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A Pedological Investigation of Soils of the Cumberland Plateau of Tennessee

Edward Gaither Arnold
University of Tennessee, Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Edward Gaither Arnold entitled "A Pedological Investigation of Soils of the Cumberland Plateau of Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Environmental and Soil Sciences.

Tom Ammons, Major Professor

We have read this thesis and recommend its acceptance:

Neal Eash, Darwin Newton

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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A PEDOLOGICAL INVESTIGATION OF SOILS OF THE CUMBERLAND PLATEAU OF TENNESSEE

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

Edward Gaither Arnold
May 2005

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ABSTRACT

Soil formation depends on the unique interactions of influential soil forming factors. Soil parent material determines many of the properties exhibited by soil formed within that parent material. The Cumberland Plateau of Tennessee is a broad, uplifted, level-bedded, block of Mississippian and Pennsylvanian age stratigraphy located from 83°40'00" W to 85°05'00" W latitude along the Kentucky border and 85°20'00" W to 86°15'00" W along the Alabama border. The Pennsylvanian stratigraphy is composed mainly of sandstone with some interbedded beds of shale. The geology of the Plateau is in many locations overlain by a deposit of silt-laden, eolian loess likely deposited in the early Holocene (~10,000-12,000 years ago) shortly after the last glacial maximum. Certain landforms such as ridge tops were conducive to loess deposition while side slope positions did not facilitate deposition. As a result, soils present on the Cumberland Plateau exhibit properties that reflect the inherent differences related to soil parent material.

The objective of this study was to examine the effects of soil parent material and slope on soil genesis and morphology. An analysis of inherent soil properties will support determinations of soil parent material type and the degree of pedogenic alteration that has occurred within that soil parent material. Sites selected for this study have soils that represent the varied landform types present on the Plateau and the differing soils formed on those landforms. In areas that allowed for loess deposition soils exhibit a parent material sequence of loess over sandstone residuum while soils on side slopes formed from residuum. Pedons sampled from sites located on the Plateau Agricultural

Experiment Station and Grassland Unit of the University of Tennessee were described and characterized through both field and laboratory investigation according to National Cooperative Soil Survey guidelines. Particle size analysis data proved useful in the examination and determination of soil parent material source. In pedons that exhibited a discontinuity a particle size analysis on a clay free basis was used to examine differences in soil parent material that would perhaps be masked by pedogenic alteration of clay minerals.

The study pedons exhibit properties that seem primarily dependent on the influence of soil parent material and soil slope. Soils in upland areas that form from transported loess over residual sandstone contain fragic properties at the interface of the two contrasting parent materials. These soils are classified as Typic Fragiudults and Typic Hapludults based their individual morphology. Soils formed on side slopes do not contain loess. The sandstone on which these soils form is highly resistant to weathering and pedogenic alteration. As a result, soils formed on steeper slopes do not exhibit a high degree of pedogenesis. These soils are classified as Typic Dystrudepts.

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THESIS OVERVIEW

The State of Tennessee is comprised of several varying physiographic regions, each with a unique set of conditions that have facilitated and influenced soil formation within each region. The Cumberland Plateau is an uplifted block of mostly level-bedded Pennsylvanian age statigraphy composed of sandstone interbedded with shale, mudstone and siltstone. Due to variability in the landscape (elevation, slope aspect, etc.), erosion has removed loess deposits from some landforms while other landforms are stable enough to maintain these deposits. Respective soils present on varied landscape positions reflect inherent differences in soil parent material. The objective of this research is to determine the effects of soil parent material and slope on soil formation. The contrast between soils formed in wind transported material and soils formed in residual parent material serves as a basis for comparison of the differing properties resulting in differing parent materials. Soils were classified to the family level of Soil Taxonomy. Part 1 is a brief overview of the research.

Part 2 focuses on soils formed from transported parent materials. The pedons examined in this section have key characteristics that indicate the influence of soil parent material as these soils formed from loess over residuum. The presence of fragipans and fragic properties supports the description of a lithologic discontinuity at the interface of the two parent materials.

Part 3 focuses on soils formed in sandstone residuum. These soils formed mostly on side slopes and locations within the landscape where the loess has eroded away. The quartz-rich nature of sandstone is highly resistant to weathering and soil formation within sandstone parent material is limited by this resiliency. The soils formed from residuum exhibit properties that reflect limited alteration by pedogenic processes.

The goal of this research is to determine the influence of soil parent material and soil slope on soil formation on the Cumberland Plateau. Analysis of soil morphology and examination of pedon location within the landscape provides a basis of relation between soil slope and potential soil parent material type. It is predicted that soils formed on apexes on the landscape of the Plateau will exhibit properties inherent to a discontinuous lithology comprised of wind-transported soil parent material overlying residual soil parent material. Examination of the expression of soil properties throughout a soil profile allows for interpretation of the processes leading to soil formation.

Part 2. Effects of pedogenesis on transported parent materials on the Cumberland Plateau of Tennessee

INTRODUCTION

Parent material is one of the five soil forming factors and is inherently a major determinant in soil formation (Jenny, 1941). As a result, soil properties express characteristics of the constituents of the parent material and consequently provide insight into the unique conditions leading to and facilitating soil development. Soil parent materials may be of alluvial, colluvial, eolian, or residual origin or may be formed in combination. Soils may develop in more than one sequence of parent material resulting in discontinuities in the soil profile. The resulting soil exhibits properties reflecting the differences between these parent materials such as particle size, silt ratio, and chemical makeup. Soil formation is related to the physical and chemical properties of the parent material sequences of soil origin.

The Cumberland Plateau of Tennessee (MLRA 125) is a broad, uplifted plateau comprised of level-bedded strata (Safford, 1900). Figure 1 is a map showing the general research area. The southernmost representation of the larger Allegheny Plateau that extends from western Pennsylvania all the way to northern Alabama; the Cumberland Plateau is characterized by its rugged topography, expansive forests, and unique geology. The trend of the stratigraphy runs from northeast to southwest in an almost unbroken band of elevated strata (Safford, 1900). Along the Kentucky border, the Plateau extends from about 83°40’00” W to about 85°05’00” W longitude. Its extent along the Alabama border stretches from about 85°20’00” W to 86°15’00” W longitude. Due to orogenic uplift the mean elevation on the plateau is 305 m (1000 ft) higher than the Valley and Ridge province to the east and the Highland Rim to the west. Due to the elevation, the average temperatures are lower and mean precipitation is higher on the Plateau than in

