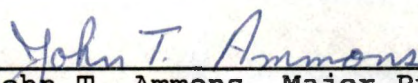
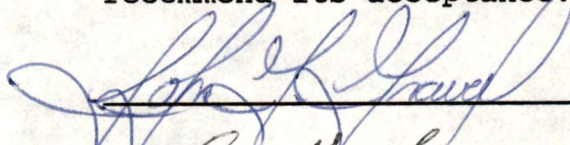
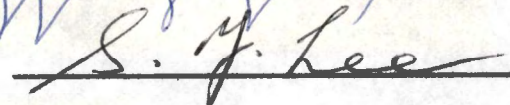
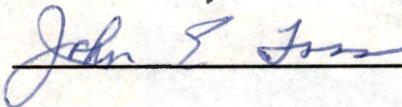


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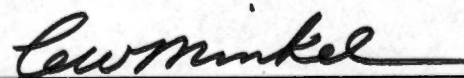
I am submitting herewith a thesis written by Ricky Edward Lambert entitled "Landform and Soil Development on the Conasauga Group of the Low-Level Waste Disposal Site at Bear Creek Valley, Tennessee." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment for the requirements for the degree of Master of Science, with a major in Plant and Soil Science.


John T. Ammons, Major Professor

We have read this thesis and
recommend its acceptance:

Accepted for the Council:


Vice Provost
and Dean of The Graduate School

LANDFORM AND SOIL DEVELOPMENT ON THE CONASAUGA GROUP OF
THE LOW-LEVEL WASTE DISPOSAL SITE AT BEAR CREEK VALLEY,
TENNESSEE

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Ricky Edward Lambert

December 1988

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I dedicate this thesis to my parents and stepparents,
Melba Faye and Wilson Brown, and Charles and Mary Lambert,
who have aided me greatly in pursuing my goals. May GOD
bless them!

ACKNOWLEDGEMENTS

Thanks are given to Dr. D. A. Lietzke for his consultation and mapping of the soils on the study area. Thanks should also be given to laboratory assistants A. B. (Tony) Jenkins, Peiyuan Qian, Debra Phillips and Pamela Alley for their field descriptions and laboratory assistance. I especially send my appreciation to Mike Timpson and Dr. John T. Ammons, Dr. John E. Foss and Dr. John G. Graveel for their efforts in editing this thesis.

I greatly appreciate the financial support provided by the Office of Defense Waste and Transportation Management, U.S. Department of Energy under contract No. DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

ABSTRACT

The landform and soil development study was completed on the proposed Low-Level Waste Disposal, Development and Demonstration project (LLWDDD) site in Bear Creek Valley, Oak Ridge, Tennessee. The objectives of the study were to complete a detailed soil characterization of major soils on the Cambrian aged Conasauga Group, and apply the information to gain an understanding of soil and landform stability. Eight pits (nine soil profiles) were excavated, described, and sampled on major soil mapping units of the upper Pumpkin Valley Shale, Rogersville Shale, Maryville Limestone, and Nolichucky Shale geologic formations. Samples were prepared and analyzed for soil physical, chemical, and mineralogical characterization. Six of the nine soil profiles are residual. Five of the six residual soil profiles are classified as Ruptic-Ultic Dystrochrepts. The remaining residual soil profile, being very severely eroded, is a Typic Udorthent. One colluvial, one colluvial over alluvial, and one alluvial soil profile are classified as Typic Hapludults.

Chemical analyses indicated that the soils were moderately acid, had cation exchange values ranging from 10 to 30 $\text{cmol}(+) \text{ kg}^{-1}$, and had base saturation values less than 30 percent. Magnesium was the predominant exchangeable ion found in residual soils. In highly developed soils, iron

and manganese had translocated through the solum into the underlying saprolite. Most residual soils were shallow to saprolite, as a result of geologic and anthropogenically accelerated erosion. This resulted in soils with low to moderate available water holding capacity, low infiltration capacities, and high runoff rates. All soils contained clays that had low liquid and plastic limits, and low activities (shrink-swell potential). Mineralogy of saprolites was dominated by illite. Kaolinite was present in high amounts in soils and saprolites of the upper Pumpkin Valley shale. Hydroxyinterlayered vermiculite was present in high amounts in soils formed from the upper Pumpkin Valley Shale. Kaolinite and hydroxyinterlayered vermiculite was found in moderate to trace amounts in other soils on the LLWDDD site.

Soil transect studies on the lower Pumpkin Valley Shale indicated that slope and permeability of soil and saprolite were factors influencing weathering and soil development. Soils on slopes greater than 45 percent seldom developed Bt horizons. Glauconitic sandstones were found to be more permeable than shales, and produced thicker soils. Because shales and sandstones alternated on the lower Pumpkin Valley Shale, soil depth to saprolite varied greatly over short distances. Broader spur ridges promoted greater soil development, contained thicker layers of colluvium, and decreased the erosion potential. Topographic reversal and

alluvial accumulation revealed past climatic effects upon these soils. Of the major soils found on the LLWDDD site, soils formed on the upper Pumpkin Valley Shale were most developed, followed by soils formed on the Nolichucky Shale, Maryville Limestone, and Rogersville Shale. Permeability, slope gradient, and presence or absence of limestones were the major factors which influenced weathering and soil development of the Conasauga Group.

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CHAPTER I

INTRODUCTION

The following study was completed on the proposed Low-Level Waste Disposal Development and Demonstration (LLWDDD) project site, in Bear Creek Valley, Oak Ridge Reservation, Tennessee. The objectives of the study were to complete a detailed soil characterization of major soils on the site and apply the characterization information, along with information from a transect study, to gain an understanding of soil and landform stability on the Cambrian-aged Conasauga Group. The study area was located in Bear Creek Valley, a northeast-southwest oriented valley underlain by limestones and shales of the Conasauga Group. The LLWDDD site comprised about 125 hectares. The site was bounded to the southwest by Tennessee Highway 95, to the southeast by Bear Creek, to the northeast by Gum Hollow Road, and to the northwest by Pine Ridge (Figure 1).

The climate of the area is characterized by mild winters, long springs and falls, and warm, humid summers. Mean annual precipitation averaged 136 cm yr^{-1} (53.5 in yr^{-1}). Rainfall amounts are greatest in spring and early summer, with less rainfall occurring in the fall. The mean annual air temperature was around 15°C . Mean annual soil temperature at a depth of 50 cm was around 16°C , with cooler and moister soils on northern aspects and warmer, drier

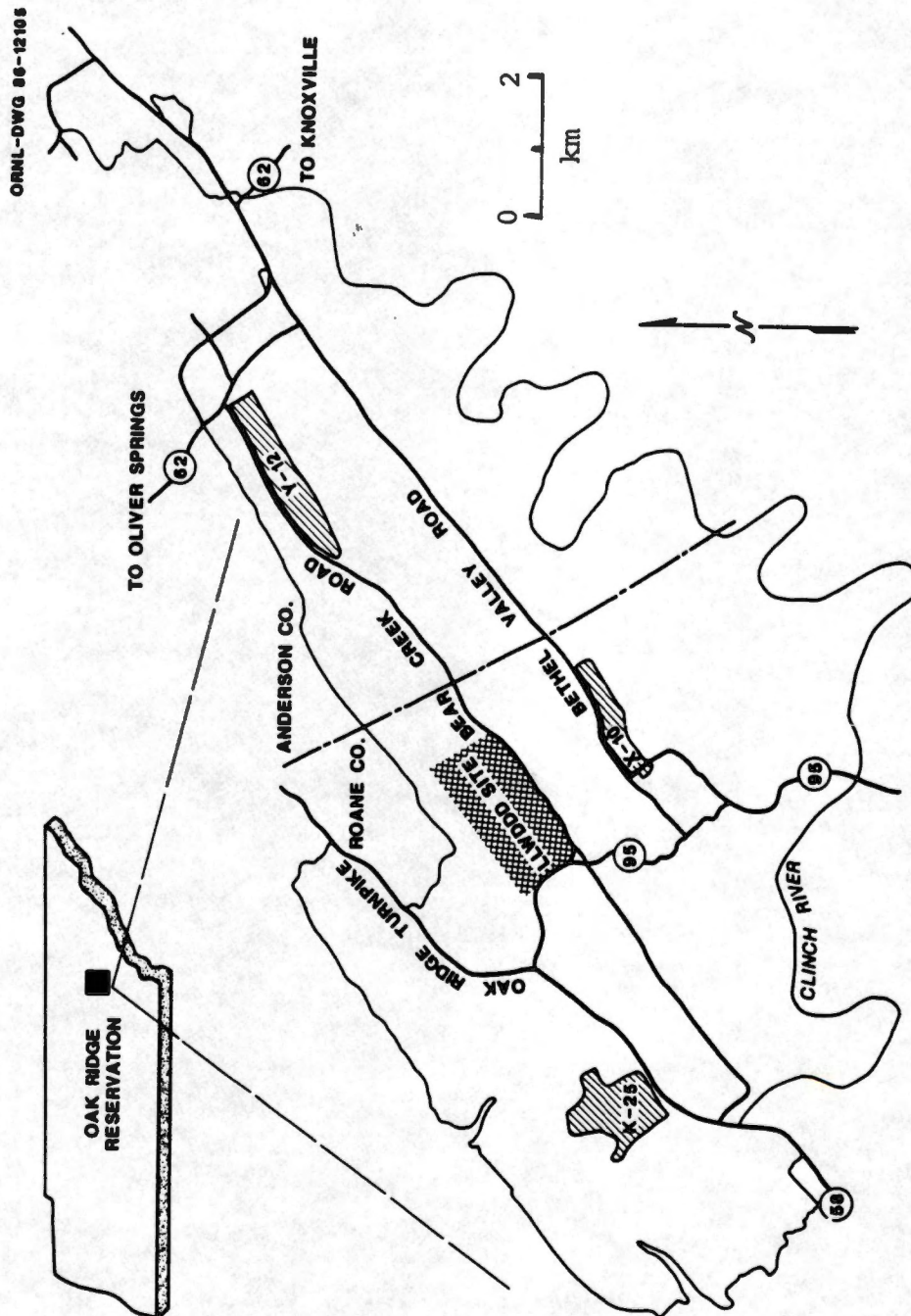


Figure 1. Map of Oak Ridge Reservation.

soils on southern aspects (Lietzke et al., 1988).

Soils on the LLWDDD site have undergone intense weathering and soil erosion cycles. Farming practices prior to the 1940's led to erosion of much of the topsoil, leaving areas of shallow soils and saprolite outcroppings. Comparisons between areas in hardwoods and areas with mixed hardwoods and transplanted pines revealed the effects of man-induced erosion. Some hardwood areas experienced slight to moderate erosion, because they had been used for periodic harvesting of timber and cattle pasturing (Lietzke et al., 1988). These areas were most likely not cultivated in the past and occurred on steep slopes (Figure 2). Most soils on nearly level to sloping landscapes were cleared and cultivated. Moderately eroded soils in areas previously cultivated have lost most of the original A horizon and part of the E horizon. Severely eroded soils have lost about fifty percent of their original solum thickness. Presence of small gullies and soils with Ap horizons directly overlying saprolites are indicators of very severely eroded areas (Lietzke et al., 1988). Observations of soils along old fence rows and among stands of large trees gave indications of original soil thickness. Distribution of woodlands and open land on the LLWDDD site, prior to 1941, can be seen in Figure 3. Considerable volumes of colluvium (soil moved and deposited by water and gravity) can be found at the foot of most ridges. Substantial areas of old

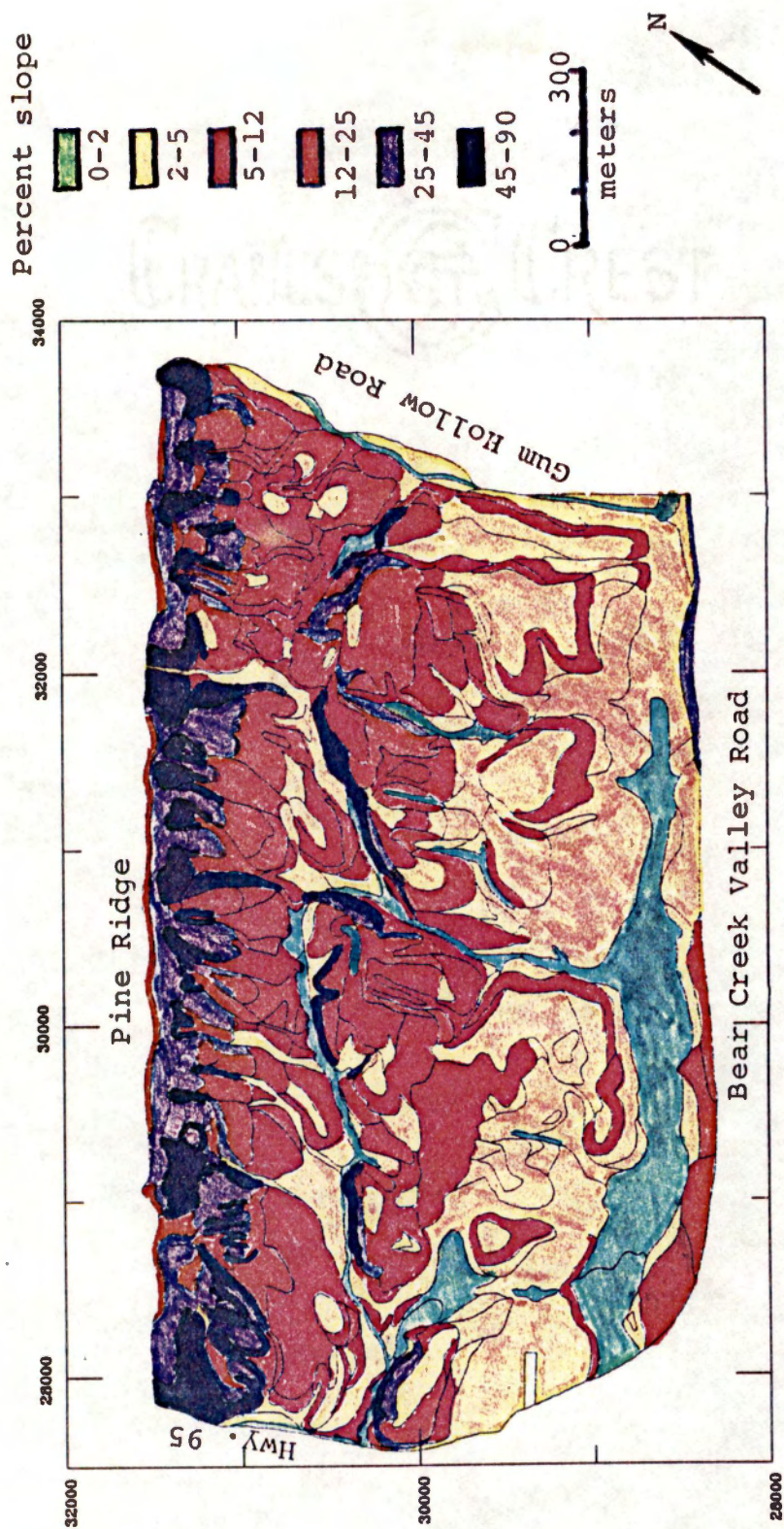


Figure 2. Soil slope class (After Lietzke et al., 1988).

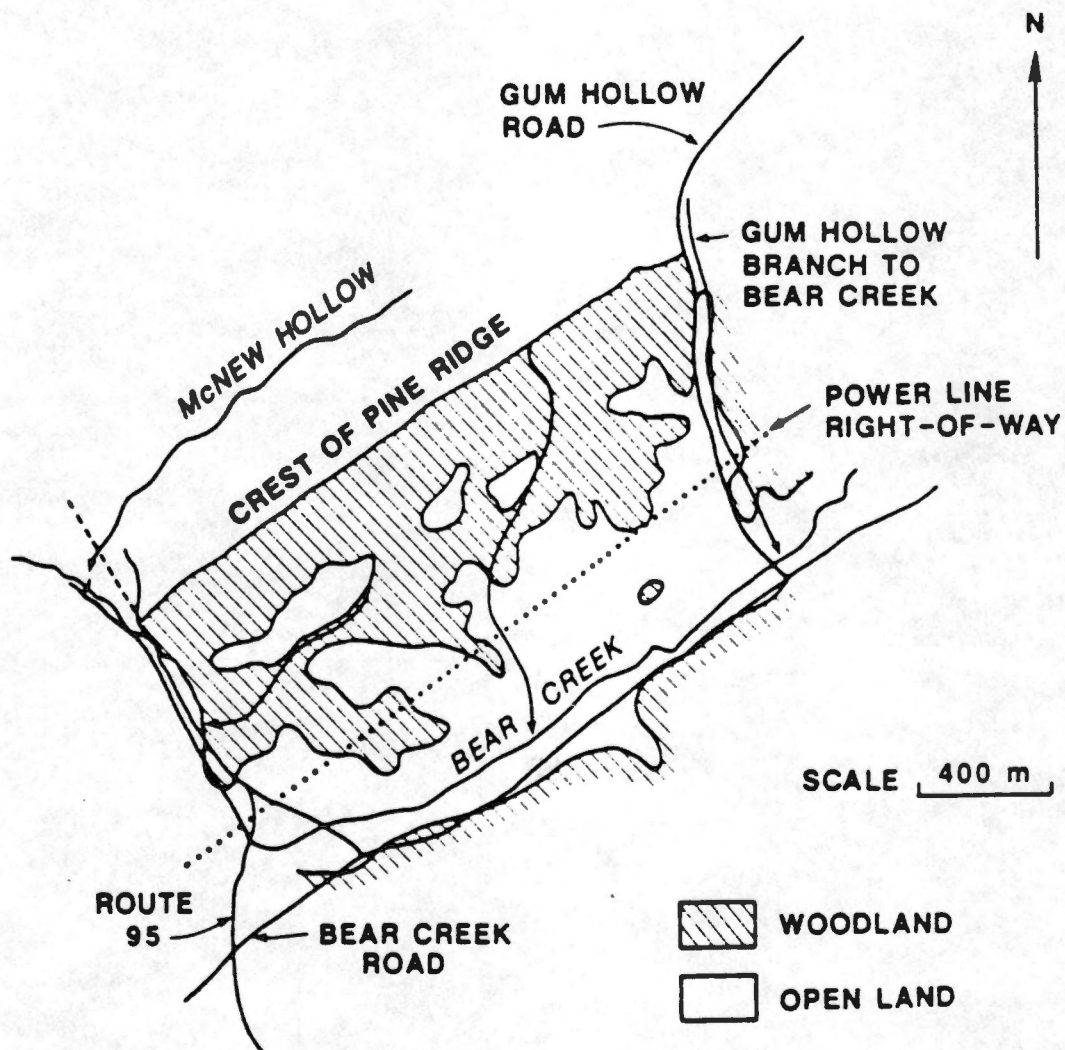


Figure 3. Pre-Atomic Energy Commission land use on the LLWDDD site (After Lietzke et al., 1983).

(possibly Pleistocene aged) and modern alluvium can be found in the Bear Creek floodplain, and on old terraces and drainageways (Figure 4) (Lietzke et al., 1988).

Soil parent materials consisted of mixtures of limestones, shales, and sandstones. Soil formation was found to vary on each of these materials, due to differences in permeability (rates), mineralogy, and degree of deformation. Folding and faulting of parent rock not only influenced soil formation, but also determined drainage patterns and development of ridges.

Most of the area is covered with hardwoods. White oak and tulip poplar occupy areas with deeper soils which contain moderate amounts of calcium. Eroded, nutrient poor soils supports stands of chestnut oak and understories of greenbriar, and blueberries. Pine plantations occupy the highly eroded soils.

Interpretation of soil and transect data will help give a better understanding of soil forming processes, weathering, and soil stability. This information will be useful in long range land-use planning for the Oak Ridge Reservation.

Surficial geology

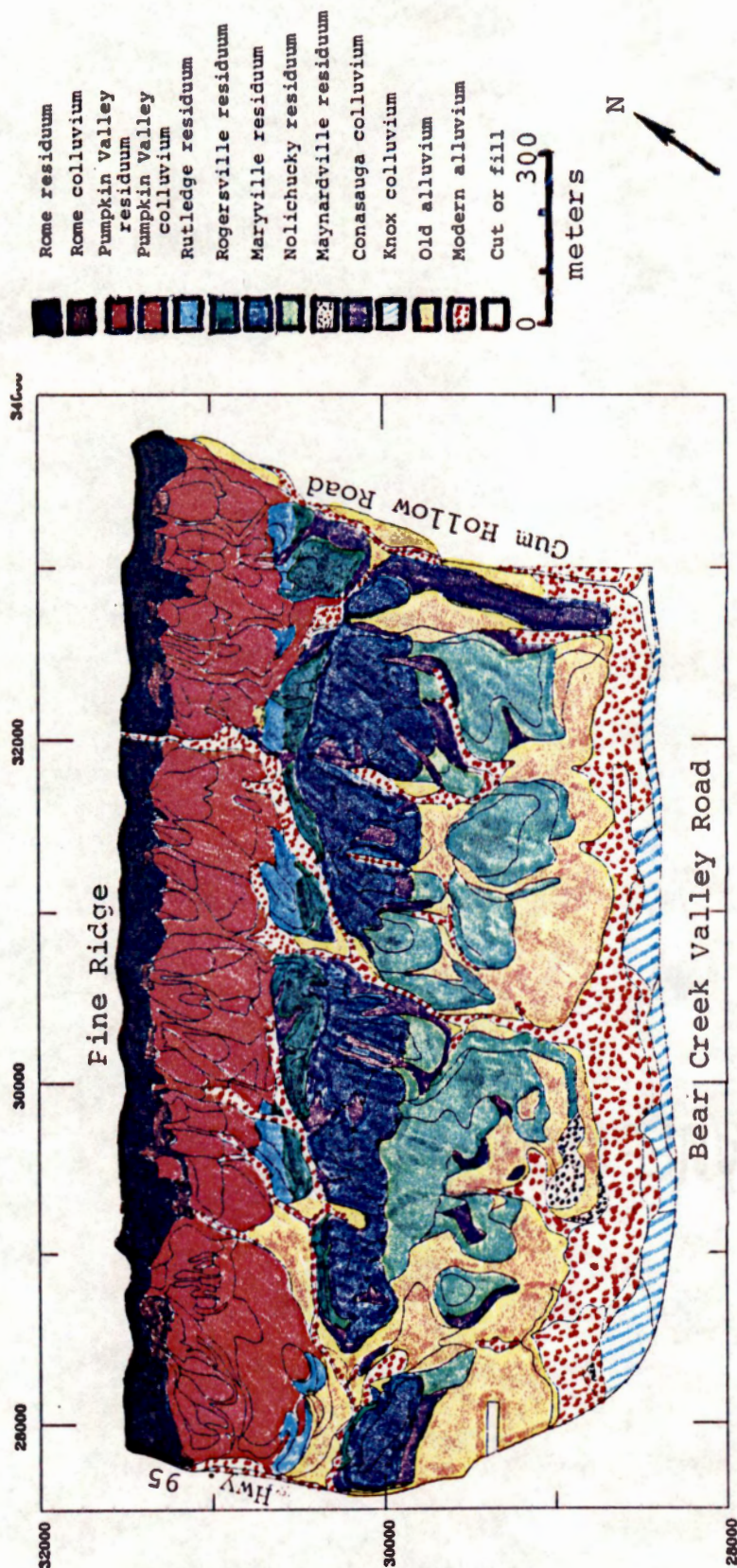


Figure 4. Surficial geology map (After Lietzke et al., 1988).

CHAPTER II

LITERATURE REVIEW

Forces Involved in Soil and Landform Stability

Many dynamic forces are involved in shaping landscapes and influencing soil development. Within a given soil profile or landform of arbitrary dimensions, there are additions, removals, transfers and transformations of materials and energy being made (Simonson, 1978). Important additions to the soil system are water and organic materials. Water is added to the soil system as precipitation, and organic components added from dying and decaying vegetation. Precipitation and vegetative growth are driven by energy inputs from the sun. As organic materials enter the soil system, they are transformed into humus and organic acids. Water, in combination with organic and inorganic acids, transform primary minerals in geologic parent materials to secondary clay minerals, hydrous oxides, cations, anions and silicic acid. The secondary clay minerals, ions, silicic acid and humus can move (transfer) to lower depths in the soil profile. Water, flowing from the soil into the geologic materials, can remove ions and silicic acid from the soil. Under conditions where the soil overlies a high water table, capillary action can transfer ions and silicic acid upward into the soil (Simonson, 1978). Water can also move laterally through a soil system,

removing or adding ions and organic and inorganic acids.

Solar energy inputs and water (as precipitation), in combination with gravity, are the driving forces for the creation of soils and landforms. Variations in solar energy inputs and precipitation upon the same geologic materials influence vegetative growth, type, and distribution, which in turn, produces soils with variable degrees of weathering. If variability within parent rock materials, topography and time are also included, then there are a great range of soils and landforms that can be formed. Changes in one of more of the above factors on a soil or landform can invoke instability. Soils and landforms must then adjust to the new conditions. These adjustments can be made swiftly (i.e. landslides caused by the saturation of soils on steep slopes and underlain by impermeable parent materials) or slowly (i.e. dissolution of minerals in soil profiles).

Mineral Weathering in Soils and Parent Materials

Jenny (1980) lists six primary silicate mineral groups that are commonly found in geologic parent materials. The six mineral groups are olivine, augite, hornblende, quartz, feldspars, and micas. These mineral groups commonly form in igneous rocks, but most can also be found in sedimentary and metamorphic rocks. Of interest to this study are the weathering of quartz, and some members of the feldspar and mica groups. Within the mica group, illite, glauconite and

chlorite are of importance. Orthoclase (potassium feldspar) is a common feldspar found on the LLWDDD site.

The micas are flaky minerals whose layer lattices are akin to those of pyrophyllite, $\text{Si}_4\text{Al}_2\text{O}_{10}(\text{OH})_2$ (Jenny, 1980). Illite is one of the common micas. Illite has a generalized chemical formula of $\text{K}_{0.6}\text{Mg}_{0.25}\text{Al}_{2.3}\text{Si}_{3.5}\text{O}_{10}(\text{OH})_2$ (Lindsay, 1979). Most illites are dioctahedral 2:1 layer alluminosilicates, but some illites can be trioctahedral. Illite can form in several different ways. First, illite has been found to form as secondary mineral polymorphs of micas such as muscovite and biotite. This process of illite formation requires a low to moderate hydrogen ion concentration to partially strip potassium ions from the interlayer positions of the mica mineral (Buol et al., 1973). Second, the weathering of orthoclase feldspars can produce illite. Finally, illite has been suspected of forming from montmorillonite in deep sea sediments. Illite is not a specific mineral, but rather an assemblage of mica minerals that constitute argillaceous sediments (Rich and Kunze, 1964).

The weathering of illite requires a moderate to high hydrogen ion concentration, to completely strip potassium ions from interlayer positions and cause mineral instability. When this condition is met, illite commonly converts to vermiculite (Buol et al., 1973). Illite can

also weather to kaolinite under conditions of high hydrogen ion concentration and approximately equal concentrations of aluminum and silicon in soil solution. Low concentrations of magnesium and other base cations must exist for this weathering sequence to occur (Buol et al., 1973).

Glaucanites are 2:1 illitic minerals that contain high amounts of substituted iron in the octahedral sheet. Glaucanites, like illites, are often dioctahedral but can exist in trioctahedral forms. Glaucanites have a marine origin and are likely formed under the influence of marine organisms. Much of the glauconite is found in the form of pellets, which are likely the fossil remains of marine fecal pellets (Burst, 1958). Glaucanite formation requires conditions of favorable oxidation potential (reducing environment), presence of organics, and adequate supplies of potassium and iron. Restricted basins or lagoons are likely places that produce the conditions favorable for glauconite formation (Burst, 1958). Glaucanites can form directly from micas such as biotite, in the presence of high iron concentrations (Gallaher, 1939). Glaucanitization of vermiculite, micas, and even kaolinitic "worms" have been suggested by Tapper and Fanning (1968). Fanning and Kerimida (1977) have formulated a reaction of kaolinite, iron oxides and potassium from sea water, with iron mobilized by reduction with organic materials as a likely method for the formulation of glauconites.

Glaucanites commonly follow two weathering pathways, with the pathway taken being influenced by pH of the weathering environment. In neutral to alkaline environments, glaucanites often weather to iron rich smectites such as nontronite, with a release in potassium (Robert, 1973). Under acid conditions, glaucanites commonly weather to goethite and dissolved minerals which are intermediates of kaolinite formation (Wolff, 1967).

Chlorites are 2:1:1 minerals in which the interlayer cations have been replaced by brucite or gibbsite layers (Birkeland, 1974). Chlorite can form from the weathering of biotite or from substitution of interlayer cations by a brucite and gibbsite sheet in minerals such as vermiculite, illite and montmorillonite (Rich and Kunze, 1964; Jenny, 1980). Chlorite often weathers to vermiculite under acid conditions. Weathering of chlorite is accomplished by the oxidation of ferrous iron in the octahedral layer, followed by dehydroxylation and removal of hydroxide, and brucite or gibbsite sheets (Ross and Kodama, 1974). Chlorite likely weathers to montmorillonite under conditions of slow leaching and high concentrations of iron and magnesium (Buol et al., 1973).

Orthoclase feldspar (KAlSi_3O_8) is common in most igneous rocks, but is also found in metamorphic and sedimentary rocks. Orthoclase commonly weathers in acidic

environments to kaolinite, but illite and halloysite can also form (Rich and Kunze, 1964; Southard and Southard, 1987).

Kaolinite can form from the weathering of several mineral groups, such as feldspars and micas. Kaolinite forms in the near absence of base cations, approximately equal concentrations of silica and aluminum and high hydrogen ion concentrations. Kaolinite is near the end of the weathering chain and is very stable under slightly to moderately acid conditions. In environments where silica is being removed from the soil solution, kaolinite may weather to gibbsite (Jenny, 1980; Karathanasis et al., 1983). If silica concentrations increase, gibbsite can readily revert back to kaolinite. Both gibbsite and kaolinite can coexist under neutral to slightly acid environments (Jenny, 1980). In the presence of vermiculite, however, the weathering of kaolinite may not lead to the formation of gibbsite but rather Al-hydroxyinterlayered vermiculite. Aluminum released from the dissociation of kaolinite is adsorbed in vermiculite interlayers at the expense of gibbsite formation. This process is referred to as the "antigibbsitic effect" (Karathanasis et al., 1983).

Many soils develop from parent materials high in carbonates. Carbonates neutralize acidic conditions necessary for mineral weathering and soil clay formation (Barshad, 1964). The net result of the presence of

carbonates in parent materials is to slow mineral weathering processes. Calcium carbonate is, however, soluble in surface soils. With increases in carbon dioxide concentration, calcium carbonate solubility increases (Krauskopf, 1967). The presence of vegetation and soil organisms can greatly increase the soil carbon dioxide concentration. The net effect of vegetation and soil organisms on soil weathering is to increase calcium carbonate solubility and removal of calcium from the soil (Krauskopf, 1967). Vegetation can also retain calcium in the soil profile by nutrient cycling. On soils derived from limestones, vegetation can recycle large amounts of calcium to the soil surface. This can cause a decrease in mineral weathering rates, as well as promote flocculation of soil clays and slow clay translocation (Krauskopf, 1967).

Erosion and its Effects on Runoff and Hydrology

Erosion (from the latin erodere) is the deterioration of the soil surface affected by such forces as water, ice, wind and man (Holy, 1980). In the southeastern U.S., ice and wind are seldom a problem. The erosive effect has a great impact on soil texture, nutrients, and vegetation. Erosion, along with soil infiltration, structure, and morphology can greatly alter soil runoff and hydrology.

One of the most visible results of erosion is a change in soil type (Crandall et al., 1936). Stripping of the

surface layers by accelerated erosion generally produces a soil with higher clay contents and differing structure. Wischmeier and Mannering (1969) noted that most of the erosion in the U.S. occurs on sandy and silty soils. Generally, field studies have shown that 87.5 percent of erodible soils have a clay content of between 9 and 35 percent, with few erodible soils in the sand class (Evans, 1980). When relating this to soil structure, the crumb or granular structured soils containing sands and silts are the most erodible. Field trials with simulated rainfall have shown that a soil aggregate size smaller than 0.5 mm in diameter is highly susceptible to erosion (Bryan, 1974). Clay or organic soils with good blocky structure tend to resist erosion because of the ability of clays and organics to form strong bonds with each other (Greenland, 1965).

The result of changes in soil structure and particle size are changes in infiltration rates and resulting runoff (Young, 1972; Grieve, 1978). Clayey soils with low organic matter content and weak blocky structure tend to impede water flow. As a result, higher runoff rates occur in such soils. Many times during rainfall events, surface crusting and soil swelling will occur on soils with expanding clays. Raindrops break up soil aggregates, and the clays within the aggregates bond together, forming a continuous particle cover on the soil surface (Farres, 1978). Swelling of

expanding clays by wetting can close off pore spaces and ped surfaces from additional water infiltration. Thus, on eroded soils, the above soil characteristics can lead to lower infiltration rates, greater amounts of runoff, and less subsurface water flow (McIntyre, 1958). The overall results are increased erodibility on a given soil, increased possibility of overland water flow and stream flooding, and increased soil drouthiness.

Vegetation can increase infiltration on eroded soils through the addition of organic components, binding of soil particles by roots, dispersing energy of falling raindrops, and by influencing the climate of the soil surface (Fitzpatrick, 1971; Grieve, 1978). Organic matter can also increase and stabilize structural pores and strengthen soil aggregates against detachment and disintegration (Russel, 1971; Thornes, 1980). The resulting additions of organic matter can decrease the possibility for runoff and can help move more water through the soil into the subsurface horizons.

Relationships of Slope to Soil Formation

Many soil properties have been shown to be related to slope gradient, shape, and position (Milne, 1935a; Milne, 1935b; Birkeland, 1984). Soil properties can vary on slopes of differing gradients, because of slope influences on such factors as vegetation, moisture, leaching and erosion. On a

given toposequence, soil-slope relationships can be thought of as a five unit model based on slope shape and form (Birkeland, 1984). These units are commonly called the flat summit, convex shoulder, linear backslope, concave footslope, and concave toeslope. This review is concerned mainly with the first three, since the footslope and toeslope positions are generally colluvial in nature. Slope shape and gradient have a significant influence on these units.

From a standpoint of moisture, Huggett (1975) describes the effect of slope shape on infiltration. In his model, he describes four basic slope possibilities that can influence water infiltration and flow. Convex slopes with concave contours allow for convergent lateral (flow parallel to the soil surface) and divergent vertical water flow (flow down through the soil). On concave slopes with convex contours, divergent lateral and convergent vertical flows occur. Soils on concave slopes and contours experience both convergent lateral and vertical flow. Divergent lateral and vertical flows occur on soils with convex slope shapes across and with the contour (Hugget, 1975). Relating this to soil formation, wherever there is convergent water flow, there is the increased possibility of weathering and leaching of soil materials.

Looking at slope steepness with respect to soil formation, one finds that steepening slopes have an

increasing impact on soil makeup. As slope gradients steepen, soils are generally thinner, contain less organic matter, have decreasing depths to a pH of 6, have a higher base saturation, and have a calcium carbonate content greater than one percent (Birkeland, 1974). Increasing soil shallowness is due, in part, to increased erosion as slope steepens. The shallower soils also tend to be less developed due to decreased infiltration. Lower organic matter contents result in less acidity being present for the breakdown of soil parent materials.

Taking into consideration the effects of slope shapes and gradients, and applying them to a toposequence model, we find the following generalizations. Connacher and Dalrymple (1977) give the characteristics of soils on flat summits (interfluves) as those that have vertical water movement, and more uniform depth and morphology. These soils tend to be shallow because water reaches the soil surface by direct precipitation only. There is little lateral water movement because of nearly level surfaces. Convex shoulder slopes (convex creep slopes) occur where lateral movement of soil materials due to gravity occurs. Slopes on this unit are steeper than those at the summit, but erosion is not a prominent process. Soil depth and development can vary, and there seems to be a relationship between soil depth and the amount of convexity present (Connacher and Dalrymple, 1977).

