fine subangular blocky structure; friable; common fine pores; common distinct clay films; many medium and coarse black concretions; clear smooth boundary.

Bt3 -- 92 to 134 cm; red (2.5YR 4/6) clay; common medium prominent strong brown (7.5YR 5/6) and yellowish brown (10YR 5/8) mottles; moderate medium subangular blocky structure; friable; common fine pores; many distinct clay films; many medium and coarse black concretions; gradual smooth boundary.

Pedon 6 (continued)

Bt4 -- 134 to 167 cm; red (2.5YR 4/6) clay; common medium distinct yellowish red (5YR 4/6) and few fine prominent brownish yellow (10YR 6/8) mottles; moderate medium subangular blocky structure; friable; common fine and medium pores; common distinct clay films; many medium and coarse black concretions; gradual smooth boundary.

Bt5 -- 167 to 190 cm; red (2.5YR 4/6) clay; common fine distinct yellowish red (5YR 5/6) mottles; moderate medium subangular blocky structure; friable; common fine and medium pores; common faint clay films; many medium and coarse black concretions; gradual smooth boundary.

Bt6 -- 190 to 260 cm; red (2.5YR 4/6) clay; common fine distinct yellowish red (5YR 5/6) mottles; weak medium subangular blocky structure; friable; common fine and medium pores; common faint clay films; common medium and coarse black concretions; gradual smooth boundary.

Bt7 -- 260 to 281 cm; red (2.5YR 4/6) clay; common fine distinct yellowish red (5YR 5/6) and few fine prominent yellowish brown (10YR 5/8) mottles; weak medium subangular blocky structure; friable; common medium pores; few faint clay films; common medium and coarse black concretions; gradual smooth boundary.

2Bt8 -- 281 to 302 cm; red (2.5YR 4/6) clay; common medium distinct yellowish red (5YR 5/6) mottles; weak fine subangular blocky structure; friable; common fine pores; few faint clay films; common medium and coarse black concretions; gradual smooth boundary.

2Bt9 -- 302 to 330 cm; red (2.5YR 4/6) clay; common medium distinct yellowish red (5YR 5/6) mottles; weak fine subangular blocky structure; friable; common fine pores; few faint clay films; few medium and coarse black concretions; gradual smooth boundary.

2BC1 -- 330 to 391 cm; yellowish red (5YR 5/8) clay; common medium distinct strong brown (7.5YR 5/8) mottles; weak fine subangular blocky structure; friable; common fine pores; few medium and coarse black concretions; clear smooth boundary.

Pedon 6 (continued)

2BC2 -- 391 to 435 cm; yellowish red (5YR 5/8) clay; common medium distinct red (2.5YR 4/8) and many medium prominent brownish yellow (10YR 6/8) and grayish brown (10YR 5/2) mottles; weak fine subangular blocky structure; friable; few very fine and fine pores; common medium and coarse black concretions; clear smooth boundary.

2Cb -- 435 to 518 cm; strong brown (7.5YR 5/8) clay; common medium prominent red (2.5YR 4/8) and common medium distinct brownish yellow (10YR 6/8) and yellowish brown (10YR 5/8) mottles; massive; friable; 2 percent weathered sandstone pebbles; many medium and coarse black concretions.

Additional comments: This alluvium is thought to be from the mid Pleistocene. The 2Cb horizon shows evidence of stratification, the red mottling occurs in distinct visible bands. The concretions effervesce in hydrogen peroxide, indicating that they are manganese concretions.

Pedon number: 7 Geologic Formation: Rogersville shale

Date: 16 Jan 1990 Vegetation: Red maple, sweetgum

Site Position: floodplain depression
Slope: 0 to 1 percent
Elevation: 280 meters
Aspect: none apparent
Erosion: none
Drainage Class: somewhat poorly drained
Taxonomic Class: (described as) Aeric Haplaquept

Colors are for moist soil.

A -- 0 to 9 cm; brown (10YR 4/3) silt loam; common fine faint dark yellowish brown (10YR 4/6) mottles; weak fine granular structure; very friable; common fine and medium roots; few fine black concretions; abrupt smooth boundary.

Bw1 -- 9 to 26 cm; yellowish brown (10YR 5/4) silt loam; common medium faint grayish brown (10YR 5/2) mottles; weak fine subangular blocky structure; very friable; common fine and medium roots; few fine black concretions; clear smooth boundary.

Bw2 -- 26 cm; yellowish brown (10YR 5/4) loam; many medium faint brown (10YR 5/3) and light brownish gray (10YR 6/2) mottles; weak fine subangular blocky structure; very friable; common fine roots; common fine and medium black concretions.

Additional comments: This description was never finished. The soil here was extremely wet and the morphology recorded here is something of a guess in places.

Pedon number: 8 Geologic Formation: Rogersville shale

Date: 16 Jan 1990 Vegetation: Red maple, sweetgum

Site Position: floodplain
Slope: 1 to 2 percent
Elevation: 280 meters
Aspect: none apparent
Erosion: none
Drainage Class: moderately well drained
Taxonomic Class: fine-silty, mixed, thermic Fluvaquentic Eutrochrept

Colors are for moist soil.

A -- 0 to 8 cm; brown (10YR 4/3) clay loam; common fine faint dark yellowish brown (10YR 4/4 and 10YR 4/6) mottles; weak fine granular structure; very friable; common fine and medium roots; abrupt smooth boundary.

Bw1 -- 8 to 21 cm; dark yellowish brown (10YR 4/4) loam; common medium faint brown (10YR 4/3) mottles; weak fine subangular blocky parting to moderate fine granular structure; very friable; common medium and coarse roots; few fine pores; common medium black concretions; clear smooth boundary.

Bw2 -- 21 to 56 cm; dark yellowish brown (10YR 4/6) silt loam; common medium faint yellowish brown (10YR 5/4) and common medium distinct pale brown (10YR 6/3) mottles; weak fine subangular blocky structure; friable; common medium roots; common fine and medium pores; common fine black concretions; clear smooth boundary.

Bw3 -- 56 to 80 cm; dark yellowish brown (10YR 4/6) silt loam; common medium distinct light brownish gray (10YR 6/2) mottles; weak fine subangular blocky structure; friable; common fine roots; few medium pores; common fine black concretions; clear smooth boundary.

Bw4 -- 80 to 109 cm; dark yellowish brown (10YR 4/4) silt loam; many medium distinct light brownish gray (10YR 6/2) mottles; weak fine subangular blocky structure; friable; common medium black concretions; clear smooth boundary.

Pedon 8 (continued).

BC -- 109 to 150 cm; dark yellowish brown (10YR 4/4) loam; many medium distinct light brownish gray (10YR 6/2) mottles and streaks; massive; friable; many fine and medium black concretions.

Additional comments: Worm holes and worm casts evident in upper profile.

Pedon number: 9 Geologic Formation: Maryville limestone

Date: 16 Jan 1990 Vegetation: mixed hardwoods

Site Position: convex upland sideslope
Slope: 12 percent
Elevation: 347 meters
Aspect: southwest
Erosion: moderate
Drainage Class: well drained
Taxonomic Class: fine, mixed, thermic Typic Hapludalf

Colors are for moist soil.

A -- 0 to 8 cm; dark yellowish brown (10YR 3/4) silty clay loam; many fine distinct brown (7.5YR 4/4) mottles; weak medium granular structure; friable; many fine and medium roots; abrupt wavy boundary.

Bt1 -- 8 to 20 cm; yellowish red (5YR 4/6) silty clay; many medium prominent brown (10YR 4/3) mottles; moderate fine subangular blocky structure; friable; common medium and few fine and coarse roots; few fine pores; common medium black concretions; clear wavy boundary.

Bt2 -- 20 to 81 cm; yellowish red (5YR 4/6) silty clay; many fine faint yellowish red (5YR 5/8) mottles; moderate medium subangular blocky structure; firm; common coarse roots; few fine and medium pores; common distinct clay films lining faces of peds; clear wavy boundary.

Bt3 -- 81 to 99 cm; yellowish red (5YR 5/6) clay; common medium distinct red (2.5YR 4/6) mottles; moderate medium subangular blocky structure; firm; few fine roots; few fine and medium pores; common distinct clay films lining faces of peds and larger pores; clear smooth boundary.

Bt4 -- 99 to 129 cm; red (2.5YR 4/8) clay; common medium faint red (2.5YR 4/6) mottles; moderate fine subangular blocky structure; firm; common distinct clay films lining faces of peds; abrupt wavy boundary.

R -- 129 cm; Hard Maryville limestone.

Additional comments: Rock outcrops and shallower soils are common in this unit. There is a thin layer (approximately 3 cm) of 2.5YR 5/4 clay lining the top of the bedrock.

Pedon number: 10 Geologic Formation: Nolichucky shale

Date: 16 Jan 1990 Vegetation: mixed woodland

Site Position: convex sideslope
Slope: 30 percent
Elevation: 366 meters
Aspect: southeast
Erosion: moderate
Drainage Class: well drained
Taxonomic Class: fine-loamy, mixed, thermic Typic Hapludult

Colors are for moist soil.

A -- 0 to 5 cm; brown (10YR 4/3) silty clay loam; moderate medium granular structure; very friable; few fine and medium roots; 3 percent channers of shale; abrupt smooth boundary.

BE -- 5 to 15 cm; yellowish brown (10YR 5/4) silt loam; weak medium subangular blocky structure; very friable; common fine and medium roots; common very fine pores; 3 percent channers of shale; clear smooth boundary.

Bt1 -- 15 to 26 cm; yellowish brown (10YR 5/6) silty clay loam; weak medium subangular blocky structure; friable; common fine and medium roots; few fine and medium pores; 12 percent fine channers of shale; common medium black concretions; clear smooth boundary.

Bt2 -- 26 to 52 cm; strong brown (7.5YR 5/6) channery silty clay loam; few fine distinct yellowish brown (10YR 5/6) mottles; weak fine subangular blocky structure; friable; few fine, medium and coarse roots; few fine pores; 23 percent fine channers of shale; abrupt irregular boundary.

Cr -- 52 cm; weathered Nolichucky shale.

Pedon number: 11 Geologic Formation: Nolichucky shale

Date: 10 Aug 1989 Vegetation: mixed hardwoods

Site Position: convex nose slope
Slope: 51 percent
Elevation: 414 meters
Aspect: south
Erosion: very severe
Drainage Class: somewhat excessively drained
Taxonomic Class: (described as) Typic Udorthent

Colors are for moist soil.

Oe -- 4 to 0 cm; organic mat of leaf litter and fibrous roots.

A -- 0 to 6 cm; yellowish brown (10YR 5/4) very channery silt loam; weak fine granular structure; very friable; many fine and medium roots; 50 percent channers of shale; clear smooth boundary.

C -- 6 to 25 cm; yellowish brown (10YR 5/4) extremely channery silt loam; massive rock controlled structure; loose; few fine and medium roots; 85 percent weathered shale; gradual smooth boundary.

Cr -- 25 cm; fractured, tilted, moderately hard Nolichucky shale.