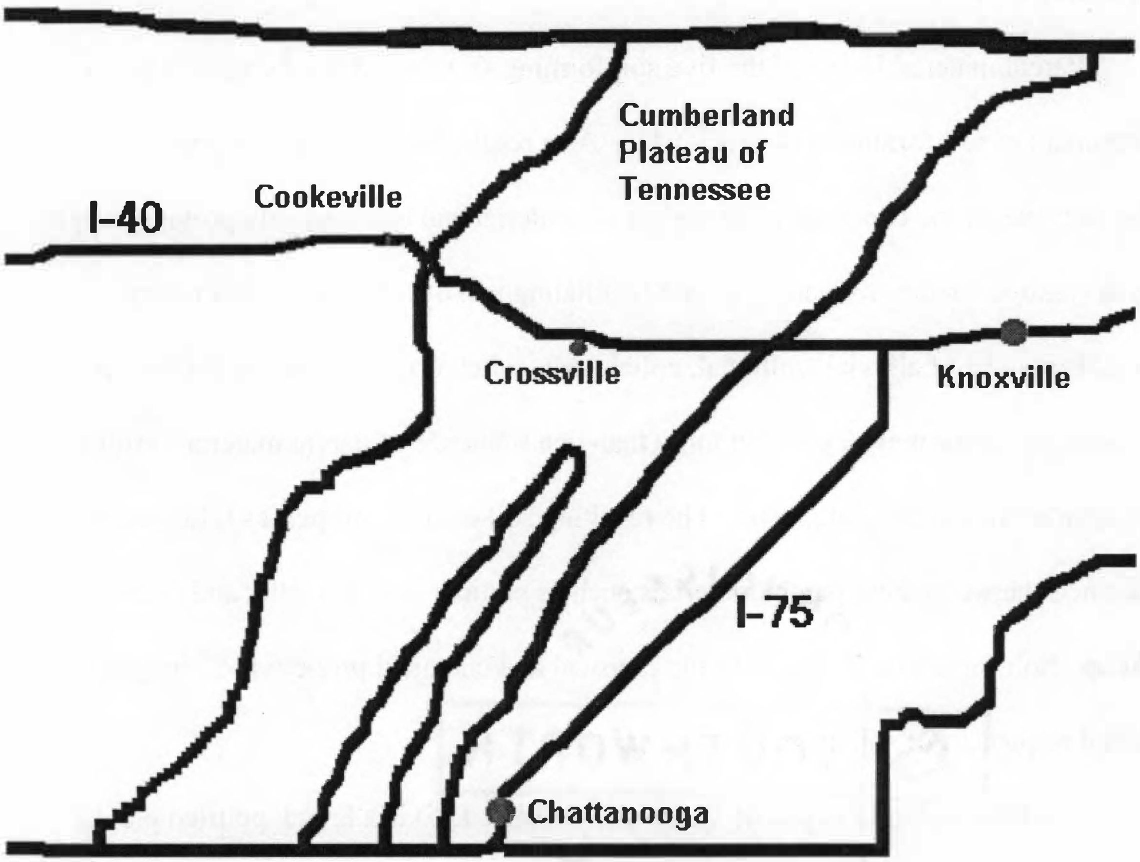

Figure 1: Map showing general research area near Crossville, Tennessee

adjoining regions of lower elevation (Bailey and Vaiksnoras, 1966). Mean annual precipitation is from 137 to 152 cm (54" to 60") on the Cumberland Plateau (Springer and Elder, 1980). On the Plateau annual soil temperature is greater than 8° C (46° F) and less than 15° C (59° F) (Springer and Elder, 1980), making the soil temperature regime mesic (Soil Survey Staff, 1999).

The Cumberland Plateau of Tennessee, as a part of the Allegheny Plateau, is the largest forest covered plateau in the world. A mixed forest of deciduous and evergreen trees covers most of the area. As a result, timber production has been a major industry on the Plateau throughout the Twentieth century and continues today with managed stands of pulpwood owned by paper producers. Although very limited now, the early part of the 1900's saw coal mining arise as another vital industry to the area. Considerable deposits of bituminous coal underlay a large portion of the Plateau, making coal mining another viable industry. In addition, quarrying of the highly sought after Crab Orchard stone is yet another industry. This sandstone is noted for its beautiful colors and patterns, making it very popular for civic as well as private construction. With proper management, soils of the Cumberland Plateau can be very agriculturally productive. While most of the agricultural land use is for pasture, vegetable production units as well as vineyards are successful enterprises. Common soil types appearing on the Plateau are Hapludults where pedogenesis has occurred and Dystrochrepts in areas of little pedogenic alteration (Springer and Elder, 1980). The objective of this study is to analyze the effects of soil parent materials and slope on soil formation on the Cumberland Plateau.

LITERATURE REVIEW

Geology

The stratigraphy of the Plateau is characterized by a caprock of weathering resistant Pennsylvanian age sandstones underlain by deposits of more soluble carbonate Mississippian rocks (Stanley, 1999). The strata of the Cumberland Plateau have its origins in the late Paleozoic Era in a period known as "The Carboniferous". In the early portion of the "Carboniferous" known as the Mississippian Period (345-310 Mya) warm, shallow seas covered much of the surface of the Earth. Vast aquatic reefs supported large populations of crustaceans, mollusks, and underwater plants. These shallow, underwater ecosystems were subject to the effects of sea level fluctuation and storm events as evidenced by the mixed stratigraphy present. These fluctuations are likely attributable to variations of glacial cycles (Sacks and Secor,1999). Interstratified layers of limestone, shale and dolostone comprise the strata underlying the younger strata of the Pennsylvanian Period. While terrestrial plants appear in the Devonian Period it was not until the Pennsylvanian that the first primeval forests were able to persist.

According to plate-tectonic theory, beds of Mississippian and Pennsylvanian age material were uplifted as a result of the subduction of the Laurentian (North American) plate beneath the Gondwanaland (African) plate during an event known as the Allegheny orogeny (Sacks and Secor, 1990). This event, occurring near the end of the Pennsylvanian period, was also responsible for the formation of the Appalachian Mountains and the uplifting of the Allegheny Plateau to its current elevation. The eastern escarpment of the Cumberland Plateau is situated along a thrust fault. As a result the stratigraphy west of this thrust fault was pushed upward in almost a continuous block of

Mississippian and Pennsylvanian material. The colliding forces of the continental impact pushed the block from the east, creating a veritable wall of strata along the eastern escarpment. The sandstones that cover the upper portions of the plateau are highly resistant to weathering and erosion. The landforms present reflect this resistance to weathering. Dissected ridges and adjoining hollows are common features where the most resistant stones hold up the landform. In addition, large, flat areas persist in many locations and are often edged by dissection.

Loess Deposition

During the Pleistocene, cycles of continental glaciations continued as evidenced by glacial landforms, glaciofluvial depositions, and loess depositions that appear in North America and other portions of the world, notably near the Yellow River of China. As interglacial warming-periods caused ice sheets to melt away, large streams of sediment-laden outwash rapidly flowed from beneath the ice. As the waters receded and former streambeds dried, the materials within were exposed for transport by westerly winds. This glacially derived loess then collected on forested areas of higher elevation that could effectively entrap the eolian material (Karanthanasis and Golrick, 1991). Such depositions likely occurred as recently as 10,000 years before present around the beginning of the Holocene epoch. Examining loess deposits from the Missouri and Mississippi river valleys, Forman and Pierson (2002), used luminescence dating in an attempt to pinpoint the time of deposition. Through their work they were able to pinpoint four distinct loess depositions occurring from 180-140 kya (thousand years ago), 100-80 kya, 60-30 kya, and 25-12 kya, respectively. While the Nashville Basin was much farther south than the glacial fringe, cyclical fluctuations likely impacted alluvial features within the Basin. The flood plains created from glacially influenced waters and the subsequent drying of the flood plains when the waters receded may be the origin of the eolian material present on the Plateau. To determine if loess deposits in Nebraska were from glacially influenced streams, JA Mason (2001), examined the Peoria loess deposit. This study revealed that glacially influenced streams were secondary sources for loess and that the primary source was from non-glacial areas, influenced more by climatic change than by direct glacial influence. While sources farther to the west in areas where glaciations were unquestionably influential provided an abundance of wind-transportable materials, distance would be a limiting factor for transport to the elevations present on the Plateau. The thickness of loess deposits is influenced by both the landforms and the slope aspects of the landforms present in the area of deposition (Karanthanasis and Golrick, 1991).