The linear backslope (transportational midslope) is the active site for erosion. This unit has the steepest slope gradients, and is prone to various mass wasting processes. Uniformity of soils with respect to soil depth and coverage on the landscape is variable to non-existent, because of varying degrees of sheet, rill and gully erosion (Connacher and Dalrymple, 1977).

Residual soils formed on shoulders, backslopes, and some summits are generally well drained and have leaching environments. Mineralogically, these soils tend to be silica depleted, and kaolinite and gibbsite clay minerals predominate (Paquet, 1969; Duchaufour, 1982). Iron oxides occur as free entities to a decreasing extent as slope gradients decrease. Individual oxide crystals form on steeper, well drained soils. As slope gradients decrease and more water infiltration occurs, iron may begin to complex with inner clay structures (i.e. montmorillonite) in basic soils or form iron nodules in acid soils. This is due to decreased soil drainage (Duchaufour, 1982).

Classification of Major Soils Present on the LLWDDD Site

The present soil classification system being used in the United States was drafted by the Soil Survey Staff in 1960 (Soil Survey Staff, 1960). This classification system was developed in order to make more reliable and quantitative interpretations of soil surveys. As the

knowledge of the nature and properties of soils increased, older classification systems failed to adequately incorporate these advances into their classification schemes. In addition, it became increasingly difficult to relate soil series to soil families, great groups and higher categories. With the present system, these relationships were more closely tied. The present classification system was designed to group soils in order to make precise predictions as to soil behavior (Soil Survey Staff, 1975).

The present soil classification groups soils into orders, suborders, great groups, subgroups, families and series. There are ten soil orders in the present soil classification system. The soil orders are Alfisols, Aridisols, Entisols, Histosols, Inceptisols, Mollisols, Oxisols, Spodosols, Ultisols and Vertisols. On the LLWDDD site, most soils classify as Inceptisols, Entisols Ultisols, or Alfisols. Ultisols cover much of the LLWDDD site, but Inceptisols are quite common. Entisols can be found on recent alluvial deposits along the Bear Creek floodplain and on very severely eroded residual soils. Aerial coverage of Entisols on the LLWDDD site is small (Lietzke et al., 1988).

Entisols

Entisols are soils which show absence of pedogenic soil horizons and show few marks of any major set of soil-forming

processes (Soil Survey Staff, 1975). Entisols form under conditions where ash or alluvium have been recently deposited, erosion rates have exceeded rate of soil formation, or in parent materials with few or no weatherable minerals (i.e. quartz sand). On the LLWDDD site, Entisols have formed from recent alluvial deposits and from very severe erosion of Inceptisols and Ultisols. Entisols are distinguished from other soil orders in that they have no diagnostic soil horizons other than an ochric, histic, or anthropic epipedon, and an albic or spodic horizon. To meet the requirements of an Entisol, the histic epipedon must consist of organic materials, and the spodic horizon must have its upper boundary deeper than two meters. Entisols can have diagnostic horizons if they are buried at a depth of greater than 50 cm, or if they are buried at a depth of between 30 and 50 cm and the buried soil is less than twice the thickness of the overlying soil (Soil Survey Staff, 1975). A common horizon sequence for Entisols would be an A horizon overlying a C or Cr horizon.

Inceptisols

Inceptisols are soils that form in humid regions that show some evidence of soil development (i.e. loss of bases, iron or aluminum) but retain some weatherable minerals (Soil Survey Staff, 1975). These soils do not contain illuvial horizons that are enriched with silicate clays containing

aluminum or contain amorphous mixtures of aluminum and organic carbon. Inceptisols can contain ochric, histic, mollic, plaggen or umbric epipedons, but mollic and histic epipedons must meet certain requirements. These soils can also contain a cambic horizon or fragipan, but cannot contain any other diagnostic horizon unless it is buried or intermittent and occupies less than half the area of each pedon (Soil Survey Staff, 1975). In summary, Inceptisols are "immature soils having profile features more weakly expressed than mature soils and retaining close resemblances to the parent material" (Buol et al., 1973). Most or all pedogenic processes are active to some extent in Inceptisols, but none predominates. Leaching processes are likely active in all Inceptisols. Both primary and secondary minerals are present in Inceptisols that occupy upland positions or young geomorphic surfaces (Buol et al., 1973).

Ultisols and Alfisols

Ultisols are the most highly weathered soils found on the LLWDD site. Ultisols contain horizons with appreciable silicate clay translocation and low base saturation. Base removal by leaching and weathering is approximately equal. Exchangeable bases often decrease with depth due to vegetative nutrient cycling (Soil Survey Staff, 1975). Ultisols are distinguished from other soil orders by having

a base saturation of less than 35 percent at the shallowest of the following depths: 125 cm below the upper boundary of the argillic horizon, 180 cm below the soil surface, 75 cm below the upper boundary of a fragipan, or immediately above a lithic or paralithic contact (Soil Survey Staff, 1975). Ultisols are characterized by having an argillic horizon, or a fragipan that meets the requirements of an argillic horizon or have clay skins (>1 mm) in some part of the fragipan. Ultisols cannot have spodic and oxic horizons, unless they are below an argillic horizon.

Ultisols have undergone intense leaching and have weathered over several thousand years. Most weatherable primary minerals have been converted to secondary clay minerals and oxides. Kaolinite dominates the clay mineralogy of most of these soils, but some vermiculites, micas, hydroxyinterlayered vermiculites and chlorite-vermiculite intergradational clays are sometimes present. Lessivage, the migration of small mineral particles from A to B horizons, has produced argillic horizons. This process is quite pronounced in most Ultisols (Buol et al., 1973).

Alfisols differ from Ultisols by having greater than 35 percent base saturation at the shallowest of the following depths: 1.25 meters below the upper boundary of the argillic horizon, 75 centimeters below the upper boundary of a fragipan, 1.8 meters below the soil surface, or immediately above a lithic or paralithic contact. Alfisols have an

ochric epipedon, but can have an umbric epipedon under wet conditions (Soil Survey Staff, 1975). Prerequisites of Alfisol development are the leaching of carbonates from the developing solum and "braunification" (Buol et al., 1973). Braunification is the process by which eluviated clays from the A and E horizons are flocculated by iron (illuviated) in the B horizon. This process results in the deposition of clay in B horizons, producing a brownish soil color (Buol et al., 1973). Continued illuviation in the B horizon produces an argillic (Bt) horizon. Alfisols normally contain an abundance of unweathered primary minerals. Alfisols are generally late-Pleistocene aged or older (Soil Survey Staff, 1975). Arnold and Riecken (1964) estimate the time of Alfisol formation in eastern Iowa to be about 5000 years.

Alfisols are found in both temperate and tropical climates. Alfisols have formed under prairie cover where melanization (darkening of the soil epipedon by addition of organic matter) has not been sufficient to form a mollic epipedon (Buol et al., 1973). Alfisols tend to form in regions between grasslands and very humid climates (Soil Survey Staff, 1975).

Because of their high base status and nutrient reserves, Alfisols are commonly used for cultivated crops. In the United States, Alfisols are utilized in the eastern Corn Belt and western wheat-producing areas for production

of small grains, corn, hay, pasture, range and forest (Buol et al., 1973).

CHAPTER III

MATERIALS AND METHODS

Field

Geology

The LLWDDD site is underlain by the early to middle Cambrian carbonates and clastics of the Conasauga group. Stratigraphic units of the uppermost Rome Formation, Pumpkin Valley Shale, Rutledge Limestone, Rogersville Shale, Maryville Limestone, Nolichucky Shale, and Maynardville Limestone were present in the study area. This stratigraphic section was a representation of a westward transgressing sea, resulting in a change from a section of terrigenous clastic sediments derived from western sources (Rome Formation) to the carbonate-rich Maynardville Limestones (Lee and Ketelle, 1988). These rock units have since been thrust faulted and dip southeastward between 30 and 70 degrees (Figure 5). The thrust fault at this locality was called the Whiteoak Mountain fault. The thrust fault ran along the north side of Pine Ridge, in the Rome formation.

The Rome formation existed as a layer of very fine grained white arkosic sandstones along the summit and upper sideslopes of Pine Ridge. The Rome graded upward into a group of alternately layered glauconitic sandstone,

siltstone, and shale bodies known as the lower Pumpkin Valley Shale. On the lower slopes of Pine Ridge, green glauconitic, fine textured sandstones and buff colored siltstones persist (Lee and Ketelle, 1988). Near the foot of many of the spur ridges of Pine Ridge, the upper Pumpkin Valley shale exists as a thinly laminated shale and thin bedded, buff colored siltstone.

Small exposures of Rutledge Limestone have been found on the LLWDDD site, but most of the Rutledge limestone has been blanketed by alluvium and/or colluvium from the Rome and Pumpkin Valley Formations. The topographic position which this stratigraphic unit commonly occupied was low, often containing a stream or drainage divide. This unit rested between Pine Ridge and a smaller ridge whose north aspect contains Rogersville shale; a greenish-gray, fissile, laminated silty clay shale with few mudstone beds (Lee and Ketelle, 1988). Near the summit of the smaller ridge running parallel to Pine Ridge, the Rogersville gave way to the Maryville Limestone.

The Maryville Limestone unit on the LLWDDD site was highly weathered, leached, and the upper saprolite appeared as alternating bands of olive brown mudstones, siltstones, and thin lenses of sandstone. The Maryville was a ridge former, forming higher topography than any other formation within the Conasauga group. At this site the Maryville Formation was in its shaly facies, in comparison to the true

"limestone" facies that existed farther to the northeast (Lee and Ketelle, 1988). This was due to a locally deeper environment of deposition. Near the boundary with the Nolichucky shale, the Maryville contained thinly bedded limestones. The Nolichucky-Maryville boundary was transitional, and the presence of carbonates often produced a swale-like (saddle) topography.

Nearly level to sloping, subdued topography developed on the Nolichucky shale. The Nolichucky shale was characterized as a dark brown, silty, internally laminated shale with beds of silty, clayey lime mudstones (Lee and Ketelle, 1988). The lower Nolichucky contained a few fine sandstone and limestone lenses. The limestone and lime mudstone lenses often weathered out near the surface, forming clay zones that alternate with shale. The upper member of the Nolichucky shale increased in carbonate content and graded into the carbonate-rich Maynardville Limestone. On the LLWDDD site, alluvial terraces of Bear Creek covered most of this boundary (Lietzke et al., 1988).

On the LLWDDD site, the Maynardville Limestone was covered by Bear Creek alluvium, except for occasional limestone outcrops. This stratigraphic unit consisted of a mottled to ribboned to nodular, fine grained limestone and stromatolitic fine grained limestone and dolostone (Lee and Ketelle, 1988).

Between 250 and 260 meters above mean sea level, a significant amount of old alluvium mantled the area. The alluvium was composed of very fine sands and coarse silts, and contained very few if any rock fragments. The origin of this material appeared to be from the Rome Formation and Pumpkin Valley Shale (Lietzke et al., 1988). The alluvium had a distinctive brownish yellow subsoil color (10YR 6/6).

Soil Profile Locations

For the soil and saprolite characterization of the LLWDDD site, pits were located on the dominant soils of the upper Pumpkin Valley, Rogersville, Maryville, and Nolichucky formations. Sites were selected by preliminary soil mapping, transect, and auger investigations. Eroded and uneroded sites were selected for both the upper Pumpkin Valley and Rogersville formations. Eroded sites were selected for Maryville and Nolichucky formations. Two sites were also selected in the old alluvium above Bear Creek. Sites were selected based on representation of that site to the dominant soil mapping unit most found on each geologic formation. At least one site was selected for each geologic formation present. Profiles were numbered using the mapping unit number plus an erosion status symbol (E for eroded, N for noneroded). Soil profiles on the Pumpkin Valley Shale were labeled 24-N and 24-E. Soil profiles on the Rogersville Shale were labeled 36-N and 36-E. The soil

profile on the Nolichucky Shale was labeled 51-E. On the Maryville Limestone, an excavation containing both a colluvial and residual soil profile was labeled 49 & 42-E (49 represented the colluvial profile and 42-E represented the residual soil profile). The first old alluvial profile, containing Pumpkin Valley colluvium over old alluvium, was labeled 26/951. The other alluvial profile was labeled 951.

All sites, with the exception of profile 24-E, were located along one of two soils transects (Figure 6). The first transect (A-A') followed a telephone line across a large expanse of old alluvium. Transect A-A' started about 310 meters east of the intersection of Tennessee Highway 95 and Bear Creek Valley Road, and ended at Highway 95 near the watergap in Pine Ridge. The second transect (B-B') ran perpendicular to geologic strike, and followed an old field road 350 meters southwest of Gum Hollow Road. The transect extended from Bear Creek to the crest of Pine Ridge.

Profile 26/951 was located at the upper end of the alluvial transect on a footslope of Pine Ridge (Latitude 35° 56'30"N, Longitude 84° 20'30"W). Profile 951 was about 190 meters down transect, on an old terrace (35° 56'26"N, 84° 20'28"W). About 165 meters northeast of Pit 951, Profile 24-E rested in the middle of a pine plantation (35° 56'35"N, 84° 20'20"W). All other profile sites were located along the first transect. Profile 51-E was located in transplanted pines, 125 meters northwest of Bear Creek (35° 56'42"N,

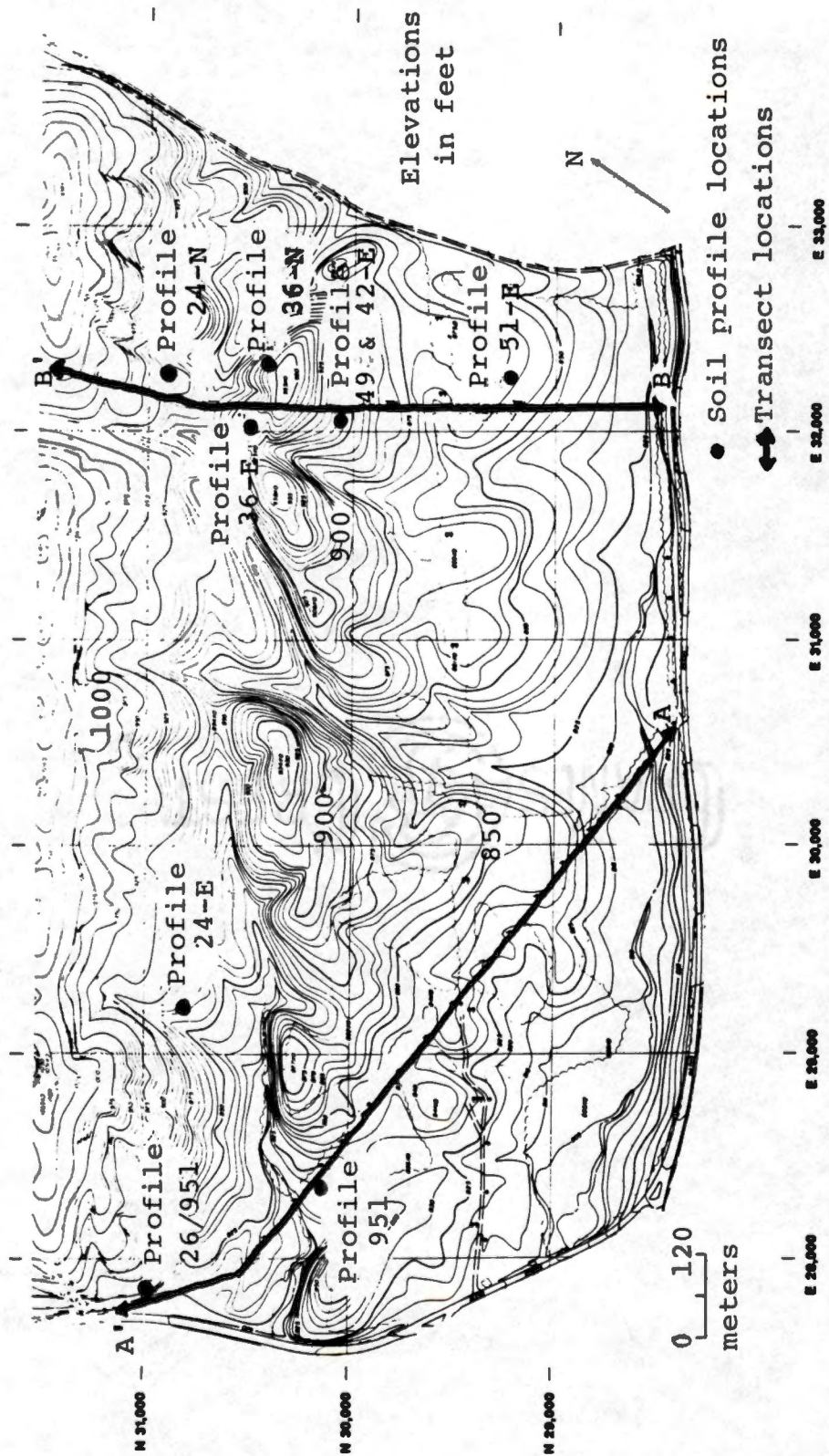


Figure 6. Topographic map of the LLWDDD site, showing location of transects and soil profiles (After Lietzke et al., 1988).

84 19'38"W). Profile 49 & 42-E was located in hardwoods on the south aspect of the small ridge formed in Maryville Limestone (35 56' 46"N, 84 19'46"W). Profile 24-N was located on the lower slopes of the south aspect of Pine Ridge (35 56'56"N 84 19'47"W). Opposite the summit of this ridge, Profiles 36-E (35 56'49"N, 84 19'50"W) and 36-N (35 56'50"N, 84 19'45"W) were located.

Pine Ridge Transect Study

Six soil transects were completed along the south aspect spur ridges of Pine Ridge. Spur ridges were grouped into three categories, according to width. Spur ridge width categories were arbitrarily set at <50 meters, 50 to 85 meters, and >85 meters. Two spur ridges were selected at random from each grouping. Soil transects were designed as t-transects. On each spur ridge investigated, a transect line was run both parallel and perpendicular to slope. Each transect line consisted of ten data points. Data collected at each point included depth to saprolite, Bt and Bw horizon thickness, slope gradient, slope shape across and with contour, and depth of colluvium.

Sample Preparation

A total of thirty-six samples were collected from the nine profiles described. Profiles containing one or more Bt horizons or an A and E horizon were bulk sampled. Samples were placed in 3 L sample bags, labeled and stored moist at

room temperature. Samples subsequently were air-dried, weighed, and passed through a 2 mm sieve to remove coarse fragments (SCS, 1984). Coarse fragment contents were reported as volume percentages. Coarse fragments and fine earth materials were retained, bagged and labeled for laboratory analysis.

Laboratory

Chemical Analysis

Total carbon was determined by dry combustion of 0.5 g of sample in a LECO CR12 carbon analyzer, model 781-700. Soil pH (1:1 soil water ratio) was measured using an Orion model 399A pH meter and combination electrode (McLean, 1982). Exchangeable aluminum and hydrogen were determined by KCl extraction (Thomas, 1982).

Cation exchange capacity was determined by ammonium saturation and sodium replacement (Chapman, 1965). The procedure was modified by placing 2.5 g of air dry soil in a 50 mL centrifuge tube. Isopropyl alcohol was replaced by ethanol. A Kjeltac 1004 distilling unit was employed to extract the ammonium. Base cations were measured with a Perkin Elmer 403 Spectrophotometer and percent base saturation determined by summation (Jackson, 1970). Calcium carbonate equivalents were calculated, using a neutralization potential procedure (Sobek et al., 1978).

Free iron oxide contents were determined, using the citrate-dithionite bicarbonate method (Olson and Ellis, 1982).

Manganese oxides were extracted and quantified by use of hydroxylamine hydrochloride (Chao, 1972).

Physical Analysis

Texture determinations were made by pipete method (EPA, 1986). Coarse fragment content was calculated to determine the need for textural modifiers. Fifty mL of clay fraction was retained for X-ray diffraction analysis.

Atterberg limits were determined by methods described by the American Society for Testing and Materials (ASTM, 1980). A Soiltest CL-205 liquid limit device was employed for the procedure. Shrinkage limit was determined by the equation $SL = 20 + \pi$, where SL is shrinkage limit, and π is the distance above or below the A-line that the plot of plasticity index and liquid limit rests on Casagrande's plasticity chart (Casagrande, 1932).

Moisture retention at 33 and 1500 kPa pressures was measured on a Soil moisture 5 bar and 15 bar Pressure Plate Extractor, model 1600 and 1500, respectively (SCS, 1984). Available water was calculated as the difference between 33 and 1500 kPa water contents, and corrected for coarse fragment content when necessary (SCS, 1984).

Bulk densities were calculated by the core method (Blake and Hartge, 1986a). Cores were collected in 7.6 cm

diameter shelly tubes using a mobile drill. Cores were taken from one profile found on each of the major geologic formations and the 951 old alluvium and 26/951 colluvium and alluvium profiles. Cores were cut by pipe cutter, weighed, oven-dried at 105 °C, and reweighed. Specific gravities (particle densities) were determined by the pycnometer method (Blake and Hartge, 1986b). Random samples were pulled from the cores for specific gravity determination. Specific gravities were determined for an A, B, and Cr horizon for each profile sampled. Total porosity was calculated from bulk density and specific gravity data.

Mineralogical Analysis

Whole soil fractions were analyzed on a DuPont Instruments 910 Differential Scanning Calorimeter, R90 Thermal Analyzer, and Hewlett Packard X-Y recorder, model 7046A. Samples (5.0 mg) were placed in gold or aluminum pans and scanned at temperatures between 100 and 585 °C.

Both dithionite treated and untreated clay specimens were prepared for X-ray diffraction (XRD), using the filter membrane peel technique (Drever, 1973). Iron-stripped clay samples were prepared for XRD, using procedures of Jackson (1970). Magnesium saturated slides were scanned at room temperature and ambient humidity and following glycerol solvation. Diffraction scans of potassium-saturated slides were made at room temperature, and after 2-hour heat

treatments at 105, 300 and 550 ° C. XRD scans began and ended at 2 and 30 degrees, 2 theta, respectively, using Cu K radiation at 35 kilovolts and 20 milliamps, on a Norelco-Phillips X-Ray diffractometer, model 3-202, computerized with a California Scientific computer system. Diffraction patterns were plotted on a X-Y plotter and data were stored on disk. XRD was run at 1 ° per minute and stepped at intervals of 0.04 ° .

CHAPTER IV

RESULTS AND DISCUSSION

Soil Morphology and Classification

Soil Classification

A soil survey map and classification of soil mapping units on the LLWDDD site are presented in Figure 7 and Table 1. Soil profile classifications are listed in Table 2. Soil profile descriptions are presented in Appendix A. Four soil orders (Entisols, Inceptisols, Alfisols and Ultisols) are represented on the LLWDDD site. Entisols are commonly found in the floodplain of Bear Creek and in very severely eroded areas. Alfisols are limited to lower terraces of Bear Creek. Inceptisols and Ultisols cover most of the LLWDDD site, but are not found on floodplains and lower terraces of Bear Creek.

Three suborders of Entisols can be found on the LLWDDD site. Orthents occupy very severely eroded residual areas in which hard saprolite is at or near the surface. Most of these soils are shallow to paralithic contacts, and root penetration of the saprolites is very restricted. Saprolite is a "thoroughly decomposed, earthy, but untransported rock" (Becker, 1894; Calvert et al., 1980). Saprolites are weathered rocks that maintain rock structure and some degree of hardness. On the LLWDDD site, the typical great group and subgroup of Orthent present is a Typic Udorthent. Soil

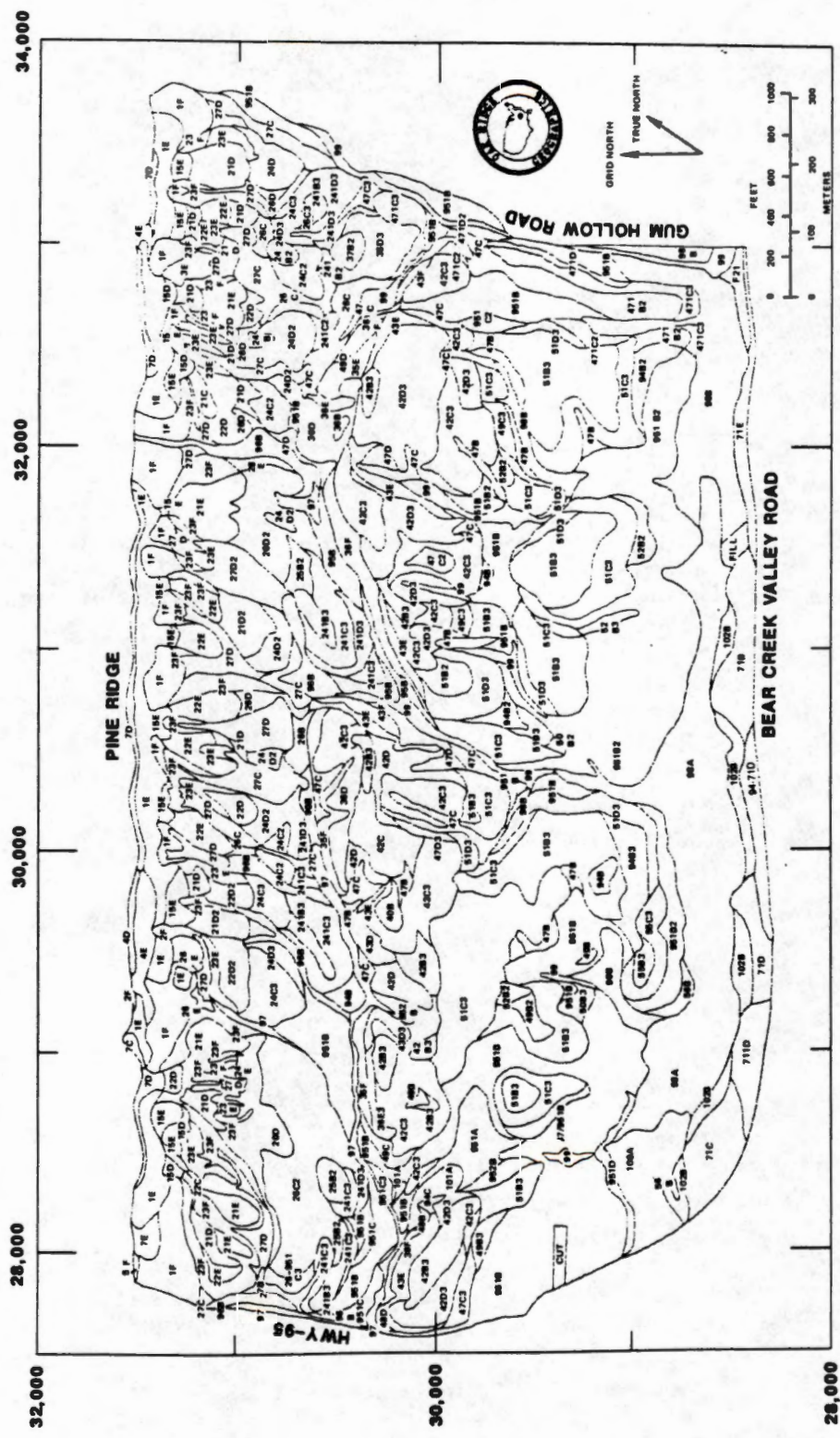


Figure 7. Soil survey map of the LLWDDD site (After Lietzke et al., 1988).

Table 1. Classification of soils on the LLWDDD site (After Lietzke et al., 1988).

Mapping unit	Taxonomic classification	Parent materials
1.	Typic Hapludults; sandy and coarse-loamy, mixed, thermic	Rome feldspathic sandstone residuum
4.	Typic Dystrachrepts; loamy-skeletal, siliceous, thermic	Rome sandstone along crest of Pine Ridge
7.	Typic Hapludults; clayey, mixed, thermic	Rome feldspathic sandstone residuum
15.	Typic Hapludults; fine-loamy, mixed, thermic	Rome colluvium
21.	Typic Hapludults; clayey, mixed, thermic	Pumpkin Valley residuum
22.	Ochreptic Hapludults; clayey, mixed, thermic	Pumpkin Valley residuum
23.	Typic Dystrachrepts; loamy-skeletal, mixed, thermic	Pumpkin Valley residuum
24.	Ruptic-Ultic Dystrachrepts; loamy-skeletal, mixed, thermic	Pumpkin Valley residuum
25.	Typic Hapludults; clayey, mixed, thermic	Pumpkin Valley colluvium
26.	Typic Hapludults; fine-loamy, mixed, thermic	Pumpkin Valley colluvium
26/951.	Typic Hapludults; fine-loamy, mixed, thermic	Pumpkin Valley colluvium overlying old alluvium
27.	Typic Hapludults; loamy-skeletal, mixed, thermic	Pumpkin Valley colluvium
30.	Ruptic-Ultic Dystrachrepts; loamy-skeletal, mixed, thermic	Rutledge residuum
35.	Typic Dystrachrepts; loamy-skeletal, mixed, thermic	Rogersville residuum
36.	Ruptic-Ultic Dystrachrepts; loamy-skeletal, mixed, thermic	Rogersville residuum
37.	Typic Hapludults; clayey, mixed, thermic	Rogersville residuum
40.	Typic Hapludults; clayey, mixed, thermic	Maryville residuum
42.	Ruptic-Ultic Dystrachrepts; loamy-skeletal, mixed, thermic	Maryville residuum
43.	Typic Dystrachrepts; loamy-skeletal, mixed, thermic	Maryville residuum
47.	Typic Hapludults; fine-loamy, mixed, thermic	Conasauga colluvium
47/951.	Typic Hapludults; fine-loamy, mixed, thermic	Conasauga colluvium overlying old alluvium
48.	Typic Fragiudults; fine-loamy, mixed, thermic	Conasauga colluvium
49.	Typic Hapludults; clayey, mixed, thermic	Conasauga colluvium
50.	Ruptic-Aquultic Dystrachrepts; loamy-skeletal, mixed, thermic	Nolichucky residuum
51.	Ruptic-Ultic Dystrachrepts; loamy-skeletal, mixed, thermic	Nolichucky residuum
52.	Typic Hapludults; clayey, mixed, thermic	Nolichucky residuum
55.	Typic Hapludults; clayey, mixed, thermic	Maynardville residuum
56.	Typic Hapludults; fine, mixed, thermic	Maynardville residuum
71.	Typic Hapludults; fine-loamy, mixed, thermic	Knox colluvium
94.	Typic Hapludults; fine-loamy, mixed, thermic	Old alluvium
94-71.	Typic Hapludults; fine-loamy, mixed, thermic	Old alluvium overlying Knox colluvium
95.	Typic Hapludults; fine-loamy, mixed, thermic	Old alluvium
96.	Typic and Aquic Udifluvents; coarse-loamy, mixed, thermic	Modern alluvium in areas of Rome and Pumpkin Valley residuum
97.	Typic and Aeris Fluvaquents; fine-loamy, mixed, thermic	Modern alluvium in areas of Rome and Pumpkin Valley residuum
98.	Typic and Aquic Udifluvents; coarse-silty, mixed, thermic	Modern alluvium in areas of Rogersville, Maryville, and Nolichucky residuum
99.	Typic and Aeris Fluvaquents; fine-silty, mixed, thermic	Modern alluvium in areas of Rogersville, Maryville, and Nolichucky residuum
100.	Typic and Aquic Udifluvents; coarse and fine-loamy, mixed, thermic	Modern alluvium in Bear Creek
101.	Aeris Ochraqualfs; fine-silty, mixed, thermic	Old alluvium
102.	Typic and Aquic Udifluvents; fine-loamy, siliceous, thermic	Modern alluvium from Knox residuum and colluvium
471.	Typic Hapludults; fine-loamy, mixed, thermic	Conasauga colluvium and alluvium
951.	Typic Hapludults; fine-silty, mixed, thermic	Old alluvium
952.	Typic and Aquic Fragiudults; fine-silty, mixed, thermic	Old alluvium

Table 2. USDA soil classification and parent materials for soil profiles on the LLWDDD site.

Profile	USDA Soil Classification	Parent Material(s)
42-E	loamy-skeletal, mixed, thermic Ruptic-Ultic Dystrochrepts	Maryville limestone
24-N	clayey, mixed, thermic Ruptic-Ultic Dystrochrepts	Pumpkin Valley Shale & Pumpkin Valley colluvium
36-E	loamy-skeletal, mixed, thermic Ruptic-Ultic Dystrochrepts	Rogersville Shale
951	fine-silty, mixed, thermic Typic Hapludults	Old Bear Creek alluvium over Pumpkin Valley Shale
24-E	loamy-skeletal, shallow, mixed, thermic Typic Udorthents	Pumpkin Valley Shale
36-N	loamy-skeletal, mixed, thermic Ruptic-Ultic Dystrochrepts	Rogersville Shale
51-E	loamy-skeletal, mixed, thermic Ruptic-Ultic Dystrochrepts	Nolichucky Shale
26/951	fine-loamy, mixed, thermic Typic Hapludults	Pumpkin Valley colluvium over old Bear Creek alluvium over Pumpkin Valley Shale
49	clayey, mixed, thermic Typic Hapludults	Old Maryville colluvium

profile 24-E is a typical example of Typic Udorthents. This profile was very severely eroded due to past agricultural practices.

The other suborders of Entisols present on the LLWDDD site are Fluvents and Aquents. These suborders are found in alluvial materials along the lower terraces and floodplains of Bear Creek (Lietzke et al., 1988). Fluvents are Entisols which do not have lithic or paralithic contacts within 25 cm of the soil surface, have irregular decreases in organic carbon to a depth of 125 cm, and rest on slopes less than 25 percent. Fluvents often contain sand stratifications throughout the soil profile (Soil Survey Staff, 1975). A common Fluvent subgroup found on the LLWDDD site is an Aquic Udifluent. Fluvents are the drier of the two Entisol suborders. Aquents are known as the wet Entisols. This suborder exists in an aquic soil moisture regime. These soils are set in reducing conditions where the soil is saturated with water most of the year. Also, the soils may change color upon exposure to air, and often have mottling with chromas of two or less. A common great group and subgroup of Aquent present on the LLWDDD site is an Aeric Fluvaquent. Aeric Fluvaquents are drier Fluvaquents which contain higher chroma subhorizons at depths between 25 and 75 cm than do Typic Fluvaquents.

One suborder of Inceptisols can be found on the LLWDDD site. The Ochrept is characterized by having an ochric epipedon, or having a mollic or umbric epipedon less than 25 cm thick. Ochrepts are found on sites that have a mesic (mean annual soil temperature of 8 to 15 °C) or warmer temperature regime. Ochrepts are light colored soils that are commonly freely drained, and have formed on nearly level to steep surfaces. Ochrepts are divided into great groups based on the presence of hardpans (fragipans, duripans), moisture regimes, and base saturation. On the LLWDDD site, Dystrochrepts are the only great group of Ochrepts present. Dystrochrepts are distinguished from other great groups by having a base saturation of less than 60 percent. These soils have formed under moderately acid conditions in which most of the exchangeable bases have been leached from the soil profile. Deciduous trees often occupy these soils.

Two subgroups of Dystrochrepts exist on the LLWDDD site. Typic Dystrochrepts are acid soils that are moderately deep or deep to hard rock. Unlike Ruptic-Ultic Dystrochrepts, Typic Dystrochrepts do not contain alternating argillic (Bt) and cambic (Bw) horizonation. Ruptic-Ultic Dystrochrepts are the second subgroup of Dystrochrepts present on the LLWDDD site. Up to 50 percent of a Ruptic-Ultic Dystrochrept can contain argillic horizonation (Soil Survey Staff, 1975). The Ruptic-Ultic Dystrochrepts found on the LLWDDD site contain broken

horizonation, due to near-vertical dipping of geologic materials. In many of these soils, B horizons alternate with and sometimes underly Cr horizons. The ruptic nature of these soils is due to differential weathering of cyclically occurring sandstone, shale or limestone beds. The Bt and Bw horizons of Ruptic-Ultic Dystrochrepts on the LLWDDD site commonly alternate over a distance of about one meter (Lietzke et al., 1988). Ruptic-Ultic Dystrochrepts are common on the LLWDDD site. Soil profiles 24-N, 36-E, 36-N, 42-E, and 51-E all classify as Ruptic-Ultic Dystrochrepts. These soils have experienced moderate to severe erosion as a result of past agriculture practices.