Pedon number: 12 Geologic Formation: Maynardville limestone

Date: 10 Aug 1989 Vegetation: mixed woodland

Site Position: backslope
Slope: 37 percent
Elevation: 402 meters
Aspect: northwest
Erosion: severe
Drainage Class: well drained
Taxonomic Class: fine-loamy, mixed, thermic Lithic Hapludalf

Colors are for moist soil.

Oe -- 3 to 0 cm; organic litter in varying stages of decomposition.

A -- 0 to 5 cm; dark brown (10YR 3/3) silt loam; common medium faint yellowish brown (10YR 5/6) mottles; moderate medium granular structure; very friable; many fine, medium and coarse roots; 10 percent small angular chert pebbles; abrupt smooth boundary.

BE -- 5 to 14 cm; yellowish brown (10YR 5/4) silt loam; common medium faint yellowish brown (10YR 5/6) mottles; moderate fine subangular blocky structure; friable; common fine and medium and few coarse roots; common fine and medium pores; 1 percent small angular chert pebbles; clear smooth boundary.

Bt -- 14 to 29 cm; strong brown (7.5YR 5/6) clay loam; commonmedium distinct yellowish brown (10YR 5/6) and common fine faint strong brown (7.5YR 4/6) mottles; moderate medium subangular blocky structure; friable; few fine and medium roots; common fine pores; common faint clay films lining faces of peds and in pores; 8 percent small angular chert pebbles; abrupt smooth boundary.

R -- 29 cm; Hard Maynardville limestone.

Pedon number: 13 Geologic Formation: Grainger formation

Date: 27 July 1989 Vegetation: mixed woodland

Site Position: ridge shoulder
Slope: 40 percent
Elevation: 360 meters
Aspect: south
Erosion: moderate
Drainage Class: well drained
Taxonomic Class: coarse-loamy, mixed, thermic Typic Hapludalf

Colors are for moist soil.

A -- 0 to 9 cm; dark brown (10YR 3/3) gravelly silt loam; weak fine subangular blocky parting to moderate medium granular structure; very friable; many fine and medium and few coarse roots; 16 percent small sandstone pebbles; clear wavy boundary.

BE -- 9 to 15 cm; brown (10YR 5/3) gravelly silt loam; common fine faint brownish yellow (10YR 6/8) mottles; weak fine subangular blocky structure; very friable; many fine and medium and common coarse roots; common fine pores; 31 percent small sandstone pebbles; few fine black concretions; clear wavy boundary.

Bw -- 15 to 40 cm; light yellowish brown (10YR 6/4) gravelly silt loam; few fine faint brownish yellow (10YR 6/6 and 10YR 6/8) mottles; weak fine subangular blocky structure; very friable; common fine, medium and coarse roots; common fine and medium pores; 25 percent sandstone and shale fragments up to 5 cm across; few fine black concretions.

Bt -- 40 to 68 cm; brownish yellow (10YR 6/6) gravelly silt loam; common medium faint yellowish brown (10YR 5/8) mottles; weak fine subangular blocky structure; very friable; common fine and medium roots; common fine and medium pores; 32 percent sandstone and shale fragments up to 7 cm across; abrupt smooth boundary.

Cr -- 68 to 84 cm; weathered, coarse-grained Grainger shale and fine-grained Grainger sandstone, interbedded.

R -- 84 cm; hard, relatively unweathered Grainger sandstone.

Pedon number: 14 Geologic Formation: Rome formation

Date: 27 July 1989 Vegetation: Pasture

Site Position: convex ridgetop
Slope: 9 percent
Elevation: 335 meters
Aspect: east
Erosion: severe
Drainage Class: somewhat excessively drained
Taxonomic Class: loamy-skeletal, mixed, thermic, Lithic Dystrochrept

Colors are for moist soil.

A -- 0 to 6 cm; yellowish brown (10YR 5/4) gravelly loam; common medium prominent olive (5Y 5/3) mottles from weathered shale; moderate fine granular structure; very friable; common fine and medium roots; 28 percent sandstone pebbles and shale channers; few fine black concretions; clear smooth boundary.

Bw -- 6 to 20 cm; yellowish brown (10YR 5/4) gravelly loam; common medium prominent olive (5Y 5/3) mottles from weathered shale; weak fine subangular blocky structure; very friable; common fine and medium roots; common fine pores; 30 percent sandstone pebbles and shale channers; few fine black concretions; clear smooth boundary.

C -- 20 to 37 cm; light yellowish brown (10YR 6/4) extremely gravelly loam; common medium distinct brownish yellow (10YR 6/8) mottles and common medium prominent olive (5Y 5/3) weathered shale mottles; massive; very friable; few fine and medium roots; 69 percent sandy shale gravels and shale channers ranging to about 8 cm across; abrupt irregular boundary.

Cr -- 37 to 47 cm; Variegated Rome shale that can be dug with some difficulty.

R -- 47 cm; Hard, variegated sandy Rome shale.

Pedon number: 15 Geologic Formation: Pumpkin Valley shale

Date: 28 July 1989 Vegetation: Hay or pasture

Site Position: shoulder of narrow convex ridge
Slope: 12 percent
Elevation: 305 meters
Aspect: southeast
Erosion: severe
Drainage Class: well drained
Taxonomic Class: loamy-skeletal, mixed, thermic, shallow Typic Dystrochrept (this is a field classification)

Colors are for moist soil.

Ap -- 0 to 8 cm; brown (10YR 4/3) loam; moderate medium granular structure; very friable; many fine and medium roots; 5 percent shale channers; abrupt smooth boundary.

Bw -- 8 to 36 cm; yellowish brown (10YR 5/4) very channery loam; weak fine subangular blocky structure; very friable; common fine and medium roots; few faint clay films; 40 percent channers of shale and siltstone; clear smooth boundary.

Cr -- 36 cm; fractured, moderately hard shale of the Pumpkin Valley formation.

Additional comments: The soils are deeper on the gently sideslope indicating that erosion is active here on the upper part of the ridge.

Pedon number: 16 Geologic Formation: Rutledge limestone

Date: 28 July 1989 Vegetation: hayfield near tobacco field

Site Position: sideslope
Slope: 12 percent
Elevation: 286 meters
Aspect: east
Erosion: severe
Drainage Class: well drained
Taxonomic Class: clayey, mixed, thermic Typic Paleudult

Colors are for moist soil.

Ap -- 0 to 8 cm; brown (7.5YR 4/4) clay loam; moderate fine subangular blocky parting to moderate medium granular structure; friable; common fine and medium roots; few fine pores; few very fine black concretions; clear smooth boundary.

Bt1 -- 8 to 23 cm; yellowish red (5YR 4/6) silty clay; common medium distinct brown (7.5YR 4/4) mottles; weak medium subangular blocky structure; friable; few fine roots; common fine and medium pores; few faint clay films; few very fine and fine black concretions; clear smooth boundary.

Bt2 -- 23 to 64 cm; yellowish red (5YR 5/8) clay; few fine prominent brownish yellow (10YR 6/8) mottles; moderate medium subangular blocky structure; friable; few fine roots; common fine and medium pores; common distinct clay films; few fine black concretions; gradual smooth boundary.

Bt3 -- 64 to 89 cm; yellowish red (5YR 5/8) clay; few fine prominent brownish yellow (10YR 6/8) mottles; friable; few fine pores; common distinct clay films; few fine black concretions; gradual smooth boundary.

Bt4 -- 89 to 109 cm; yellowish red (5YR 5/8) clay; common medium prominent brownish yellow (10YR 6/6 and 10YR 6/8) mottles; weak medium subangular blocky structure; friable; few fine and medium pores; common distinct clay films; few very fine black concretions; gradual smooth boundary.

Pedon 16 (continued).

Bt5 -- 109 to 150 cm; yellowish red (5YR 5/6) clay; many medium prominent brownish yellow (10YR 6/6 and 10YR 6/8) and many medium distinct red (2.5YR 4/6) mottles; weak medium subangular blocky structure; friable; few fine and medium pores; common faint clay films; few very fine black concretions.

Pedon number: 17 Geologic Formation: Rogersville shale

Date: 20 July 1990 Vegetation: Pasture

Site Position: floodplain
Slope: 1 percent
Elevation: 280 meters
Aspect: none apparent
Erosion: none
Drainage Class: moderately well drained
Taxonomic Class: fine-loamy, mixed, thermic Fluvaquentic Eutrochrept (this is a field classification)

Colors are for moist soil.

Ap -- 0 to 16 cm; brown (10YR 4/3) silt loam; moderate fine granular structure; very friable; many fine and medium roots; abrupt smooth boundary.

Bw1 -- 16 to 41 cm; dark yellowish brown (10YR 4/6) silt loam; weak medium subangular blocky structure; very friable; many fine and medium roots; common fine pores; common fine black concretions; clear smooth boundary.

Bw2 -- 41 to 73 cm; dark yellowish brown (10YR 4/6) loam; common medium distinct grayish brown (10YR 5/2) and pale brown (10YR 6/3) mottles; weak medium subangular blocky structure; very friable; common very fine and fine roots; common fine pores; common fine black concretions; clear smooth boundary.

Bw3 -- 73 to 107 cm; yellowish brown (10YR 5/4) loam; many medium distinct grayish brown (10YR 5/2) and pale brown (10YR 6/3) mottles; weak medium subangular blocky structure; very friable; common fine pores; 5 percent fine channers of shale; many fine black concretions; gradual smooth boundary.

C -- 107 to 150 cm; dark yellowish brown (10YR 4/4) fine sandy loam; many medium distinct grayish brown (10YR 5/2) and pale brown (10YR 6/3) mottles; massive; very friable; few very fine pores; 5 percent fine channers of shale; many fine black concretions.

Pedon number: 18 Geologic Formation: Maryville limestone

Date: 28 July 1989 Vegetation: Pasture

Site Position: convex sideslope
Slope: 17 percent
Elevation: 314 meters
Aspect: northeast
Erosion: moderate
Drainage Class: well drained
Taxonomic Class: fine, mixed, thermic Typic Hapludalf (this is a field classification)

Colors are for moist soil.

Ap -- 0 to 5 cm; brown (7.5YR 4/4) silty clay loam; moderate medium granular structure; friable; common fine and medium roots; abrupt smooth boundary.

Bt1 -- 5 to 43 cm; yellowish red (5YR 5/6) silty clay; common medium distinct red (2.5YR 5/8) mottles; moderate medium subangular blocky structure; friable; common fine and medium roots; few fine pores; common distinct clay films; clear smooth boundary.

Bt2 -- 43 to 84 cm; red (2.5YR 5/8) silty clay; moderate medium subangular blocky structure; firm; common fine roots; few fine pores; common distinct clay films; abrupt smooth boundary.

R -- 84 cm; Hard Maryville limestone.

Pedon number: 19 Geologic Formation: Nolichucky shale

Date: 28 July 1989 Vegetation: mixed woodland

Site Position: convex toeslope
Slope: 22 percent
Elevation: 348 meters
Aspect: west
Erosion: severe
Drainage Class: well drained
Taxonomic Class: clayey, mixed, thermic shallow Ochreptic Hapludult (this is a field classification)

Colors are for moist soil.