Fragipans

Since fragipans were first described in the field, the origin and mechanics of fragipan formation has been under continuous discussion. A fragipan is "an altered subsurface horizon, 15 cm or more thick that restricts the entry of water and roots into the soil matrix" (Soil Survey Staff, 1999). Redoximorphic features are common in many fragipans due to the restriction of water movement. Many have noted the presence of fragipans within soils as indicators of differing parent materials (Bockheim, 2003; Smeck and Ciolkosz, 1989; Duncan and Franzmeier, 1999). There are several prevailing theories as to the actual mechanisms by which fragipans form, most of which attempt to explain fragipans in loess materials. Smeck et al., (1989) present three main mechanisms that are generally accepted as components of fragipan formation. Close packing of soil particles is the mechanism described in several studies (Fitzpatrick, 1956; Crampton, 1965; Petersen et al., 1970; Wang and Arnold, 1973; Ritchie et al., 1974). Through close packing of soil particles the bulk density of the soil increases as pore space is reduced within the soil. This reduction in pore space and increase in density is apparent in fragipans. Bryant proposed a theory of hydroconsolidation that suggests that the wetting and loading of loess causes the compaction and cementation inherent to fragic soil materials. According to hydroconsolidation, as loess materials are subjected to water and the weight and pressure associated with the moisture soil particles collapse to form a fragipans. The second proposed mechanism, clay bridging, is examined by Grossman and Cline (1957); Knox (1957); Yassoglou and Whiteside (1960); Hutcheson and Bailey (1964); Horn and Rutledge (1965); Lynn and Grossman (1970); Miller et al., (1971b); and Wang et al., (1974). The mechanism of clay bridging requires an optimal proportion of clay within the soil to facilitate the illuviation of clay minerals within pores of the pan horizon to effectively bind soil particles. Assallay et al., 1998, further developed Bryant's hypothesis examining the features common to soils with fragipans. They found that an optimal range of the clay particle size class within parent materials was a likely requirement. Also, they noted that slopes of less than 12% were also necessary for stable formation. The third generally accepted mechanism is amorphous bonding (Krusekopf, 1942; Winters, 1942; Knox, 1957; Anderson and White, 1958; Romans, 1962; Nettleton et al., 1968b; DeKimpe, 1976; Harlan et al., 1977; Bull and Bridges, 1978; Norton and Franzmeier, 1978; Hallmark and Smeck, 1979; Steinhardt and Franzmeier, 1979; Norton et al., 1984; Karathanasis, 1987a, b). In amorphous bonding, binding agents such as silica precipitate from within soil minerals as aluminum replaces silica in weathering. Duncan and Franzmeier, (1999), examined the role of Si, Al, and Fe in fragipan formation and found that substitution of Al for Si in minerals within the fragic materials could be a cause for the cementation of the horizon. In this study Duncan and Franzmeier found as aluminum replaces silica within clay minerals the silica goes into solution where it can bind with other minerals within the pan. In contrast, Aide and Marshaus (2002), in a study of fragipan genesis in East Central Missouri found no evidence of silica as a binding agent. They suggest that fragipan genesis is more influenced by the architecture of soil particles within the pedon than by chemical cementation. Smeck et al., (1989) further examine the role of an amorphous bonding agent as a result of a weathering discontinuity. They define a weathering discontinuity as "a transitional zone between highly weathered horizons and less weathered horizons" and note the existence of weathering discontinuities in soils formed from a loess mantle overlying a residual soil. They suggest that the interface of highly weathered subsoil with a relatively unweathered overlying material facilitates fragipan formation. A calcareous unweathered material such as loess is deemed optimal in this study as components from the calcareous loess react with hydrous oxides of Si and Al in the preexisting weathered soil to form an amorphous bonding agent.

In studies of loess deposits within the Lower Mississippi River Valley, Lindbo et al., (1997) attempt to isolate fragipan occurrence within a particular sequence of loess. They find that fragipan formation is independent of a specific transported material and occurs in varied sequences within their study area. Some propose that fragipan formation occurs at the time of deposition of an overlying material, while others contend that fragipan formation is an ongoing process. A consistent depth of the boundary of fragic horizons also appears in most fragipans. While the causes of fragipan formation have been argued since the earliest recognition of their existence, it is known that fragipans and fragic soil properties are common at discontinuities. It is difficult to determine which soil chemical and physical properties lead to fragipan formation as the conditions facilitating fragipan development occur in combination. In addition, the freeze-thaw effects of periglacial activity perhaps play a role in fragipan formation. The changes that occur to soil architecture as the soil is repeatedly frozen and thawed may affect fragipan development. High elevation and a cool climate make conditions on the Cumberland Plateau suitable for periglacial alteration.

Consideration must be given to the presence and nature of fragipans and fragic properties. Landscape position, relief and landform type as well as physical and chemical processes affect soil formation. The extent of these factors indicates the varying conditions and circumstances under which pedogenesis occurs. The presence of fragipans within a soil body is an invaluable indicator of soil formation. Examination of fragipans and their location within the landscape allows for a better understanding of soil pedogenic processes.

MATERIALS AND METHODS

Site Description

In this study, two pedons were examined from sites located on the Crossville and Grassland Agricultural Experiment Stations located near Crossville in Cumberland County, TN. Figure 2 is a map showing the location of the experiment stations. These sites were selected to determine if these soils are derived from more than one parent material and how landscape positions affect soil formation. Pedon 1 was located at 36° 01' 08"N latitude and 85° 07' 47"W longitude on the Crossville Experiment Station. The

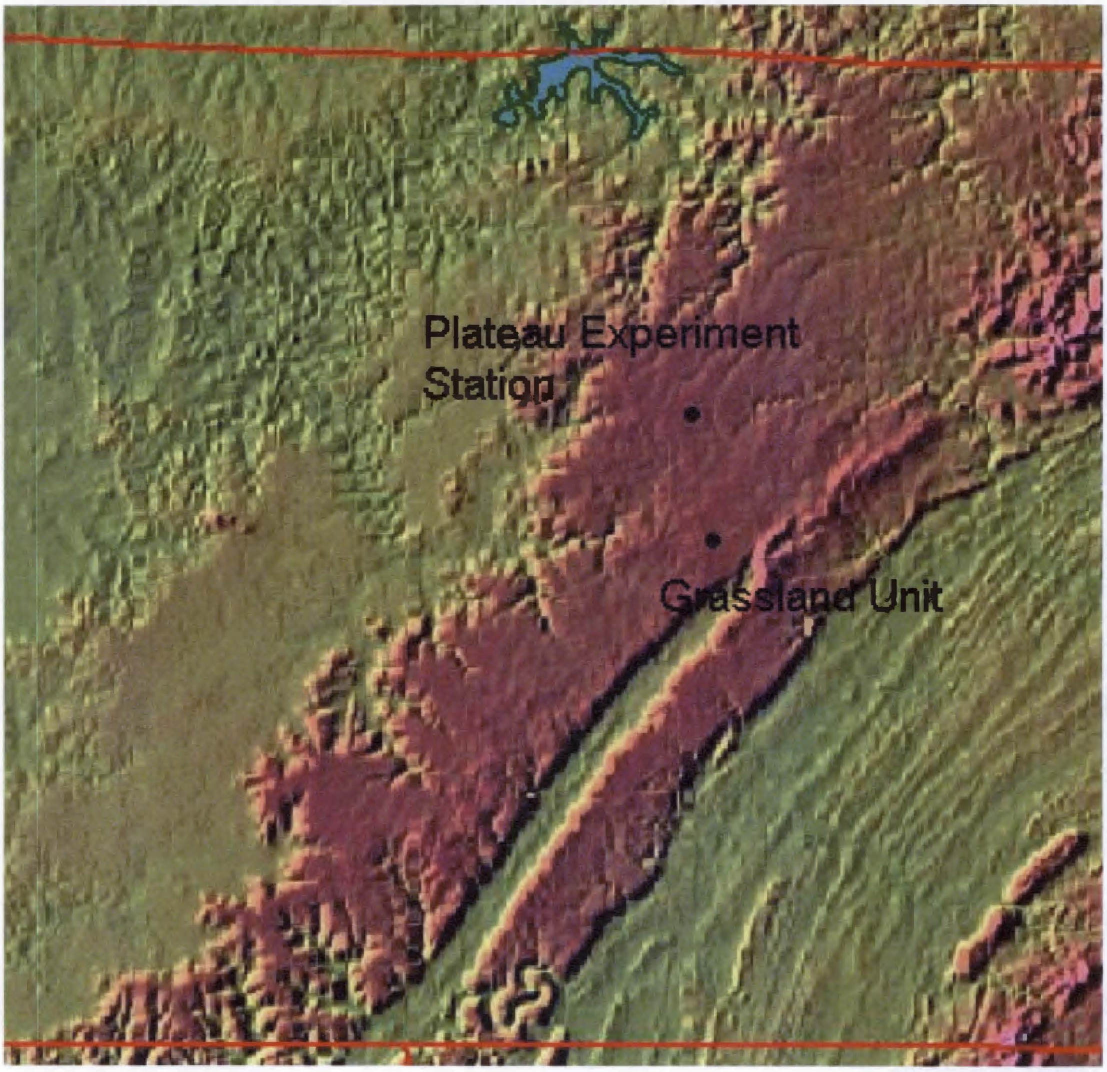

Figure 2: Map showing general location of experiment stations.