Only one suborder of Ultisol, the Udult, is present on the LLWDDD site. Udults are characterized by having a udic moisture regime. These soils are mostly freely drained and have lightly colored upper horizons resting on a yellowish-brown to reddish argillic horizon (Soil Survey Staff, 1975). Two great groups of Udults, Fragiudults and Hapludults, are present on the LLWDDD site. Fragiudults can be differentiated from Hapludults by the presence of a fragipan in or below an argillic horizon. Low chroma mottles can be seen along some ped faces of the fragipan at depth. This is characteristic of the Typic Fragiudult, which is the only subgroup of Fragiudult present on the LLWDDD site (Lietzke et al., 1988).

Hapludults contain an ochric epipedon and a thin to moderately thick argillic horizon. Two subgroups of Hapludults (Typic and Ochreptic Hapludults) are found on the LLWDDD site. Typic Hapludults differ from Ochreptic Hapludults by having an argillic horizon greater than 25 cm thick. On the LLWDDD site, Ochreptic Hapludults are mostly restricted to residual soils. Typic Hapludults occur on all types of soils (colluvial, alluvial and residual). Soil profiles 49, 951, and 26/951 are all classified as Typic Hapludults. Profile 49 was formed from colluvium, Profile 951 was formed from alluvium, and Profile 26/951 was formed from both colluvium and alluvium.

One occurrence of an Alfisol (Aeric Ochraqualfs) does exist on the LLWDDD site. This soil subgroup is characterized as having an ochric epipedon, argillic horizon, base saturation greater than 35 percent under the same depth requirements mentioned for Ultisols, and being saturated with water during much of the year (Soil Survey Staff, 1975). On the LLWDDD site, Aeric Ochraqualfs occupy areas of old alluvium along abandoned paleo-floodplains of Bear Creek (Lietzke et al., 1988). A related study of soils formed from Maryville Limestone and Nolichucky Shale on the Oak Ridge Reservation (Solid Waste Storage Area 6), found Alfisols that formed from residuum (Phillips 1988).

Soil Morphology

Field morphology of all soil profiles was recorded on form SCS-S01-232. Profile 24-E (Figure 8a) had a 15 cm Ap horizon, abruptly overlying a dark reddish gray shale Cr horizon. The Cr material was coated with iron stains and patchy clay skins, indicating the presence of a clay enriched subsoil horizon. Profile 24-N (Figure 8b) had alternating Bt and Bw horizons interrupted by Cr materials. An abrupt, inclined and highly irregular Cr boundary existed at 66-118 cm, and the Cr material was composed of alternating bands of dipping mudstones and glauconitic sandstones. Discontinuous red iron stains and continuous faint reddish brown clay skins coated Cr surfaces.

Profiles 36-E and 36-N (Figures 8c and d) also contained alternating Bt and Bw horizons. In profile 36-E, the Cr material occurred between depths of 25 and 33 cm. The weathered shale saprolite of the Cr was coated with patchy clay films and iron coats. Thin clay zones were present along the left side of the pit, and followed the bedding of the steeply dipping Cr material. Saprolite (Cr) horizons occurred between depths of 29 and 50 cm in Profile 36-N. Patchy dark red iron stains and yellowish red clay skins coated saprolite fragment surfaces. Below 130 cm patchy black manganese coats were present.

The west face of Pit 49 & 42-E (Figure 8e) contained a yellowish red colluvial Bt horizon, underlain by saprolite



a. Photograph of profile 24-E (Scale in centimeters).

Figure 8. Photographs of LLWDDD site soil profiles.



b. Photograph of profile 24-N (Scale in centimeters).

Figure 8. (Continued)



c. Photograph of profile 36-E (Scale in centimeters).

Figure 8. (Continued)



d. Photograph of profile 36-N (Scale in centimeters).

Figure 8. (Continued)



e. Photograph of profile 49 (Scale in centimeters).

Figure 8. (Continued)



f. Photograph of profile 51-E (Scale in centimeters).

Figure 8. (Continued)



g. Photograph of profile 951 (Scale in centimeters).

Figure 8. (Continued)



h. Photograph of profile 26/951 (Scale in centimeters).

Figure 8. (Continued)

at 100 cm (Profile 49). The colluvium was part of an old gully fill. The weathered bedrock (Cr) horizons were extremely firm and were coated by many dark red iron and few manganese coats. The right pit face (Profile 42-E) had a residual Bw horizon with Cr material appearing at 16 cm.

Profile 51-E (Figure 8f) contained a solum with an Ap horizon 18 cm thick, and alternating Bw and Bt horizons. Weathered saprolite (Cr) material occurred between depths of 40 and 81 cm, alternating with 5 to 20 cm thick argillaceous limestone strata which had weathered to clay and possessed pedogenic structure. Both the Cr material and clay zones dipped southeastward at 25 to 30 degrees. The saprolitic Cr material was a strong brown shale, containing many continuous manganese and discontinuous very dusky red iron stains on fragment surfaces. Profile 951 (Figure 8g) contained two accumulations of brownish yellow alluvium. The upper 76 cm contained silt loam and silty clay loam textured horizons. From 76 to 121 cm, the profile contained E and B horizons having loam textures and prismatic structures. Below 100 cm, the soil became gleyed with many light gray mottles. The Cr horizons below a depth of 121 cm contained olive brown Rogersville shale with many iron-manganese stains on saprolite fragment surfaces.

Profile 26/951 (Figure 8h) was characterized by 122 cm of Pumpkin Valley colluvium over old alluvium (soil no. 951) and Pumpkin Valley Shale residuum. The colluvium contained

alternating BC or CB horizons with high shale chip content and Bt horizons. The BC, CB, and Bt horizons were generally 15 to 20 cm thick. The Bt horizons were yellowish red to reddish brown in color and had clay loam textures. Between depths of 122 and 270 cm, a clay loam alluvium persisted. Structure was subangular blocky to weak prismatic, and thin dark brown clay skins coated the ped surfaces. Soft Cr materials occurred below a depth of 325 cm and contained bluish-green glauconite with bluish clay coats.

Physical Characteristics

Particle Size Distribution

Particle size analyses of all nine LLWDDD soil profiles are presented in Table 3. Surface horizons of most soils had silt loam or loam textures (Table 3). In some instances, where erosion was severe and clayey Bt horizons were closer to the surface, surface textures were clay loam. Soils commonly increased in clay with depth and developed clay loam textures in Bt or Bw horizons. The exception was profile 24-N, which had a clay textured Bt/Bw horizon. This soil profile developed on the highly weathered upper Pumpkin Valley Shale. Soil textures in Cr horizons were either loams or sandy loams. Although sand percentages commonly increased in the Cr horizons, some of the sand increase could be attributed to disintegration of rock fragments in the soil sieving process. Evidence of this can be seen in

Table 3. Pipette particle size distribution and textures for soil profiles on the LLWDDD site.

Class & particle diameter in mm															
Pit	Horizon	Depth cm	Coarse fragments >2	Sand				Silt				Total			
				VCOS 2-1	COS 1-5	MS .5-.25	FS .25-.1	VFS .1-.05	COSI .05-.02	FSI .02-.002	Sand 2-.05	Silt .05-.002	Clay <.002	Texture modifier	Texture
			-- % --	----- % -----				----- % -----				----- % -----			
49 & 42-E	A-E*	0-14	23	5.0	3.9	1.6	4.5	18.2	28.3	26.8	33.2	55.1	11.7	shaly	silt loam
	A-Bw**	0-16	31	10.9	4.7	1.7	4.5	12.6	23.1	24.6	34.4	47.7	17.9	shaly	loam
	Bt1-Bt2	14-84	11	4.6	3.1	1.2	2.1	5.9	14.8	22.9	16.9	37.7	45.4	-	clay
	2CB	84-102	54	5.1	2.5	0.9	2.1	4.1	15.7	24.5	14.7	40.2	45.1	very sh.	silty clay
	2Cr1	102-149	87	17.4	9.2	2.7	4.7	7.7	10.3	15.6	41.7	25.9	32.4	ext. sh.	clay loam
	2Cr2	149+	80	12.2	4.8	1.8	2.3	3.1	10.2	27.1	24.2	37.3	38.5	ext. sh.	clay loam
36-N	A	0-9	19	2.1	3.4	2.1	8.4	16.4	1.9	49.0	32.4	50.9	16.7	shaly	silt loam
	Bw	9-29	30	7.4	3.6	2.0	9.5	14.0	16.3	25.0	36.5	41.3	22.2	shaly	loam
	Cr1	29-130	71	26.9	7.6	3.2	8.1	9.4	9.0	11.5	55.2	20.5	24.3	ext. sh.	sandy clay loam
	Cr2	130+	74	19.5	10.3	2.8	5.1	5.9	15.0	18.8	43.6	33.8	22.6	ext. sh.	loam
24-E	Ap	0-15	25	2.3	5.0	2.9	8.1	13.9	16.2	29.0	32.2	45.2	22.6	shaly	loam
	Cr1	15-58	76	7.9	6.4	1.9	2.8	3.3	10.3	34.5	22.3	44.8	32.9	ext. sh.	clay loam
	Cr2	58+	98	18.8	10.1	3.2	5.4	6.1	3.7	29.0	43.6	32.7	23.7	ext. sh.	loam
951	Ap	20-28	4	1.7	1.7	0.7	6.3	22.3	33.8	27.5	32.7	61.3	6.0	-	silt loam
	E1-E2	28-48	4	1.6	0.8	0.5	4.8	18.9	36.2	25.3	26.6	61.5	11.9	-	silt loam
	Bt	48-76	-	1.2	0.5	0.3	5.7	17.6	26.1	20.9	25.3	47.0	27.7	-	clay loam
	2E/B-2Btg	76-121	2	0.6	0.9	1.4	5.5	30.2	28.2	12.1	38.6	40.3	21.1	-	loam
	3Cr	121+	97	20.4	8.2	2.2	5.6	10.0	14.5	19.5	46.4	34.0	19.6	ext. sh.	loam

Table 3. (Continued)

Class & particle diameter in mm															
Pit	Horizon	Depth	Coarse fragments >2	Sand			Silt			Total			Texture modifier	Texture	
				VCOS 2-1	COS 1-0.05	MS .05-.25	FS .25-.1	VFS 1-1.05	COSI .05-.02	FSI .02-.002	Sand 2-0.05	Silt .05-.002			Clay <.002
		CM	-- X --	----- X -----			----- X -----			----- X -----					
24-N	A-E	0-25	25	2.0	1.8	1.0	9.1	29.9	19.4	24.7	43.8	44.1	12.1	shaly loam	
	Bw-Bt	25-66	19	2.8	1.5	0.7	2.9	7.4	9.6	25.2	15.3	34.8	49.9	shaly clay	
	B/Cr	66-118	69	6.7	3.1	1.2	2.2	6.5	10.0	28.6	20.5	38.6	40.9	ext. sh. clay	
	Cr1 (G)	66-118	13	9.1	6.9	6.0	50.9	12.0	6.1	3.5	84.9	9.6	5.5	- loamy fine sand	
	Cr2	118+	76	11.0	6.1	3.7	40.4	15.8	6.7	6.6	77.0	13.3	9.7	ext. sh. fine sandy loam	
36-E	A-Bw	0-25	19	5.0	4.0	2.2	4.9	9.1	14.0	28.2	25.2	42.2	32.6	shaly clay loam	
	Cr1	25-200	65	14.8	10.2	3.3	6.0	4.0	7.0	18.0	38.3	25.0	36.7	ext. sh. clay loam	
	Cr1 (G)	100	90	8.9	6.4	4.3	18.4	10.7	13.6	10.0	48.7	23.7	27.7	ext. sh. sandy clay loam	
	Cr2	200+	82	30.1	13.0	3.7	7.1	6.2	7.3	14.3	60.1	21.6	18.3	ext. sh. coarse sandy loam	
51-E	Ap	0-18	9	4.1	2.7	1.3	3.0	6.2	29.2	28.8	17.3	58.0	24.7	- silt loam	
	Cr	18-175	88	20.1	10.3	2.9	3.0	2.1	9.5	19.3	38.4	28.8	32.8	ext. sh. clay loam	
	2Cr	150-250	79	13.0	4.0	1.6	2.0	7.1	21.8	25.8	27.7	47.6	24.7	ext. sh. loam	
	3Cr (R)	250+	94	9.3	11.6	2.2	2.7	2.3	26.8	18.4	28.1	45.2	26.7	ext. sh. loam	
	3Cr (Y)	250+	89	14.3	5.0	1.4	2.6	8.8	20.5	22.0	32.1	42.5	25.4	ext. sh. loam	
26/951	Ap	0-21	24	1.8	2.3	1.9	12.0	30.4	11.7	19.8	48.4	31.5	20.1	gravelly loam	
	Bt1-4Bt	21-122	9	5.8	2.2	0.9	8.5	17.5	18.3	18.6	34.9	36.9	28.2	- clay loam	
	5Bt1-6Bw2	122-270	-	0.3	0.1	0.4	8.3	22.8	19.4	16.2	31.9	35.6	32.5	- clay loam	
	7C-7Cr	270+	86	9.6	4.9	2.5	17.4	10.8	11.1	22.2	45.2	33.3	21.5	ext. gr. loam	

* Colluvial face (Profile 49) ** Residual face (Profile 42-E)

(G) - Glauconitic

(G) - Glauconitic

(R) = Reddish coats (iron)

(Y) - Yellowish (iron and/or clay) coats

ext. = extremely sh. = shaly gr. = gravelly

ext. = extremely sh. = shaly gr. = gravelly

Cr horizons of profile 24-N, where sand percentages increase 60 percent from overlying horizons. This sand increase can be explained by the nature of the saprolite that had been sieved. The Cr material was a highly weathered glauconitic sandstone, which would slough during the sieving process. The majority of the sand particles were fine and very fine sands. In profile 26/951, very coarse sand, coarse sand, and medium sand percentages decreased greatly between the Bt and 5Btg horizons. These same three sand fraction percentages greatly increased between the 5Btg and 7Cr horizons. These differences in particle size gave evidence of discontinuities. The Bt horizon of profile 26/951 had a colluvial parentage, and was full of small shale chips. The 5Btg horizon was composed of old alluvium, containing mostly fine sands and coarse silts. The 7Cr horizon was residual, composed of glauconitic sandstone. Profile 951 contained discontinuities at 76 and 121 cm. The discontinuity at 76 cm formed the boundary between two deposits of alluvium. The discontinuity at 121 cm denoted the boundary between the alluvium and the underlying Rogersville Shale saprolite.

Atterberg Limits

Liquid limit, plastic limit, plasticity index, shrinkage limit, and soil activity data are presented in Table 4. Average liquid limit values for most profiles ranged from approximately 35 in A horizons to 50 to 60 in B

Table 4. Atterberg limits of soil profiles on the LLWDDD Site.

Pit	Horizon	Depth cm	Atterberg limits					Shrinkage limit	Activity ratio
			Liquid limit	Plastic limit	Plasticity index	Flow index			
49 & 42-E	A-E*	0-14	33.1	29.1	4.0	7.9	25.6	0.34	
	A-E**	0-16	27.9	26.7	1.2	31.7	24.6	0.06	
	Bt1-Bt2	14-84	58.3	30.8	27.5	12.1	20.5	0.61	
36-N	A	0-9	42.6	35.2	7.4	6.0	29.1	0.44	
	Bw	9-29	32.4	21.9	10.5	7.4	18.6	0.47	
24-E	Ap	0-15	35.0	25.1	9.9	13.7	21.1	0.44	
951	Ap	20-28	27.3	22.0	5.3	5.3	20.0	0.88	
	E1-E2	28-48	21.9	18.5	3.4	2.0	18.0	0.28	
	Bt	48-76	40.6	20.1	18.5	15.2	16.5	0.67	
	2E/B-2Btg	76-121	30.1	18.1	12.0	4.7	15.4	0.59	

Table 4. (Continued)

Pit	Horizon	Depth cm	Atterberg limits					Activity, ratio
			Liquid limit	Plastic limit	Plasticity index	Flow index	Shrinkage limit	
24-N	A-E	0-25	28.3	24.3	4.0	4.6	22.1	0.33
	Bw-Bt	25-66	60.9	33.0	27.9	30.1	22.0	0.56
36-E	A-Bw	0-25	46.0	31.5	14.5	24.2	24.5	0.44
51-E	Ap	0-18	35.9	24.9	11.0	2.2	20.6	0.44
26/951	Ap	0-21	32.1	22.9	9.2	7.5	19.6	0.46
	Bt1-4Bt	21-122	40.8	23.6	19.2	11.5	18.0	0.68
	5Bt1-6Bw2	122-270	45.3	20.9	24.4	14.6	14.1	0.75

* Colluvial face (Profile 49) ** Residual face (Profile 42-E)

(G) = Glauconitic

(R) = Reddish coats (iron)

(Y) = Yellowish (iron and/or clay) coats

horizons. Average plastic limit values were 25 for both A and B horizons. Plasticity index values ranged from 5 in A horizons to 20 to 25 for B horizons. Shrinkage limit values averaged 20 in A horizons, but decreased slightly in B horizons. Soil activities were less than 0.75 for most soil horizons. Atterberg data indicated that the soils on the LLWDDD site contained neutral activity clays with low shrink-swell potential. Higher amounts of organic matter were responsible for higher shrinkage limits and soil activities in A horizons. Organic matter absorbs water and thus increases the water content at which a soil ceases to shrink. Including the additions of organic carbon, the soil activities suggest that 1:1 kaolinitic or 2:1 non-swelling (illitic) clay minerals were present in all soil profiles on the LLWDDD site.

Bulk Density and Porosity

Bulk density, specific gravity, and total porosity values are given in Table 5. Soil cores were taken from soil profiles when soil moisture levels were low, but most of the moisture was retained until the time of analysis (as indicated by reported field moisture contents). Bulk density values ranged from 1.2 Mg m^{-3} in A horizons, to 1.5 Mg m^{-3} in B and 1.6 Mg m^{-3} in Cr horizons. Values found in the solum of most LLWDDD site soils were within the optimum range for adequate water and air movement and vegetative

Table 5. Bulk density, specific gravity, and total porosity for soil profiles on the LLWDDD site.

Pit	Horizon	Depth	1	Bulk density	Specific gravity	Total porosity
			Field moisture			
		cm	-- % ---	-3 Mg m	-3 Mg m	-- % ---
49 &	A-E*	0-14	16.59	0.94	2.59	63.67
42-E	A-Bw**	0-16	16.59	0.94	2.59	63.67
	Bt1-Bt2	14-84	16.45	1.24	2.67	53.58
	2CB	84-102	18.30	1.38	2.67	48.31
	2Cr1	102-149	18.42	1.59	2.67	42.04
	2Cr2	149+	16.57	1.55	2.67	42.01
36-N	A	0-9	1.00	1.57	2.64	45.54
	Bw	9-29	8.40	1.38	2.56	46.08
	Cr1	29-130	0.87	1.63	2.66	38.82
	Cr2	130+	0.87	1.63	2.66	38.82
24-E	Ap	0-15	11.10	1.22	2.60	53.14
	Cr1	15-58	12.23	1.57	2.74	42.85
	Cr2	58+	12.23	1.57	2.74	42.85
951	Ap	20-28	14.35	1.34	2.63	49.14
	E1-E2	28-48	13.14	1.32	2.66	50.38
	Bt	48-76	14.24	1.32	2.66	50.38
	2E/B-2Btg	76-121	10.42	1.62	2.66	39.11
	3Cr	121+	7.42	1.88	2.73	31.20

Table 5. (Continued)

Pit	Horizon	Depth	Field ¹ moisture	Bulk density	Specific gravity	Total porosity
		cm	-- % ---	Mg m ⁻³	Mg m ⁻³	-- % ---
24-N	A-E	0-25	11.10	1.22	2.60	53.14
	Bw-Bt	25-66	14.67	1.47	2.69	45.41
	B/Cr1	66-118	12.23	1.57	2.69	41.64
	Cr1	66-118	12.23	1.57	2.74	42.85
	Cr2	118+	12.23	1.57	2.74	42.85
36-E	A-Bw	0-25	1.00	1.57	2.64	45.54
	Cr1	25-200	0.87	1.63	2.66	38.82
	Cr1 (G)	100	0.87	1.63	2.66	38.82
	Cr2	200+	0.87	1.63	2.66	38.82
51-E	Ap	0-18	15.65	1.44	2.60	44.70
	Cr	18-150	19.53	1.34	2.72	50.74
	2Cr	150-250	17.63	1.55	2.72	43.16
	3Cr (R)	250+	14.35	1.26	2.72	53.68
	3Cr (Y)	250+	14.35	1.26	2.72	53.68
26/951	Ap	0-21	6.41	1.14	2.63	56.66
	Bt1-4Bt	21-122	10.83	1.55	2.66	41.73
	5Bt1-6Bw2	122-270	15.09	1.46	2.66	45.11
	7C-7Cr	270+	14.36	1.59	2.73	41.76

* Colluvial face (Profile 49)

** Residual face (Profile 42-E)

(G) = Glauconitic

(R) = Reddish coats (iron)

(Y) = Yellowish (iron and/or clay) coats

¹ - Moisture contents (% by wt.) present in core samples at time of analysis.

establishment. Only severely eroded profiles (profile 24-E), and profiles exhibiting limited soil development (profiles 36-N, 36-E) had high bulk density values within 50 cm of the soil surface. Specific gravity (particle density) values averaged 2.60 Mg m^{-3} in A horizons, 2.66 Mg m^{-3} in B and 2.73 Mg m^{-3} in Cr horizons. Cr horizons were dense with respect to the overlying solum. Highly weathered saprolites were not as dense as harder, less weathered saprolites, but were still dense enough to lower total porosity. In one case (3Cr horizon of profile 951), bulk density approached 1.9 Mg m^{-3} and total porosity was 31.2 percent. Such values may limit permeability. Gleying of soil horizons above the saprolite in profile 951 was evidence of slow permeability and subsequent perching of water. Gleying of soil horizons above Cr materials in other profiles (51-E and 26/951) were also related to lowered permeability rates.

Moisture Retention

Thirty-three and 1500 kPa moisture retention data are presented in Table 6. Available water holding capacity values were highest in A horizons, decreased greatly in B horizons and increased slightly in Cr horizons. When adjusted for coarse fragment content, available water holding capacity values were highest for A horizons, but gradually decreased with depth. Adjusted Cr horizon values were extremely low. The highest available moisture values

Table 6. 33 and 1500 kPa moisture retention, and available water holding capacity for soil profiles on the LLWDDD site.

Pit	Horizon	Depth cm	Coarse fragments % Z	Moisture retention							TAWC				
				2			3								
				33 kPa	1500 kPa	AWC1	AWC adjusted density	Bulk density	AWC	AWC					
cm				-----			Mg m ⁻³		-1		cm cm		cm profile ⁻¹		
49 & 42-E	A-E*	0-14	22.4	30.28	14.69	15.59	12.10	0.94	11.37	0.11					
	A-Bw*	0-16	32.4	30.98	17.55	13.43	9.08	0.94	8.54	0.08					
	Bt1-Bt2	16-84	11.0	36.40	27.09	9.31	9.31	1.24	11.54	0.12					
	2CB	84-102	65.3	34.15	26.08	8.07	2.80	1.38	3.86	0.04					
	2Cr1	102-149	94.4	28.75	20.54	8.21	0.46	1.59	0.73	0.01					
	2Cr2	149+	89.6	31.32	22.25	9.07	0.94	1.55	1.46	0.01					11.5
36-N	A	0-9	28.9	30.21	20.07	10.14	7.21	1.57	11.32	0.11					
	Bw	9-29	41.2	24.83	18.64	6.19	3.64	1.38	5.02	0.05					
	Cr1	29-130	85.1	26.53	17.95	8.58	1.28	1.63	2.09	0.02					
	Cr2	130+	88.2	23.73	15.99	7.74	0.91	1.63	1.48	0.01					4.0
24-E	Ap	0-15	33.2	25.06	18.56	6.50	4.34	1.22	5.29	0.05					
	Cr1	15-58	87.4	25.74	19.74	6.00	0.76	1.57	1.19	0.01					
	Cr2	58+	98.4	22.17	15.21	6.96	0.11	1.57	0.17	0.00					1.2
951	Ap	20-28	4.5	28.32	8.94	19.38	19.38	1.34	25.97	0.26					
	E1-E2	28-48	3.8	22.25	10.91	11.34	11.34	1.32	14.97	0.15					
	Bt	48-76	0.2	26.18	18.83	7.35	7.35	1.32	9.70	0.09					
	2E/B-2Btg	76-121	1.6	21.81	13.48	8.33	8.33	1.62	13.49	0.13					
	3Cr	121+	96.6	24.98	15.14	9.84	0.33	1.88	0.62	0.01					13.5

Table 6. (Continued)

Pit	Horizon	Depth cm	Curase fragments	Moisture retention							TANC ³
				33 kPa	1500 kPa	AMC ¹	AMC ² adjusted	Bulk density	ANC	ANC by volume	
			----	-----	-----	-----	-----	Mg m ⁻³	%	cm cm ⁻¹	cm profile ⁻¹
24-N	A-E	0-25	31.7	26.46	11.67	14.79	10.10	1.22	12.32	0.12	
	Bw-Bt	25-66	27.7	36.23	27.96	8.27	5.98	1.47	8.79	0.08	
	B/Cr	66-118	80.9	30.12	22.67	7.45	1.42	1.57	2.23	0.02	
	Cr1 (G)	66-118	18.1	15.50	10.42	5.08	4.16	1.57	6.53	0.07	
	Cr2	118+	87.7	17.62	11.16	6.46	0.79	1.57	1.24	0.01	7.6
36-E	A-Bw	0-25	29.0	31.92	23.20	8.72	6.19	1.57	9.72	0.09	
	Cr1	25-200	77.1	28.56	20.78	7.78	1.78	1.63	2.90	0.03	
	Cr1 (G)	100	94.1	28.17	21.25	6.92	0.41	1.63	0.67	0.01	
	Cr2	200+	91.3	21.76	15.05	6.71	0.58	1.63	0.95	0.01	6.0
51-E	Ap	0-18	13.1	27.50	19.19	8.31	8.31	1.44	11.97	0.12	
	Cr	18-150	95.0	29.03	22.73	6.30	0.32	1.34	0.43	0.00	
	2Cr	150-250	88.8	32.91	20.37	12.54	1.40	1.55	2.17	0.02	
	3Cr (R)	250+	96.2	21.01	17.52	3.49	0.13	1.26	0.16	0.00	
	3Cr (Y)	250+	94.7	38.21	21.02	17.19	0.91	1.26	1.15	0.01	2.2
	Ap	0-21	28.0	21.15	16.16	4.99	3.59	1.14	4.09	0.04	
26/951	Bt1-4Bt	21-122	13.4	26.52	20.01	6.51	6.51	1.55	10.09	0.10	
	5Bt1-6Bw2	122-270	0.1	27.37	19.70	7.67	7.67	1.46	11.20	0.11	
	7C-7Cr	270+	93.2	25.20	17.37	7.83	0.53	1.59	0.84	0.01	14.0

* Colluvial face (Profile 49) ** Residual face (Profile 42-E)

(G) = Glauconitic

(R) = Reddish coats (iron)

(Y) = Yellowish (iron and/or clay) coats

1 - Available water holding capacity

2 - Available water holding capacity adjusted for coarse fragments (>15% fragments)

3 - Total available water holding capacity for the top 150 cm of the soil profile (or to the upper boundary of hard saprolite)

were found in the alluvial and colluvial profiles (profiles 951, 26/951 and 49). Deeper soil profiles, loamy subsurface textures, and lower coarse fragment contents contributed to the higher available moisture values. Adjusted for bulk density, available water holding capacities averaged 0.20 cm^{-1} for alluvial materials and 0.10 cm^{-1} for colluvium. Examining the total available moisture values for the LLWDDD profiles, profiles 951, 26/951, 49, 42-E and 24-N had low available water holding capacity values (7.5 to 15 cm water per profile). All other profiles had very low available water holding capacity values ($< 7.5 \text{ cm}$ water per profile).

Chemical Characteristics

Cation Exchange Capacity and Exchangeable Acidity

Soil pH, total carbon, exchangeable acidity, exchangeable aluminum, and exchangeable hydrogen values are presented in Table 7. Cation exchange capacity, exchangeable bases, base saturation, and calcium carbonate equivalent values are presented in Table 8. Total carbon values for most profiles ranged from an average of 2.1 percent in A horizons to 0.2 percent in B and Cr horizons. Total carbon values in saprolites approached zero at 200 cm depth in most soil profiles. Soil pH values ranged from around 4.5 at the surface to slightly over 5.0 at a depth of 2 meters. An exception was found in profile 951, where a pH value >6.0 existed in the 3Cr horizon. Exchangeable

Table 7. pH, KCl exchangeable acidity, aluminum and hydrogen, and total carbon for soil profiles on the LLWDDD site.

Pit	Horizon	Depth cm	pH	Total carbon	KCl exchangeable acidity		
					Total	Al ³⁺	H ⁺
					-----	cmol(+) kg ⁻¹	-----
49 & 42-E	A-E*	0-14	4.65	2.76	3.2	2.6	0.6
	A-Bw**	0-16	4.71	2.13	3.7	3.3	0.4
	Bt1-Bt2	14-84	4.65	0.35	10.0	9.0	1.0
	2CB	84-102	4.81	0.16	10.6	9.8	0.8
	2Cr1	102-149	4.85	0.13	10.1	8.9	1.2
	2Cr2	149+	5.22	0.18	7.7	6.8	0.9
36-N	A	0-9	4.40	3.47	6.9	6.1	0.8
	Bw	9-29	4.62	0.56	8.8	8.0	0.8
	Cr1	29-130	4.72	0.15	16.6	15.5	1.1
	Cr2	130+	5.00	0.05	13.8	12.2	1.6
24-E	Ap	0-15	4.92	1.14	2.5	2.3	0.2
	Cr1	15-58	5.10	0.23	5.9	5.2	0.7
	Cr2	58+	4.90	0.11	6.0	5.4	0.6
951	Ap	20-28	4.35	1.81	2.9	2.1	0.8
	E1-E2	28-48	4.05	0.32	3.1	2.7	0.4
	Bt	48-76	4.42	0.22	8.5	7.6	0.9
	2E/B-2Btg	76-121	4.81	0.10	6.5	5.3	0.8
	3Cr	121+	6.29	0.24	0.3	0.3	0.0

Table 7. (Continued)

Pit	Horizon	Depth cm	pH	Total carbon	KCl exchangeable acidity		
					Total	Al ³⁺	H ⁺
				-- % --	----- cmol(+) kg ⁻¹ -----		
24-N	A-E	0-25	4.49	2.03	3.0	2.6	0.4
	Bw-Bt	25-66	4.58	0.31	10.9	9.7	1.2
	B/Cr	66-118	4.75	0.16	12.8	11.6	1.2
	Cr1 (G)	66-118	4.76	0.06	13.7	12.7	1.0
	Cr2	118+	4.84	-	13.7	12.6	1.1
36-E	A-Bw	0-25	4.46	2.64	8.5	7.8	0.7
	Cr1	25-200	4.76	0.18	14.4	13.4	1.0
	Cr1 (G)	100	4.35	0.23	20.3	18.6	1.7
	Cr2	200+	5.00	-	13.3	12.4	0.9
51-E	Ap	0-18	4.70	1.30	5.9	5.2	0.7
	Cr	18-150	4.81	0.08	12.7	12.0	0.7
	2Cr	150-250	4.95	0.10	13.0	12.4	0.6
	3Cr (R)	250+	4.82	0.25	10.9	10.2	0.7
	3Cr (Y)	250+	4.82	0.11	10.3	9.4	0.9
26/951	Ap	0-21	4.70	1.71	3.5	3.2	0.3
	Bt1-4Bt	21-122	4.91	0.12	7.0	6.9	0.1
	5Bt1-6Bw2	122-270	4.96	0.09	6.4	6.3	0.1
	7C-7Cr	270+	5.10	-	8.8	8.5	0.3

* Colluvial face (Profile 49) ** Residual face (Profile 42-E)

(G) = Glauconitic

(R) = Reddish coats (iron)

(Y) = Yellowish (iron and/or clay) coats

Table 8. Cation exchange capacity, exchangeable bases, percent base saturation, and calcium carbonate equivalents for soil profiles on the LLWDDD site.

Pit	Horizon	Depth cm	Exchangeable bases					pH	Ca ²⁺	Mg ²⁺	K ⁺	Na ⁺	Total bases	CEC	Base saturation %	Calcium carbonate equivalent
			----- cmol(+) kg ⁻¹ -----													
49 & 42-E	A-E*	0-14	4.65	2.52	0.59	0.24	0.03	3.38	13.50	25.0	-----	-----	-----	-----	-----	-----
	A-Bw**	0-16	4.71	2.82	1.12	0.31	0.03	4.28	13.46	31.8	-----	-----	-----	-----	-----	-----
	Bt1-Bt2	14-84	4.65	2.84	1.83	0.37	0.02	5.06	23.87	21.2	-----	-----	-----	-----	-----	-----
	2CB	84-102	4.81	0.10	0.82	0.28	0.02	1.22	23.87	5.1	-----	-----	-----	-----	-----	-----
	2Cr1	102-149	4.85	0.08	2.22	0.29	0.08	2.67	23.26	11.5	-----	-----	-----	-----	-----	-----
	2Cr2	149+	5.22	1.58	3.71	0.33	0.19	5.81	22.64	25.7	-----	-----	-----	-----	-----	0.49
36-N	A	0-9	4.40	1.98	0.58	0.28	0.03	2.87	18.97	15.1	-----	-----	-----	-----	-----	-----
	Bw	9-29	4.62	0.52	1.24	4.00	0.01	5.77	23.26	24.8	-----	-----	-----	-----	-----	-----
	Cr1	29-130	4.72	0.04	1.13	0.95	0.06	2.18	28.15	7.7	-----	-----	-----	-----	-----	-----
	Cr2	130+	5.00	0.52	2.16	0.26	0.16	3.10	26.32	11.8	-----	-----	-----	-----	-----	-----
24-E	Ap	0-15	4.92	5.01	1.48	0.31	0.01	6.81	18.36	37.1	-----	-----	-----	-----	-----	-----
	Cr1	15-58	5.10	3.68	2.02	0.31	0.03	6.04	23.26	26.0	-----	-----	-----	-----	-----	-----
	Cr2	58+	4.90	2.38	3.36	0.43	0.03	6.20	23.26	26.7	-----	-----	-----	-----	-----	2.50
951	Ap	20-28	4.35	0.42	0.12	0.05	0.02	0.61	8.57	7.1	-----	-----	-----	-----	-----	-----
	E1-E2	28-48	4.05	0.16	0.03	0.05	>0.01	0.24	6.12	3.9	-----	-----	-----	-----	-----	-----
	Bt	48-76	4.42	0.68	0.43	0.12	>0.01	1.23	15.97	7.7	-----	-----	-----	-----	-----	-----
	2E/B-2Btg	76-121	4.81	2.86	0.82	0.11	0.03	3.64	17.14	21.2	-----	-----	-----	-----	-----	-----
	3Cr	121+	6.29	17.02	2.72	0.18	0.01	19.93	22.03	90.5	-----	-----	-----	-----	-----	10.23

Table 8. (Continued)

Pit	Horizon	Depth cm	pH	Exchangeable bases					Total bases	CEC	Base saturation	Calcium carbonate equivalent
				Ca ²⁺	Mg ²⁺	K ⁺	Na ⁺	cmol(+) kg ⁻¹				
24-N	A-E	0-25	4.49	0.32	0.07	0.12	>0.01	0.51	9.18	5.6	-----	-----
	Bw-Bt	25-66	4.58	0.38	1.20	0.33	>0.01	1.91	25.70	7.4	-----	-----
	B/Cr	66-118	4.75	0.16	0.65	0.23	0.02	1.06	16.52	6.4	-----	-----
	Cr1 (G)	66-118	4.76	0.20	1.15	0.27	>0.01	1.62	21.42	7.6	-----	-----
	Cr2	118+	4.84	0.03	1.14	0.18	0.01	1.36	21.42	6.4	-----	-----
36-E	A-Bw	0-25	4.46	2.44	3.69	0.29	0.03	6.45	22.03	29.3	-----	-----
	Cr1	25-200	4.76	0.06	0.52	0.52	0.03	1.13	22.03	5.1	-----	-----
	Cr1 (G)	100	4.35	0.08	0.53	0.46	0.02	1.09	30.60	3.6	-----	-----
	Cr2	200+	5.00	0.02	1.23	1.38	0.09	2.72	23.76	11.7	-----	-----
51-E	Ap	0-18	4.70	1.12	0.44	0.27	0.02	1.85	15.30	12.1	-----	-----
	Cr	18-150	4.81	0.16	0.84	0.36	0.05	1.41	22.40	6.3	-----	-----
	2Cr	150-250	4.95	0.05	0.56	0.23	0.09	0.93	34.15	2.7	-----	-----
	3Cr (R)	250+	4.82	0.28	1.15	0.36	0.17	1.96	21.05	9.3	-----	-----
	3Cr (Y)	250+	4.82	0.14	0.91	0.23	0.06	1.34	20.56	6.5	-----	-----
26/951	Ap	0-21	4.70	2.10	0.66	0.28	0.03	3.07	13.22	23.2	-----	-----
	Bt1-4Bt	21-122	4.91	1.29	0.55	0.10	0.09	2.03	15.05	13.5	-----	-----
	5Bt1-6Bw2	122-270	4.96	0.31	0.45	0.17	0.03	0.96	16.77	5.7	-----	-----
	7C-7Cr	270+	5.10	0.26	0.93	0.24	0.04	1.47	17.75	8.3	-----	-----

* Colluvial face (Profile 49) ** Residual face (Profile 42-E)

(G) = Glauconitic

(R) = Reddish coats (iron)

(Y) = Yellowish (iron and/or clay) coats

aluminum values were lowest in A horizons, increased and reached a maximum in B horizons, and decreased in the Cr horizons. The amount of exchangeable acidity present was related to the amount of clay and iron oxides present. Exchangeable acidity in most LLWDDD site soils was dominated by aluminum.