A -- 0 to 5 cm; very dark grayish brown (10YR 3/2) channery silty clay loam; moderate fine subangular blocky structure; friable; common fine and medium roots; 15 percent channers of shale up to 3 cm across; abrupt smooth boundary.

Bt -- 5 to 18 cm; brown (10YR 4/3) channery clay; common fine faint brownish yellow (10YR 6/6) mottles; weak medium subangular blocky structure; friable; common fine and medium roots; 20 percent channers of shale up to 3 cm across; clear smooth boundary.

C -- 18 to 36 cm; yellowish brown (10YR 5/6) very channery silt loam; common fine faint brownish yellow (10YR 6/6) mottles; massive; friable; few fine roots; 30 percent channers of shale up to 8 cm across; abrupt wavy boundary.

Cr -- 36 cm; Relatively soft, brownish Nolichucky shale.

Additional comments: This is adjacent to a rough gullied severely eroded area in the Nolichucky shale. There are also some shaly limestone rock outcrops and some loose fragments of shaly limestone scattered here and there on the ground surface.

Pedon number: 20 Geologic Formation: Maynardville limestone

Date: 28 July 1989 Vegetation: mixed hardwoods

Site Position: backslope
Slope: 67 percent
Elevation: 408 meters
Aspect: north
Erosion: moderate
Drainage Class: well drained
Taxonomic Class: fine, mixed, thermic Typic Hapludalf (this is a field classification)

Colors are for moist soil.

A -- 0 to 9 cm; brown (10YR 4/3) silt loam; weak fine granular structure; very friable; common very fine and fine roots; 10 percent channers of shaly limestone; abrupt smooth boundary.

Bt1 -- 9 to 23 cm; yellowish brown (10YR 5/4) channery silty clay loam; weak fine subangular blocky structure; friable; common fine and medium roots; common fine pores; 20 percent channers of shaly limestone; few fine black concretions; clear smooth boundary.

2Bt2 -- 23 to 44 cm; yellowish brown (10YR 5/4) channery silty clay; common medium faint yellowish brown (10YR 5/6) mottles; weak fine subangular blocky structure; friable; common fine roots; common fine and medium pores; few faint clay films; 20 percent channers of shaly limestone; few fine black concretions; clear smooth boundary.

2Bt3 -- 44 to 68 cm; yellowish brown (10YR 5/6) channery silty clay; weak medium subangular blocky structure; friable; common fine roots; few fine and medium pores; few faint clay films; 30 percent channers of shaly limestone; abrupt smooth boundary.

2R -- 68 cm; Hard shaly limestone of the Maynardville formation.

Pedon number: 21 Geologic Formation: Maynardville limestone

Date: 28 July 1989 Vegetation: cedars and mixed hardwoods

Site Position: ridgetop
Slope: 11 percent
Elevation: 463 meters
Aspect: west
Erosion: severe
Drainage Class: well drained
Taxonomic Class: clayey, mixed, thermic Lithic Hapludalf
(this is a field classification)

Colors are for moist soil.

A -- 0 to 7 cm; brown (10YR 4/3) silty clay loam; weak fine granular structure; friable; common fine and medium roots; 3 percent fine shale channers; abrupt smooth boundary.

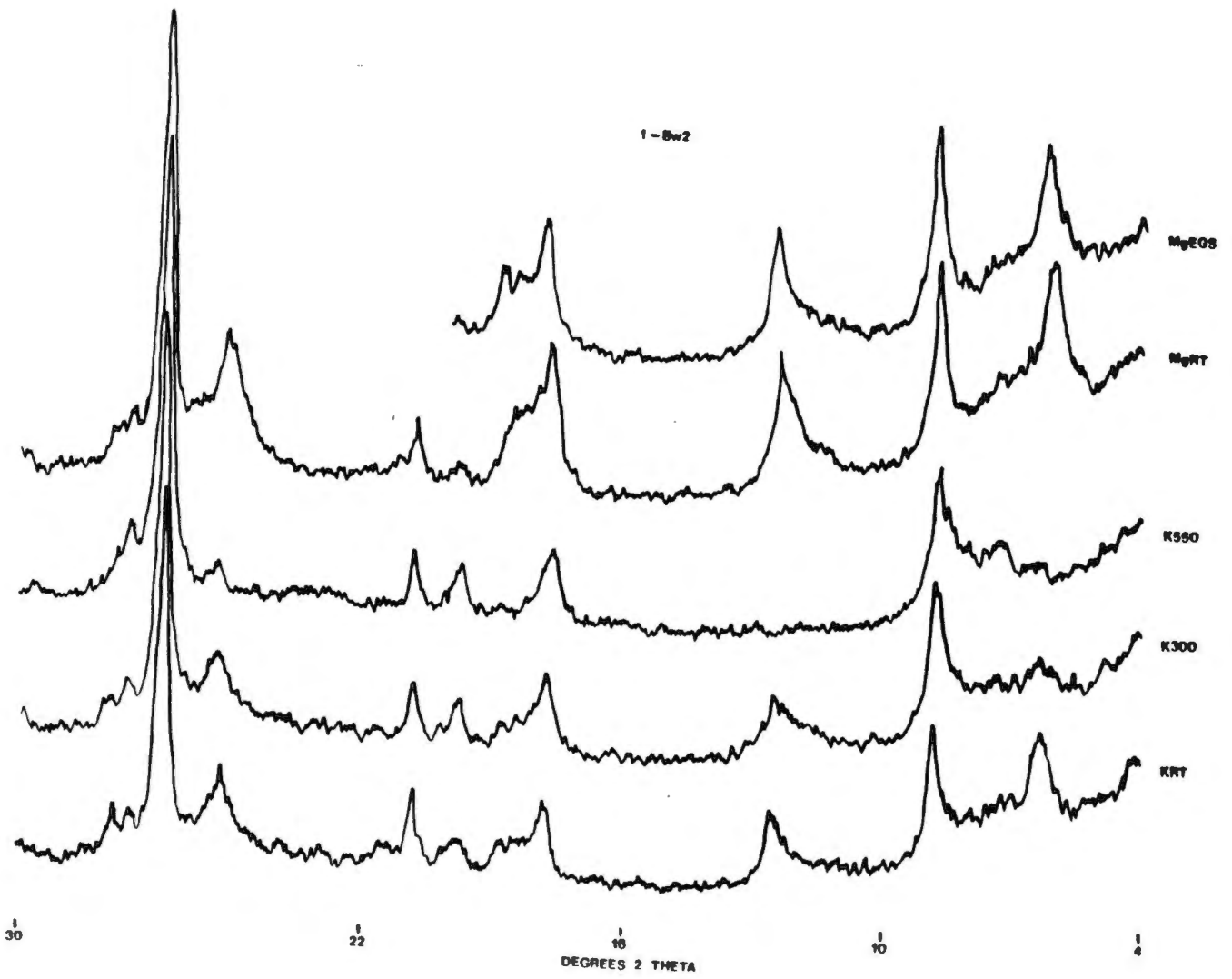
Bt -- 7 to 32 cm; brownish yellow (10YR 6/6) clay; common fine faint brown (10YR 4/3) and yellowish brown (10YR 5/6) mottles; weak medium subangular blocky structure; friable; common fine roots; 3 percent fine shale channers; abrupt smooth boundary.

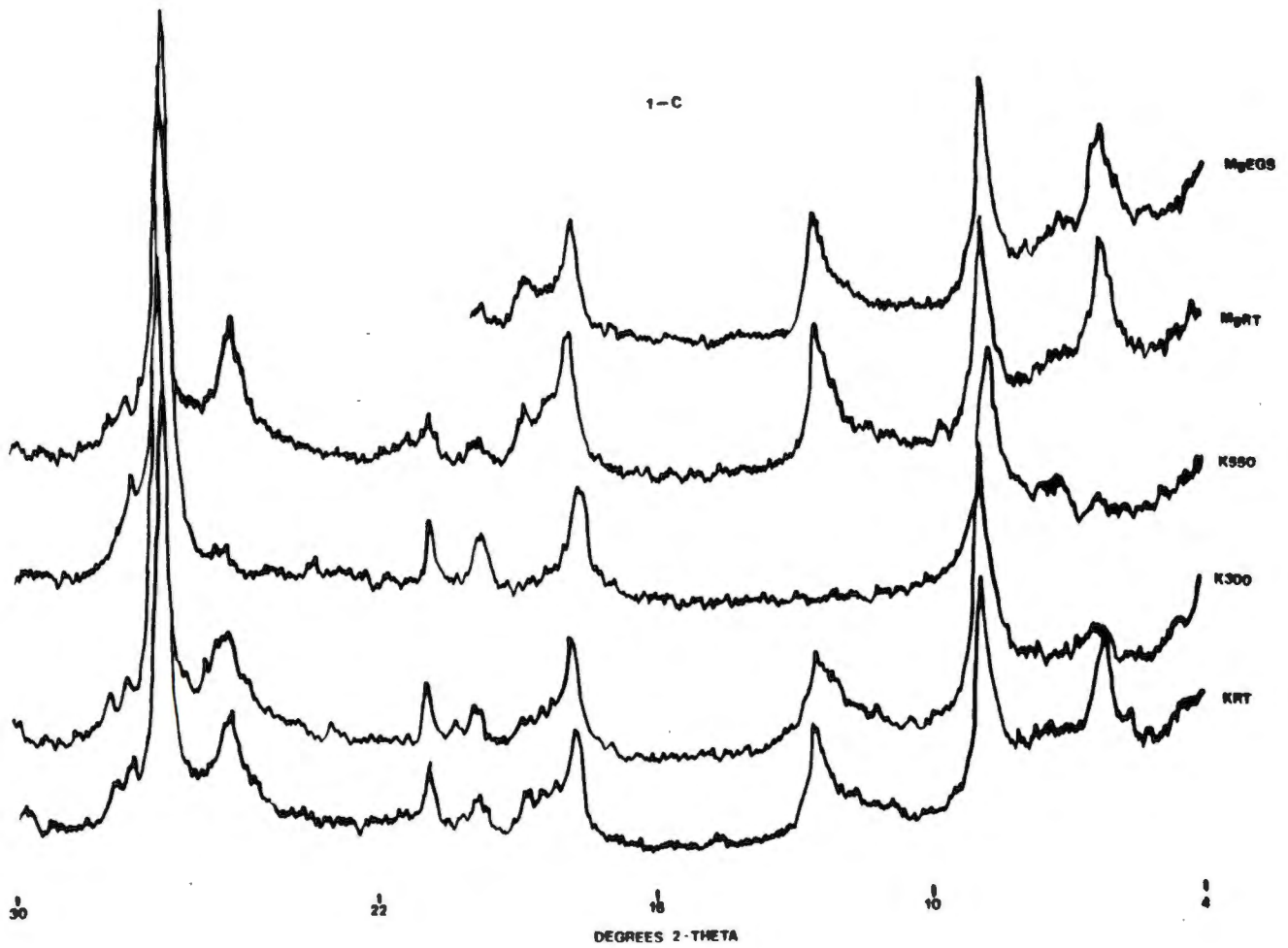
R -- 32 cm; Hard Maynardville limestone.