landuse was pasture for this pedon with the vegetative cover primarily composed of fescue. This pedon was on a somewhat rolling upland with a soil slope of 3%. Slope aspect for Pedon 1 was around 165° and elevation was around 590 meters. Pedon 2 was located at 35° 50' 30"N latitude and 85° 04' 03"W longitude on the Grassland Farm Unit of the University of Tennessee Experiment Station. This pedon was located on top of an upland knob at an elevation of 579 meters. The slope aspect is 270°. The vegetative cover for this site was mixed grass and clover pasture. The Rockcastle Conglomerate geologic formation underlay both locations and served as the residual soil parent material (Hardeman, 1966). This geologic unit was comprised of conglomeratic sandstone and sandstone that was gray to brown in color and fine to coarse grained in texture (Hardeman, 1966).

Field Methods and Sample Preparation

Sites were selected based on their upland locations within the landscape. Both pedons were sampled according to Soil Survey Division Staff Guidelines (1993), with samples taken from each horizon described. Horizons were described based on the properties present within the pedon. Notes regarding characteristics unique to the soil profiles in question were made to aid in interpretation. Field samples were air-dried, crushed and weighed according to Soil Survey Investigation Report No. 42, 1996. Samples are sieved to less than 2mm.

Laboratory Methods

All laboratory analyses were performed and the National Soil Science Laboratory in Lincoln, Nebraska. Particle size analysis was performed using the pipette method (Kilmer and Alexander, 1949). A clay-free particle size analysis is noted by the Soil

Survey Staff (1999) as a viable means of determining the presence or absence of lithologic discontinuities and has been employed in studies by Karanthanasis and Macneal (1994) to evaluate uniformity criteria for parent materials in loess derived soils. For this analysis the sum of very fine and fine sand divided by the sum of total sand and silt is calculated. This calculation is performed to reveal any inherent differences in soil texture that have been masked by pedogenic illuviation of clay. Fractionation of sands into very coarse, coarse, medium, fine, and very fine was performed according to Gee and Bauder, 1986. Analysis of the ratio of total silt to total sand is valuable in this study to delineate loess derived soil parent material from residual soil parent material. Since the residual soil parent material is composed of sandstone the ratio of silt to sand further indicated the contrast between the eolian and residual soil parent material. In addition, the ratio of coarse silt to fine silt was calculated to aide in the interpretation of the proximity of the loess source to the study area. A ratio of nearly 1:1 would indicate a local source of loess as a coarser material falls nearer to its point of origin than a finer material. The finer material is lighter, resulting in distances that exceed those possible in transporting coarse materials.

Exchangeable bases were found using the ammonium acetate rapid distillation method according to Chapman (1965). Base saturation was determined mathematically as described by the Soil Survey Staff (1996). Total carbon was found using atomic combustion analysis. Since the pedons on the Plateau are not calcareous it was assumed that total carbon represented the organic carbon portion of the soil. Free iron is a useful indicator of weathering as iron bearing minerals are the product of weathering. Free iron was determined by the dithionate-citrate extraction method. A 1:1 pH was performed on each sample with H_2O (McLean, 1982). The culmination of field and laboratory data led to the classification of study pedons to the family level of soil taxonomy (Soil Taxonomy, 1999).

RESULTS AND DISCUSSION

Transported Site 1

The parent material sequence for this pedon is eolian loess over Pennsylvanian sandstone residuum. This pedon extends to a depth of 155 cm where paralithic contact with the underlying soft and weathered Pennsylvanian geology occurs. Slope at this position is 3%. A map of the research location appears in Figure 3.

Soil morphology for Pedon 1 appears in Table 1. This soil contains a diagnostic argillic horizon (25-155 cm). At the 48 cm depth, a sequence of two horizons exhibiting fragic properties occurs and extends to a depth of 94 cm. Two horizons within the fragic material interface at a depth of 66 cm. This boundary separates the two differing parent materials of this pedon. A Btx horizon exhibits properties inherited from loess material including a high proportion of silt. The 2Btx horizon apparently formed in residual material contains the brittleness, blind pores, leached vertical seams and weak prismatic structure that are characteristic of fragipans. In order for a fragipan to be diagnostic within a soil certain conditions must be met. The horizon must be 15cm or more thick, must show signs of pedogenesis, and must contain 60% or more by volume masses that are firm or firmer in rupture resistance class, are brittle at or near field capacity and contain virtually no roots within the matrix (Soil Taxonomy, 1999). Given this criteria, the 2Btx fragic horizon within Pedon 1 is diagnostic in classification while

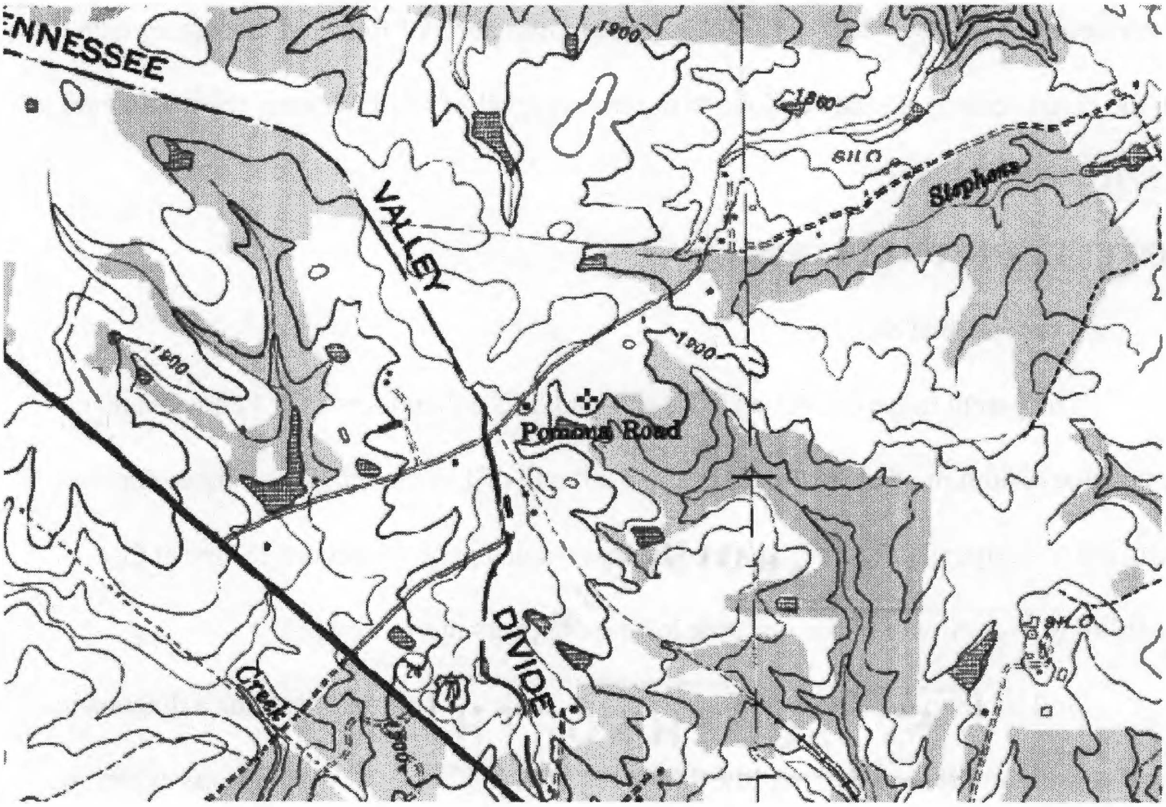

Figure 3: Map of location of Pedon 1. Formed in loess over sandstone residuum.