Cation exchange values commonly ranged from 10 $\text{cmol}(+) \text{kg}^{-1}$ in A horizons to around 25 $\text{cmol}(+) \text{kg}^{-1}$ in B and Cr horizons. Values were slightly lower in alluvial and colluvial soils, due to a lower clay content, or less mineral weathering and clay formation and/or differing mineralogies. These cation exchange capacity values were higher than those commonly associated with soils dominated by kaolinitic minerals, thus some form of weathered vermiculite or illite most likely dominated clay mineralogy.

Average base saturation values for all profiles studied were less than 35 percent. The 3Cr horizon of profile 951 had artificially high base saturation due to the presence of free carbonates in the slightly weathered Rogersville Shale saprolite. This material had a calcium carbonate equivalent of 10.23 percent, and calcium carbonates were readily soluble in the neutral normal ammonium acetate solution used to extract the exchangeable bases. The 2Cr2 horizon of profile 49 and Cr2 horizon of profile 24-E were the only other horizons containing positive calcium carbonate equivalents; however, magnesium was still the dominant

exchangeable cation.

For residual soils, exchangeable bases were dominated by magnesium. Exceptions could be found in A horizons, where biotic activity was concentrated and calcium was recycled. The LLWDDD site soils, for the most part, were weathered to such a degree that calcium had leached from the upper two to three meters of the solum and saprolite. Exchangeable calcium did increase with depth, but seldom exceeded values of exchangeable magnesium. Exceptions can be found in profiles 24E and 36-E, where high exchangeable calcium values in the surface horizon may be the result of past liming practices.

Exchangeable calcium values were found to be highest in colluvial horizons of the soil profiles studied. In colluvial horizons of profiles 49 and 26/951, calcium dominated the exchange complex. Exchangeable calcium values may be higher in colluvial materials because processes have not been sufficient to completely leach out all carbonates, or there has been a recharge of carbonates from higher areas where there are limestone strata.

In all profiles studied, exchangeable potassium and sodium values were low. Weathering had been sufficient to remove most mineral forms of potassium and sodium. Exchangeable potassium values were, on average, equally distributed throughout all soil horizons. Exchangeable

sodium generally increased with depth, reaching a maximum in the lower Cr horizons. Exchangeable sodium values were highest in Cr horizons of profiles 49 and 42E. This could be expected, since the Maryville limestone is known to contain appreciable amounts of halite.

Iron and Manganese

Iron and manganese data are presented in Table 9. Sodium citrate-dithionite extractable iron oxide values ranged from 0.53 to 4.83 percent for the eight soil profiles studied (Table 9). Iron contents were highest in B and upper Cr horizons. Soils formed in the upper Pumpkin Valley Shales (profiles 24-N, 24-E), on average, contained the highest iron oxide content. This result was expected, since Pumpkin Valley parent materials contained large amounts of chlorite and glauconite, iron rich clay minerals (Lee et al., 1987). Weathering of chlorite and glauconite proceeded fairly rapidly, due to the upper Pumpkin Valley saprolite having relatively higher permeability rates. Iron contents in the upper Pumpkin Valley profiles were high deep into the saprolite. This indicates that weathering processes had penetrated the Pumpkin Valley Shale relatively deeply. Profiles 49 and 42-E also contained high amounts of iron oxides, indicating that weathering and iron movement had penetrated relatively deeply into the Maryville saprolite.

Profiles 951 and 26/951 contained the least amount of

Table 9. Sodium citrate - dithionite extractable iron and manganese and Hydroxylamine HCl reducible manganese for soil profiles on the LLWDDD site.

Pit	Horizon	Depth	CBD extractable		Hydroxylamine HCl reducible
			Free iron oxides	Free manganese oxides	Manganese
		cm	----- % -----		-1 -- mg kg --
49 & 42-E	A-E*	0-14	1.92	0.04	86
	A-Bw**	0-16	2.13	0.03	255
	Bt1-Bt2	14-84	3.67	>0.01	12
	2CB	84-102	3.99	0.01	26
	2Cr1	102-149	3.16	0.05	80
	2Cr2	149+	2.14	0.12	1200
36-N	A	0-9	1.24	0.09	795
	Bw	9-29	1.62	0.02	1
	Cr1	29-130	2.36	0.06	91
	Cr2	130+	2.27	0.32	3095
24-E	Ap	0-15	2.92	0.04	91
	Cr1	15-58	3.65	0.02	102
	Cr2	58+	3.28	0.34	2660
951	Ap	20-28	0.53	>0.01	41
	E1-E2	28-48	1.11	0.04	238
	Bt	48-76	1.39	0.01	98
	2E/B-2Btg	76-121	0.52	>0.01	14
	3Cr	121+	2.29	0.28	2700

Table 9. (Continued)

Pit	Horizon	Depth	CBD extractable		Hydroxylamine HCl reducible
			Free iron oxides	Free manganese oxides	Manganese
		cm	-----	% -----	-- mg kg ⁻¹ --
24-N	A-E	0-25	1.49	0.02	187
	Bw-Bt	25-66	4.35	0.00	8
	B/Cr	66-118	3.87	0.19	1460
	Cr1 (G)	66-118	4.17	>0.01	13
	Cr2	118+	2.30	0.12	1190
36-E	A-Bw	0-25	2.63	0.04	295
	Cr1	25-200	4.83	>0.01	10
	Cr1 (G)	100	3.93	>0.01	17
	Cr2	200+	2.47	>0.01	10
51-E	Ap	0-18	2.36	0.10	855
	Cr	18-150	2.62	0.18	1630
	2Cr	150-250	2.26	0.08	131
	3Cr (R)	250+	2.35	0.11	1225
	3Cr (Y)	250+	2.94	0.19	1595
26/951	Ap	0-21	2.14	0.03	246
	Bt1-4Bt	21-122	2.77	0.02	48
	5Bt1-6Bw2	122-270	1.92	0.01	53
	7C-7Cr	270+	4.09	0.02	135

* Colluvial face (Profile 49) ** Residual face (Profile 42-E)

(G) = Glauconitic

(R) = Reddish coats (iron)

(Y) = Yellowish (iron and/or clay) coats

free iron oxides. The colluvial Ap and Bt horizons of profile 26/951 contained appreciable amounts of iron, but deeper alluvial horizons had less iron. Free iron oxides increased in the 7Cr horizon, due to weathering of chloritic and glauconitic materials present in the Pumpkin Valley residuum. Profile 951 also contained low amounts of iron oxides within the alluvial horizons. The extremely low amounts of iron present in the 2Btg horizon suggested that reducing conditions persisted for an appreciable amount of time, and iron migration from the horizon had occurred. Iron oxides increased in the 3Cr horizon, where hard saprolite was encountered and iron had been translocated.

Dithionite extractable manganese values ranged from 0 to 0.3 percent in the nine profiles studied (Table 9). Manganese oxides reached maximum concentrations deep within the Cr horizons. Within the LLWDDD site soil profiles, manganese had migrated much deeper into the saprolites than had iron. Soil profile 51-E (developed on the Nolichucky Shale) contained the highest amounts of manganese oxides, and their distribution was nearly equal throughout the soil and saprolite profile. Alluvial profiles 951 and 26/951 were almost devoid of manganese oxides, with the exception of the 3Cr horizon of profile 951. The hard saprolite present in the 3Cr horizon restricted vertical flow of water, and manganese had accumulated on weathered rock surfaces and along fracture planes. Similar restrictions to

water flow in profiles such as 51-E had produced numerous iron and manganese coatings on saprolite fragment surfaces.

Hydroxylamine HCl reducible manganese values were commonly low (< 300 ppm) in A and B horizons and high (often >1200 ppm) in lower Cr horizons. Values were commonly lowest in B horizons. Hydroxylamine reducible manganese values were a good indicator of degree of mineral weathering and translocation of manganese in the soil system. With the highest values being found in lower Cr horizons of most profiles studied, weathering had progressed several meters into the saprolites. Manganese coatings could be seen on Cr materials. Exceptions were found in two soil profiles (36-E and 26/951), where only trace amounts of hydroxylamine reducible manganese occurred in deeper saprolites. These profiles were less weathered, relative to the other soil profiles.

Mineralogical Characteristics

X-ray Diffraction

X-ray diffraction data are presented in Table 10. The X-ray diffraction patterns are presented in Appendix B. Mineralogy was quantified by estimates made from x-ray diffraction peaks. The geologic formations of the LLWDDD site were high in illite. Of the geologic formations studied, the Cambrian aged Pumpkin Valley Shale contained the highest amount of illite (Lee et al., 1987). Both the

Table 10. Summary of clay mineralogy for soil profiles on the LLWDDD site.

Pit	Horizon	Depth cm	1 Minerals Present in Clay Fraction (< 0.002 mm)				
			2				
			Vermiculite	HIV	Illite	Kaolinite	Quartz
24-N	A-E	0-25	tr	H	tr	H	M
	Bw-Bt	25-66	L	M	L	H	L
	B/Cr	66-118	M	L	M	H	L
	Cr1 (G)	66-118	M	tr	tr	L	L
24-E	Ap	0-15	M	tr	L	H	M
	Cr1	15-58	M	tr	M	H	M
36-N	A	0-9	L	tr	M	M	M
	Bw	9-29	M	tr	M	L	M
	Cr1	29-130	H	ND	H	L	L
36-E	A-Bw	0-25	L	tr	M	H	M
	Cr1	25-200	L	tr	H	M	tr
49 & 42-E	A-E*	0-14	tr	M	L	tr	M
	Bt1-Bt2*	14-84	H	M	M	tr	L
	2Cr2	149+	M	L	M	tr	L
51-E	Ap	0-18	tr	L	M	tr	M
	Cr	18-150	L	tr	H	tr	tr
	3Cr (R)	250+	L	tr	H	tr	tr
	3Cr (Y)	250+	L	L	M	tr	tr
951	Ap	20-28	tr	M	ND	L	L
	Bt	48-76	M	tr	H	H	L
	3Cr	121+	M	tr	M	L	tr
26/951	Ap	0-21	L	M	L	H	M
	Bt1-4Bt	21-122	M	L	L	M	L
	5Bt1-6Bw2	122-270	M	M	L	H	L
	7C-7Cr	270+	H	tr	M	L	M

* Colluvial Face (Profile 49)

(G) = Glauconitic (R) = Reddish coats (Iron)

(Y) = Yellowish (iron and/or clay) coats

1- Mineral amounts present in the following relative terms as estimated from x-ray diffractograms:

ND = not detected, t = trace (<10%), L = low (10 - 20%),

M = moderate (20 - 30%), H = high (>30%)

2 - HIV = Al-hydroxyinterlayered vermiculites

unweathered Nolichucky and Pumpkin Valley Shales contained moderate to high amounts (10-20%) of chlorite and kaolinite. The chlorite weathered to vermiculite as the shales became leached and oxidized. The clay fraction of the uneroded soil formed on the upper Pumpkin Valley Shale (Profile 24-N) contained traces of vermiculite and illite, high amounts (>30%) of hydroxyinterlayered vermiculites (HIV) and kaolinite, and medium amounts (20-30%) of quartz in the A and E horizons. With depth in profile 24-N, vermiculite increased to medium amounts (20-30%), HIV decreased to trace amounts, kaolinite and quartz decreased to low (10-20%) amounts, and illite increased to medium amounts (20-30%). Trace amounts of illite were found in the glauconitic saprolite. Most of the kaolinite found in the soil and saprolite of profile 24-N was inherited from the parent rock.

Comparing the non-eroded (Profile 24-N) and eroded (Profile 24-E) soil formed on the upper Pumpkin Valley Shale, HIV amounts differed greatly. Because of severe erosion, most of the soil and some of the highly weathered saprolite of profile 24-E had been eroded. As a result, HIV was present in only trace amounts in profile 24-E.

Both non-eroded (Profile 36-N) and eroded (Profile 36-E) soils formed on the Rogersville Shale had similar clay mineralogies. Hydroxyinterlayered vermiculite was present in trace amounts or are not detectable in both soils. Also,

kaolinite was present in lower amounts, compared to the soils formed in the upper Pumpkin Valley Shale. The mineralogy data presented showed that the soils formed on the Rogersville Shale were less weathered than soils formed on the upper Pumpkin Valley Shale.

The colluvial soil found on the Maryville Limestone (Profile 49) contained traces of kaolinite but medium amounts (20-30%) of HIV. The colluvium (Profile 49) was highly weathered as indicated by the presence of trace amounts of kaolinite and medium amounts of HIV. The aluminum needed for HIV formation most likely came from the dissolution of kaolinite.

The soil formed on the Nolichucky shale (Profile 51-E) generally contained only trace amounts of kaolinite and HIV in the clay fraction. Profile 51-E contained a high amount of illite. This profile was only moderately weathered. Erosion had outpaced weathering and soil development, resulting in a lower presence of kaolinite and HIV. The clay coated saprolites (Horizon 3Cr (Y)) did contain higher amounts of HIV than iron coated saprolites. Such clay zones denoted water flow zones within the Nolichucky saprolite. These zones had experienced more intense weathering and clay translocation.

The old alluvial soil (Profile 951) was highly weathered. High amounts (>30%) of kaolinite were present in

the Bt horizon, and medium amounts (20-30%) of HIV could be found in the Ap horizon. The 3Cr horizon of Profile 951 was in the Rogersville Shale saprolite. The saprolite was not very weathered, as indicated by the medium amounts (20-30%) of illite and vermiculite and low to trace amounts of kaolinite and HIV. Kaolinite and HIV present in the saprolite was in clay zones between shale faces.

Profile 26/951 contained several discontinuities and weathering sequences. The first 122 cm of the soil profile contained old colluvium derived from the Pumpkin Valley Shale. The colluvium had been deposited long enough to experience a moderate to high degree of weathering. Kaolinite was present in high (>30%) to medium (20-30%) amounts. Hydroxyinterlayered vermiculites were present in medium (20-30%) to low (10-20%) amounts. Vermiculite, illite, and quartz were also present in medium to low amounts.

From 122 to 270 cm in profile 26/951, the soil was derived from alluvial parent materials. The alluvial sequence was also highly weathered, prior to being buried by colluvium. Amounts of clay fraction kaolinite, HIV, illite, vermiculite, and quartz were similar to those present in the colluvium. Visual observations of clay skins on alluvial ped faces suggested that some of the clays found in the alluvial sequence had been translocated from the overlying colluvial materials.

The final sequence present in the 26/951 profile was derived from the Pumpkin Valley Shale residuum. The residual soil and saprolite contained only trace amounts of HIV and low amounts (10-20%) of kaolinite. Quartz, vermiculite, and illite were present in medium amounts (20-30%). These materials were moderately weathered but still maintained a moderate parent material mineralogy (vermiculite, illite, and quartz).

Landform Development

Soil and landform development is a function of the five factors of soil formation; climate, relief, biota, time, and parent materials. Although climate was the most important factor in driving the forces of geologic weathering and soil development, differences in soil development due to climate on each of the four major geologic rock units present on the LLWDDD site were minor. In soils developed on the Rogersville Shales, however, parent material and slope influences were most likely as important as climate in controlling soil development. The Rogersville Shale landform was the only landform on the LLWDDD site which rests on steep obsequent slopes. Geologic parent materials dipped perpendicular to the soil surface and past geologic weathering was concentrated on ends of the shale bodies rather than along bedding planes. The Rogersville shale saprolite, however, was highly impermeable to water

movement. This has resulted in slower weathering rates and less soil development, despite the Rogersville saprolite bedding planes being near vertical and being more susceptible to water infiltration. More importantly, the steep slopes on which the soils of the Rogersville Shale formed has increased erosion and decreased water infiltration. The effect of slope and geologic parent materials can be seen in Figures 9 and 10, which are transect investigations of major geologic formations found on the LLWDDD site. Geologic and accelerated erosion outpaced soil development on much of the Rogersville landscape, leading to shallow soils. Clay, iron, and manganese formation and movement had been restricted to zones within the saprolite where shattering of shale bodies had occurred due to faulting. These were the zones where water was able to penetrate the raw, partially weathered saprolites. The presence of higher concentrations of manganese oxides (Table 9) denoted areas where vertical water movement was slowed or stopped.

Soils formed on the upper Pumpkin Valley Shale (Profiles 24-N, 24-E) had been highly weathered. They existed on south aspect slopes of Pine Ridge and were underlain by permeable glauconitic and illitic sandstones and shales. These soils have recieved more direct sunlight than have those formed on the Rogersville Shale. As a

result, the soils of the upper Pumpkin Valley Shale have undergone more wet-dry cycles which promotes more clay translocation into the B horizons (Table 3). Also, lower slope gradients decreased susceptibility to erosion. On uneroded sites, clay percentages exceeded 45 percent in Bt horizons, and these clays (as well as the whole soil) contained a high percentage of iron oxide coatings (Table 9). Slightly and moderately eroded soils formed on the upper Pumpkin Valley Shales were high in kaolinite and Al-hydroxyinterlayered vermiculite (Table 10). High iron contents extended well into the saprolites. The iron most likely originated from the chloritic and glauconitic (ferrous illite) materials inherent in the saprolites and hard rock. Soil hues on uneroded sites often were 5YR to 2.5YR. Because of the apparent permeability of saprolites, weathering had proceeded quite deeply. The saprolites were soft and did not refuse auger penetration to depths approaching one meter. These properties were passed on to the overlying soils. The loamy textures of A horizons permitted excellent infiltration, and the B horizons allowed for considerable vertical water flow. Based on the data of profile 24-N, residual soils formed on the upper Pumpkin Valley Shale had the highest available water holding capacity of all residual soils. This property enhanced the ability of these soils to resist erosive forces, as well as providing adequate moisture for vegetation. Evidence of

thicker soils on the upper Pumpkin Valley Shale could be seen in Figure 9. Also, the transect results showed extreme variability of soil development due to parent materials. More permeable beds of parent materials produced deeper soils. The permeable parent materials were cyclically alternating with more resistant, less permeable parent materials.

The chemical data (Tables 7 and 8) are other indicators of the intense weathering of upper Pumpkin Valley soils. The uneroded profile (24-N) had the lowest base saturation and calcium carbonate equivalent values of any soil profile studied. The unweathered upper Pumpkin Valley shale probably had the lowest carbonate content of any geologic formation within the LLWDDD site. Exchangeable acidity values were also the highest in any profile. Although exchangeable aluminum dominated the exchangeable acidity, exchangeable hydrogen values were somewhat higher than those found in other profiles. Although carbonates were present in low quantities throughout the Pumpkin Valley Shales, weathering processes had removed them from the uppermost saprolites. Evidence of small quantities of carbonates were found in the saprolite of the very highly eroded soil profile 24-E (Table 8), where a measurable calcium carbonate equivalent was found in the lower saprolite. Past farming and foresting activities have stripped the soil and some of

the uppermost saprolite from this site, bringing relatively fresh, less weathered materials closer to the surface.

A soil and landform development study was conducted on the soils formed on the lower Pumpkin Valley Shale. The lower Pumpkin Valley Shale occupied the south aspect spur ridges of Pine Ridge. Six transects were completed on selected spur ridges (Figure 11). Each transect consisted of nineteen data points. Looking at 114 transect points, the correlation between Bt horizon and solum thicknesses were very good ($r = 0.88$) (Figure 12). This suggests that Bt horizon development has influenced solum and soil stability on the lower Pumpkin Valley Shale. Thick Bt horizons developed over several thousand years, and are stable due to their high degree of permeability. Permeability traits of thick Bt horizons are inherited from parent materials. The lower Pumpkin Valley Shale contains glauconitic sandstones which have been observed to be permeable. A highly permeable Bt horizon reduces runoff and erosion, as well as supplying adequate moisture for further leaching and weathering of saprolites.

Slope gradient appeared to have an influence on soil development and stability for soils formed on the lower Pumpkin Valley Shale. Comparing slope gradients with residual Bt horizon thicknesses (Figure 13), slope gradients appear to have a curvilinear response on residual Bt thicknesses. On an average, Bt horizons did not develop on

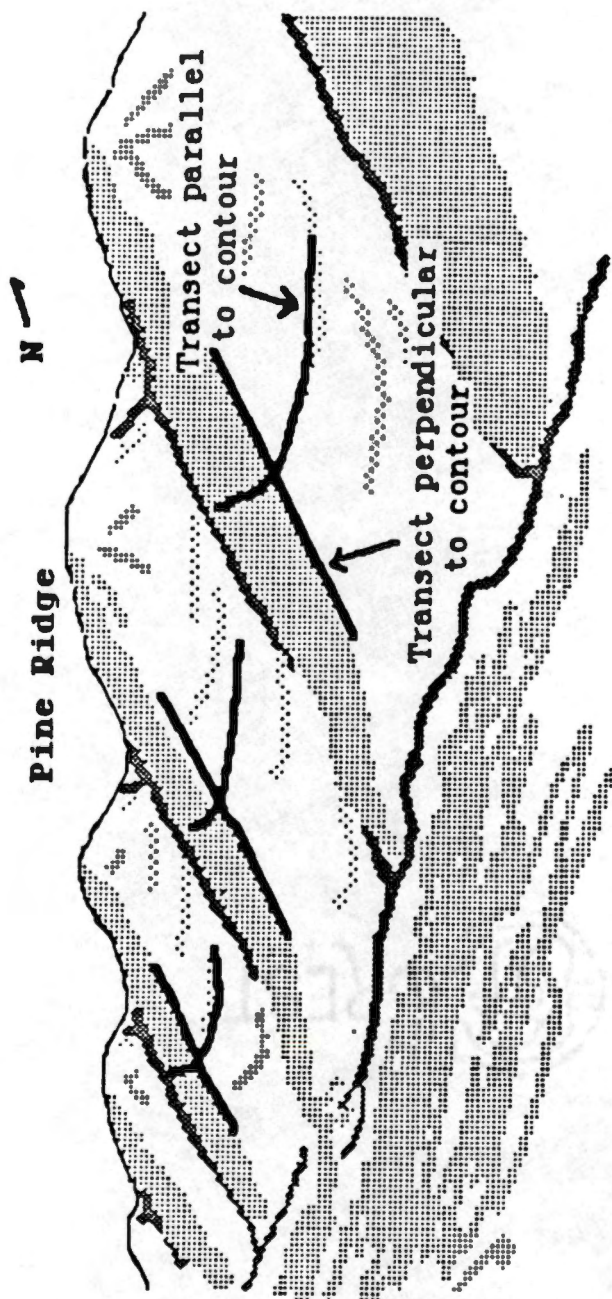


Figure 11. Illustration of transect placement on spur ridges of Pine Ridge.

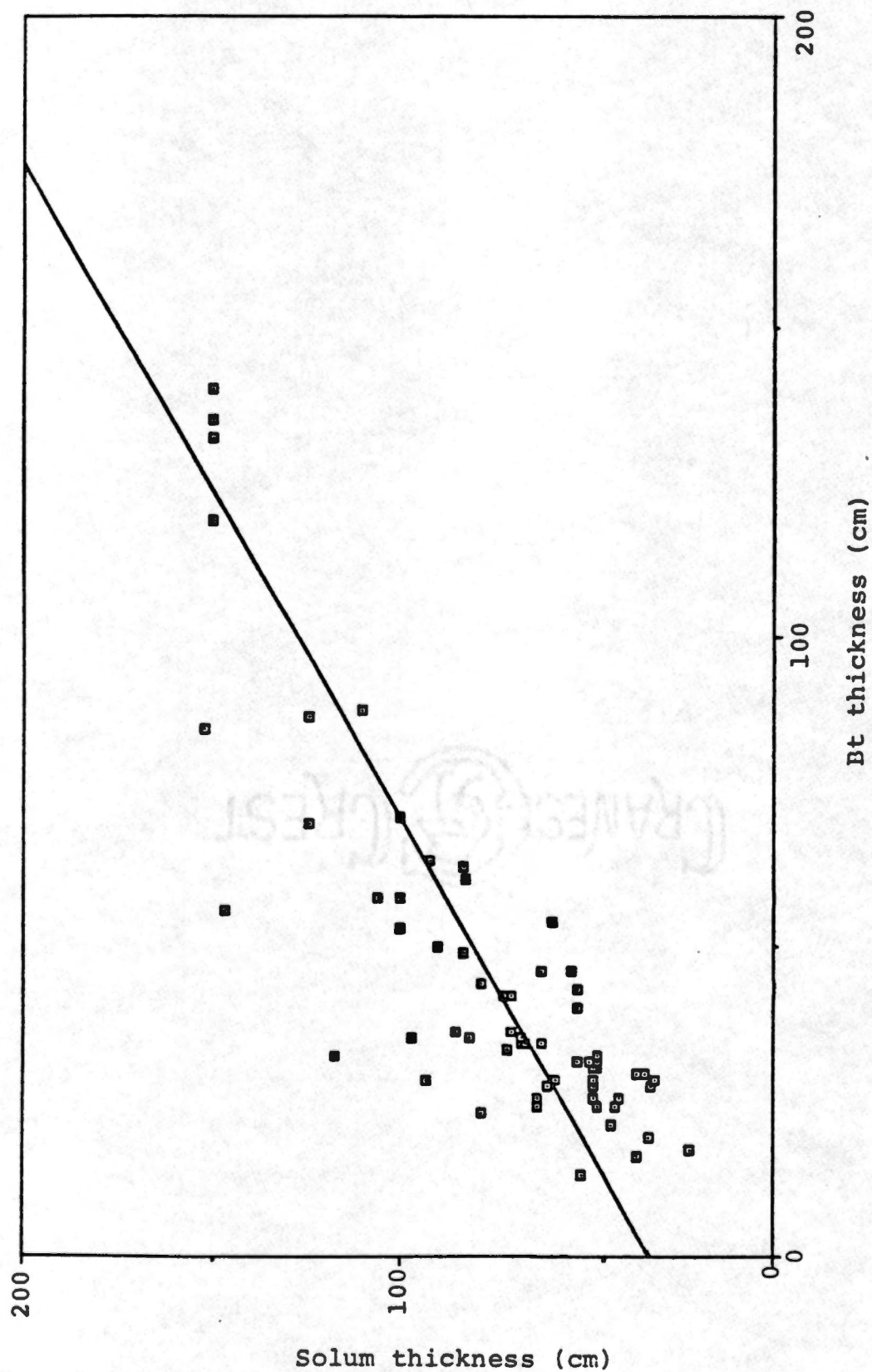


Figure 12. Correlation between Bt horizon and solum thickness for six spur ridges of Pine Ridge.

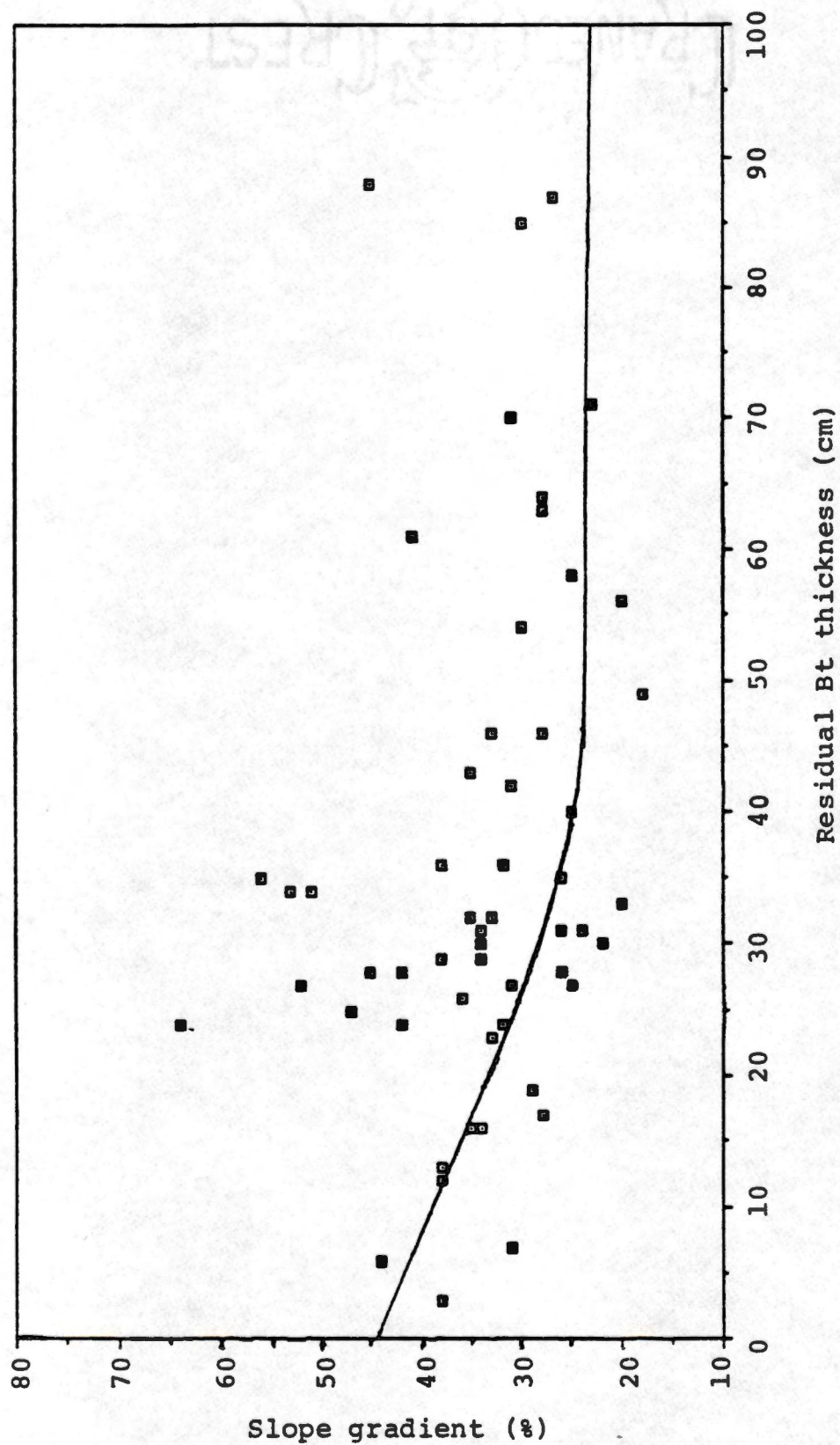


Figure 13. Comparison of Bt horizon thicknesses and slope gradients for six spur ridges of Pine Ridge.

slopes greater than 45 percent. Exceptions could be found in soils blanketed with colluvium. For slopes less than 45 percent, Bt horizon thicknesses increase exponentially as slope gradients decrease. Increasing Bt thicknesses likely resulted from decreased runoff velocities and lowered erosion potentials. Potential for soil creep also likely decreased with decreasing slope gradients. Lower slope gradients promoted increased soil stability to the degree that weathering outpaced erosive forces and Bt horizons were able to develop. As slope gradients approached 45 percent, a threshold was reached where erosion equalled or outpaced weathering.

Parent materials also played a significant role in soil development and stability. The lower Pumpkin Valley Shale consisted of shales, siltstones, silty sandstones and glauconitic sandstones. Residual Bt horizon thicknesses (Table 11) were greatest on glauconitic sandstones and siltstones. Shales produced relatively shallow soils. Because of different weathering rates among parent materials, highly variable soil thicknesses were found on transects that ran perpendicular to geologic strike. Soil variability was cyclic perpendicular to geologic strike, due to the cyclic occurrence of different parent materials.

Soil color and texture were found to be a good indicator of soil development on the soils formed from the lower Pumpkin Valley Shale. As Bt horizon and solum

Table 11. Comparison of Bt horizon and solum thickness to soil texture, dominant soil color hue and parent materials.

	<u>Soil texture</u>				<u>Dominant Munsell color hue</u>				<u>Parent materials</u>		
	C ¹	CL ²	L ³	VFSL ⁴	2.5YR	5YR	7.5YR	10YR	Silt. ⁵	S.S. ⁶	Sh. ⁷
Bt horizon thickness (cm)	42	28	8	5	47	36	22	6	13	23	12
Solum thickness (cm)	76	55	38	30	84	63	39	28	47	48	42

- 1 - C - clay
- 2 - CL - clay loam
- 3 - L - loam
- 4 - VFSL - very fine sandy loam
- 5 - Silt. - siltstones
- 6 - S.S. - greenish glauconitic sandstones
- 7 - Sh. - purplish and brownish shales

thicknesses increased, soil colors became proportionally redder. Argillic horizons generally were not present or were extremely thin when soil color hues were 10YR. Cambic (Bw) horizons dominated soils with these hues. As soils weathered, secondary clay minerals developed and migrated. The lower Pumpkin Valley Shale had abundant iron-rich minerals such as chlorite and glauconite. Increased weathering of primary minerals destroyed rock structure, increased soil thicknesses and produced increasing amounts of iron oxides. The increased presence of iron oxides coated clay surfaces and gave the soils a redder color. As a result, soils having dominant color hues of 2.5 YR had the greatest solum and Bt horizon development. With respect to soil texture, very fine sandy loam textures were present in soils with Bw and thin Bt horizons. Weathering had not proceeded to a great degree in these soils, and the soil mineralogy was composed of primary minerals from the parent materials. As soil Bt horizons developed and increased in secondary clay minerals, soil thickness increased proportionally. Differential scanning calorimetry of selected Bt and Bw horizons (Table 12) showed an increase in hydroxyinterlayered vermiculite (HIV) and kaolinite as subsurface horizonation became more pronounced and Bt horizons developed. Kaolinite dissolution under acid conditions most likely provided aluminum for the formation of HIV. Further weathering increased clay contents, leading

Table 12. Mineralogy of parent materials and subsurface horizons for six transects on spur ridges of Pine Ridge.