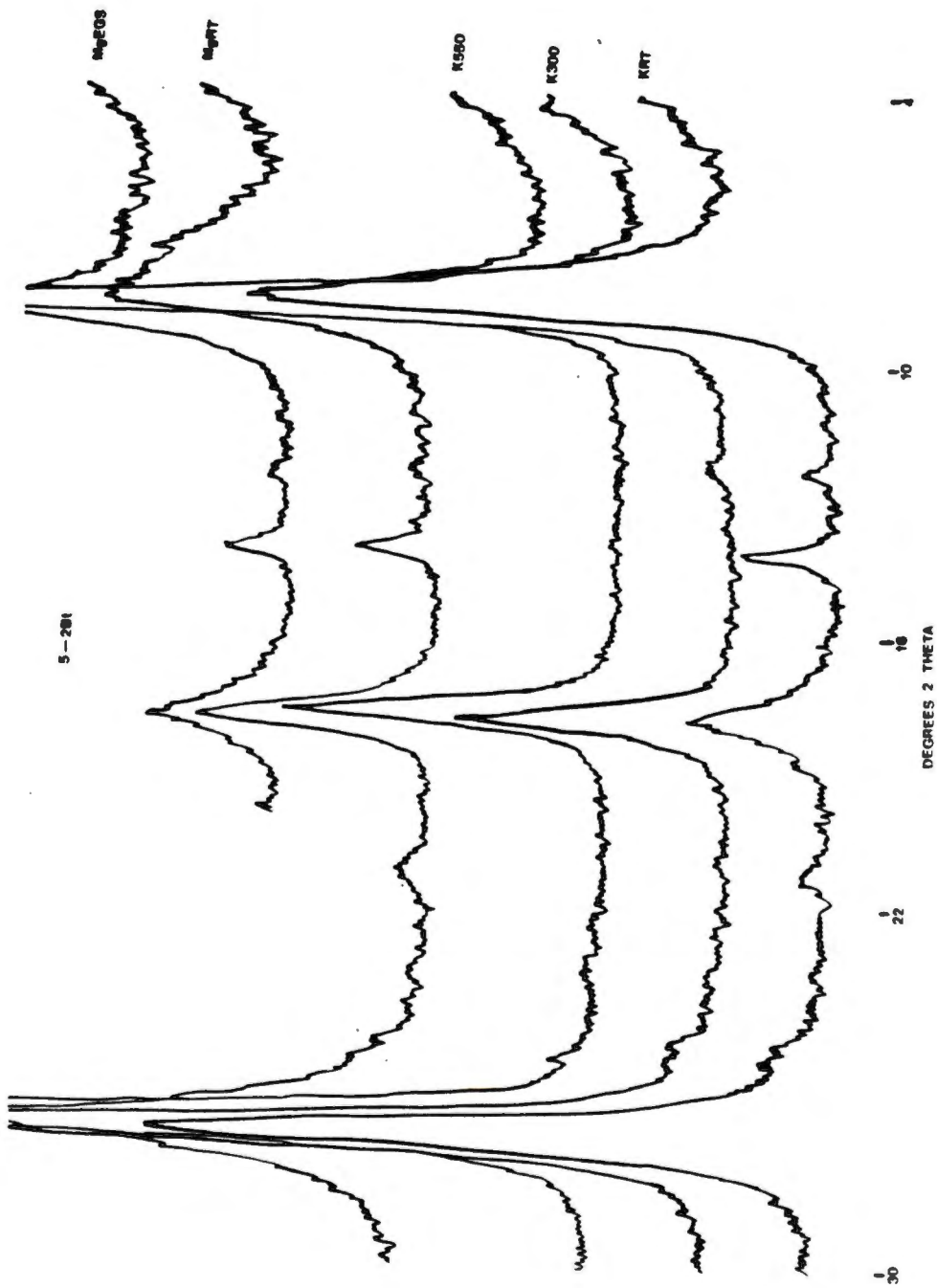
APPENDIX B

X-RAY DIFFRACTOGRAMS

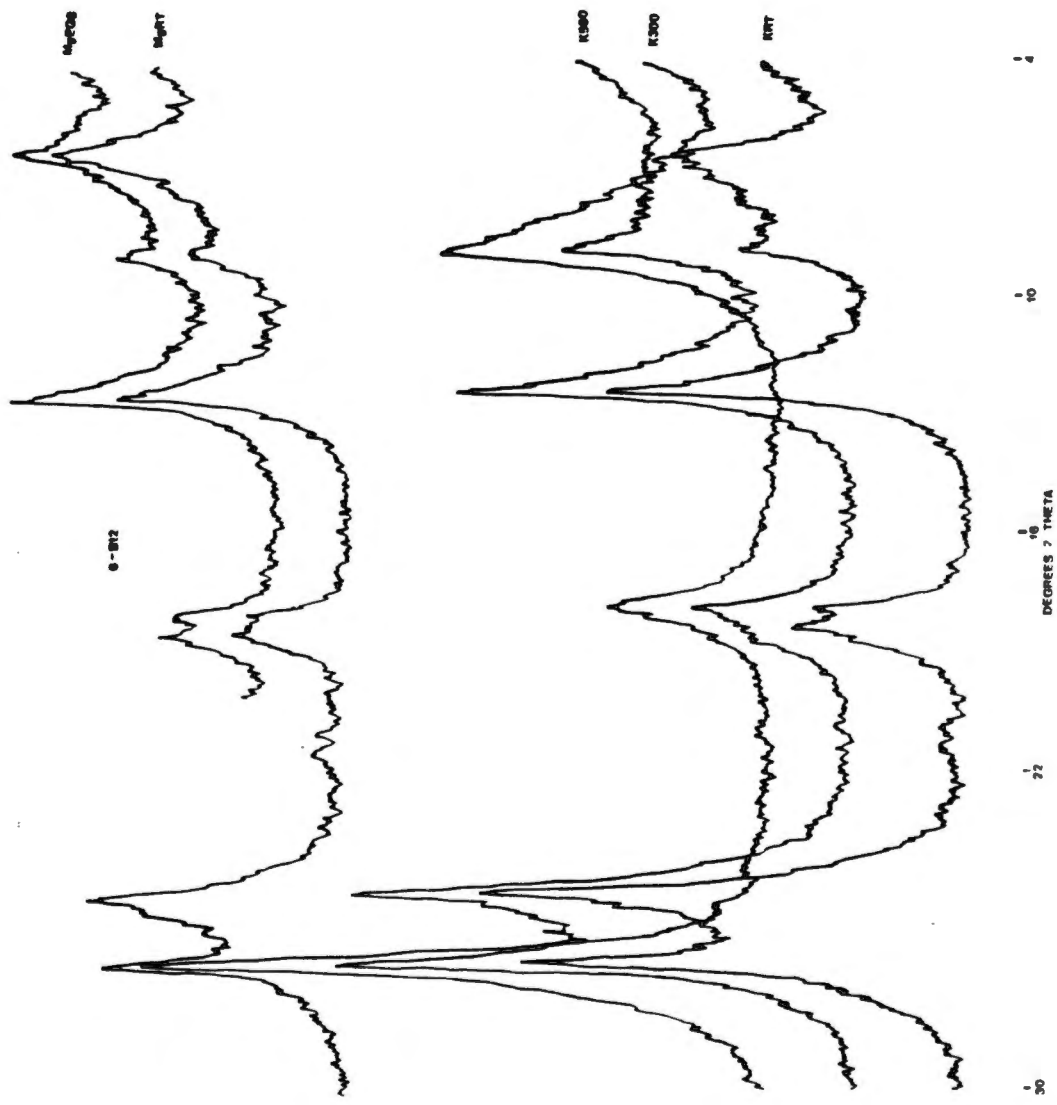
These diffractograms are for the samples discussed in the text. The pedon and horizon designations are indicated by the pedon number followed by a dash and then the horizon designation. Treatments are indicated by the following: KRT, K300, K550, MgRT, and MgEGS. The treatments marked with "K" are potassium saturated and those marked with "Mg" are magnesium saturated. The designation "RT" indicates room temperature for potassium saturated samples and room temperature and ambient relative humidity for magnesium saturated samples. The "300" and "550" indicates the temperature in degrees Celsius of the heat treatment used. On the magnesium saturated slides, "EGS" indicates overnight solvation in ethylene glycol vapor at room temperature.