Table 1: Soil morphology data for Transported Pedon 1. Formed in loess over residuum.

Horizons	Depth (cm)	Color	Texture[a]	Rupture Class & Structure[b]	Boundary[c]	Redoximorphic Features	Notes
Ap1	0 to 12	10YR 4/3	SiL	friable: mo gr	C-smooth		Many fine & very fine roots; few fine interstitial and tubular pores
Ap2	12 to 25	10YR 4/3	SiL	friable: wk gr	A-smooth		Common very fine & fine roots between peds; few fine interstitial and tubular pores
Bt	25 to 48	10YR 5/4	SiL	friable: mo sbk	G-smooth		Common very fine roots between peds; common fine and medium tubular pores
Btx	48 to 66	10YR 5/4	SiL	firm: wk sbk	G-wavy	Common light gray mottles (2.5Y 7/2)	Few very fine roots between peds; common medium tubular pores; about 40% of horizon occupied by massive and brittle bodies
2Btx	66 to 94	7.5YR 4/6	CL	firm: wk pr	G-wavy	Common medium brownish yellow (10YR 6/6),	Common medium olive yellow (2.5Y 6/8) and common fine red (2.5YR 5/8) mottles; common discontinuous pores; about 60% brittle and massive bodies
2Bt1	94 to 132	7.5YR 5/6	CL	friable: mo sbk	G-smooth	Common medium brownish yellow (10YR 6/6),	Common medium red (2.5YR 5/8), and common medium brownish yellow (10YR 6/8) mottles; few fine and medium tubular pores
2Bt2	132 to 155	7.5YR 5/6	CL	friable: wk sbk	G-smooth	Common medium brownish yellow (10YR 6/6),	Common fine red (2.5YR 5/8) mottles;
2Cr	155+						

a: Si=silt; L=loam; CL=clay loam

b: mo=moderate; wk=weak; gr=granular; sbk=subangular blocky; pr=prismatic

c: A=abrupt; G=gradual; C=clear

the Btx horizon is not. The Btx horizon does not have the volume of brittle bodies necessary for diagnostic status and there are some fine roots present. Low chroma mottles (2.5Y 7/2) occur in the Btx horizon. Perched water is the apparent cause for these mottles as they appear in an otherwise uniform matrix having a hue in the 10YR range. Soil structure differs markedly above and below the discontinuity. The upper horizons formed in loess have weak subangular blocky structure while horizons formed in the residual sandstone have moderate subangular blocky structure. While this structural contrast could simply be the result of differential pedogenic development within the respective soil parent materials, the strength of expression of soil structure in this pedon seems to be a result of a longer duration of pedogenesis.

Particle size analysis data for Pedon 1 appears in Table 2 with a cumulative plot of particle size distribution at depth presented in Figure 4. Inspection of this data further supports the occurrence of a discontinuity within Pedon 1. Soil horizons above the 66cm depth have silt loam textures with high proportions of silt (>50% silt) compared to the clay loam textures of the residual horizons (<30% silt). Comparison of the clay contents of horizons formed in loess versus horizons formed in residuum supports a difference in the duration of pedogenic development. Although the loess on the Cumberland was likely deposited as few as 10,000 years ago, pedogenesis has occurred in the silty mantle to the degree that an illuviated argillic horizon is expressed. Clay content increases from 16.6% of the total particle size in the surface horizons (Ap1, Ap2) to 18.9% clay in the Bt horizon. The argillic horizon extends into the second parent material. The clay content in the 2Bt1 horizon is 37.1%, well above the maximum clay content in the loess-derived horizons. Although this difference could represent the maximum expression of the

Table 2: Total particle size analysis data for Transported Pedon 1. Includes calculated proportions.

		(TOTAL)			(SILT)		(SAND)					CFPS %	Silt/ Sand Ratio	Coarse Silt/Fine Silt Ratio
	Depth (cm)	Clay (<.002)	Silt (.002-.05)	Sand (.05-2)	Fine (.002-.02)	Coarse (.02-.05)	Very Fine (.05-.10)	Fine (.10-.25)	Medium (.25-.50)	Coarse (.5-1)	Very Coarse (1-2)			
Ap1	0 to 12	16.6	57.1	26.3	41.9	15.2	8.4	12.2	4.9	0.5	0.3	0.2470	2.1711	0.3628
Ap2	12 to 25	16.6	57.7	25.7	41.5	16.2	8.0	12.1	5.0	0.5	0.1	0.2410	2.2451	0.3904
Bt	25 to 48	18.9	56.9	24.2	42.0	14.9	8.1	11.4	4.2	0.3	0.2	0.2404	2.3512	0.3548
Btx	48 to 66	18.55	54.1	27.4	38.3	15.8	9.7	13.3	4.1	0.2	0.1	0.2822	1.9745	0.4125
2Btx	66 to 94	33.2	39.8	27.0	28.1	11.7	10.5	12.3	3.8	0.2	0.2	0.3413	1.4741	0.4164
2Bt1	94 to 132	37.1	29.6	33.3	19.6	10.0	14.4	14.9	3.3	0.4	0.3	0.4658	0.8889	0.5102
2Bt2	132 to 155	34.1	25.6	40.3	15.3	10.3	23.0	15.7	1.3	0.1	0.2	0.5872	0.6352	0.6732
Cr	155+													