Minerals ¹	<u>Parent materials</u>			<u>Subsurface horizons</u>	
	Silt. ²	S.S. ³	Sh. ⁴	Bt	Bw
	-----	& -----		-----	& -----
Kaolinite	7	6	1	7	4
Quartz	20	33	35	23	31
Hydroxyinter-layered vermiculite (relative amounts)	XX	X	t	XX	t

¹ - Mineralogical analysis done using a differential scanning calorimeter (DSC)

² - Silt. - siltstones

³ - S.S. - greenish glauconitic sandstones

⁴ - Sh. - purplish and brownish shales

XX - moderate amounts X - small amounts t - trace

to soils with higher percentages of clay.

There was a relationship between the widths of Pine Ridge spur ridges and degree of colluviation on the lower Pumpkin Valley Shale landforms. The size of spur ridges was controlled by the presence of localized spur faults. Spur ridges ranged in width from less than 50 meters to more than 85 meters. The data for Bt horizon, solum and colluvium thicknesses and slope gradients are given in Table 13. Colluvial deposition was greatest on spur ridges with widths greater than 50 meters (Figure 14). Narrow spur ridges were blanketed with only thin layers of colluvium. The presence of large amounts of colluvium on broader spur ridges was likely due to lower slope gradients and slower runoff rates. Also, narrow spur ridges offered a smaller area over which colluvium could be deposited. Thus, broader spur ridges are more stable with respect to colluvial deposition.

Broad spur ridges were also more stable for soil development. Decreased slope gradients tend to reduce runoff and allow for more infiltration. As a result, soil weathering could outpace erosion and Bt horizons could develop and thicken.

Overall, soil development and landform stability on the lower Pumpkin Valley Shale was influenced by slope gradient and type of parent material. Lower slope gradients and permeable parent materials decreased the erosion potential and weathering of primary minerals outpaced erosion. This

Table 13. Average Bt horizon, solum, and colluvium thicknesses, and slope gradients for six transects on spur ridges of Pine Ridge.

	Transect (and width class)	Bt horizon thickness	Solum thickness	Depth of colluvium	Slope gradient
	--- meters --	----- cm -----	-----	-----	--- % --
1	>85	43	92	53	34
2	50-85	10	44	0	38
3	<50	17	42	0	36
4	<50	8	37	25	46
5	50-85	40	68	77	37
6	>85	39	67	55	40

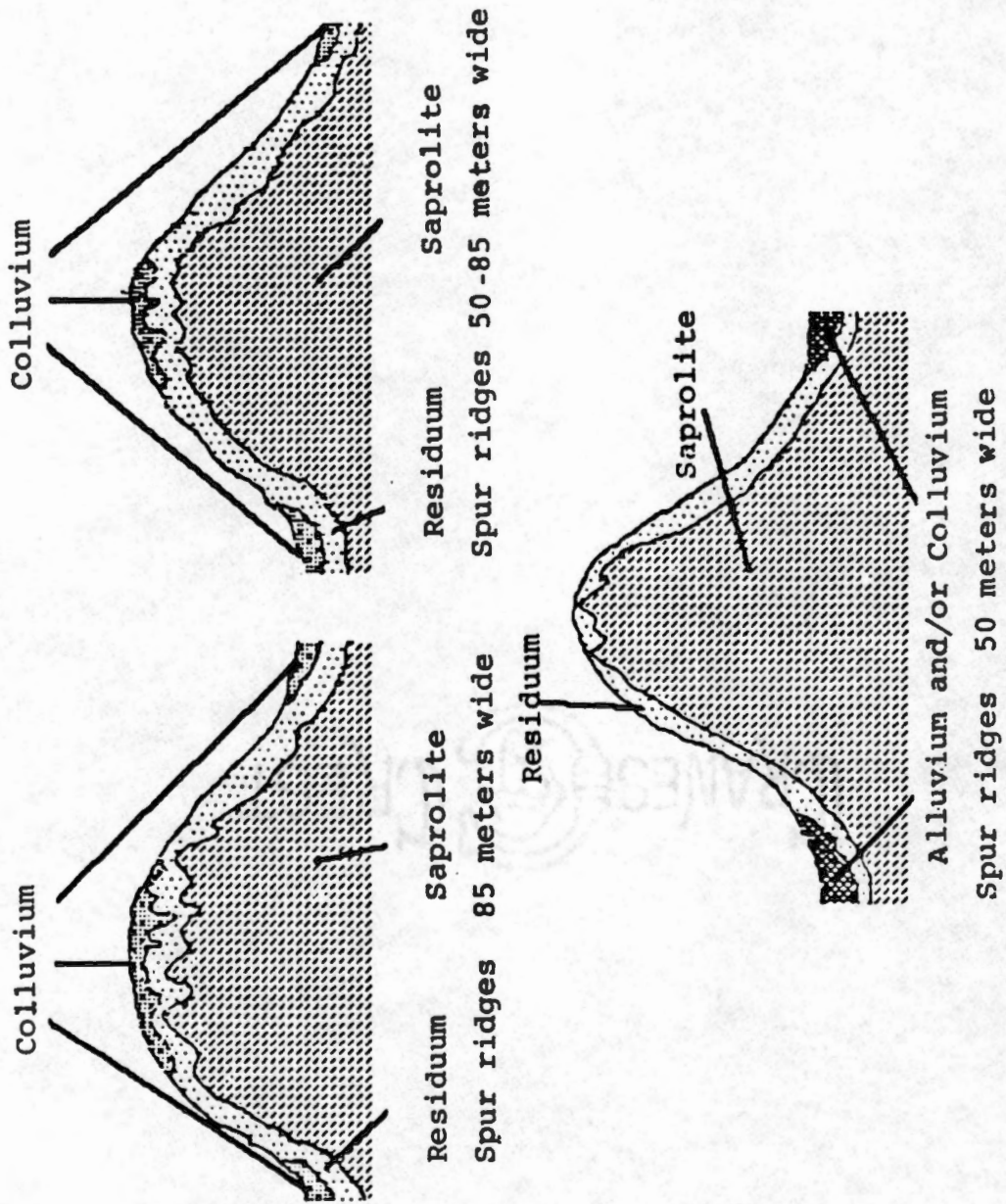


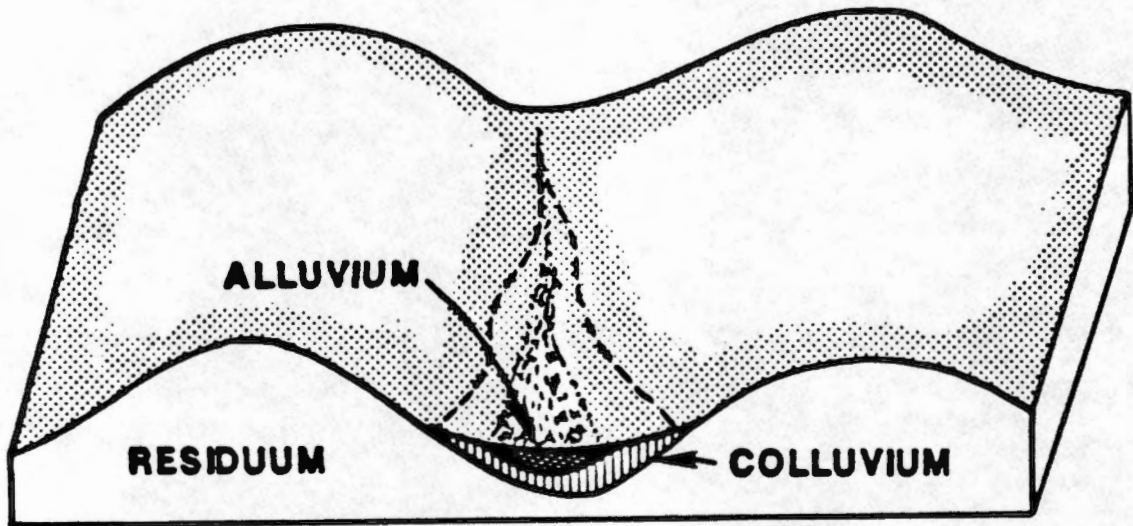
Figure 14. General cross-sections of the three spur ridge groups found on Pine Ridge.

led to soils that have maintained stability and development over time. The degree of soil development could be estimated by the texture and color of the B horizon. Soils were most stable on spur ridges with widths greater than 50 meters having slope gradients less than 45 percent.

Both the upper and lower Pumpkin Valley Shales have undergone significant episodes of colluviation in the past. During the Pleistocene, climatic conditions were such that soils on the Pumpkin Valley Shale were unstable. Intense freeze-thaw cycles and runoff likely caused large amounts of soil and saprolite material to flow through drainageways, choking them with coarse sediments (Lietzke et al., 1988). The streams diverted to the sides of choked streambeds, and cut into the residuum and saprolites. By the time the climate became less severe, new stream channels had developed in positions once occupied by spur ridges, and old stream channels were now in the higher positions of the landscape. This form of topographic reversal is diagrammed in Figure 15.

Overall, three major episodes of colluviation have been identified on the south aspect of Pine Ridge. The oldest colluviation probably occurred at the outset of Pleistocene climatic instability. The second most likely occurred in late Pleistocene. The latest was Holocene in origin, and the soils show minimal soil horizonation. The second colluvial episode was represented in profile 26/951.

DURING PLEISTOCENE



MODERN TOPOGRAPHY

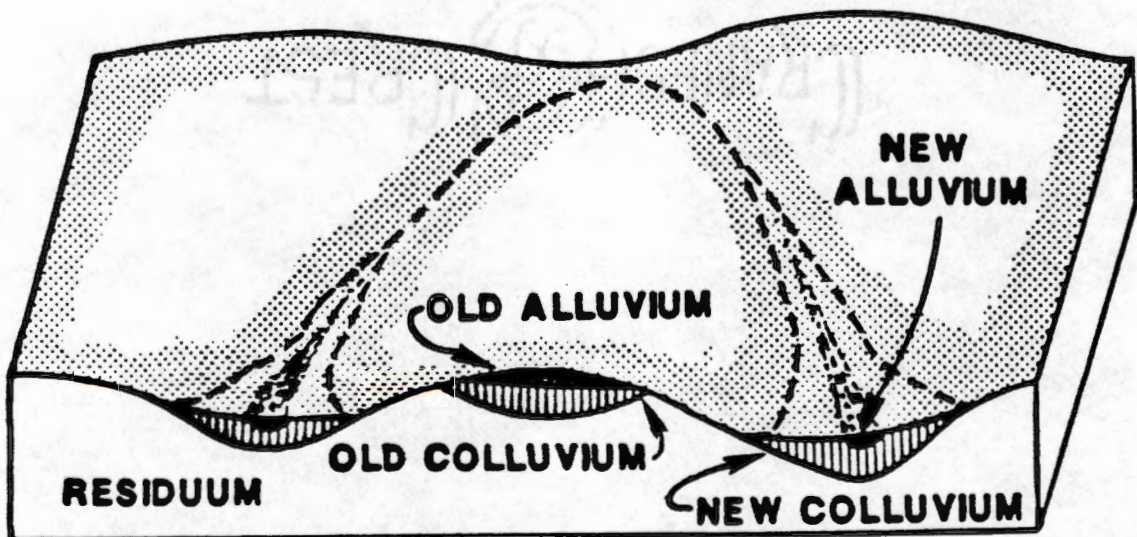


Figure 15. Diagram of topographic reversal (After Lietzke et al., 1988).

Alternating bands of weathered shale chips and clay-rich argillic horizons in the upper 146 cm of profile 26/951 denoted moderately old colluviation of Pumpkin Valley materials. This material had a clay loam texture (Table 3), and was moderately weathered (as shown by iron oxide content in Table 9). This material covered considerable areas of the lowermost slopes of the south aspect of Pine Ridge, but was found to be less than two meters thick.

Soils formed on the Maryville Limestone (Profiles 49 and 42-E) were found on the south aspect of a smaller lateral ridge southeast of Pine Ridge. These soils formed under climatic and topographic conditions similar to those that favored weathering of Pumpkin Valley Shale. Parent materials, however, differed. The Maryville parent materials were initially higher in limestones, which delayed saprolite weathering and clay formation. Evidence of residual carbonates was found in the lower saprolites (Table 8) by the presence of measurable calcium carbonate equivalents and higher amounts of exchangeable calcium. Residual B horizons were quite high in clay when soils were on low sloping landforms. But on steep slopes (>25%), shallow residual soils (Ruptic-Ultic and Typic Dystrocrepts) with Bw and intermittent shallow Bt horizons were common (Figure 10). These soils, like those found on the Pumpkin Valley Shale, showed extreme soil variability with respect to depth and development.

The residual soil profile on the Maryville Limestone contained a shallow A and Bw horizon (0 - 16 cm) over saprolite in various stages of weathering. The solum (A and Bw horizons) contained very little clay (Table 3) with low amounts of free iron oxides (Table 9). Available water holding capacities (cm cm^{-1} soil) were somewhat lower than those found in the Pumpkin Valley soils (Table 6). The saprolite was highly weathered to about 150 cm, where the weathered rock became massive and water movement was restricted (as indicated by accumulations of manganese oxides (Table 9)).

The colluvial profile of the soil formed on the Maryville Limestone (Profile 49) was a cut along the long axis of an old gully fill. Gully fills, such as this one, were common on Maryville and Pumpkin Valley landscapes (Figure 10). The profile 49 gully fill was 84 cm thick. This colluvium has been in place for some time and was highly weathered. The Bt horizon contained a high percentage of clay (Table 3) and free iron (Table 9). The colluvium was younger than the underlying residuum, as indicated by the dominance of exchangeable calcium on soil exchange sites (Table 8). The colluvial materials contained calcium bearing coarse fragments, which have not completely weathered. The colluvium did have a moderate to high available water holding capacity (Table 6), and appeared to

be more permeable than the associated residual soil. This appeared to be common to all soils developed on the Maryville Limestone which were investigated.

The Nolichucky Shale underlies low-lying, gently to moderately sloping landforms between the Maryville Limestone ridge and Bear Creek. Profile 51-E represented the typical soils found on the Nolichucky Shale. These soils formed on massive, interbedded shale and argillaceous limestone parent materials. Due to the lower calcium carbonate content, Nolichucky parent materials were more highly weathered than Maryville parent materials. Free iron and manganese contents (Table 9) were high throughout the soil and saprolite profile. Both iron and manganese had migrated through macropores and cracks, deeply into the saprolite. Exchangeable acidity values (Table 7) were high, and base saturation values (Table 8) were low. These chemical indicators show that the soils formed on the Nolichucky Shale were highly weathered.

Because of the relative impermeability of the Nolichucky Shale saprolite, even on gently sloping landscapes, overland runoff and surface erosion had been quite severe. As a result, saprolites occurred close to the surface. These soils were used for agriculture prior to the 1940's, and much of the soil had been eroded away as a result. The remnants of the soil solum existed as tonguings of Bt and Bw material that penetrated into the more

permeable saprolite zones. These tonguings were often the residual remains of thin strata of weathered limestones that alternated with the harder shale saprolites.

The LLWDDD site contained a large expanse of old alluvium (Profiles 951 and 26/951), which rests on terraces above Bear Creek (Figure 9). These soils contained higher amounts of sand and silt, most of which occurred in the coarse silt and very fine sand fractions (Table 3). This material was most likely deposited in a slow water (backwater or lake) environment. Based on the relatively uniform particle size of the old alluvial sediments, water velocities at the time of deposition were calculated to be less than 0.3 cm sec^{-1} (Hjulstrom, 1939). The old alluvium was most likely deposited by either the damming of Bear Creek or by backwater flooding from the Clinch River. The alluvial soils, due to their high silt and very fine sand contents, had the highest available water holding capacities of any soils on the LLWDDD site (Table 6). Free iron and manganese oxide contents (Table 9) were not high, possibly because of reduction and losses from the soil profiles. These soils have high water tables which promote reducing environments. The lower soil horizons of these profiles were gleyed. The soils have been weathered to some extent, as indicated by low base saturation and exchangeable calcium values (Table 8), and high exchangeable acidity values

(Table 7). Based on the data presented for the nine profiles studied, the soils formed on the Pumpkin Valley Shale were most highly weathered. The order of weathering and soil formation for soils found on the four geologic formations of the LLWDDD site were as follows:

Upper Pumpkin Valley > Nolichucky > Maryville > Rogersville.

The upper Pumpkin Valley Shale was more permeable and contained an initially low calcium carbonate (limestone) content (Lietzke et al., 1988). The Nolichucky Shale also contained few limestone lenses, but the saprolite was less permeable. The high limestone content of the Maryville Limestone greatly limited soil development. Finally, the least weathered soils were found on the Rogersville Shale due to steep slopes and low permeability of the shales.

CHAPTER V

SUMMARY

The landform and soil development study took place on the LLWDDD site in an attempt to characterize the major soils present and to gain an understanding of the relationship between factors of soil formation and soil development. Nine soil and saprolite profiles were characterized, using standard soil survey techniques. A transect study was also conducted on the soils of the lower Pumpkin Valley Shale. Residual soil profiles 24-N, 36-N, 36-E, 42-E and 51-E were classified as Ruptic-Ultic Dystrochrepts. Soil profile 24-E, a very highly eroded residual soil, was classified as a Typic Udorthent. Colluvial and alluvial soil profiles 49, 26/951 and 951 were Typic Hapludults.

Chemical analyses indicated that the soils were moderately acid, had cation exchange values ranging from 10 to 30 $\text{cmol}(+) \text{ kg}^{-1}$. Magnesium was the dominant exchangeable ion in residual soils. Iron and manganese had translocated through the solum into the underlying saprolite in highly weathered soils. Bulk density values ranged from 1.2 Mg m^{-3} in A horizons, to 1.5 Mg m^{-3} in B and 1.6 Mg m^{-3} in Cr horizons. Particle density values ranged from 2.60 Mg m^{-3} in A horizons, to 2.66 Mg m^{-3} in B and 2.73 Mg m^{-3} in Cr horizons. Atterberg Limits data indicated that LLWDDD site

soils contained neutral activity clays (kaolinite and illite) with low shrink-swell potential.

The presence of kaolinite, illite, vermiculite, and Al-hydroxyinterlayered vermiculites (HIV) in LLWDDD soils was confirmed by x-ray diffraction analysis. Illite and vermiculite was present in moderate to high amounts in most LLWDDD saprolites. High amounts of kaolinite was present in Pumpkin Valley Shale saprolites. Moderate to high amounts of HIV were present in highly weathered soils formed on the Pumpkin Valley Shale. Less weathered soils formed on the Rogersville Shale contained HIV in trace amounts.

Soils formed on the upper Pumpkin Valley Shale had been weathered the most, as indicated by high clay contents, low exchangeable calcium and base saturation values, and high exchangeable aluminum and iron oxide contents. Soil formation on the lower Pumpkin Valley Shale was greatly influenced by slope and parent material permeability. Permeable glauconitic sandstones produced soils with the thickest Bt horizons. Broader spur ridges promoted increased soil stability, colluviation and weathering. Evidence of Pleistocene landform instability and topographic reversal was found on the Pumpkin Valley Shale. Soils formed on the Rogersville Shale were least weathered as a result of occupying north aspect obsequent slopes, where steep slopes increased runoff and erosion. Soils formed on

the Maryville Limestone and Nolichucky Shale were highly weathered, but steep slopes and/or lower permeability rates had allowed anthropogenic erosion to remove most of the soil profile.

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APPENDICES



APPENDIX A: Soil Profile Descriptions



Soil No: 51-E (Soil Derived from Cambrian aged Nolichucky shale)

Location: LLWDDD Site. E30230, N29250 Y-12 grid

Classification: Ruptic Ultic Dystrochrepts; loamy-skeletal, mixed, thermic.

Pedon Classification: Ruptic Ultic Dystrochrepts; loamy-skeletal, mixed, thermic.

Geomorphic Position: Upper slightly convex sideslope of low hillsides.

Slope: 4% with southeast aspect.

Parent material: Nolichucky saprolite (Saprolite from claystone, siltstone and argillaceous limestone along with thin strata of very fine sandy loam).

Described by: Lambert, Lietzke and Jenkins. March 13, 1987

Notes: Because of the ruptic nature of the soil, it was necessary to describe three profiles in order to encompass the "cyclic" variability of one pedon.

Part 1 - ULTIC PORTION

Oi 2 to 0 cm; leaf litter

Ap 0 to 18 cm; Dark yellowish brown (10YR 4/4) silt loam; moderate fine granular structure; very friable; many fine and medium roots between peds; many fine pores; pH 4.7; abrupt wavy boundary.

Bt 18 to 33 cm; Mottled yellowish red (5YR 5/8), yellowish brown (10YR 5/6) and strong brown (7.5YR 5/6) silty clay; moderate medium subangular blocky structure; firm; common fine prominent brownish gray (10YR 6/2) mottles in ped interiors; many continuous and distinct brown (7.5YR 5/4) clay films on ped faces; few fine and medium roots between peds; common fine pores; pH 4.8; clear irregular boundary. (Argillic Horizon part of pedon)

BC 33 to 64 cm; Strong brown (7.5YR 5/6) shaly silty clay loam; weak medium subangular blocky structure; firm; common medium prominent light brownish gray (2.5Y 6/2) mottles in ped interiors; many continuous distinct brown (7.5YR 5/4) clay films on ped faces and coating rock fragments; common discontinuous prominent red (2.5YR 4/6) iron stains on some ped faces; common fine and medium roots; few to common pores; pH 4.8; abrupt inclined boundary. (Thin sandstone strata are 10YR 6/8)

- C 64 to 71 cm; Strong brown (7.5YR 5/6) very shaly clay loam; massive rock controlled structure; firm; common discontinuous faint brown (7.5YR 5/4) clay films on rock fragments; few fine roots in cracks; common fine pores; about 50% shale and siltstone fragments; pH 4.8; abrupt inclined boundary.
- 2CB 71 to 81 cm; Yellowish red (5YR 5/6) clay; massive; firm; many discontinuous distinct brown (7.5YR 5.4) clay films on fracture and joint faces; few fine roots; few fine pores; pH 4.8; abrupt irregular inclined boundary. (Argillaceous limestone saprolite stratum sandwiched between shale and siltstone saprolite)
- 3Cr 81 to 92 cm; Oxidized and leached saprolite from siltstone and shale; fragment interiors are brown (7.5YR 5/6); common discontinuous prominent red (2.5YR 4.6) iron-clay films on fragment faces; water flow zones are light brownish gray (2.5Y 6/2).
- 4Cr2 92 to 100 cm; Oxidized and leached saprolite from siltstone and claystone ; fragment interiors are 10YR 5/6 and 7.5YR 5/6; very firm; many discontinuous prominent red (10R 4/8) stains on fragment faces; few discontinuous distinct strong brown (7.5YR 4/6) clay coatings on fragment faces in flow zones; very few fine roots in flow zones; pH 4.8.

Part 2-- Located about 3 feet away from Part 1.
RUPTIC PORTION

- Oi 2 to 0 cm; leaf litter; abrupt smooth boundary
- Ap 0 to 20 cm; Dark yellowish brown (10YR 4/4) silt loam; moderate fine granular structure; very friable; many fine roots throughout; many fine and medium tubular pores; pH 4.7; abrupt wavy boundary.
- Bw 20 to 40 cm; Brown (7.5YR 5/4) extremely shaly silty clay loam; weak medium subangular blocky structure; firm; many continuous faint brown (7.5YR 5/4) clay films on some ped faces and on most shale fragments; few fine roots; many pores; pH 4.8; clear irregular inclined boundary. (Cambic part of soil profile).

Cr 40 to 70 cm; Oxidized and leached saprolite from claystone and siltstone; fragment interiors have (10R 4/8) iron coatings on some fragment faces; common discontinuous prominent black manganese coatings on other fragment faces; many discontinuous brown (7.5YR 5/4) clay films on other rock fragments in more permeable zones; water flow zones have gray (10YR 5/1) streaks; root mats continue down through gray areas; pH 4.8.

Part 3 located about 3 feet away from Part 2
RUPTIC PORTION

Ap 0 to 18 cm; Dark yellowish brown (10YR 4/4) silt loam; weak fine granular structure; very friable; many fine and medium roots between peds; many fine pores; pH 4.7; abrupt wavy boundary

Cr 18 to 30 cm; Oxidized and leached saprolite from siltstone and claystone; fragment interiors are (10YR 5/6 or 7.5YR 5/6) rock controlled structure; very firm; fragments are coated with either brown (7.5YR 5/4) clay or black manganese coatings; few fine roots in cracks; pH 4.8; abrupt inclined boundary.

2Bt 30 to 66 cm; Yellowish brown (10YR 5/6) clay loam; moderate coarse subangular blocky structure; firm; common fine prominent gray (10YR 6/1) mottles in ped interiors; ped exteriors are coated with continuous brown (7.5YR 5/4) clay; common fine and medium roots between peds; common fine and medium pores; pH 4.8; abrupt inclined boundary. (This horizon formed in saprolite from argillaceous limestone. This section was described just above the massive C horizon zone which perched water into this Bt zone).

3Cr 66 to 117 cm; oxidized and leached saprolite from siltstone and claystone; rock controlled structure; very firm; many discontinuous prominent red (2.5YR 4/6) iron stains on some fragment faces; other fragments are partially coated by black manganese oxides; no clay films were noted on fragments. Water seems to flow in the unsaturated mode in this material. pH 4.9.

Soil No: 49 (Colluvial face of soil derived from
Cambrian aged Maryville Limestone)

Location: LLWDDD Site. E32060. N30200 Y-12 grid
Classification: Typic Hapludults; clayey mixed, thermic.
Geomorphic Position: Narrow old gully fill on upper
slightly convex sideslope of hillside
Slope: 18% with southeast aspect.
Parent material: Old colluvium derived from Maryville
and Rogersville residuum

Described by: Lambert and P. D. Alley. June 11, 1987.

Oi 2 to 0 cm; leaf litter and pine needles; abrupt wavy
boundary.

A 0 to 5 cm; Very dark grayish brown (10YR 3/2) silt
loam; moderate fine medium granular structure;
friable; many fine roots throughout; many fine pores;
pH 4.6; clear smooth boundary.

E 5 to 14 cm; Dark yellowish brown (10YR 4/4) loam; weak
fine subangular blocky structure; friable; common fine
roots throughout; common fine pores; pH 4.7; clear
smooth boundary.

Bt1 14 to 50 cm; Mottled yellowish red (5YR 4/6 and 5/8)
clay; strong medium subangular blocky structure; firm;
many continuous faint yellowish red (5YR 4/6) clay
films on faces of peds; few fine roots between peds;
few to common pores; pH 4.6; gradual wavy boundary.

Bt2 50 to 84 cm; Mottled yellowish brown (10YR 5/4),
strong brown (7.5YR 5/6) and red (2.5YR 4/6) clay;
moderate medium subangular blocky structure; firm;
common discontinuous distinct yellowish brown
(10YR 5/4) clay films on faces of some peds; few
fine roots between peds; pH 4.8; clear wavy boundary.

2CB 84 to 102 cm; Highly mottled red (2.5YR 4/6) black
(5Y 2/1) and olive (5Y 5/6) extremely shaly silty clay;
massive; rock controlled structure; very firm; many
continuous distinct red (2.5YR 4/6) clay films on rock
fragments; common patchy black manganese coatings on
some fragment faces; few fine roots on fragment faces;
pH 4.8; clear steeply inclined boundary.

- 2Cr1 102 to 149 cm; Oxidized and leached saprolite from claystone and siltstone that has olive brown (2.5YR 4/4) fragment interiors; rock controlled structure; very firm; many continuous prominent dark red (10R 3/6) iron oxide coatings and black manganese coatings on fragment faces; few fine root mats in upper part where roots extend downward on dip planes; pH 4.8; steeply inclined gradual boundary (60 degree dip).
- 2Cr2 148 to 300 cm; Oxidized and leached saprolite from claystone and siltstone; fragment interiors are olive (5Y 4/4) to olive gray (5Y 5/2); rock controlled structure; very firm; most fragments are coated with weak red (10R 4/4) iron oxides or black manganese oxides; some fragments in water flow zones are coated with olive gray (5Y 5/2) clay; pH 5.2.

Soil No: 42-E (Residual Face of soil derived from Cambrian aged Maryville Limestone)

Location: LLWDDD Site. E32060, N30200 Y-12 grid

Classification: Ruptic Ultic Dystrochrepts; loamy-skeletal, mixed, thermic.

Geomorphic Position: Upper third of convex sideslope.

Slope: 18% with southeast aspect.

Parent material: Saprolite from claystone, siltstone along with thin strata of very fine sandstone.

Described by: Lambert and P. D. Alley. June 11, 1987

(This profile was described in the same pit as the No.49 colluvial profile but on the wall to the left of the colluvial wall)

RUPTIC PORTION

- A 0 to 5 cm; Dark brown (10YR 3/3) shaly silt loam; moderate fine and medium granular structure; friable; many fine roots and pores throughout; pH 4.7; clear smooth boundary.
- Bw 5 to 16 cm; Dark yellowish brown (10YR 4/4) shaly loam; weak fine and medium subangular blocky structure; firm; common fine and medium roots and pores throughout; pH 4.7; gradual inclined boundary

The intermittent Bt horizon (ULTIC PORTION) occurs at about the same depth and extends deeper down dip into the Cr horizon beneath. It has a 5YR to 2.5YR hue and clayey texture.

Soil No: 36-N (Slightly eroded soil formed on the Cambrian aged Rogersville Shale)

Location: LLWDDD Site. E32325, N30480 Y-12 grid

Classification: Ruptic Ultic Dystrochrepts; loamy-skeletal, mixed, thermic.

Geomorphic Position: Upper third of summit with northwest aspect.

Parent material: Saprolite from claystone and siltstone along with strata of glauconitic very fine grained sandstone.

Described by: Lambert June 25, 1987

RUPTIC PORTION

- Oi 3 to 0 cm; leaf litter and thin sapric material with many fine roots; abrupt smooth boundary.
- A 0 to 9 cm; Dark grayish brown (10YR 4/2) shaly silt loam; moderate fine granular structure; very friable; many fine roots and pores throughout; pH 4.4; clear wavy boundary.
- Bw 9 to 29 cm; Yellowish brown (10YR 5/6) very shaly loam; weak fine and medium subangular blocky structure; firm; few patchy brown (10YR 5/3) silt coatings on ped faces; few fine roots and common to many pores; pH 4.6; gradual wavy boundary.
- Cr1 29 to 130 cm; Varigated pale olive (5Y 6/4), yellowish red (5YR 5/6) and light gray (5BG 7/1) oxidized and leached saprolite from claystone and siltstone; extremely firm; many nearly continuous distinct yellowish red (5YR 5/6) clay films on fragment faces; common patchy prominent red (10R 4/8) iron stains on some fragments; fine root mats in upper part; pH 4.7; gradual inclined boundary. (This zone contains thin glauconitic sandstone strata)
- Cr2 130 to 200 cm; Light gray (5BG 7/1) yellowish red (5YR 5/6) oxidized and leached saprolite from claystone and siltstone; extremely firm; few patchy prominent black manganese oxide coatings on some fragment faces and dark red (10R 3/6) iron coatings on other fragments; few patchy distinct yellowish red (5YR 5/6) clay films coating fragment faces in water flow zones; pH 5.0. (Note: BG hues are of less oxidized fragment interiors).

ULTIC PORTION

- A 0 to 9 cm; Dark grayish brown (10YR 4/2) shaly silt loam; moderate fine granular structure; very friable; many fine roots and pores throughout; pH 4.4; clear wavy boundary.
- E 9 to 30 cm; Brown (10YR 5/3) shaly silt loam; weak fine subangular blocky structure; friable; few fine roots throughout; many fine pores; pH 4.4; clear wavy boundary.
- Bt 30 to 50 cm; Yellowish red (5YR 5/6) shaly clay; moderate medium subangular blocky structure; firm; many continuous yellowish red (5YR 4/6) clay films on ped faces; few fine roots between peds; common pores; pH 4.6; clear highly irregular boundary.
- Cr1 50 to 95 cm; Dark yellowish brown (10YR 4/6), yellowish red (5YR 4/6), light olive brown (2.5Y 5/6) oxidized and leached saprolite from claystone and siltstone; very firm; many nearly continuous distinct yellowish red (5YR 4/6) clay films on fragment faces; few patchy prominent red (10R 4/6) iron stains on some fragments; few fine root mats in upper part; pH 4.7.

Soil No: 36-E (Severely eroded soil formed on the Cambrian aged Rogersville Shale)

Location: LLWDDD Site. E32025 N30540 Y-12 grid

Classification: Ruptic Ultic Dystrochrepts; loamy-skeletal, mixed, thermic.

Geomorphic Position: Upper convex sideslope and summits of low hills.

Slope: 10% with west aspect.

Parent material: Saprolite from claystone, siltstone and thin to thick strata of glauconitic very fine grained sandstone

Described by: Lambert March 14, 1987

RUPTIC PORTION

Oi 2 to 0 cm; leaf litter.

A 0 to 4 cm; Very dark grayish brown (10YR 3/2) shaly clay loam; moderate medium granular structure; friable; many fine roots and pores throughout; pH 4.5; abrupt wavy boundary.

Bw 4 to 25 cm; Yellowish brown (10YR 5/4) shaly loam; moderate fine and medium subangular blocky structure; friable; common patchy yellowish brown (10YR 5/6) clay films on ped faces and coating most fragments in the lower part; common medium and fine roots and pores throughout; pH 4.5; gradual inclined boundary.

Cr1 25 to 200 cm; Varigated light gray (5BG 7/1), yellowish red (5YR 5/6), and yellowish brown (10YR 5/6) oxidized and leached saprolite from claystone and siltstone; extremely firm; common discontinuous yellowish red (5YR 5/6) iron-clay films on fragment faces; and discontinuous yellowish brown (10YR 5/6) clay films on fragment faces; few root mats in upper part; pH 4.7; clear inclined boundary.

Cr2 200 to 300 cm; Varigated light gray (5BG 7/1), reddish yellow (7.5YR 6/6), and red (2.5YR 4/6) oxidized and leached saprolite from claystone and siltstone; extremely firm; common distinct reddish yellow (7.5YR 5/6) and red (2.5YR 4/6) iron-clay coatings on fragment faces; pH 5.0.

ULTIC PORTION

- Oi 2 to 0 cm; leaf litter.
- A 0 to 4 cm; Very dark grayish brown (10YR 3/2) shaly clay loam; moderate medium granular structure; friable; many fine roots and pores throughout; pH 4.5; abrupt wavy boundary.
- E 4 to 12 cm; Yellowish brown (10YR 5/4) shaly clay loam; moderate fine and medium subangular blocky structure; friable; common fine and medium roots and pores throughout; pH 4.5; clear wavy boundary.
- Bt1 12 to 25 cm; Yellowish brown (10YR 5/6) shaly clay loam; moderate medium subangular blocky structure; firm; discontinuous brown (10YR 5/3) skeletal on some ped faces; common fine and medium roots between peds; common pores; pH 4.6; clear wavy boundary.
- Bt2 25 to 33 cm; Yellowish brown (10YR 5/6) very shaly clay loam; moderate medium subangular blocky structure; firm; discontinuous yellowish brown (10YR 5/4) clay films on ped faces and coating most fragments; common fine pores; pH 4.7; clear irregular boundary.
- Cr1 33 to 200 cm; Varigated light gray (5BG 7/1), yellowish red (5YR 5/6), and yellowish brown (10YR 5/6) oxidized and leached saprolite from claystone and siltstone; extremely firm; common discontinuous yellowish red (5YR 5/6) iron-clay films on fragment faces; and discontinuous yellowish brown (10YR 5/6) clay films on fragment faces; few root mats in upper part; pH 4.7; clear inclined boundary.
- Cr2 200 to 300 cm; Varigated light gray (5BG 7/1), reddish yellow (7.5YR 6/6), and red (2.5YR 4/6) oxidized and leached saprolite from claystone and siltstone; extremely firm; common distinct reddish yellow (7.5YR 6/6) and red (2.5YR 4/6) iron-clay coatings on fragment faces; pH 5.0. (A glauconitic zone had a 1:1 water pH of 4.3)

Soil No: 24-E (Very severely eroded soil formed on the Cambrian aged Pumpkin Valley Shale)

Location: LLWDDD Site. E29250 N30815 Y-12 grid

Series Classification: Ruptic Ultic Dystrochrepts;
loamy-skeletal, mixed, thermic.