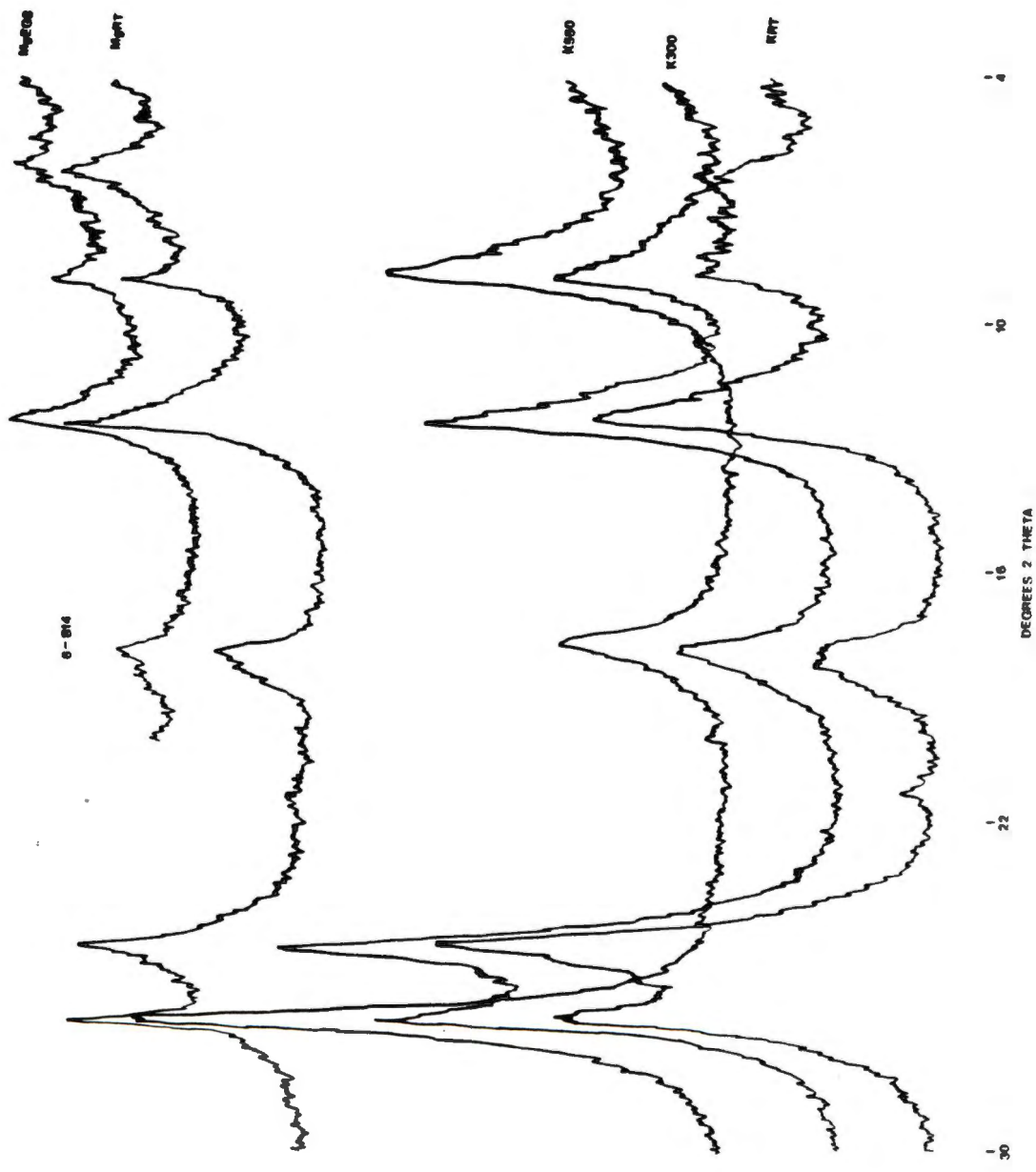

1 - Bw2
MgEOS
MgRT
K550
K300
KRT
30
22
18
10
4
DEGREES 2 THETA

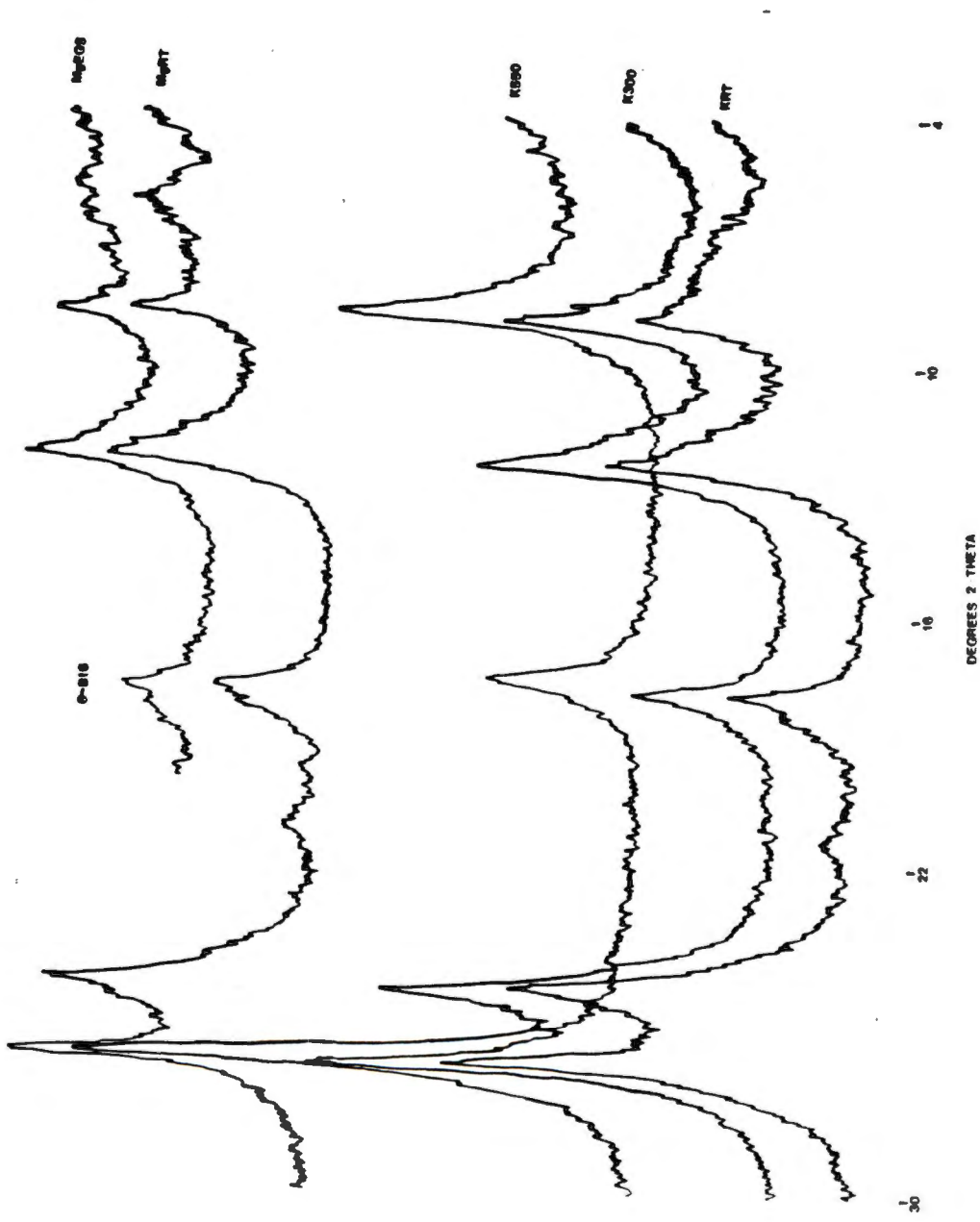

1-C
MgEGS
MgRT
K550
K300
KRT
30
22
18
10
4
DEGREES 2-THETA

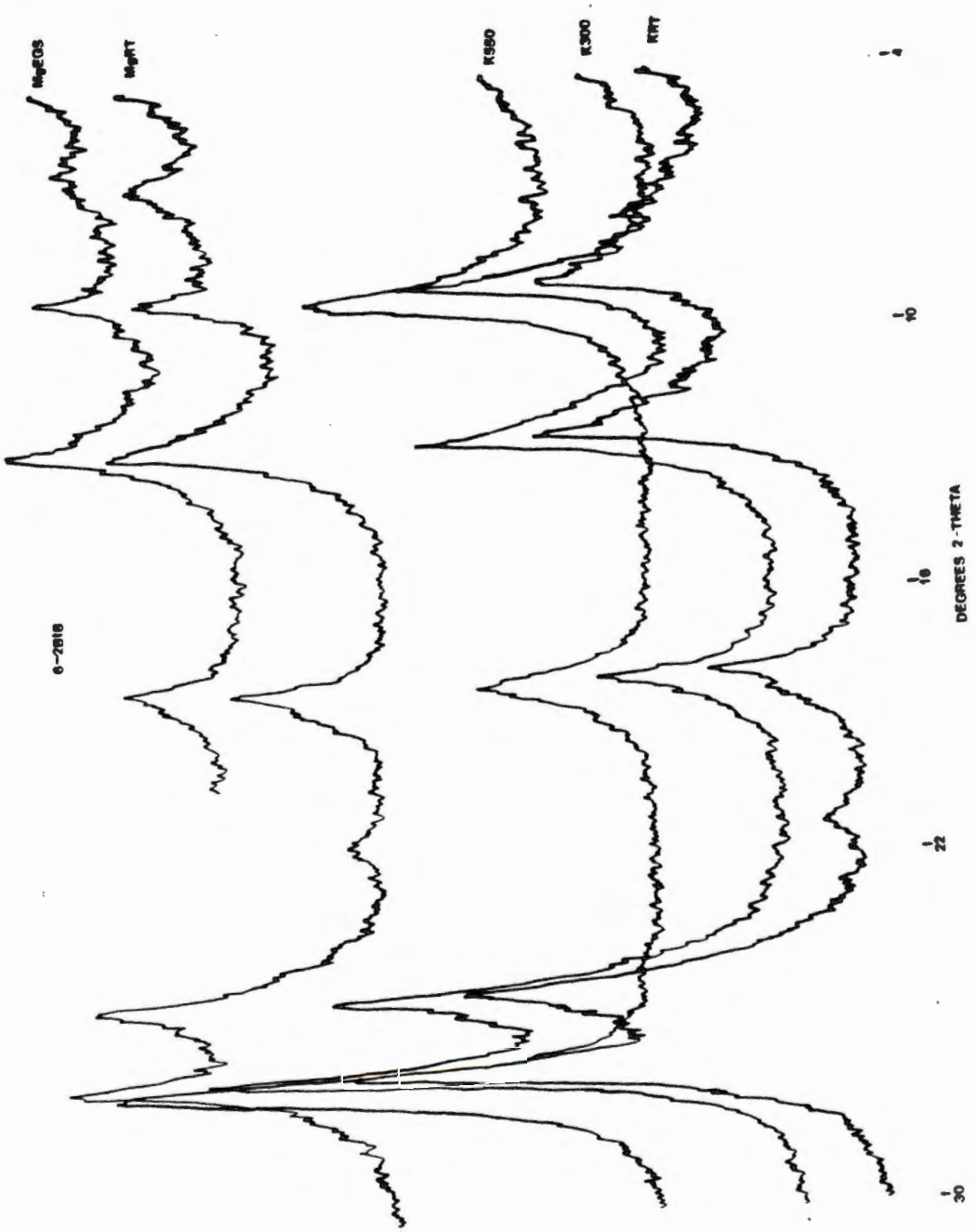

MgEG3
MgRT
K580
K300
KRT
5-281
30
22
16
10
DEGREES 2 THETA

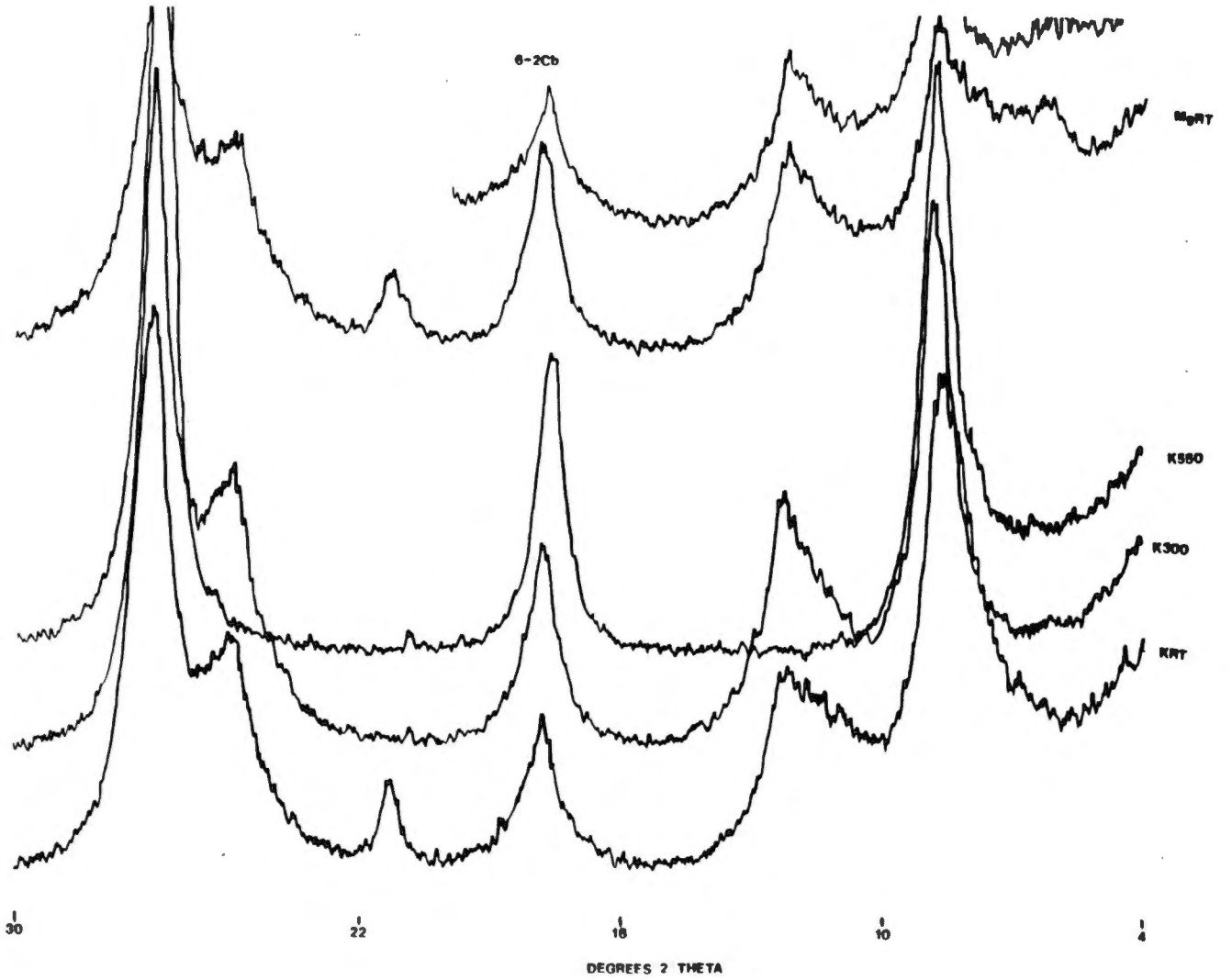
MgEOS
MgRT
B-811
E580
E300
RT7
DEGREES 2 THETA