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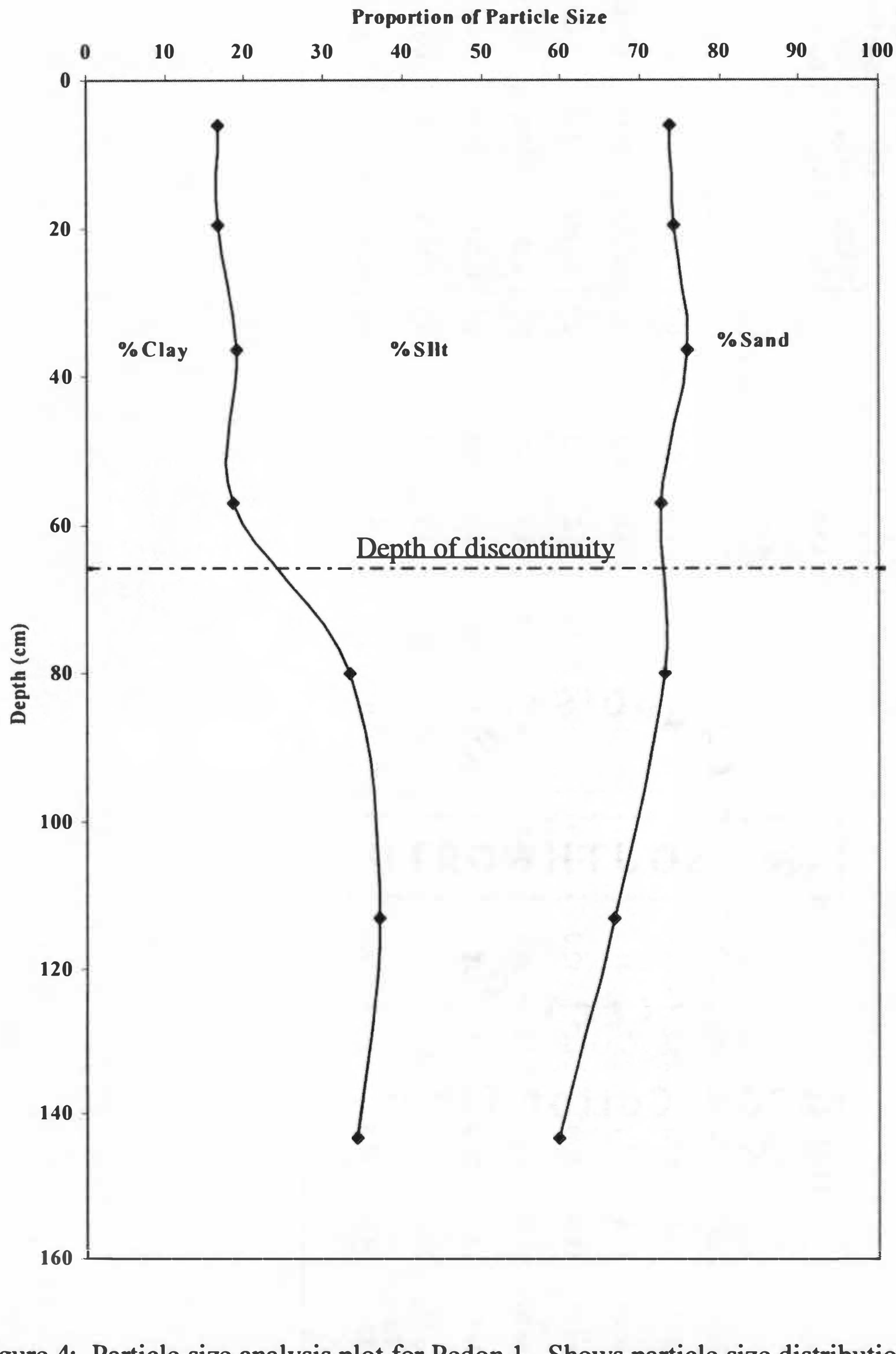

Figure 4: Particle size analysis plot for Pedon 1. Shows particle size distribution above and below lithologic discontinuity. Silt loam textures occur in the horizons formed from loess and clay loam textures occur in horizons formed from sandstone residuum.

argillic, other properties such as color, texture, and structure resulting from inherent differences in the soil parent materials indicate that the argillic horizon in the residual material likely formed prior to loess deposition. The formation of the fragipan has influenced the pedogenic alteration of the residual material as percolation of water through the profile has been impeded by the pan. Deposition of the loess material itself altered the role of water, organic matter, and oxygen in the residual material as well A clay free particle size analysis is another indicator of the presence of lithologic discontinuities as the effects of pedogenic clay accumulation are disregarded. Figure 5 contains the particle size analysis on a clay free basis for Pedon 1. Although the inflection in this curve is not strong, the absolute difference in the proportion of fine and very fine sand is of note. The upper horizons of this pedon have a low ratio of fine and very fine sand to total sand + silt relative to the lower horizons (20-30% upper loess vs. 40-60% lower residuum). The proportion of very fine and fine sand in the lower horizons indicates the siliceous origin of the residual material as it is composed of quartz grains that have been pedogenically altered. Even considering possible experimental error resulting in the inclusion of some very fine sand into the silt fraction the difference in the ratio is sufficient to consider two parent material sources. Continued examination of particle size data for this pedon allows for a comparison of the ratios of silt to sand as horizons descend in the profile. Figure 6 shows the decrease in the ratio of silt/sand occurring with increasing depth. This data indicates a marked difference in soil particle size distribution and texture (upper ~2.25/1 vs. lower ~0.75/1) as a result of formation in two parent materials. A plot of the ratio of coarse silt to fine silt for Pedon 1 appears in Figure 7. The ratio of coarse silt to fine silt increases with depth with the largest gain

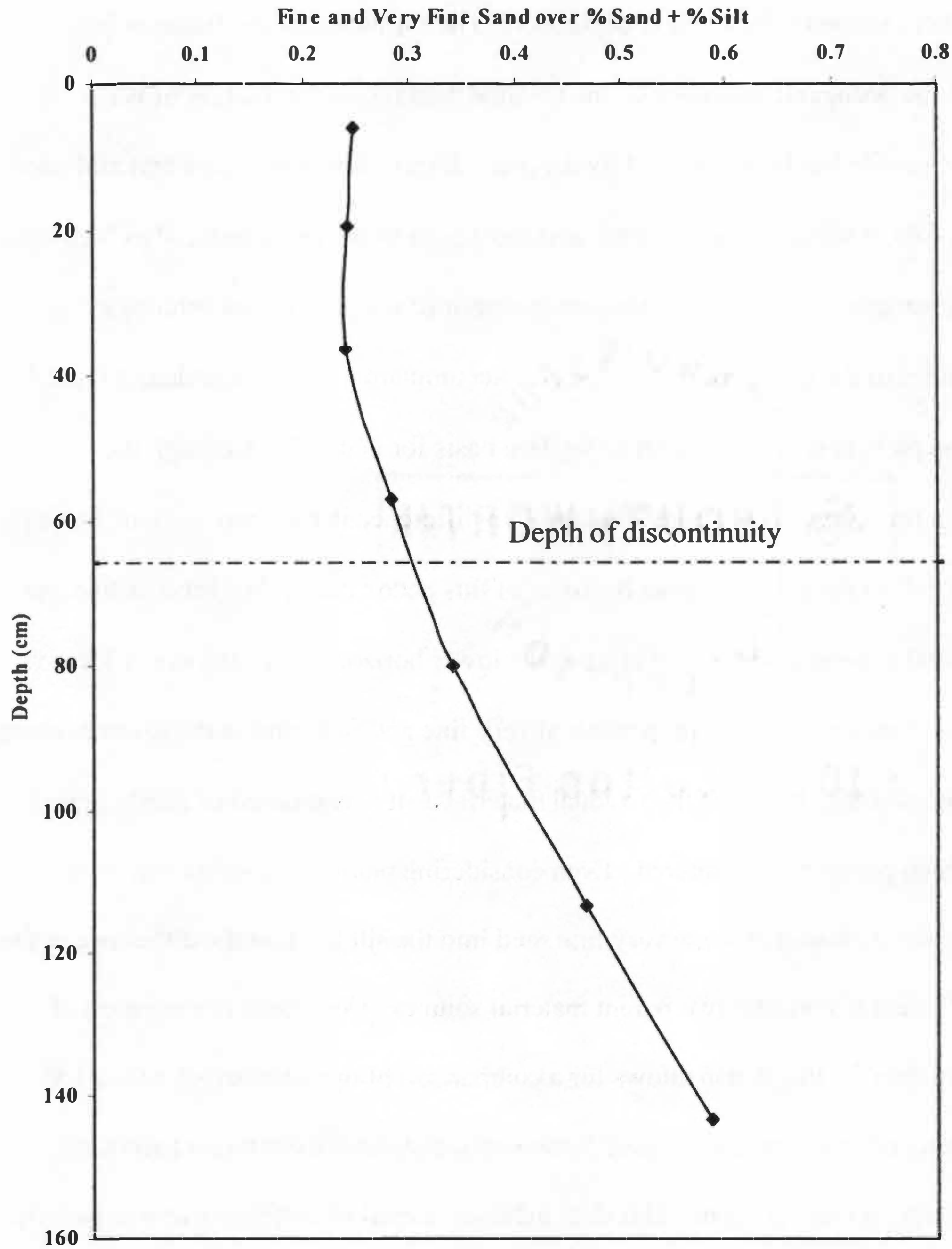

Figure 5: Clay free particle size analysis for Pedon 1. Shows percent sand and silt separates on a clay free basis above and below the discontinuity.