Pedon Classification: Typic Udorthents; loamy-skeletal,
shallow, mixed, thermic.

Geomorphic Position: Convex sideslope and summits of low hills.

Slope: 13% with southeast aspect.

Parent material: Saprolite from claystone, siltstone and thin to thick strata of glauconitic very fine grained sandstone of middle member.

Described by: Lambert May 21, 1987

Ap 0 to 15 cm; Dark brown (10YR 4/3) shaly loam; moderate fine and medium granular structure; friable; common fine and medium roots and pores throughout; pH 4.9; clear smooth boundary.

Cr1 15 to 58 cm; Varigated strata of dark reddish brown (5YR 4/2), yellowish brown (10YR 6/8) and red (2.5YR 4/6) oxidized and leached saprolite from siltstone, claystone and glauconitic very fine grained sandstone; extremely firm; common discontinuous dark brown (10YR 4/3) iron oxyhydroxide stains on fragments; few red (2.5YR 4/6) iron coatings on other fragments; few root mats in upper part that extend downward along dip planes; pH 5.1; gradual inclined boundary.

Cr2 58 to 200 cm; Varigated strata of dark reddish gray (5YR 4/2), light gray (5BG 7/1) and brown (10YR 5/3) oxidized and leached saprolite from siltstone, claystone and glauconitic very fine grained sandstone; extremely firm; common discontinuous dusky red (10R 3/4) iron stains on fragment faces, and black manganese oxide coatings on other fragment faces; pH 4.9.

Soil No: 24-N (Slightly eroded soil formed on the
Cambrian aged Pumpkin Valley Shale)

Location: LLWDDD Site. E32275 N30840 Y-12 grid
Series Classification: Ruptic Ultic Dystrochrepts; clayey,
mixed, thermic.

Geomorphic Position: Convex sideslopes and summits of low
hills.

Slope: 10% with southeast aspect.

Parent material: Saprolite from claystone, siltstone and
thin to thick strata of glauconitic very
fine grained sandstone of middle member.

Described by: Lietzke and Lambert April 3, 1987

Oi 2 to 0 cm; leaf litter

A 0 to 8 cm; Dark grayish brown (10YR 4/2) shaly loam;
moderate fine granular structure; friable; common to
many fine and medium roots and pores throughout;
pH 4.5; clear smooth boundary.

E 8 to 25 cm; Light yellowish brown (10YR 6/4) shaly
loam; weak fine and medium subangular blocky
structure; friable; common fine roots throughout;
many pores; pH 4.5; gradual wavy boundary (gradual
boundary includes a thin strong brown (7.5YR 4/4) Bt1
horizon).

Bw 25 to 55 cm; Yellowish red (5YR 4/6) very shaly clay
loam; weak fine and medium subangular blocky
structure; firm; nearly continuous red (2.5YR 4/8)
clay films on fragment faces and on some ped faces;
Few patchy red (10R 4/8) iron oxide-clay coatings on
some fragment faces; few to common fine roots; common
to many pores; pH 4.7; clear inclined boundary.
[RUPTIC PORTION OF PEDON]

Bt 25 to 66 cm; Yellowish red (5YR 4/6) shaly clay;
moderate medium subangular blocky structure; firm;
continuous reddish brown (5YR 4/4) clay films on ped
faces; few to common fine roots between peds; many
pores; pH 4.5; clear inclined boundary.
[ULTIC PORTION OF PEDON]

B/Cr1 66 to 118 cm; Weak red (2.5YR 4/2) extremely shaly
clay; weak medium subangular blocky structure
(B part) and massive (Cr part); very firm; nearly
continuous reddish brown (5YR 4/4) clay films on
fragment faces; few fine roots; many pores; Ph 4.7;
abrupt irregular inclined boundary.

Cr2 118 to 200 cm; Highly varigated weak red (2.5YR 4/2) red (2.5YR 5/6) oxidized and leached saprolite from siltstone, claystone and glauconitic very fine grained sandstone; extremely firm; nearly continuous reddish brown (5YR 4/4) clay coatings on fragment faces; patchy red (10R 4/8) iron oxide coatings on some fragment faces; very few fine roots in cracks; pH 4.8.

Soil No: 951 (Old Alluvial soil over hard Rogersville saprolite)

Location: LLWDDD Site. E28360 N30175 Y-12 grid

Series Classification: Typic Hapludults; fine-silty, siliceous, thermic.

Geomorphic Position: slightly dissected terraces with some convexity

Slope: 5% with west aspect.

Parent material: Pleistocene alluvium derived from mostly local sources.

Described by: Lambert June 15, 1987

Oi 2 to 0 cm; Leaf litter

C 0 to 20 cm; Dark brown (10YR 4/3) silt loam; massive; very friable; many fine roots and pores; clear broken boundary (This soil material, from clearing and bulldozing was pushed off of the telephone cable right of way where this pit was located)

A 20 to 28 cm; Very dark grayish brown (10YR 3/2) silt loam; weak fine granular blocky structure; very friable; common fine roots throughout; many pores; pH 4.3; clear smooth boundary.

E1 28 to 37 cm; Brown (10YR 5/3) silt loam; weak fine subangular blocky structure; very friable; few fine roots throughout; many pores; pH 4.0; clear smooth boundary.

E2 37 to 48 cm; Light yellowish brown (10YR 6/4) silt loam; weak fine subangular blocky structure; very friable; very few fine roots throughout; many pores; pH 4.1; gradual wavy boundary.

Bt 48 to 76 cm; Brownish yellow (10YR 6/6) and light yellowish brown (10YR 6/4) clay loam; strong medium subangular blocky structure; friable; thin discontinuous light yellowish brown (10YR 6/4) clay films on ped faces; few patchy black manganese oxide stains on some ped faces; common to many 1-2 mm iron-manganese nodules; few to common roots between peds; common to many pores; pH 4.4; clear wavy boundary.

- 2E/B 76 to 101 cm; Light yellowish brown (2.5Y 6/4) silt loam (E part) and mottled yellowish red (5YR 5/6) and brownish yellow (10YR 6/8) loam; moderate medium and coarse subangular blocky structure; very friable; thin patchy yellowish brown (10YR 5/6) clay films on some peds (B part) and brownish yellow (10YR 6/8) skeletons on some peds (E part); few fine roots between peds; many pores; pH 4.4; clear wavy boundary.
- 2Btg 101 to 121 cm; highly mottled light gray (5Y 7/2), yellowish brown (10YR 5/6) and light red (2.5YR 6/6) loam; weak to moderate medium prismatic structure parting to moderate medium and coarse subangular blocky structure; friable; continuous yellowish brown (10YR 5/6) clay films on prism faces; few patchy manganese oxide coatings on some peds in prism interiors; light greenish gray (5G 6/1) reduced zones in root channels; few fine roots between prisms; pH 4.8; abrupt wavy boundary.
- 3Cr 121 to 200 cm; Olive brown (2.5Y 4/4), strong brown (7.5YR 5/6) extremely shaly loam Rogersville saprolite; many discontinuous manganese oxide stains on fragment faces; some strong brown (7.5YR 5/6) iron oxyhydroxides on other fragment faces and few dusky red (2.5YR 3/2) iron oxide stains on other fragment faces; light greenish gray (5G 6/1) reduced zones around fine root mats along joint planes; pH 6.3.

Soil No: 26/951 (Pumpkin Valley colluvium over old
alluvium over Pumpkin Valley residual
soil and saprolite)

Location: LLWDDD Site. E27875 N30780 Y-12 grid

Series Classification: Typic Hapludults; fine-loamy, mixed,
thermic.

Geomorphic Position: low terrace covered toeslope with some
convexity

Slope: 10% with west aspect.

Parent material: Pumpkin Valley colluvium over Pleistocene
Alluvium derived from mostly local sources
over Pumpkin valley residuum.

Described by: Lambert and Lietzke June 9, 1987

Ap 0 to 21 cm; Dark brown (10YR 4/3) gravelly loam;
moderate medium and coarse granular structure; friable;
common fine and very fine roots throughout; many pores
throughout; pH 4.7; abrupt smooth boundary.

Bt1 21 to 43 cm; Yellowish red (5YR 4/6) and brownish
yellow (10YR 6/8) gravelly clay loam; weak fine and
medium subangular blocky structure; firm; thin
continuous reddish brown (5YR 4/6) clay films on ped
faces; few fine roots between peds; many pores;
pH 4.9; clear wavy boundary.

[BASE OF YOUNGEST COLLUVIUM]

2Bt2 43 to 55 cm; Yellowish red (5YR 4/6) and reddish brown
(5YR 4/4) clay loam; moderate medium subangular blocky
structure; firm; thin continuous reddish brown
(5YR 4/4) clay films on ped faces; few fine roots
between peds; many pores; pH 4.9; clear wavy boundary.

2BC 55 to 74 cm; Yellowish red (5YR 4/6) and yellow (5Y 7/6)
gravelly clay loam; weak medium subangular blocky
structure; firm; thin discontinuous yellowish red
(5YR 4/6) clay films on ped faces; few patchy manganese
oxide coatings on some ped faces; few fine roots; many
fine pores; pH 4.9; clear wavy boundary.

3Bt 74 to 87 cm; Reddish brown (5YR 4/4) and yellowish
red (5YR 4/6) clay loam; moderate medium subangular
blocky structure; firm; thin continuous yellowish red
(5YR 4/6) clay films on ped faces; few fine roots
between peds; many fine pores; pH 4.9; clear wavy
boundary.

[BASE OF INTERMEDIATE COLLUVIUM]

4Ab 87 to 95 cm; Mottled light brownish gray (2.5Y 6/2) and yellowish red (5YR 4/6) loam; weak fine and medium subangular blocky structure; firm; thin patchy yellowish red (5YR 4/6) clay films on ped faces, and patchy strong brown (7.5YR 4/4) iron oxyhydroxide stains throughout; few to common fine roots between peds; many fine pores; pH 4.9; clear irregular boundary.

4Bt 95 to 122 cm; brownish yellow (10YR 6/8), yellow (2.5Y 8/8) and light greenish gray (5BG 6/2) gravelly clay loam; weak fine and medium subangular blocky structure; very firm; thin discontinuous dark yellowish brown (10YR 4/4) clay films on ped faces; common patchy strong brown (7.5YR 5/6) iron oxyhydroxide coatings on some ped faces; very few fine roots between peds; many fine pores; pH 4.9; clear wavy boundary.

[BASE OF OLDEST COLLUVIUM]

5Bt1 122 to 146 cm; Dark brown (7.5YR 4/4), yellowish brown (10YR 5/4), and brownish yellow (10YR 6/8) loam; moderate medium subangular blocky structure; very firm; thin discontinuous dark brown (7.5YR 4/4) clay films on ped faces; patchy manganese oxide stains on some ped faces; very few fine roots between peds; common fine pores; pH 4.9; clear wavy boundary.

5Bt2 146 to 202 cm; Dark brown (7.5YR 4/4) and yellowish brown (10YR 5/4) clay loam; weak coarse subangular blocky structure; very firm; thin continuous dark brown (7.5YR 4/4) clay films on ped faces; patchy manganese oxide stains on ped faces; very few fine roots between peds; many fine pores; pH 4.9; clear wavy boundary.

[BASE OF UPPER ALLUVIUM]

6Bw1 202 to 234 cm; light olive brown (2.5Y 5/4) loam; weak medium subangular blocky structure; firm; patchy manganese oxide coatings on some ped faces, and patchy brownish yellow (10YR 6/8) iron oxyhydroxide stains on other ped faces; very few fine roots between peds; pH 4.9; clear wavy boundary.

6Bw2 234 to 270 cm; mottled dark yellowish brown (10YR 4/8), and light olive brown (2.5Y 5/4) loam; weak medium subangular blocky structure; firm; thin discontinuous reddish brown (5YR 4/4) clay films on faces of primary peds; patchy manganese coatings on secondary ped faces; very few fine roots between peds; few to common fine pores; pH 4.9; clear wavy boundary.

[BASE OF OLDER ALLUVIUM]

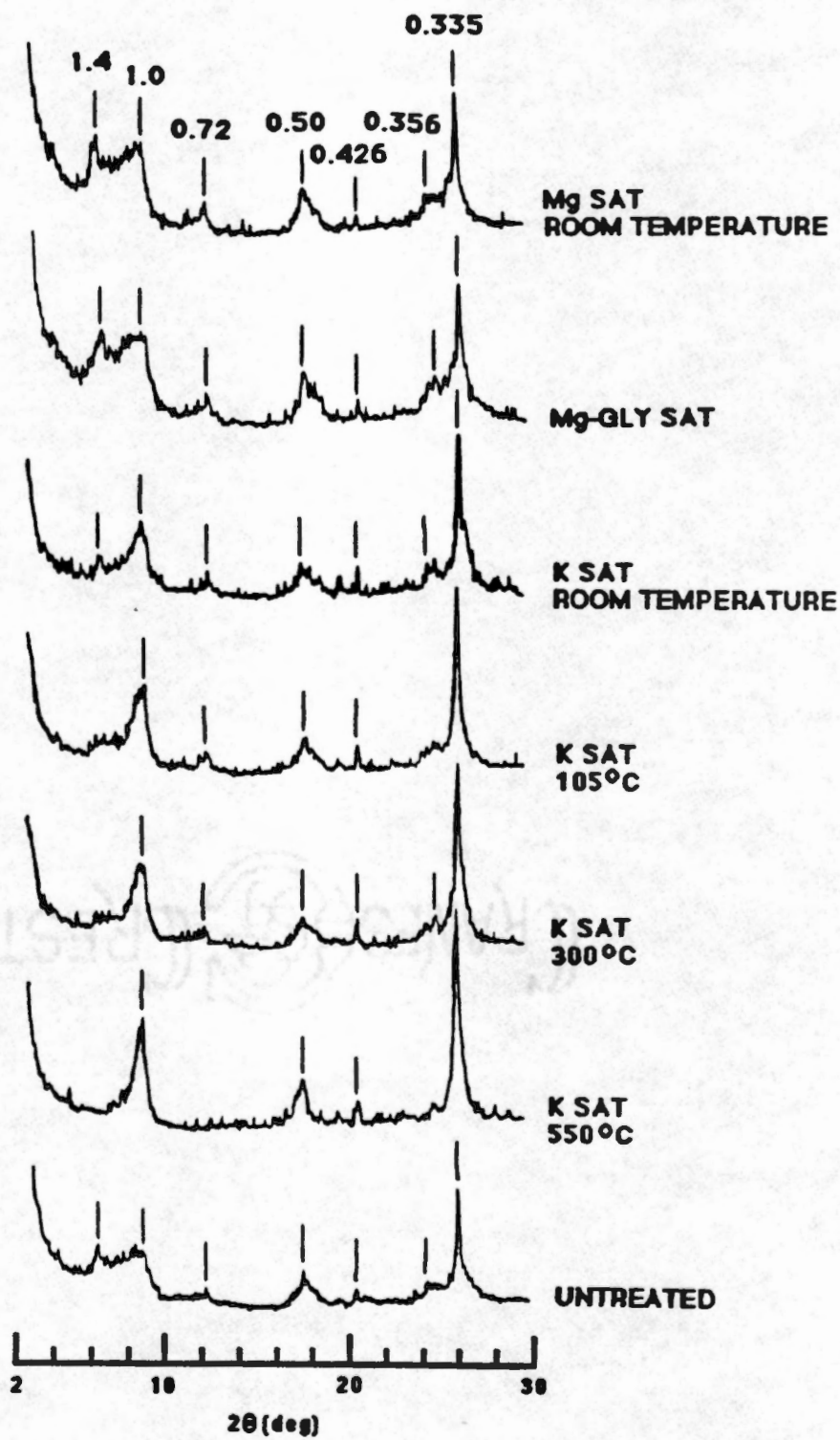
- 7C 270 to 325 cm; Mottled brownish yellow (10YR 6/8), yellow (2.5Y 7/8) and olive yellow (5Y 6/6) oxidized and leached saprolite from middle member of Pumpkin Valley Formation; contains greenish glauconitic strata; firm; common patchy dark red (10R 3/6) iron stains on joint and fracture faces; few very fine roots along dip planes; pH 5.0; clear inclined boundary.
[PUMPKIN VALLEY RESIDUUM]
- 7Cr 325 to 350 cm; Highly varigated and mottled oxidized and leached saprolite from middle member of Pumpkin Valley; very firm; few root mats in upper part along dip planes; pH 5.1.

**APPENDIX B: X-ray Diffractograms of Clay Fractions
from Selected Soil Horizons**



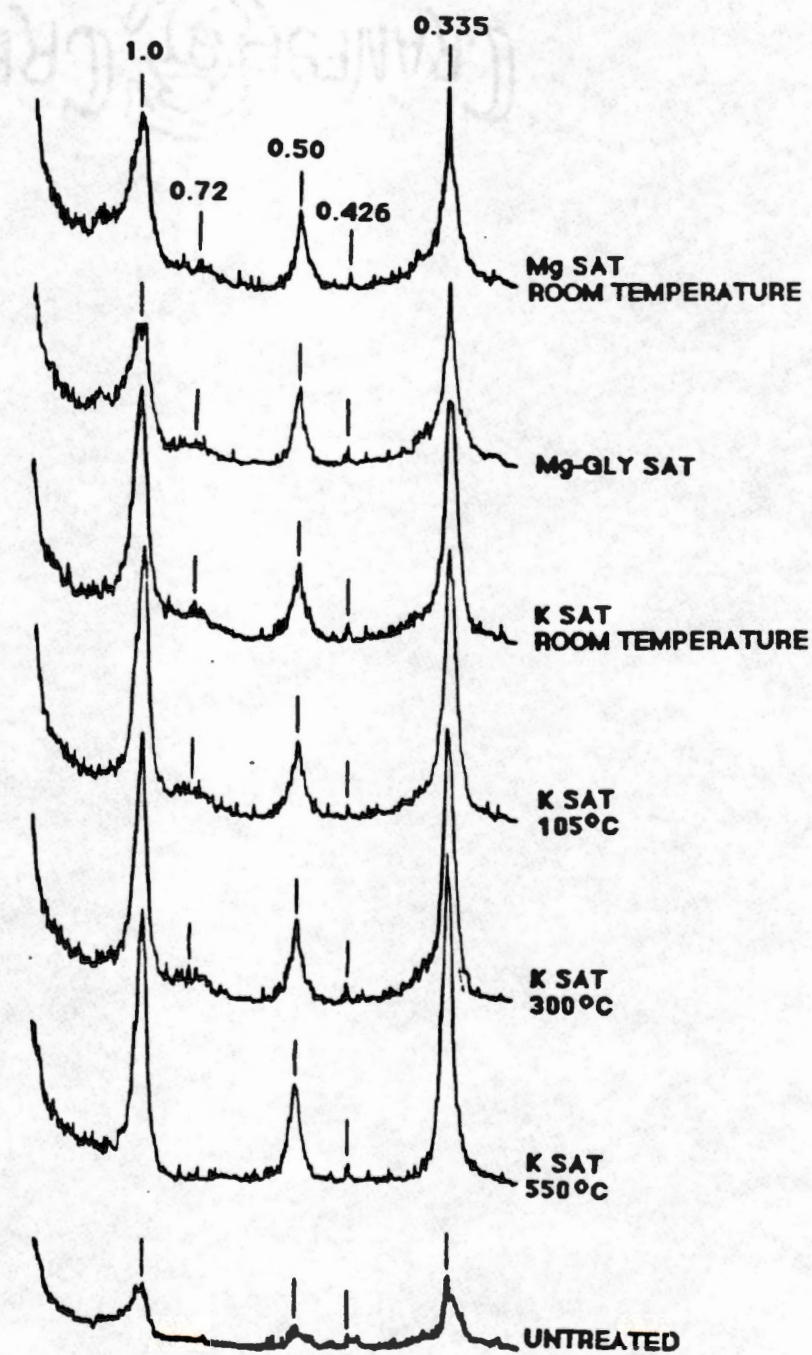
PROFILE 51-E
Ap (0-18 cm)

<2 μm



PROFILE 51-E
Cr (18-150 cm)

$\leq 2 \mu\text{m}$



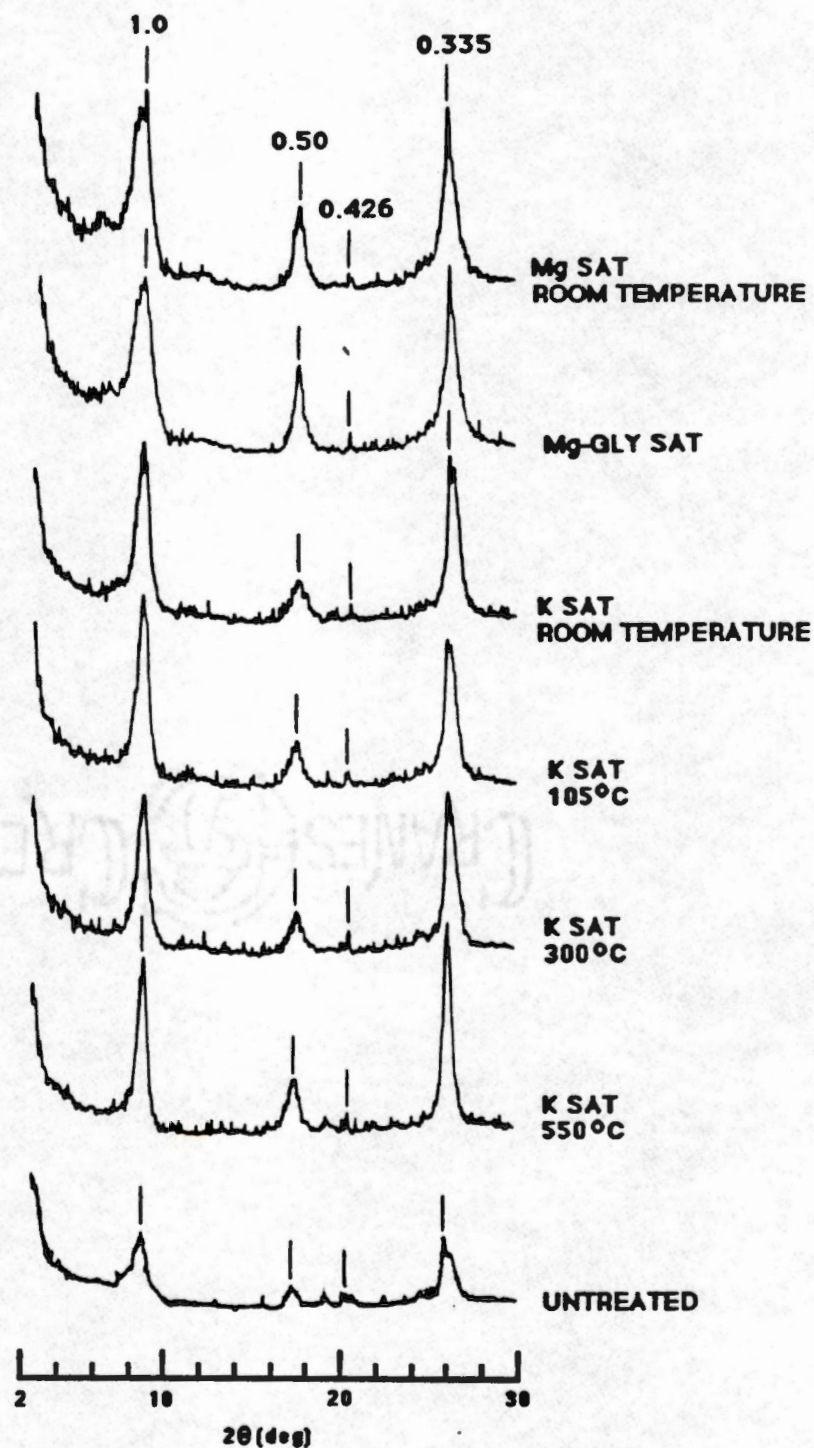
2 10 20 30

2θ (deg)

140

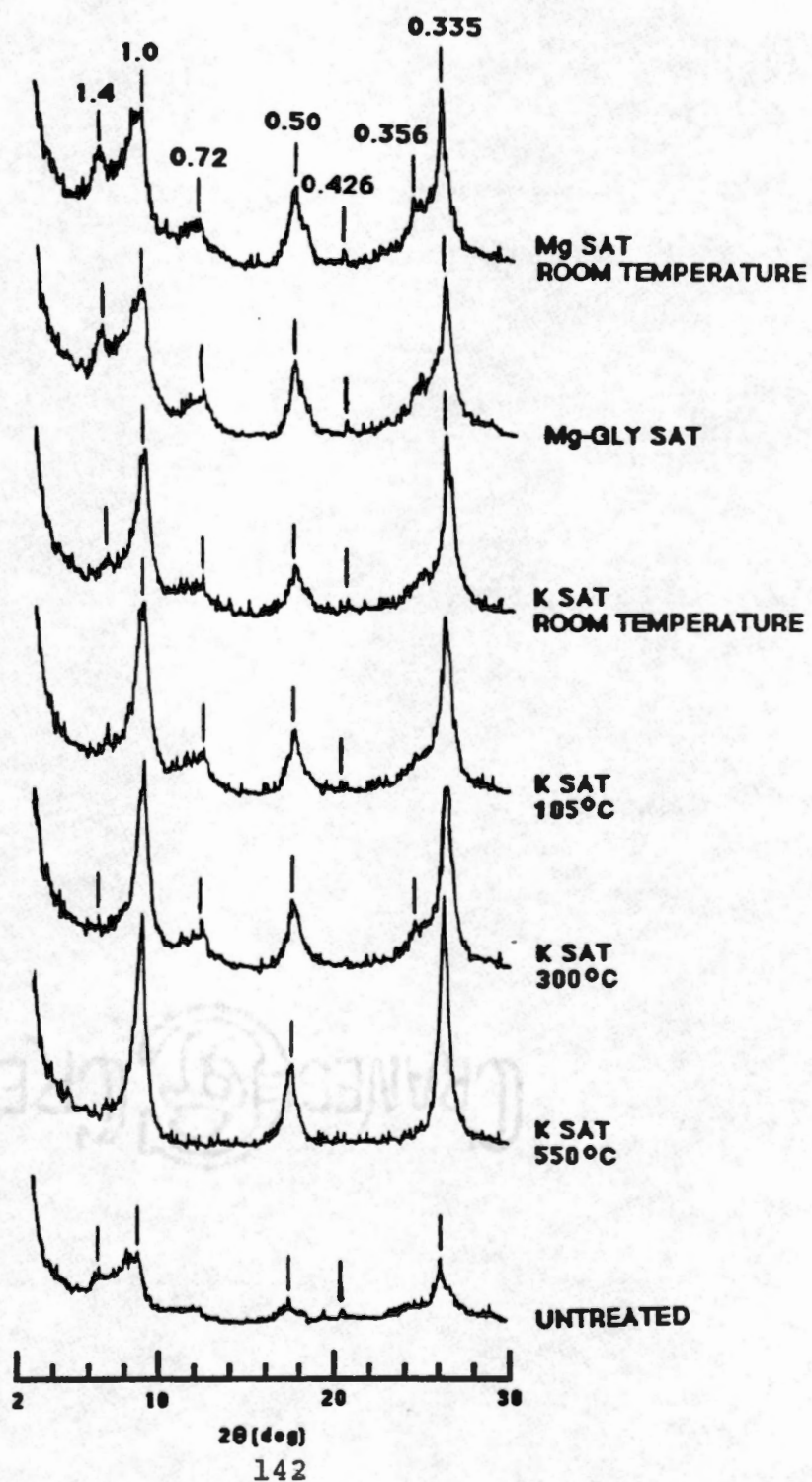
PROFILE 51-E
3Cr (R) (250+ cm)

$\leq 2 \mu\text{m}$



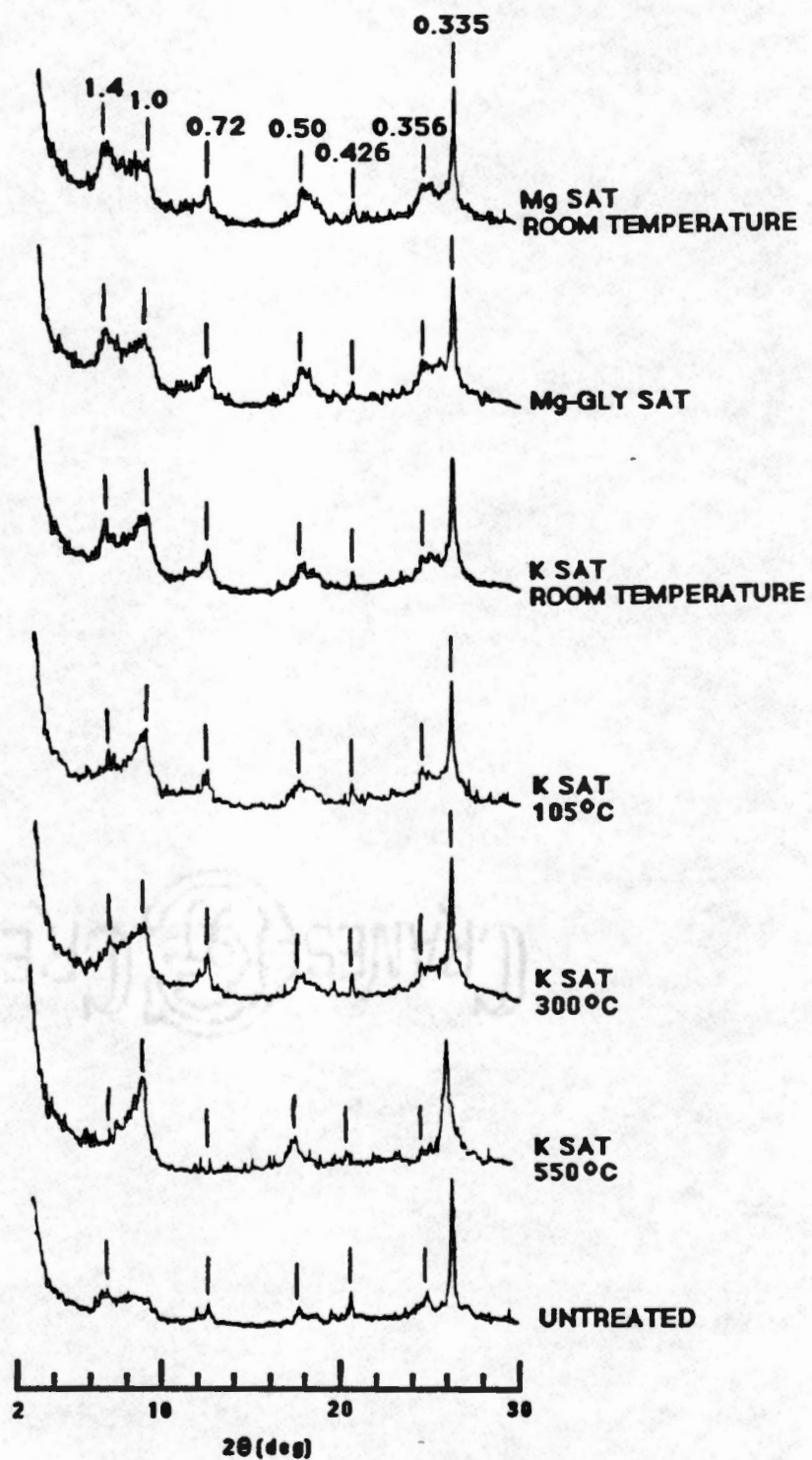
PROFILE 51-E
3Cr (Y) (250+ cm)

$\leq 2 \mu\text{m}$



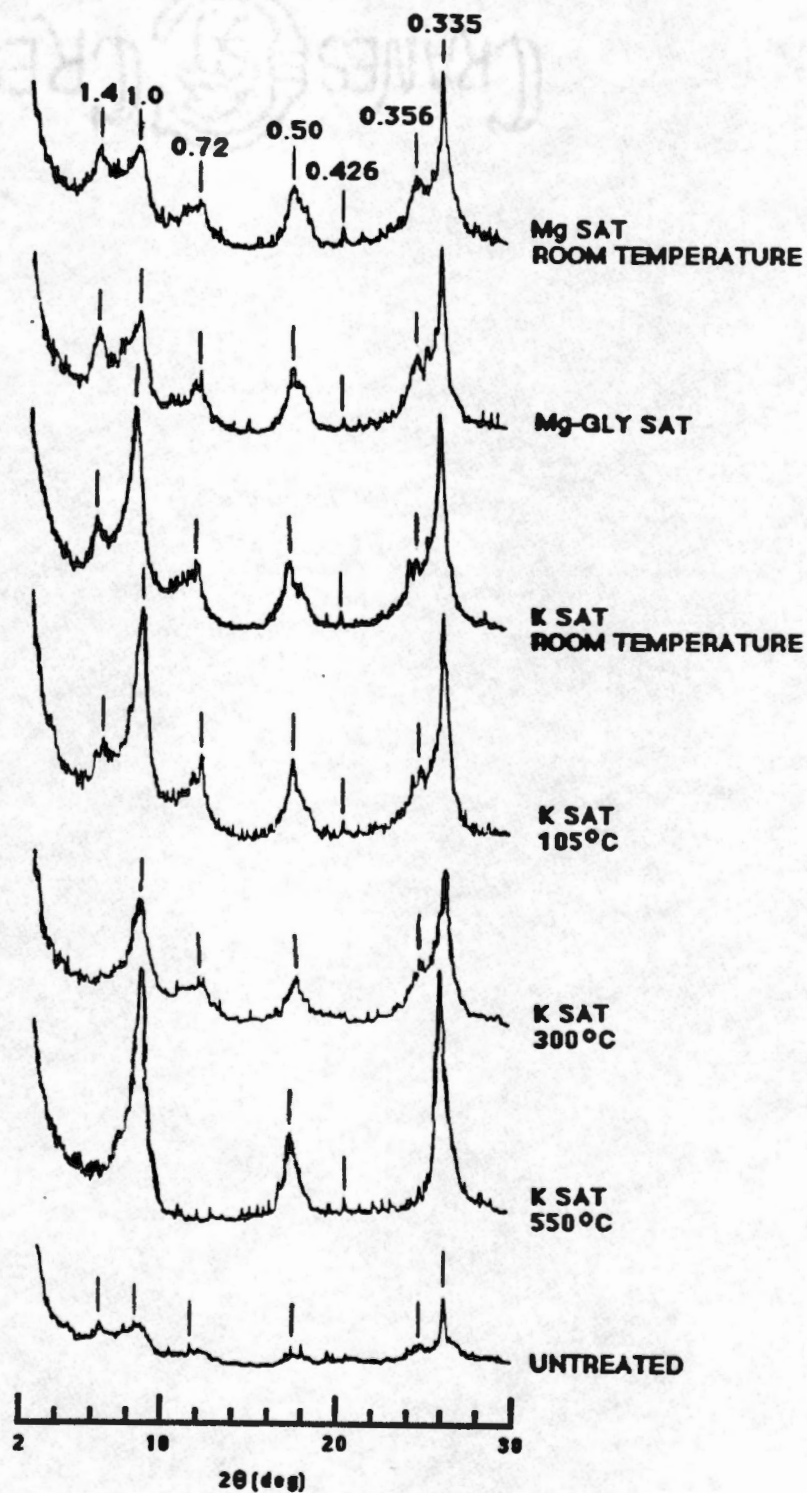
PROFILE 42-E
A-E (0-14 cm)