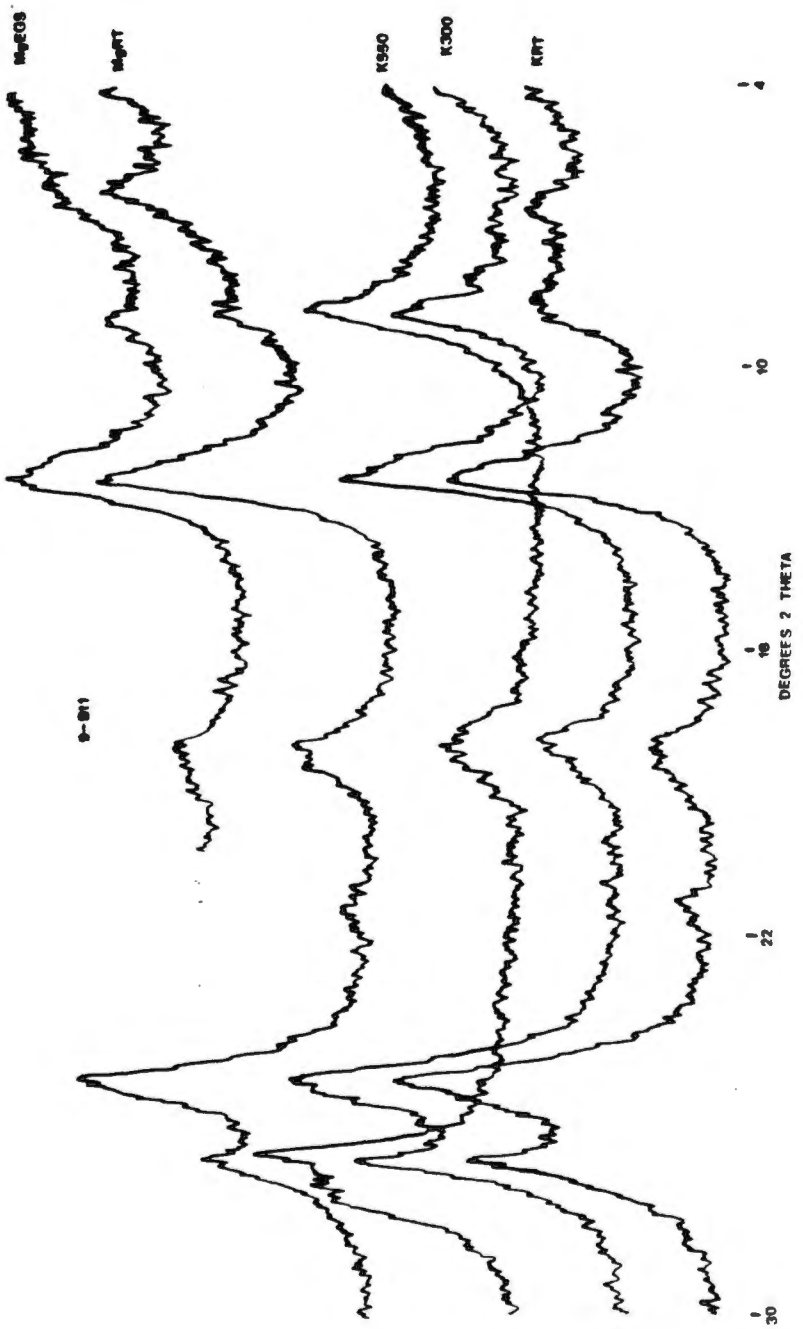

MgSO4
MgRT
K560
K300
KRT
6-BI2
30
22
10
4
DEGREES 2 THETA

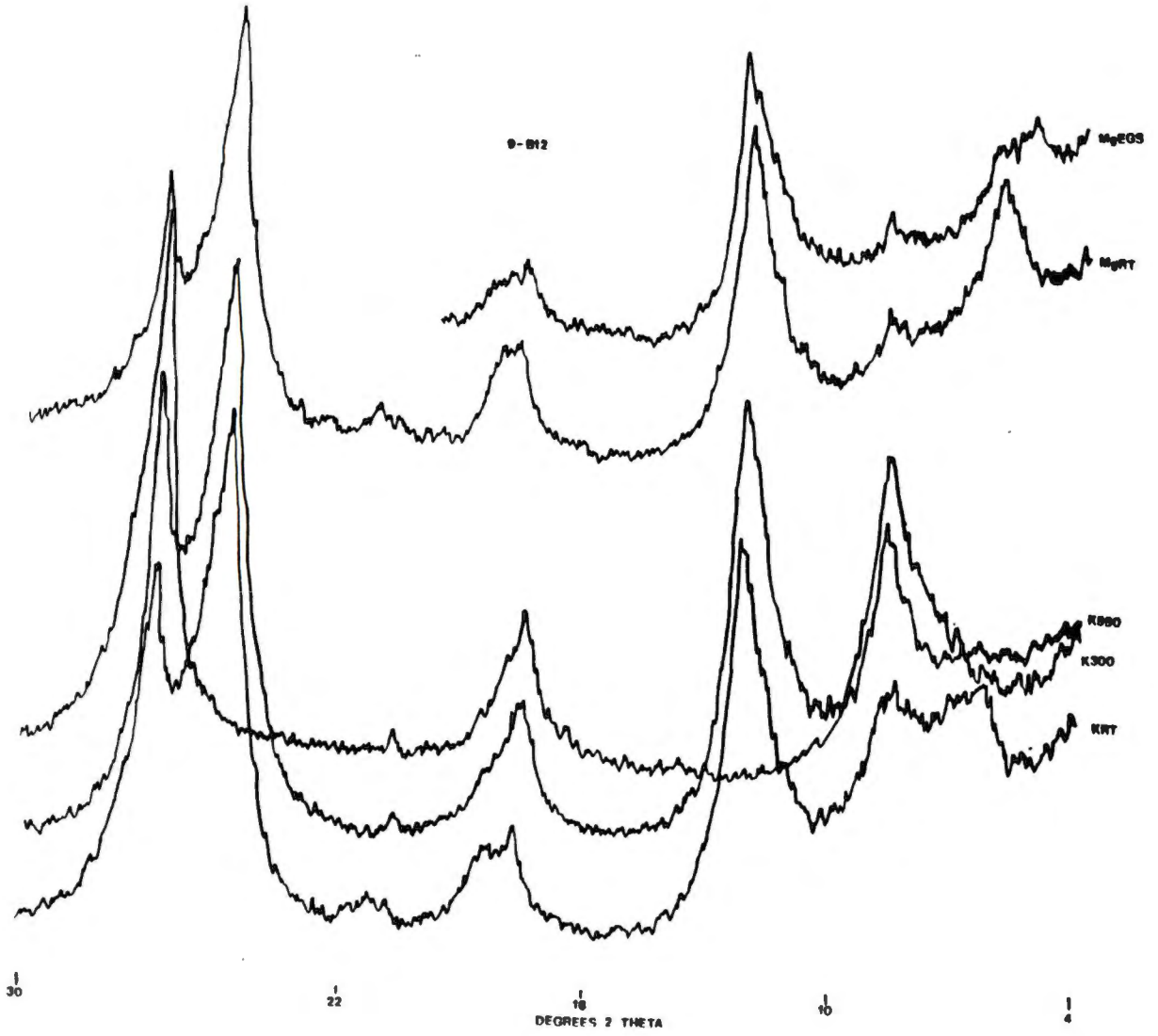

MgRT
K300
RRT
DEGREES 2 THETA

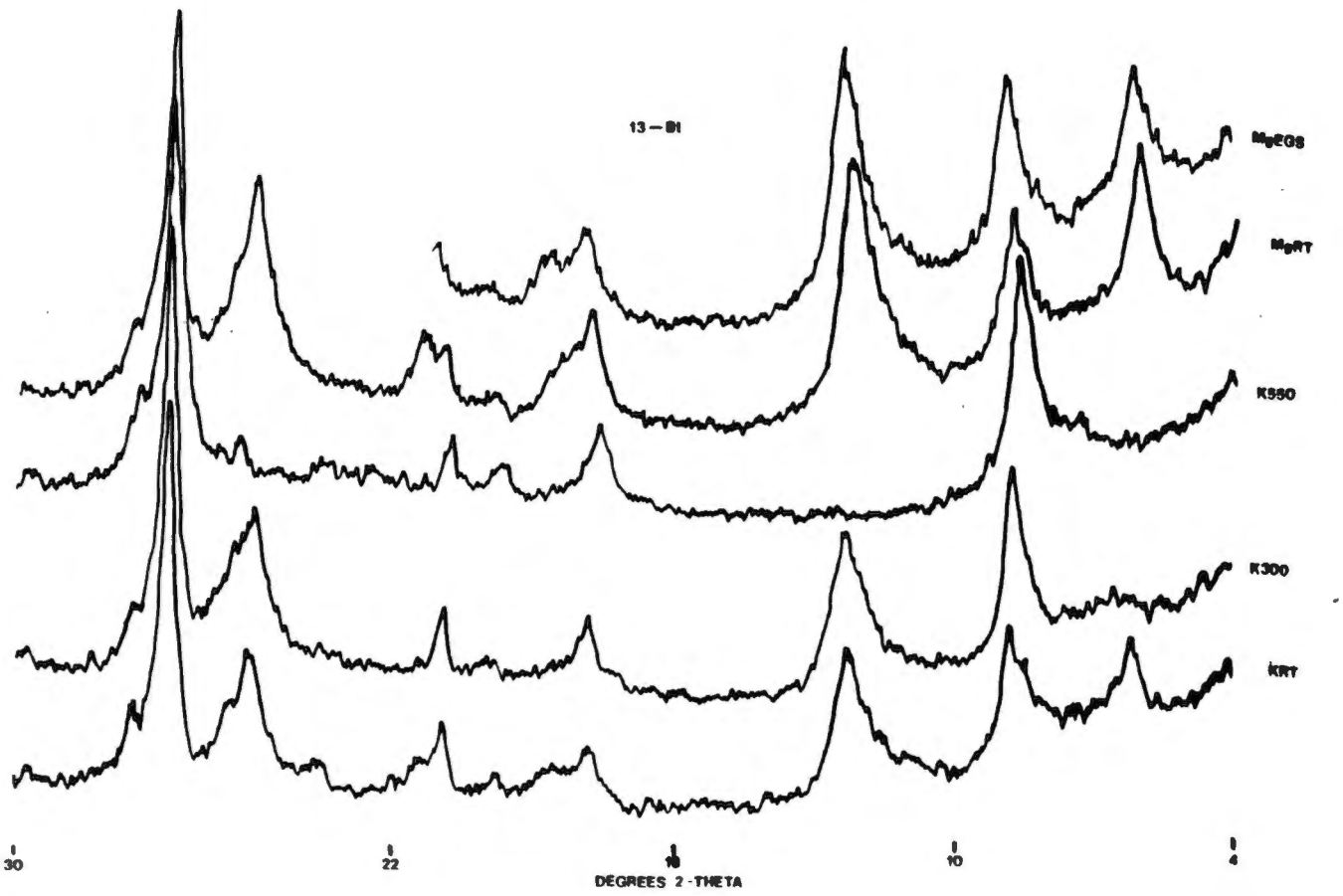

MgEOS
MgRT
G-B16
K550
K300
KRT
DEGREES 2 THETA

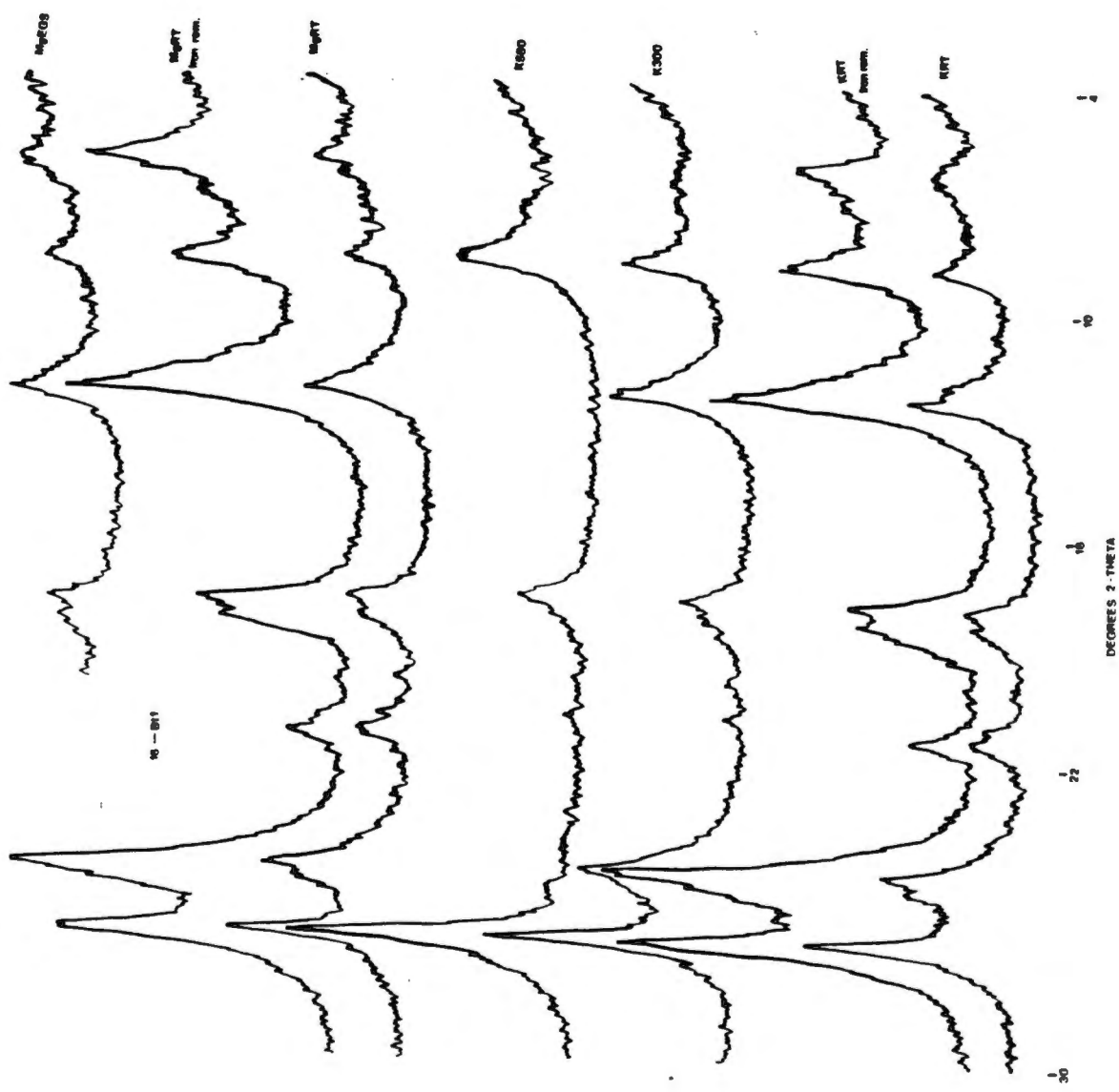

MgEOS
MgRT
K350
K300
RRT
6-2316
1/4
1/10
1/16
1/22
1/30
DEGREES 2-THETA

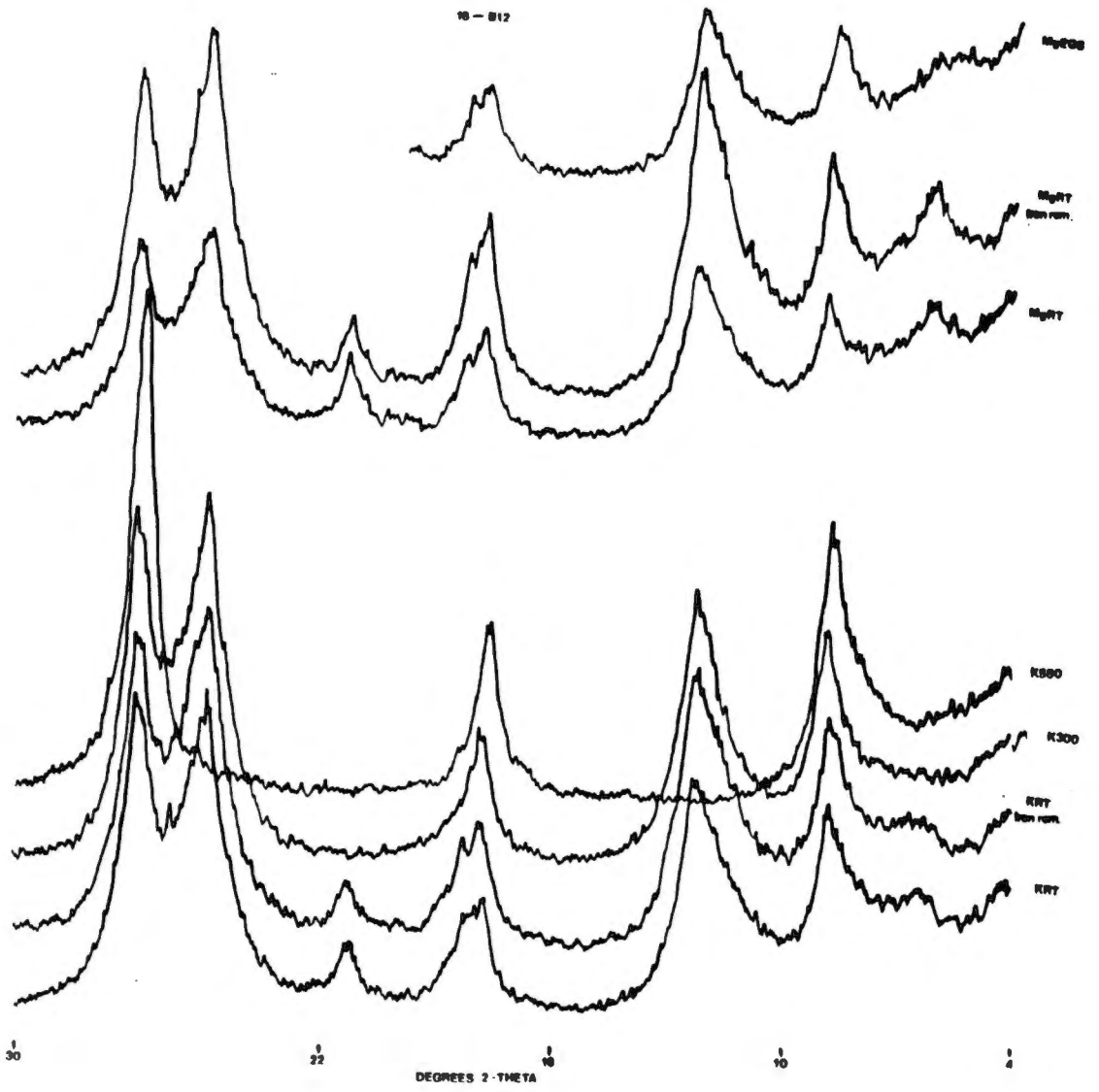

6-2Cb
K550
K300
KRT
30
22
18
10
4
DEGREES 2 THETA

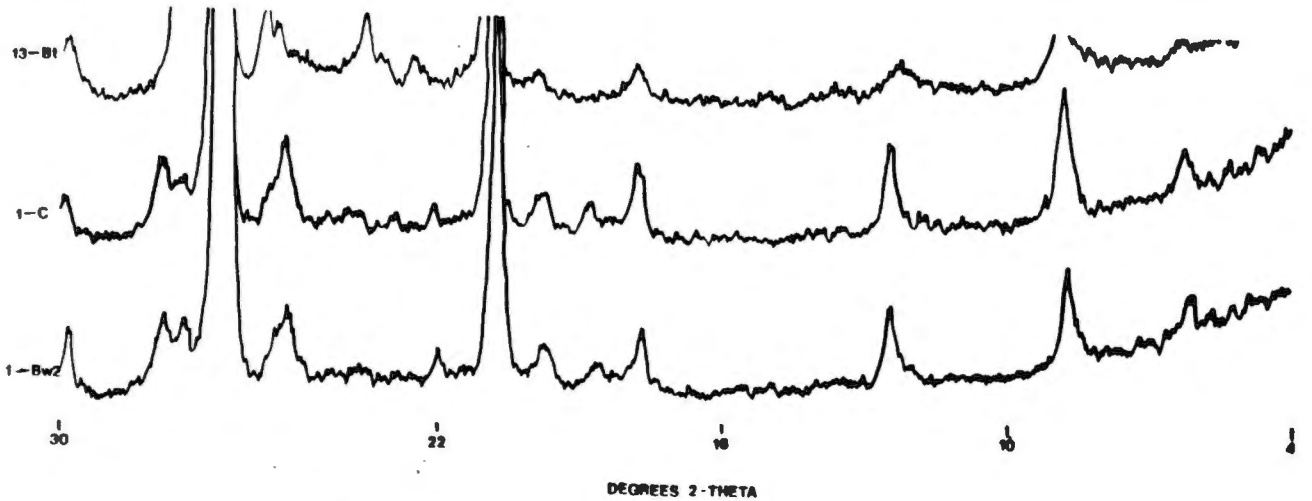

MgEOS
MgRT
K950
K300
KRT
9-811
30
22
14
6
DEGREES 2 THETA

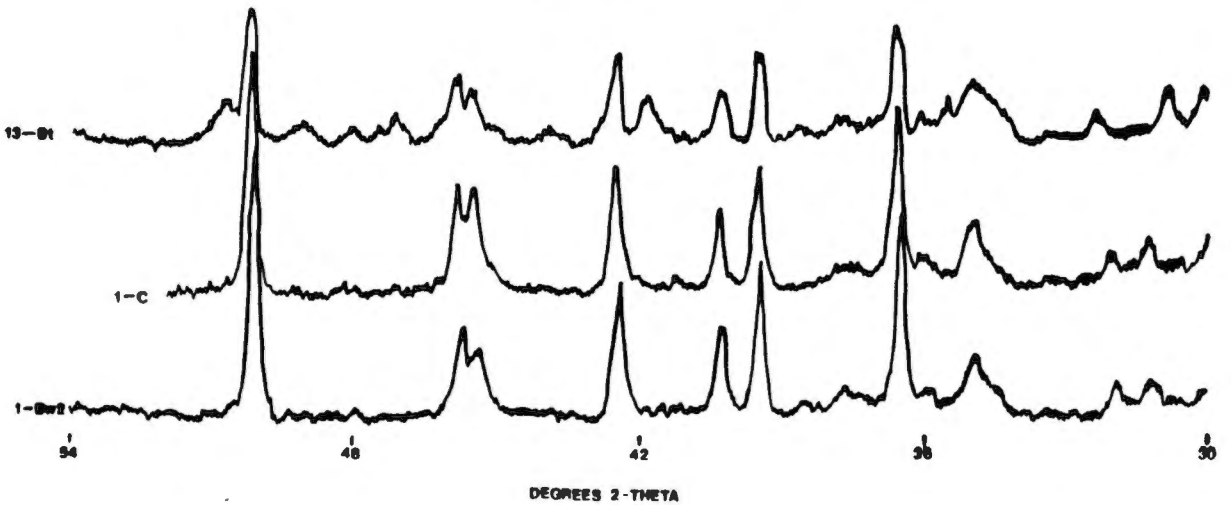

9-B12
M_9EGS
M_9RT
K550
K300
KRT
30
22
18
10
4
DEGREES 2 THETA


13—BI
MgEGS
MgRT
K550
K300
KRT
30
22
16
10
4
DEGREES 2-THETA


HgFE09
HgFT
HgFT
R580
R300
KFT
KFT
DEGREES 2-THETA


10 — B12
K560
K300
KRT
KRT
30
22
18
10
4
DEGREES 2-THETA





UNTREATED SILT SCANS
from slides

APPENDIX C

ADDITIONAL LABORATORY DATA

Table 33. Additional laboratory data not presented in the text.

Horizon	Exchangeable cations Ca	Mg	Na	K	$CaCl_2$ pH	Rock fragments weight	volume
	---- cmol kg^{-1} ----					------- % -------	
				Pedon 1			
A	12.3	2.5	0.1	0.4	5.5	37.8	26
Bw1	2.6	0.8	0.0	0.5	4.4	31.7	21
Bw2	1.3	0.6	0.0	8.4	4.2	59.5	45
C	0.8	0.5	0.0	5.6	4.0	65.9	52
				Pedon 5			
Ap	9.6	3.4	0.1	0.5	6.3	5.6	4
BE	6.7	2.1	0.1	0.2	6.1	17.9	12
2Bw	7.1	1.2	0.1	0.2	4.8	10.4	7
2Bt	9.3	1.0	0.1	0.3	4.4	4.3	2
				Pedon 6			
Ap	7.9	2.6	0.1	7.1	6.5	--	--
AB	6.4	1.8	0.1	5.4	6.2	--	--
Bt1	7.0	1.9	0.0	5.8	5.9	--	--
Bt2	6.9	2.0	0.1	6.0	5.7	--	--

Table 33. Continued.

Horizon	Exchangeable cations Ca	Mg	Na	K	$CaCl_2$ pH	Rock fragments weight	volume
	---- cmol kg^{-1} ----					------- % -------	
				Pedon 6 (continued)			
Bt3	5.7	1.9	0.0	0.3	4.8	--	--
Bt4	4.9	1.5	0.0	0.4	4.5	--	--
Bt5	4.6	1.4	0.1	0.4	4.6	--	--
Bt6	4.7	1.4	0.1	0.4	4.6	--	--
Bt7	4.6	1.6	0.1	0.4	4.6	--	--
2Bt8	4.7	1.7	0.1	0.4	4.6	--	--
2Bt9	4.0	1.6	0.1	0.4	4.5	--	--
2BC1	2.9	1.4	0.1	0.4	4.4	--	--
2BC2	2.3	1.5	0.1	0.4	4.3	--	--
2Cb	2.1	1.5	0.1	0.5	4.3	4.3	2
				Pedon 8			