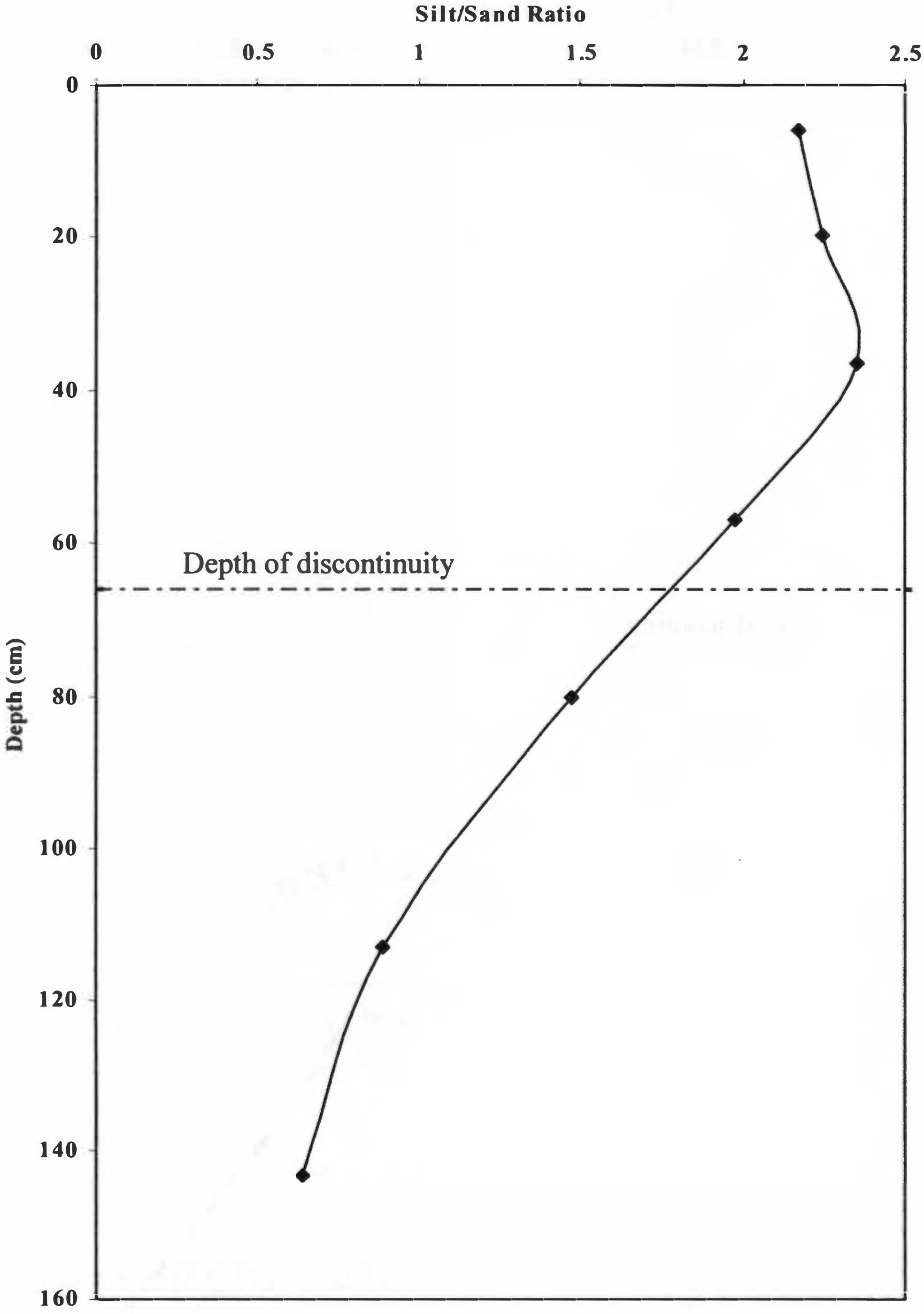

Figure 6: Ratio of silt to sand for Pedon 1. Shows difference above and below lithologic discontinuity.

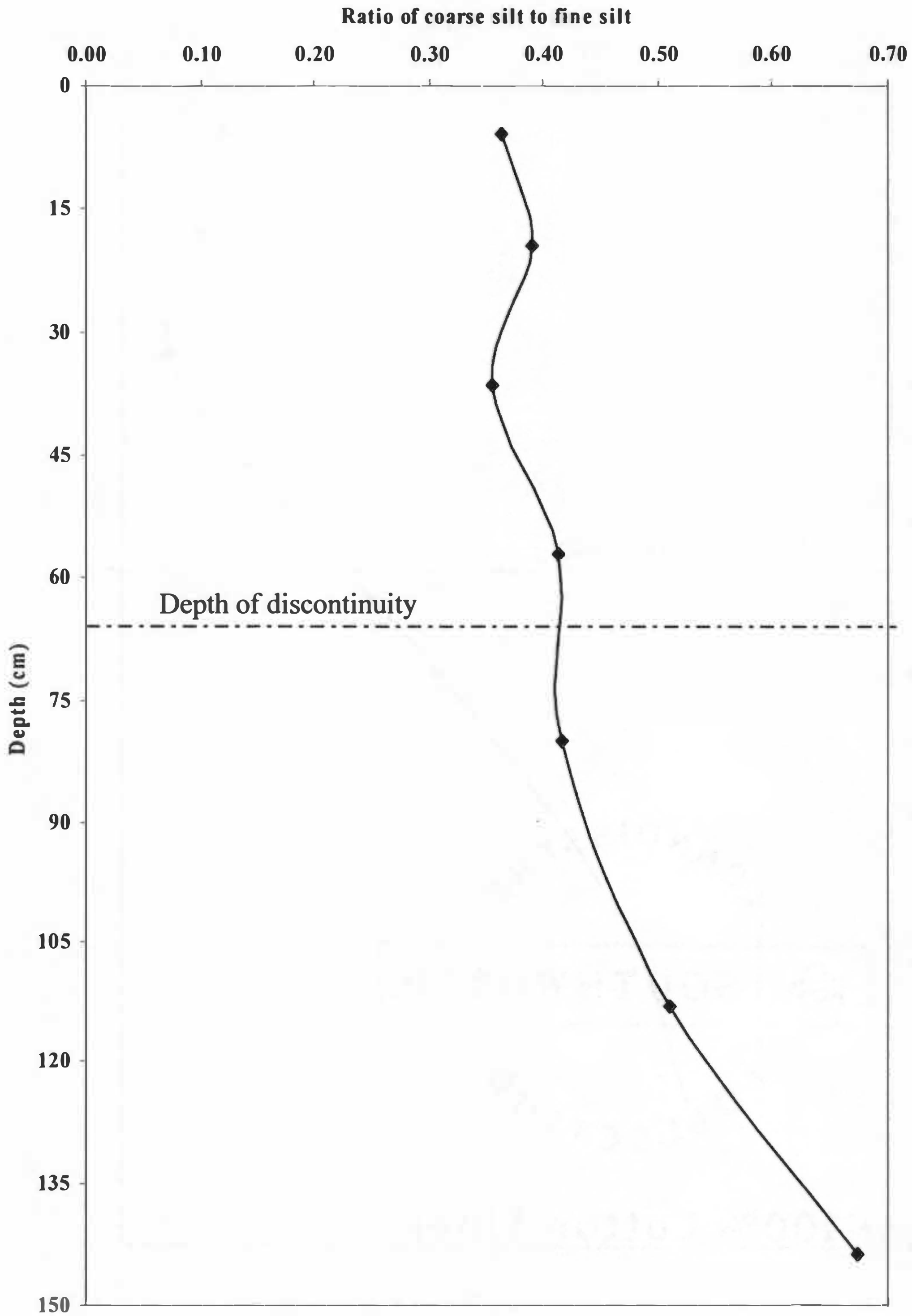

Figure 7: Plot of coarse silt to fine silt ratio for Pedon 1

occurring around the point of the discontinuity. A couple of inferences are garnered through this analysis. The first inference can be made about the difference in parent material apparent in this ratio. Horizons formed in loess have a high proportion of fine silt while horizons formed in residual parent material have a ratio that approaches 1:1. An more even distribution of silt suggests that the lower horizons were indeed formed in place. The second inference lies in the proximity of the study location to the loess source. An almost even ratio of coarse silt to fine silt indicates a local source of loess as larger particles require more energy to move and are thereby deposited nearer to the source of origin than are finer silt particles. The fine fraction of silt in the upper horizons is large suggesting that the material was transported over a long distance.