$\leq 2 \mu\text{m}$



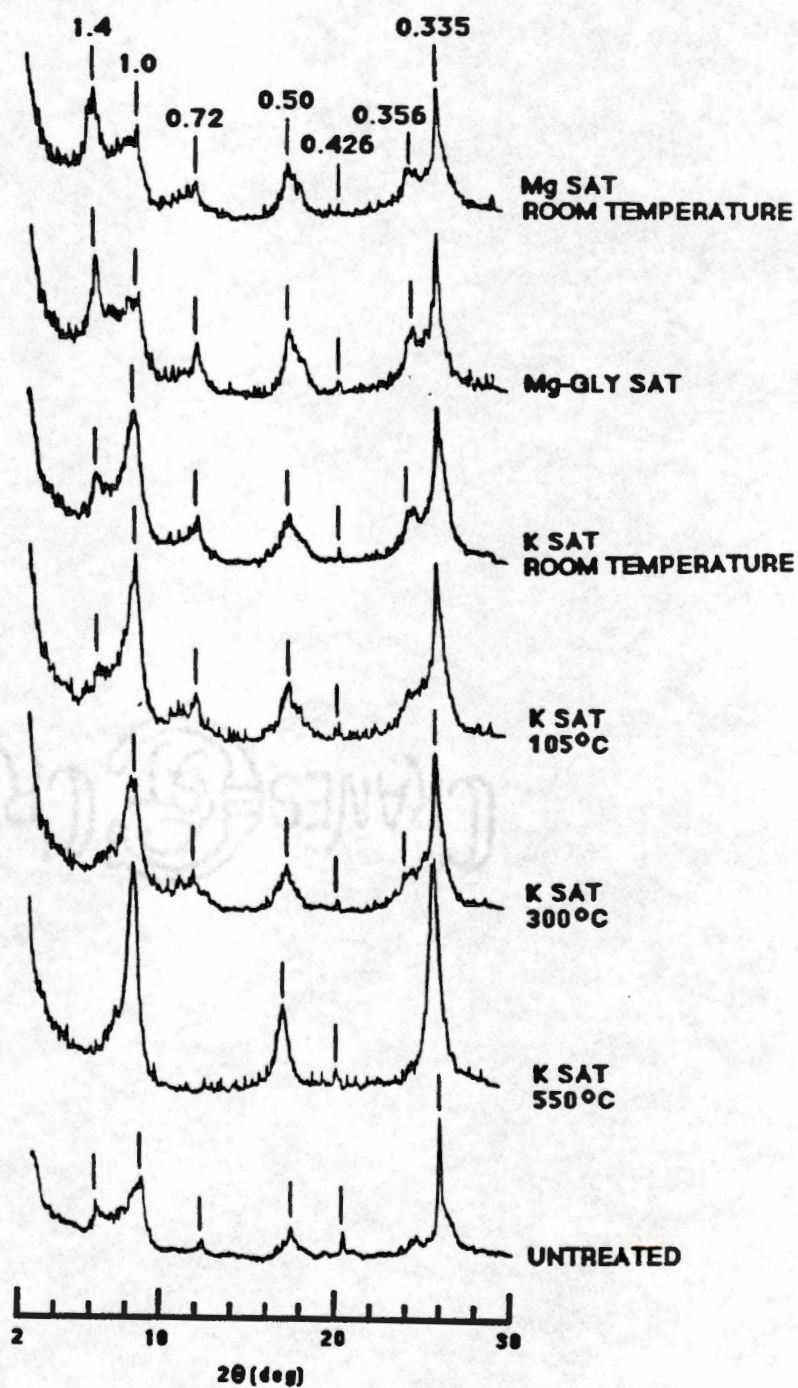
PROFILE 42-E
Bt1-Bt2 (14-84 cm)

<2 μm



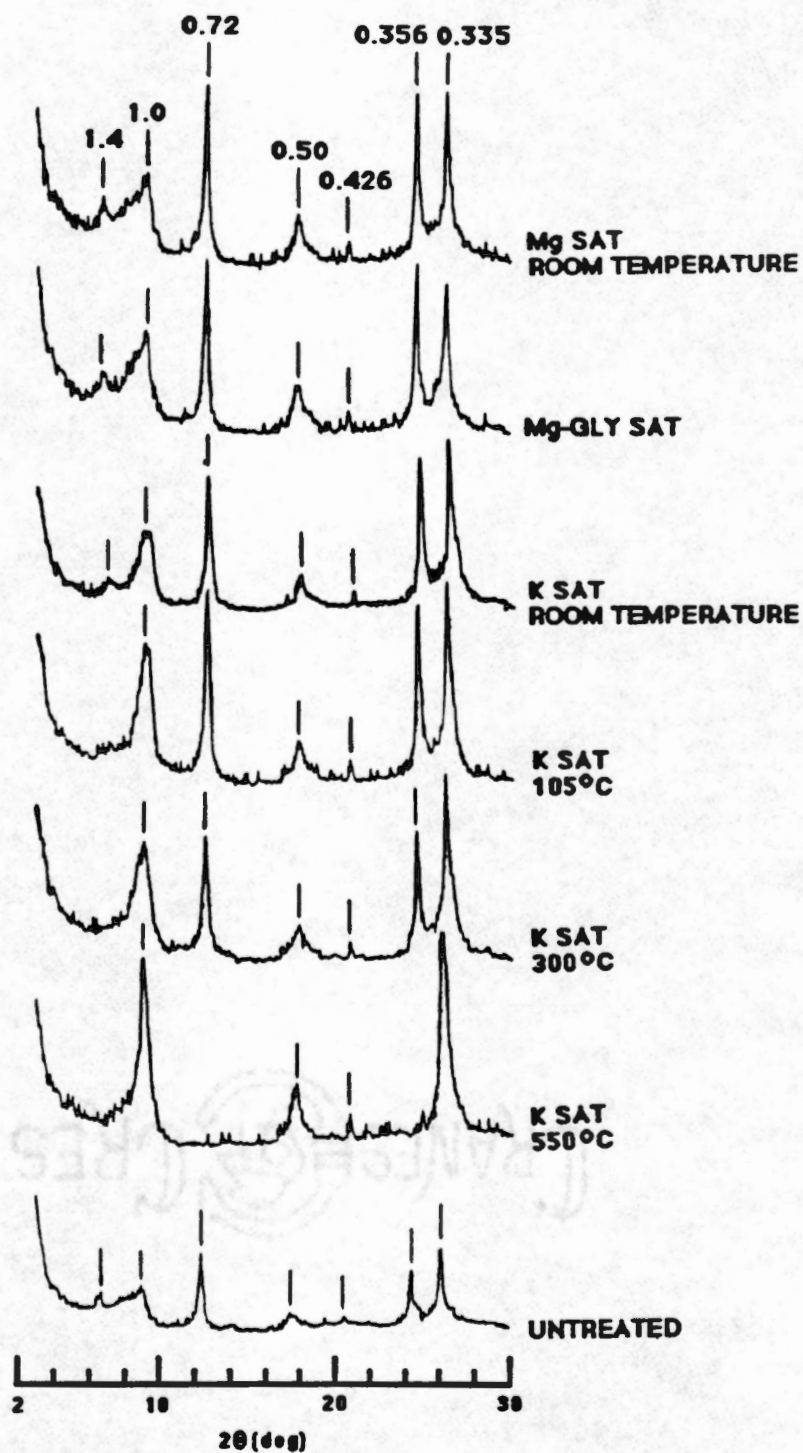
PROFILE 42-E
2Cr2 (149+ cm)

< 2 μ m



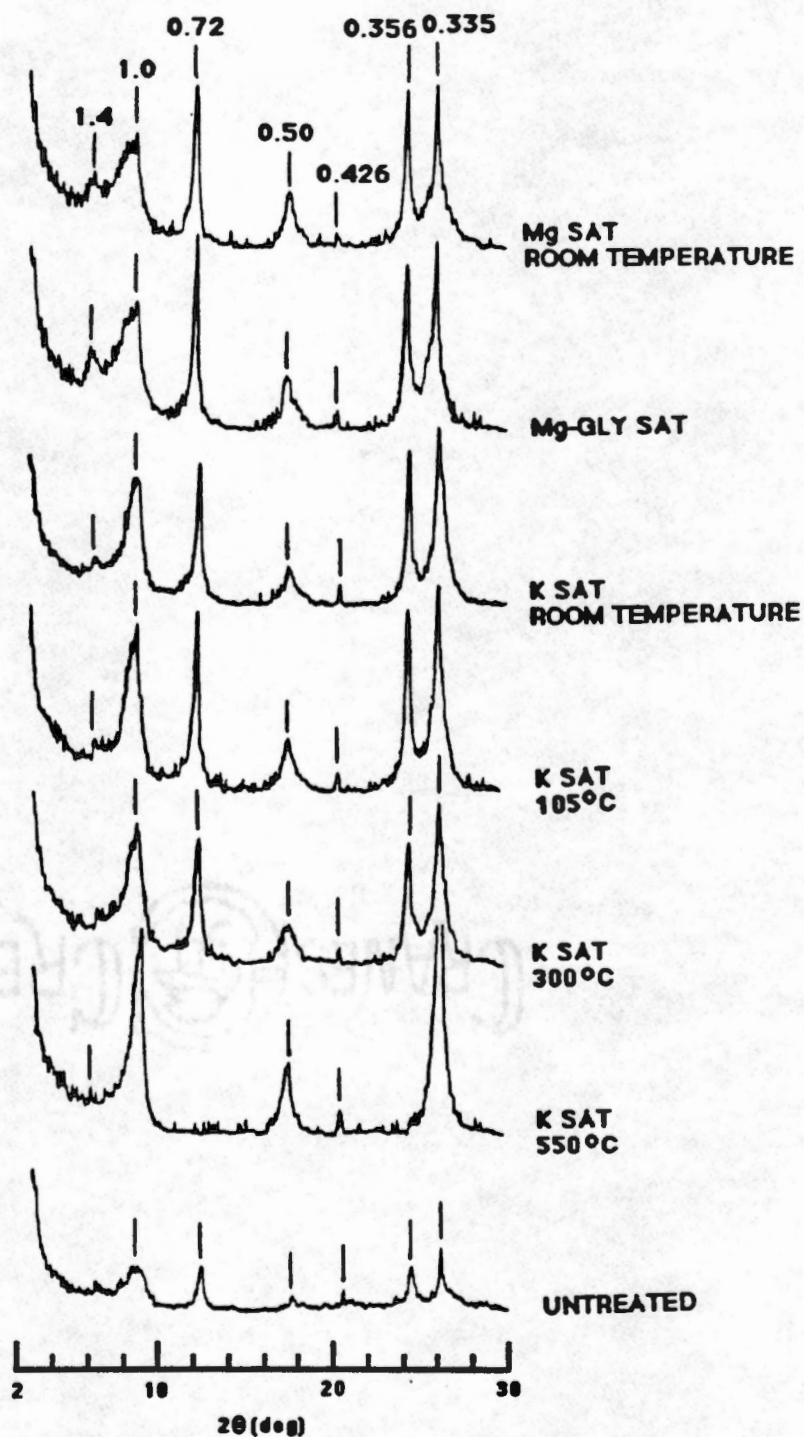
PROFILE 24-E
Ap (0-15 cm)

$<2 \mu\text{m}$



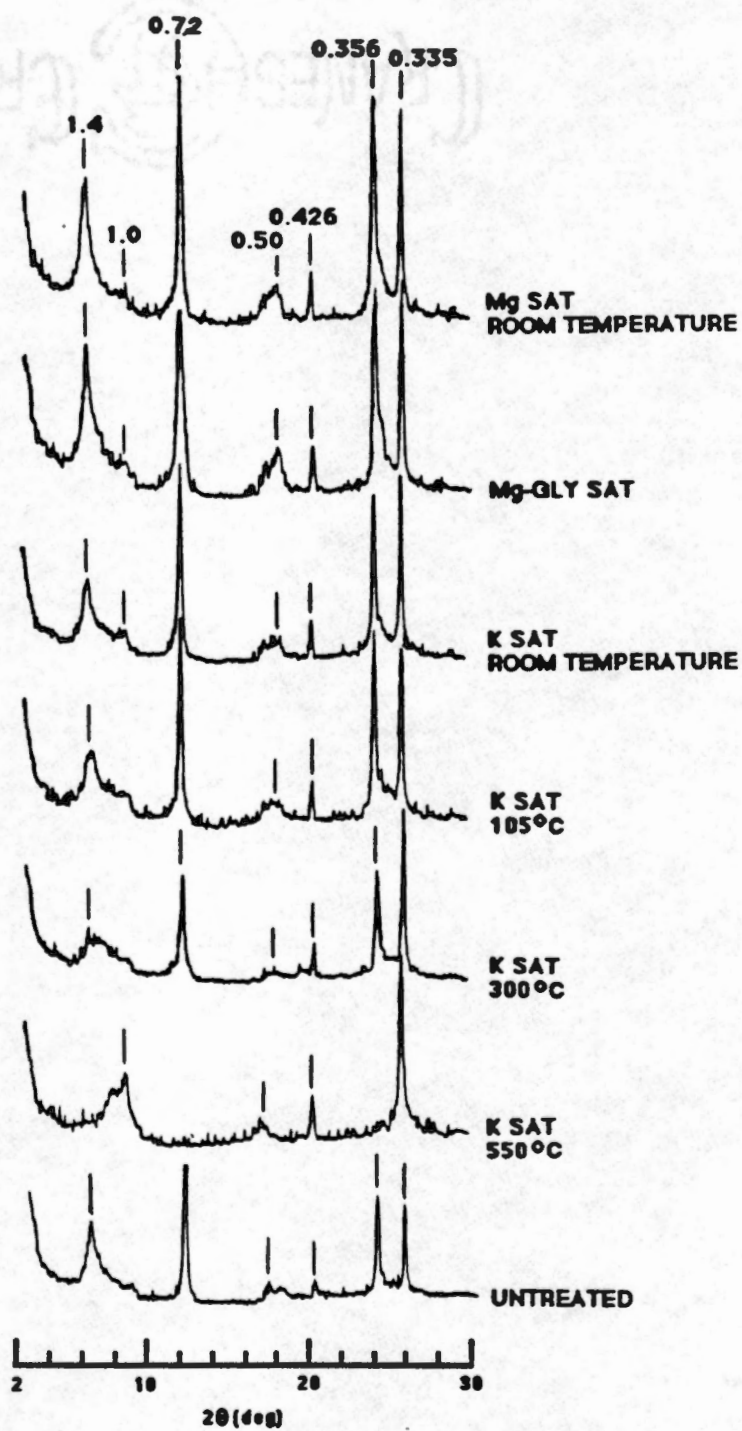
PROFILE 24-E
Cr1 (15-58 cm)

<2 μ m

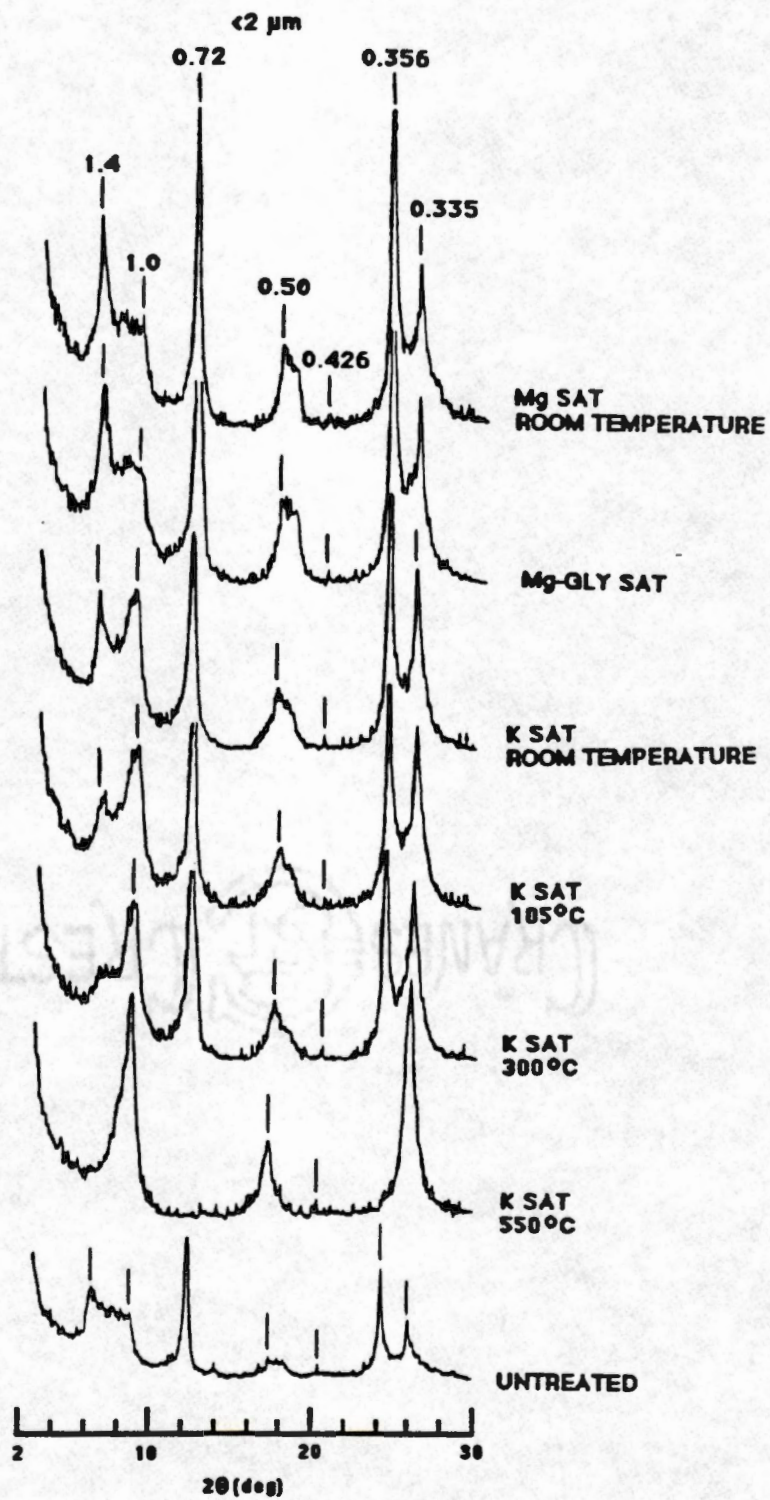


PROFILE 24-N
A-E (0-25 cm)

<2 μ m

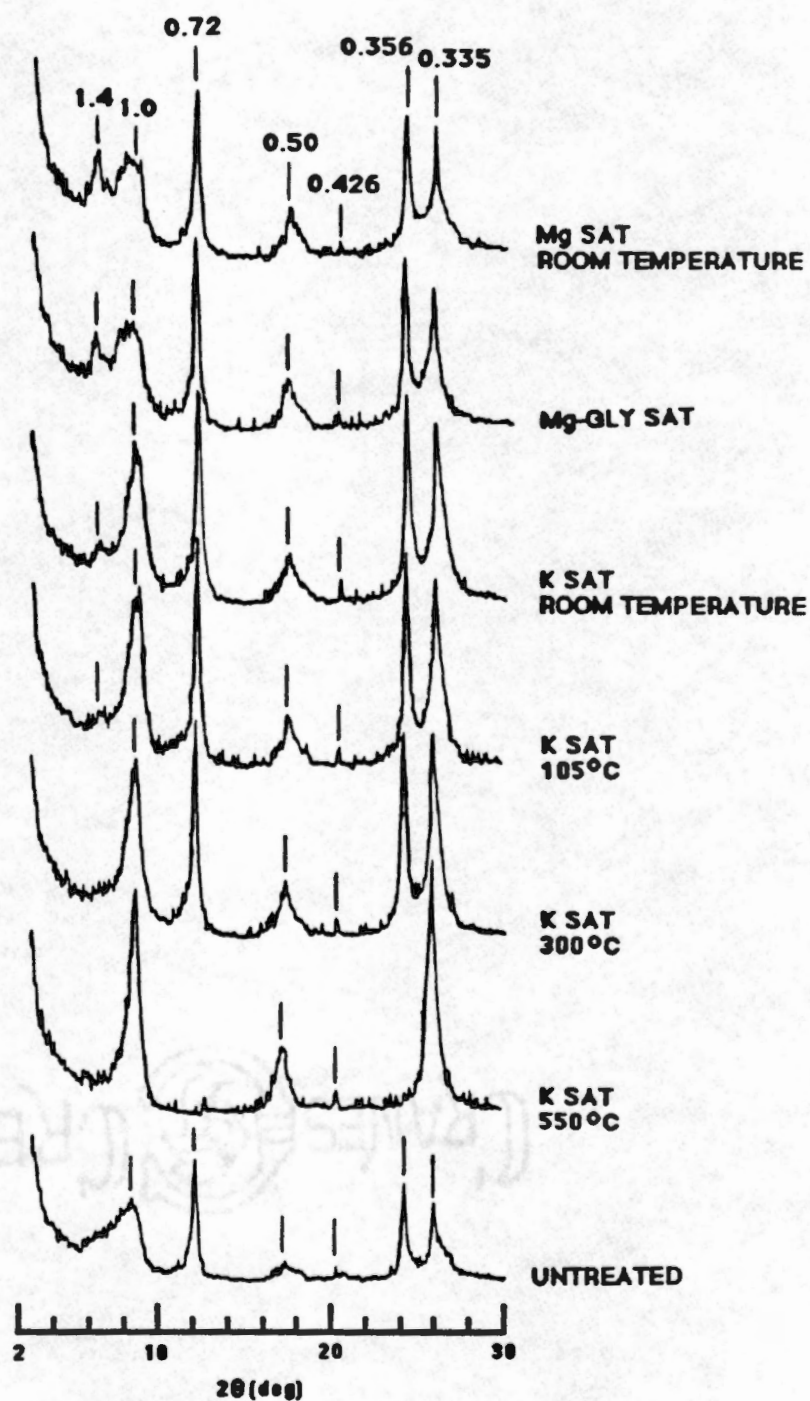


PROFILE 24-N
Bw-Bt (25-66 cm)



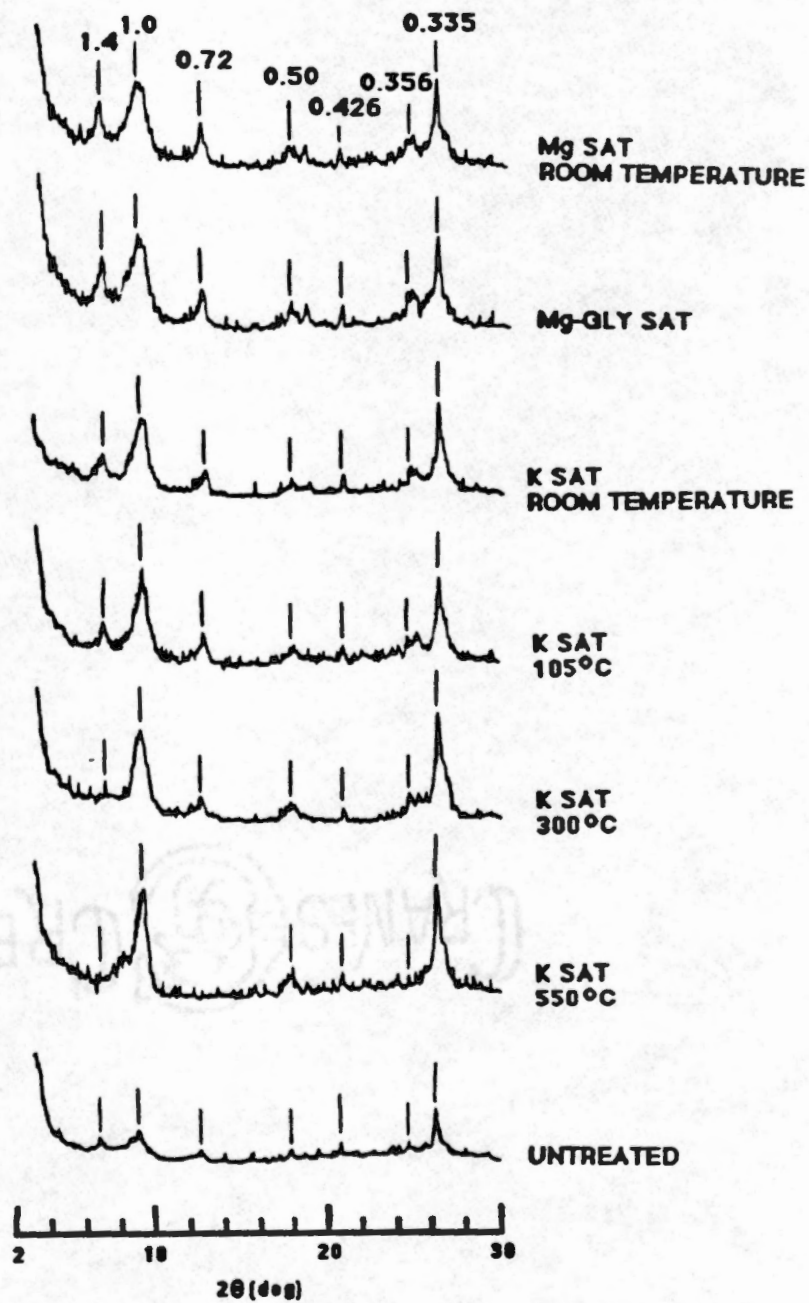
PROFILE 24-N
B/Cr (66-118 cm)

$\leq 2 \mu\text{m}$

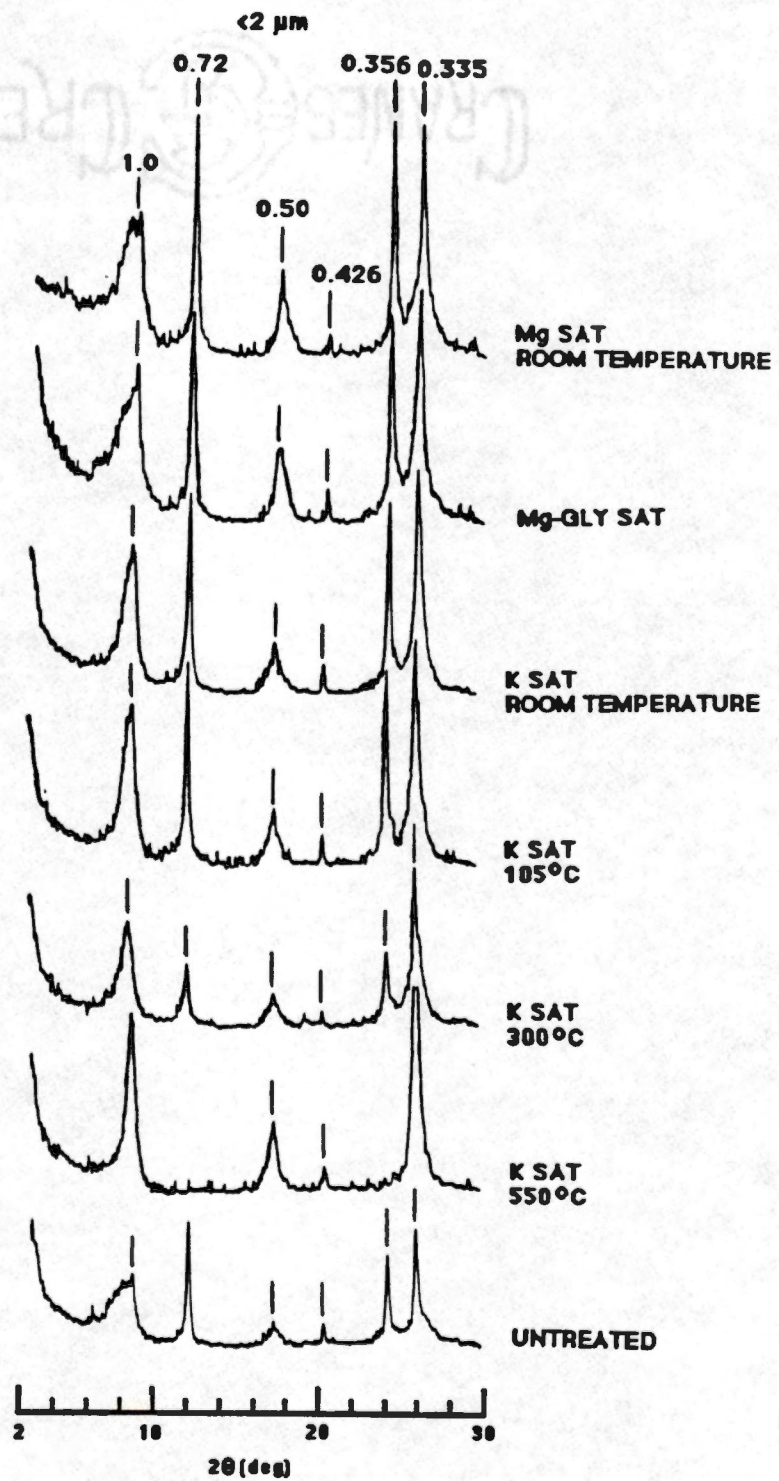


PROFILE 24-N
Cr1 (G) (66-118 cm)

<2 μm

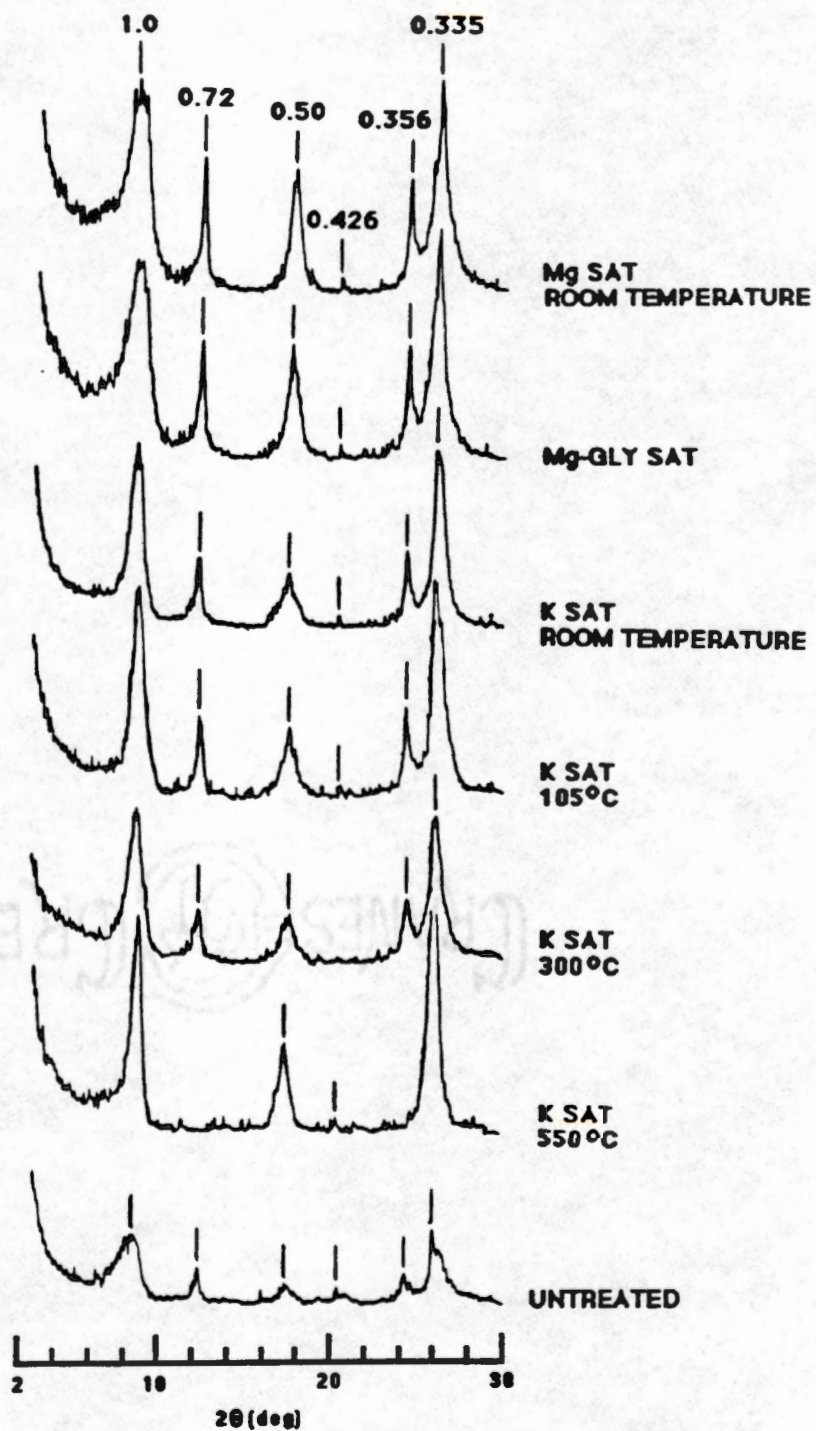


PROFILE 36-E
A-Bw (0-25 cm)



PROFILE 36-E
Cr1 (25-200 cm)

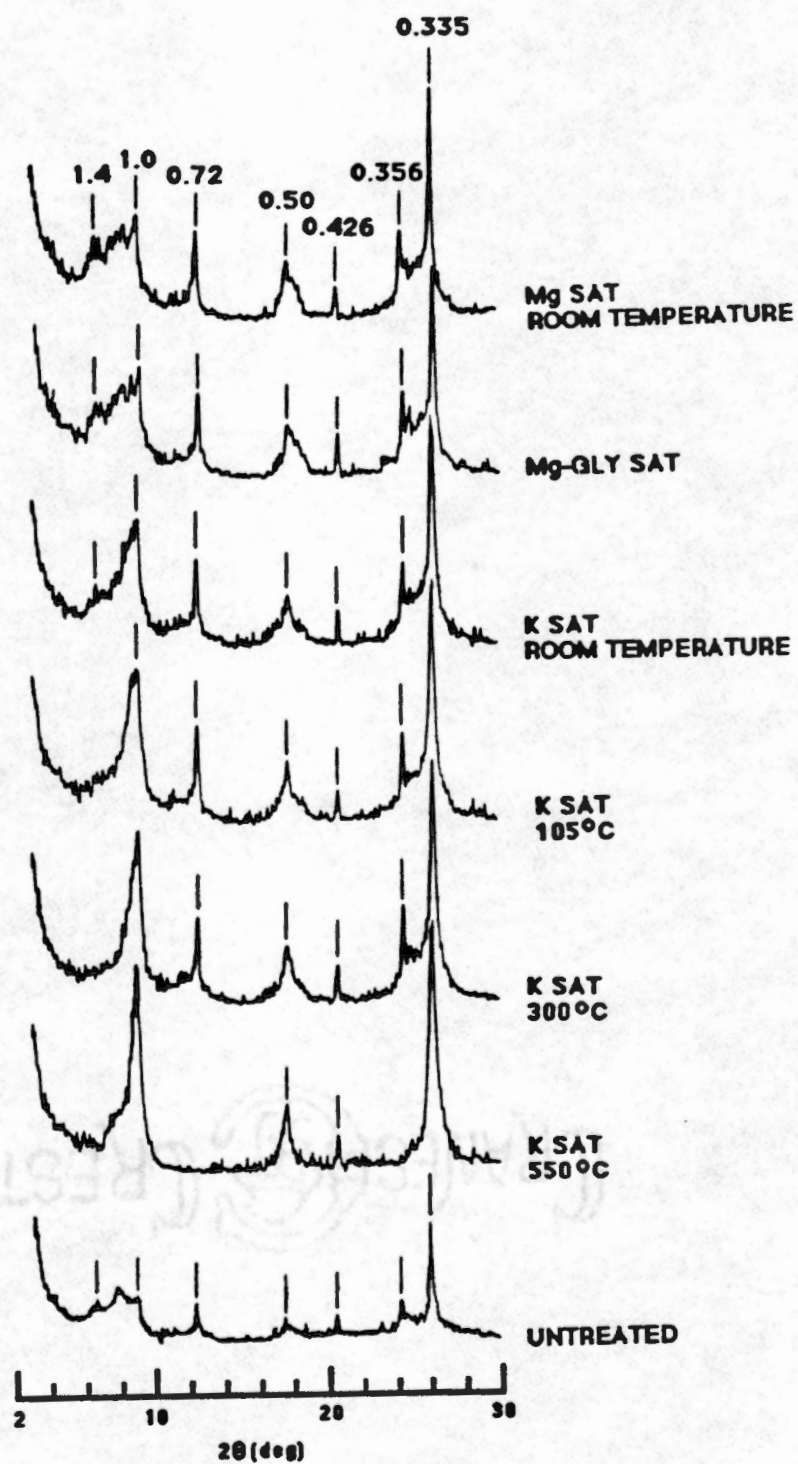
<2 μ m



PROFILE 36-N

A (0-9 cm)