A	15.6	1.9	0.1	0.2	6.2	--	--
Bw1	12.6	1.4	0.1	0.4	6.2	--	--
Bw2	11.3	1.2	0.1	6.5	5.9	--	--
Bw3	10.1	0.9	0.1	5.7	5.7	--	--
Bw4	9.1	0.8	0.1	5.0	5.8	--	--
BC	8.1	0.9	0.1	4.1	6.2	--	--

Table 33. Continued.

Horizon	Exchangeable cations Ca	Mg	Na	K	$CaCl_2$ pH	Rock fragments weight	volume
	---- cmol kg^{-1} ----					------ % -------	
				Pedon 9			
A	24.6	1.9	0.1	0.2	6.7	--	--
Bt1	18.1	1.4	0.1	0.5	6.6	--	--
Bt2	15.4	1.4	0.1	7.8	6.0	--	--
Bt3	17.8	1.4	0.1	7.4	5.3	--	--
Bt4	24.4	1.9	1.0	0.3	5.8	--	--
				Pedon 10			
A	11.1	2.3	0.1	0.2	5.9	4.6	3
BE	4.8	1.9	0.1	0.6	4.8	5.0	3
Bt1	0.8	0.7	0.1	0.3	4.1	18.1	12
Bt2	1.2	1.1	0.1	0.4	4.1	33.9	23
				Pedon 12			
A	11.8	2.2	0.0	0.1	6.3	14.9	10
BE	7.9	1.9	0.0	0.4	6.2	1.1	1
Bt	6.5	2.8	0.0	8.2	6.2	13.4	8

Table 33. Continued.

Horizon	Exchangeable cations Ca	Mg	Na	K	$CaCl_2$ pH	Rock fragments weight	volume
	---- cmol kg^{-1} ----					------ % -------	
				Pedon 13			
A	8.2	0.9	0.1	6.3	5.3	25.8	16
BE	3.8	0.3	0.1	3.4	5.1	45.2	31
Bw	1.2	0.3	0.1	3.4	4.4	38.7	25
Bt	2.0	0.8	0.0	6.0	4.3	45.9	32
				Pedon 14			
A	3.0	1.2	0.1	0.4	4.2	41.5	28
Bw	2.3	0.6	0.0	0.1	4.2	42.0	30
C	1.6	0.5	0.0	0.0	4.1	81.6	69
				Pedon 16			
Ap	13.4	4.4	0.1	0.3	6.8	--	--
Bt1	9.4	3.2	0.1	5.7	6.9	--	--
Bt2	12.2	3.3	0.1	8.2	6.7	--	--
Bt3	7.5	2.3	0.1	0.4	4.6	--	--
Bt4	2.7	1.1	0.0	0.1	4.2	--	--
Bt5	1.8	1.0	0.1	0.1	4.1	--	--

Table 34. Calculated values related to clay mineralogy. These values are calculated from measured chemical and physical properties.

Pedon-Horizon	CEC on clay basis cmol kg^{-1} (apparent CEC)	CEC to clay ratio
1 - Bw2	51.04	.51
1 - C	49.25	.49
5 - 2Bt	41.60	.42
6 - Bt1	18.81	.19
6 - Bt2	30.02	.30
6 - Bt4	28.57	.28
6 - Bt6	18.26	.18
6 - 2Bt8	23.28	.23
6 - 2Cb	29.46	.29
9 - Bt1	47.42	.47
9 - Bt2	35.04	.35
13 - Bt	45.13	.45
16 - Bt1	30.73	.31
16 - Bt2	21.67	.22

APPENDIX D

EXPLANATION OF ABBREVIATIONS USED IN THE MORPHOLOGY TABLES

I. Soil texture.

A. Modifiers of soil texture.

cn = channery
cnv = very channery
gr = gravelly
grx = extremely gravelly

B. Texture classes.

l = loam
sil = silt loam
sicl = silty clay loam
cl = clay loam
sic = silty clay
c = clay

II. Soil structure.

A. Grade of structure.

1 = weak
2 = moderate

B. Size of structure.

f = fine
m = medium

C. Type of structure.

gr = granular
sbk = subangular blocky
ma = massive

III. Moist consistence

vfr = very friable
fr = friable
fi = firm

VITA

Nathan T. Hartgrove was born on August 6, 1961 in Kingsport, Tennessee, to Mr. and Mrs. Donald L. Hartgrove. He completed elementary, middle and high school in the Kingsport City School System. Upon graduation from Dobyns-Bennett High School in 1979, he entered the College of Engineering at Tennessee Technological University. During his studies at Tennessee Tech, he developed an interest in soils and physical sciences, and entered a new major in the School of Agriculture. While at Tennessee Tech, he was active in the agronomy club, serving a term as president as well as in other offices. He was a member of the Residence Hall Association and the University Programming Council. Additionally, he was a member of the collegiate soil judging team for three years. In 1984, he was inducted as a member of Delta Tau Alpha agricultural honor society. He received his B.S. in Agriculture from Tennessee Tech University in 1985, with a major in plant and soil science and minors in biology and mathmatics.

From 1985 to 1988, he worked as a soil scientist for the Sullivan County, Tennessee Soil Conservation District and as an employ of the USDA-Soil Conservation Service. He was married in April, 1988, to Laura K. Hartgrove. In

the fall of 1988, he entered the Institute of Agriculture at the University of Tennessee, Knoxville to pursue a Master's Degree in plant and soil science. He is a present member of Gamma Sigma Delta honor society, a student member of the American Society of Agronomy, and a member of the Soil Scientist's Association of Tennessee. Upon completion of the M.S. degree, the author will resume his work with the Soil Conservation Service in Rutledge, Tennessee.