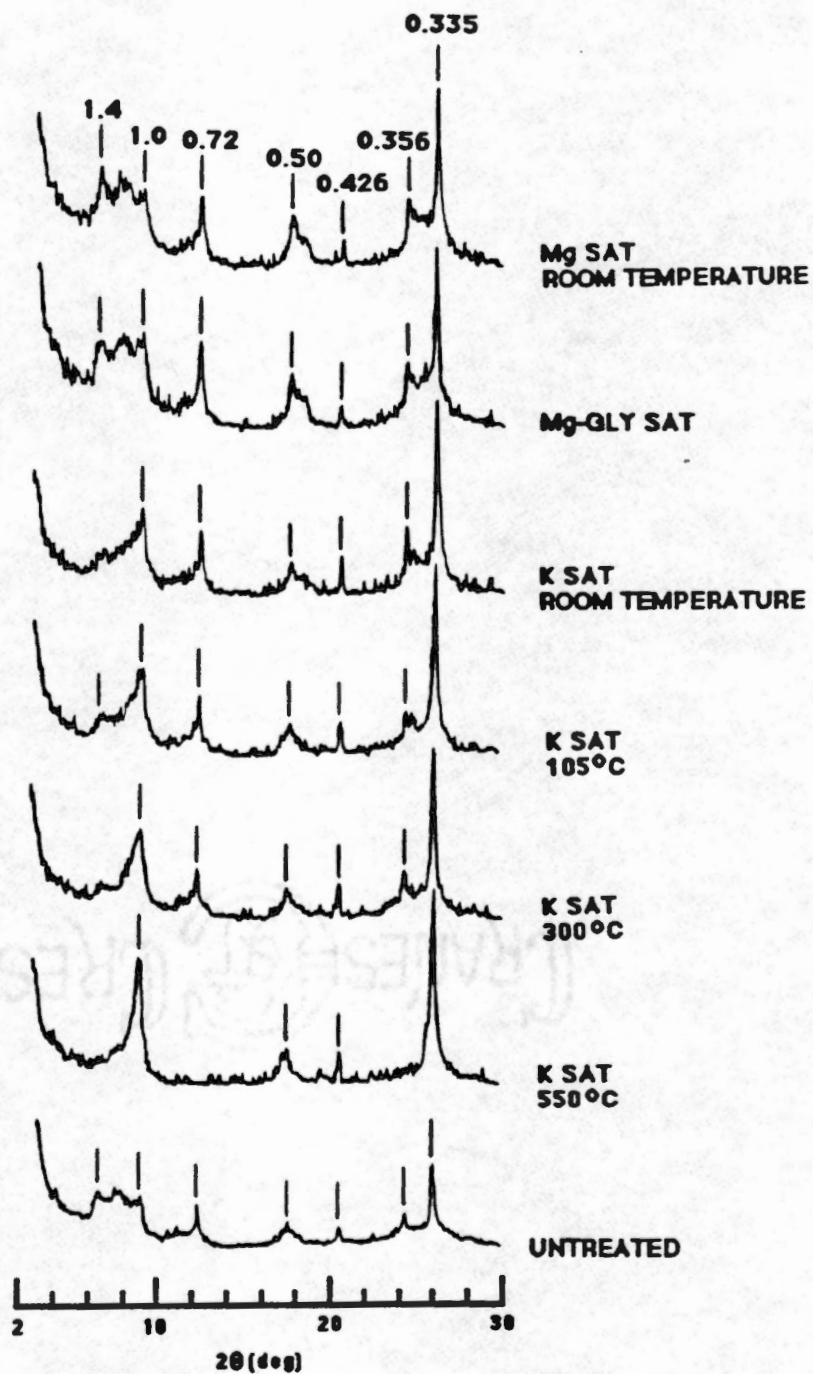
<2 μ m



PROFILE 36-N

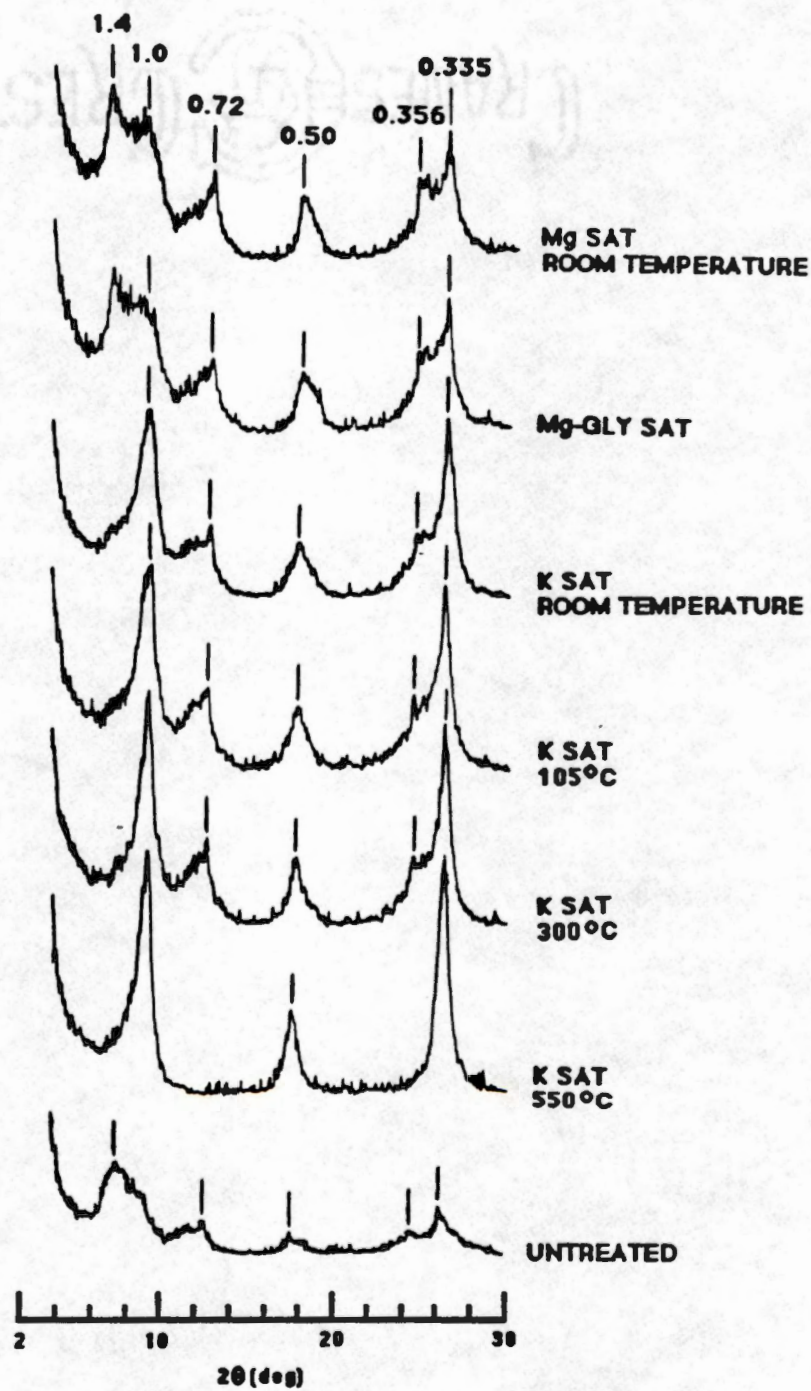
Bw (9-29 cm)

<2 μ m



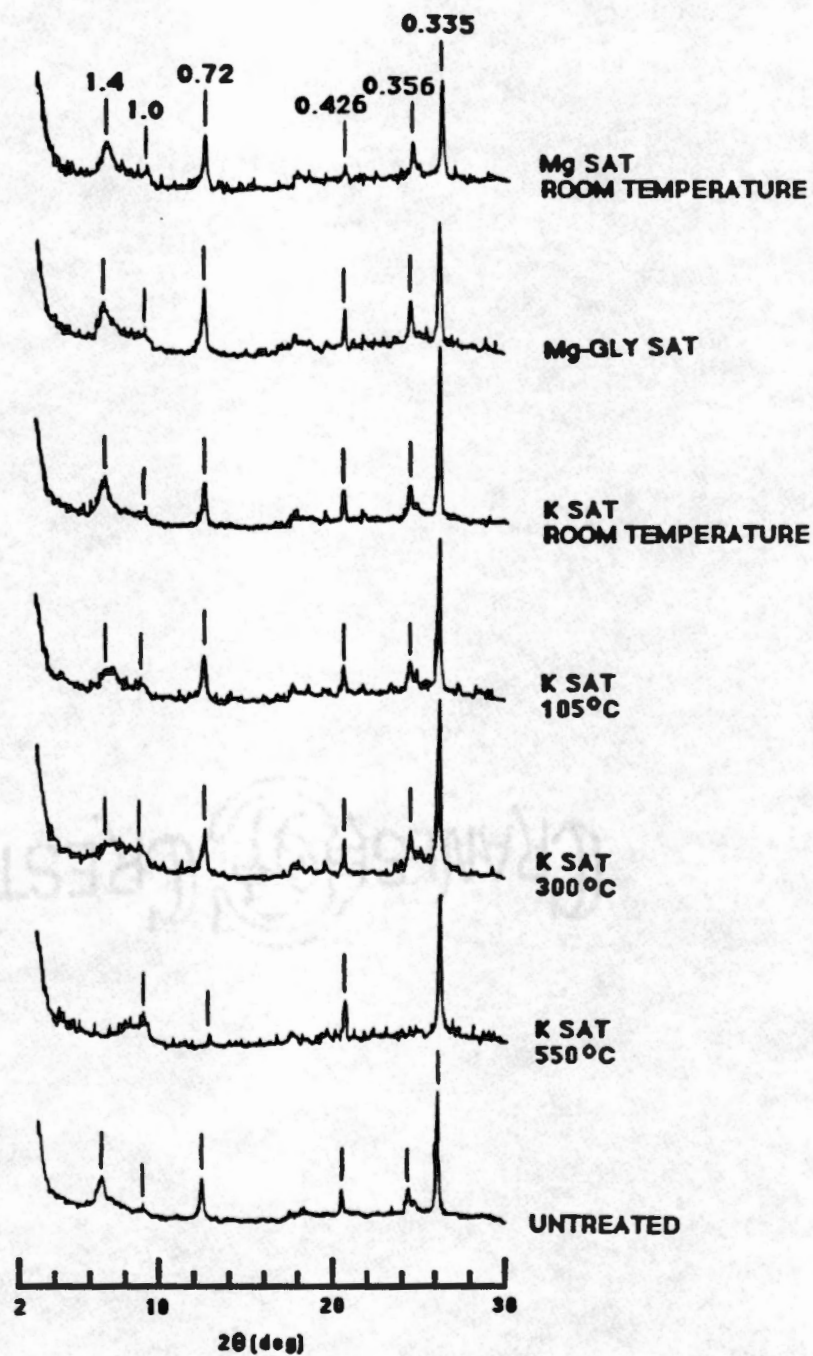
PROFILE 36-N
Cr1 (29-130 cm)

<2 μm



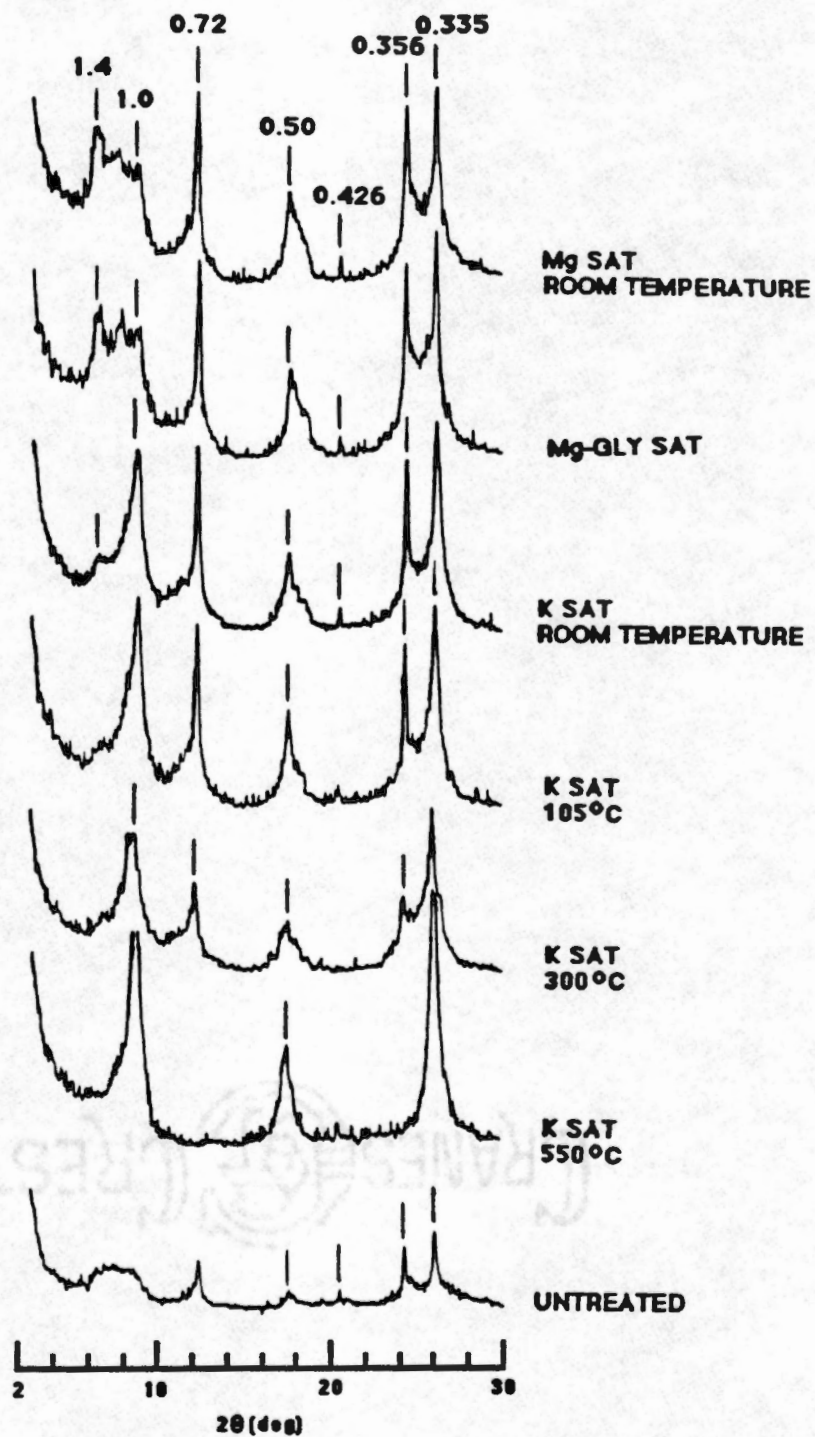
PROFILE 951
Ap (20-28 cm)

<2 μ m



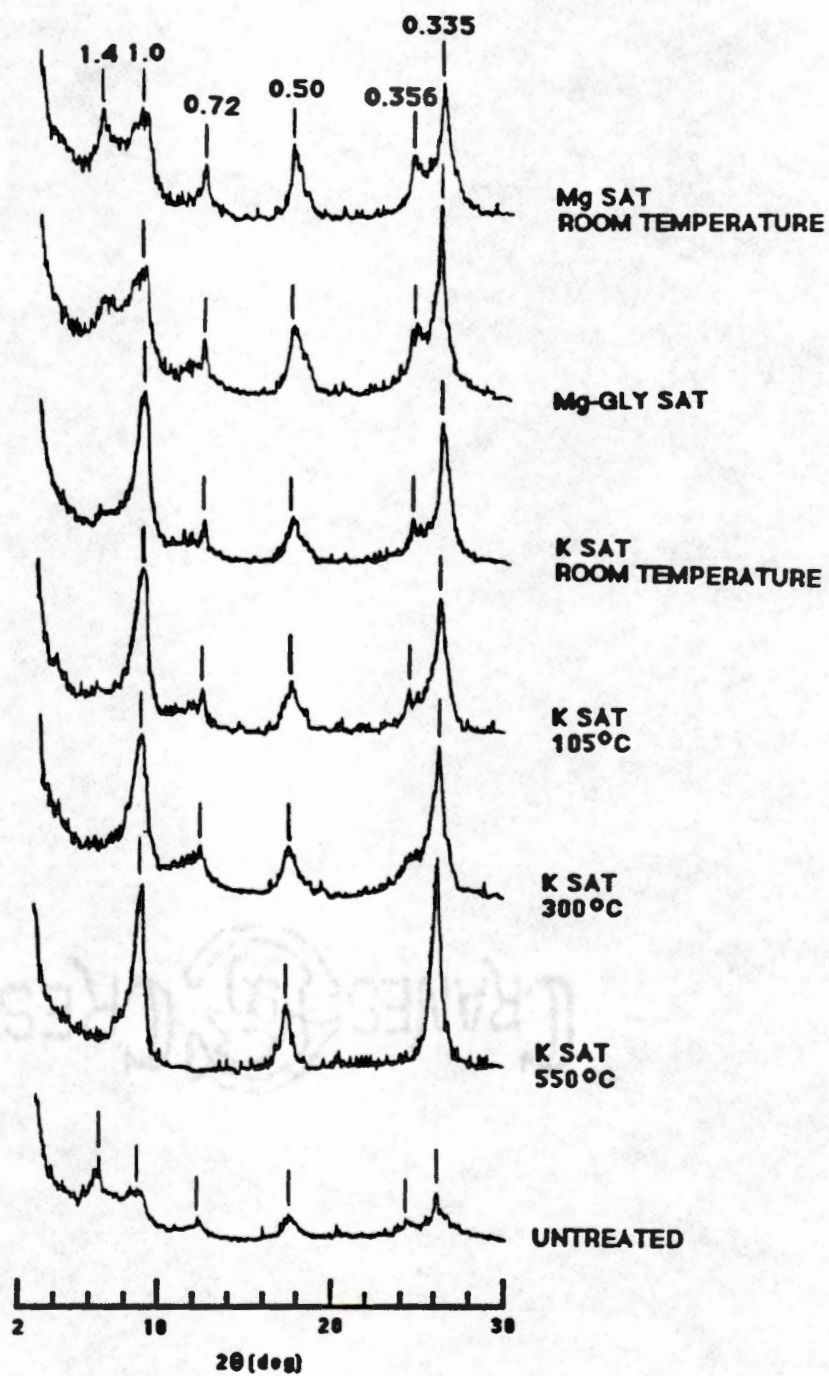
PROFILE 951
Bt (48-76 cm)

<2 μ m



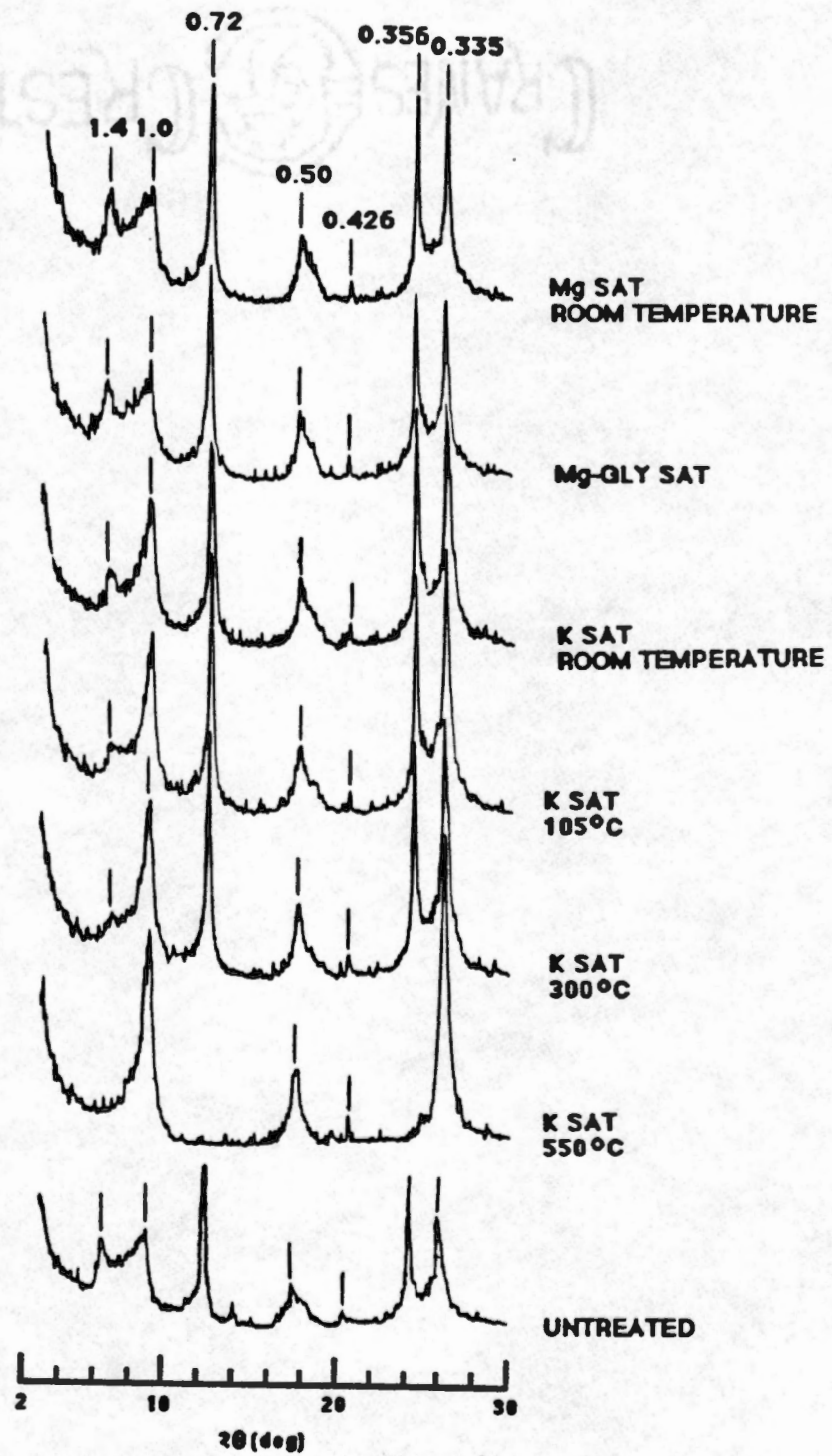
PROFILE 951
3Cr (121+ cm)

<2 μm



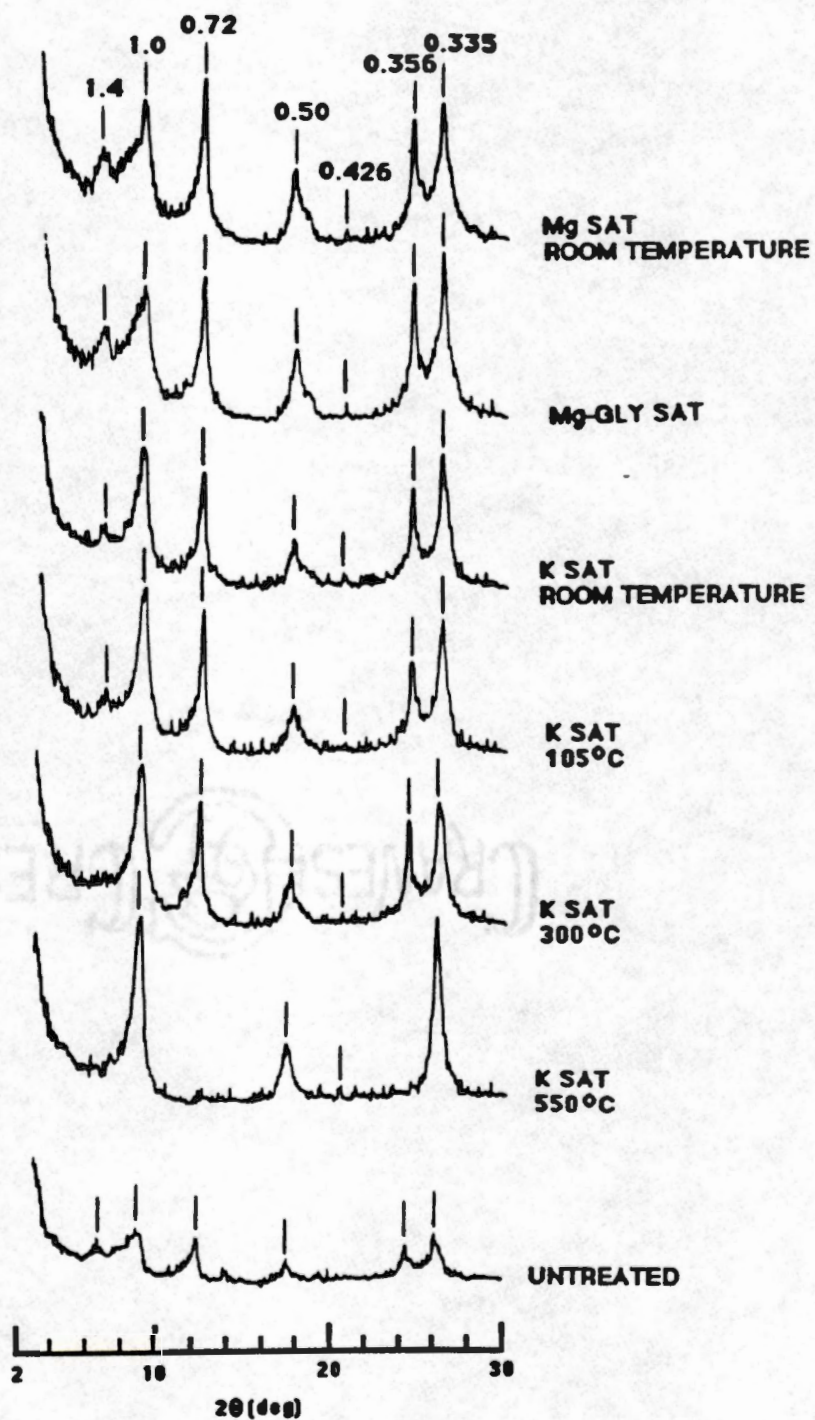
PROFILE 26/951
Ap (0-21 cm)

<2 μm

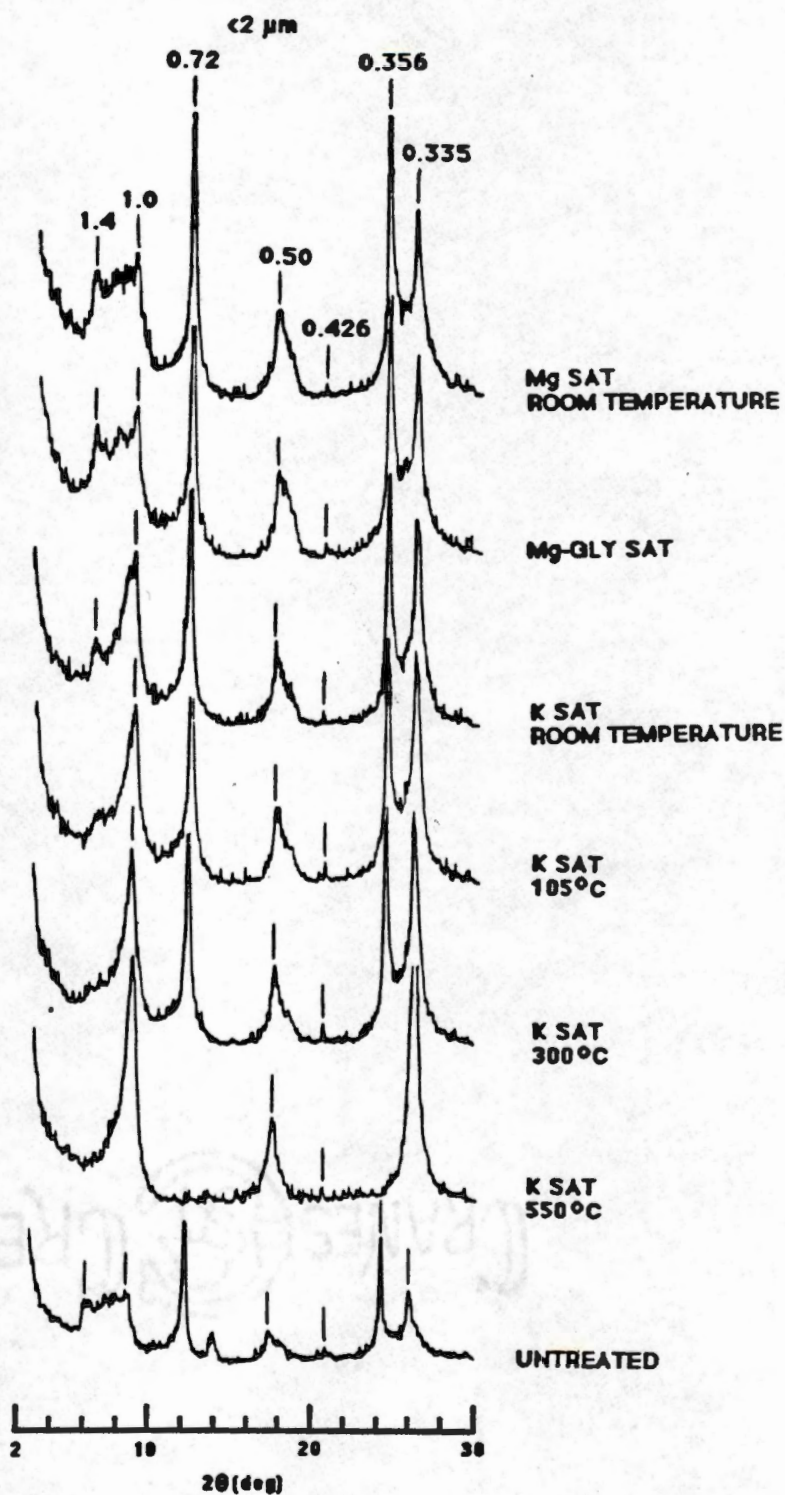


PROFILE 26/951
Bt1-4Bt (21-122 cm)

<2 μm

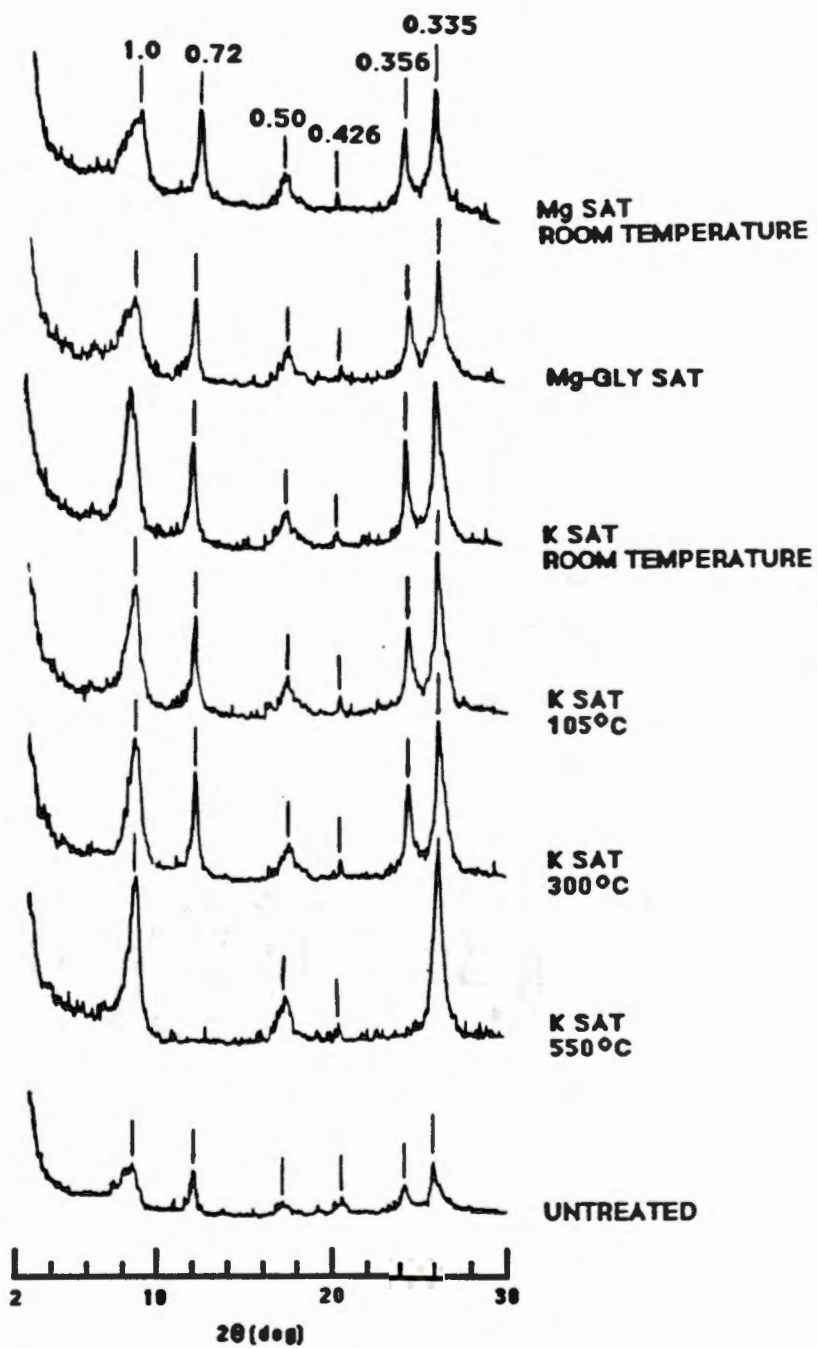


PROFILE 26/951
5Bt1-6Bw2 (122-270 cm)



PROFILE 26/951
7C-7Cr (270+ cm)

<2 μm



VITA

Ricky Edward Lambert was born on February 20, 1964, in Lebanon, Tennessee, to Mr. and Mrs. Charles E. Lambert. After completing his primary and secondary education in Lebanon, he entered the College of Agriculture at The University of Tennessee, Knoxville.

While in high school and college, he was active in vocational agriculture activities such as soil judging, public speaking, parliamentary procedure and farm skills. He ran for State FFA office in 1983. While in college, he did considerable volunteer activities for the Wilson County, Tennessee Soil Conservation District. In 1985 Mr. Lambert was a trainee for the University of Tennessee Agricultural Extension Service in Greene County, Tennessee, on a Phillip Morris Scholarship.

After receiving his B.S. degree in 1986, he reentered the College of Agriculture as a graduate research assistant. The author is presently a member of Phi Kappa Phi and Gamma Sigma Delta honorary societies, and is a student member of the American Society of Agronomy, Soil Science Society of America, and the Geological Society of America.