Soil chemistry data for Pedon 1 is presented in Table 3. Organic carbon decreases as expected with depth from 1.23% to 0.08% reflecting the organic fraction of the surface horizon. Free iron by depth is presented in Figure 8. A major inflection appears in the curve at the discontinuity indicating the relative differences in weathering of the two parent materials. Upper horizons formed in loess have around 1.5% free iron while horizons formed in residual material have around 3.9% free iron. Since the formation of iron bearing minerals is a product of weathering the contrast in the two parent materials is clear. Residual material has been weathered for a longer duration than has the loess that covers it.

Table 3: Soil chemistry data for Transported Pedon 1. Formed in loess over residuum.

	Organic Carbon	**Free Iron**	**CEC**	**CEC/clay**	**% Base Saturation**	**pH**
	(Percent < 2mm)					(1:1)
Ap1	1.23	1.5	8.1	0.49	96	6.3
Ap2	1.08	1.7	7.5	0.45	92	6.5
Bt	0.16	1.6	6.1	0.32	49	5.2
Btx	0.07	1.5	5.5	0.30	29	4.8
2Btx	0.09	3.7	9.0	0.27	39	4.4
2Bt1	0.08	4.2	9.6	0.26	9	4.3
2Bt2	0.08	3.7	9.6	0.28	32	4.5
2Cr						

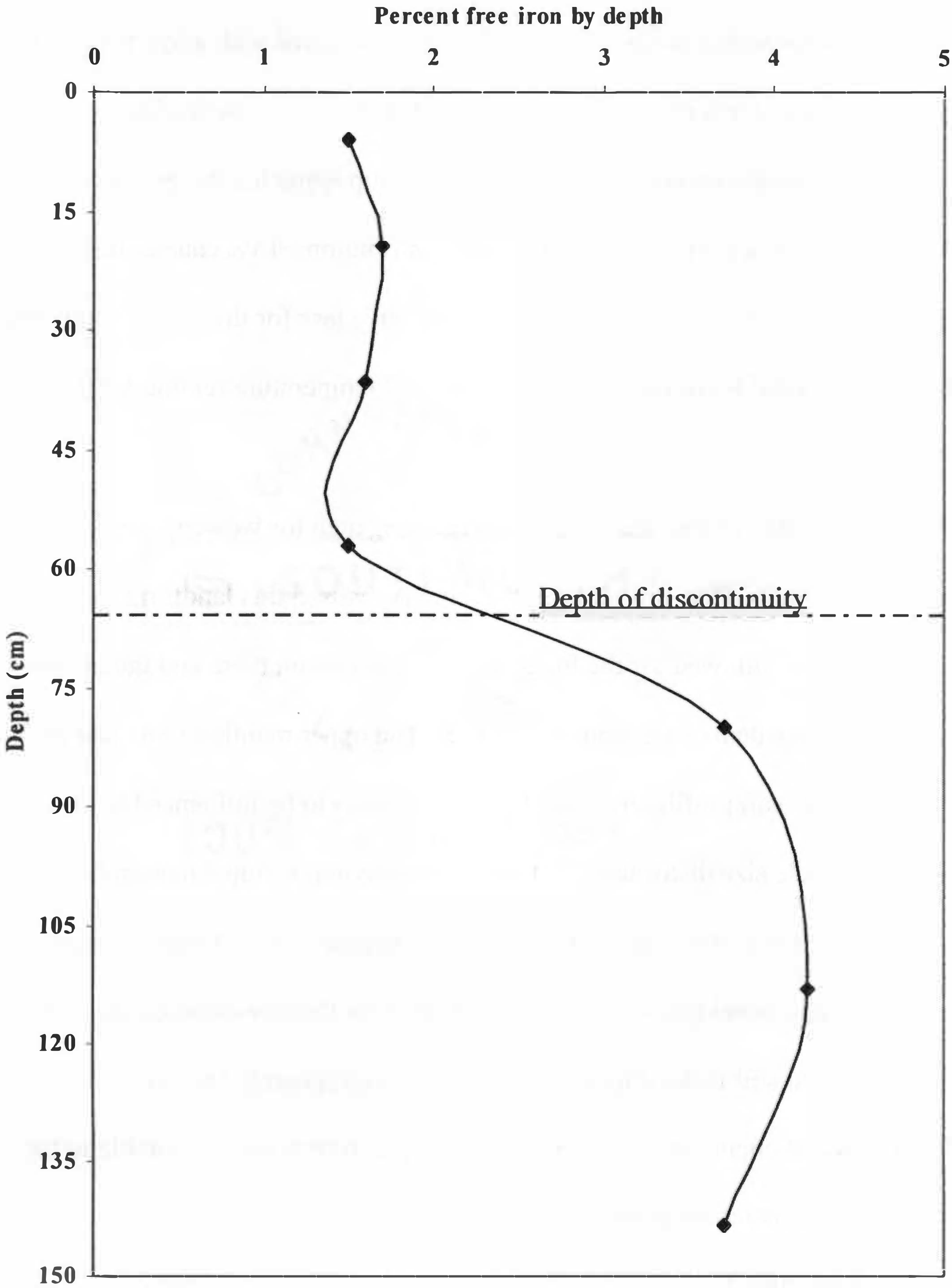

Figure 8: Plot of percent free iron by depth in Pedon 1. Indicates relative weathering.

This soil is classified as a fine-loamy, siliceous, semiactive, mesic Typic Fragiudult. The presence of a diagnostic argillic horizon coupled with a low percent base saturation at the critical depth places this soil in the order Ultisol. The fragipan in this soil is diagnostic, a distinction reflected in the Great Group name for this pedon. Family particle size class is fine loamy due to particle size distribution >15% coarser than 0.1mm and >18% clay over the control section. The clay activity class for this soil is semiactive with the C.E.C./clay ratio between .24 and .40. The soil temperature regime for this pedon is mesic.

The upland nature of this site makes it a receiving area for westerly derived windblown loess deposits. The low slope at this site has caused this landform to be stable over a duration that has allowed for the loess deposited to remain there and factor into soil development rather than erode from side slopes. The upper mantle of this soil profile is indeed silty. In this soil profile, fragipan formation seems to be influenced by the contrasting soil particle size distribution between the loess and residual material. Such a variation in particle size as the result of the inherent differences in soil parent material may facilitate fragipan development. The contrast between the unweathered loess and the weathered residual soil is the impetus for fragipan development. Quantification of the degree of physical and chemical contributions to fragipan formation attributable to the contrast in soil parent materials is difficult if not impossible.

Transported Site 2

Pedon 2 is formed from two parent materials: loess over Pennsylvanian sandstone residuum. This pedon is described to a depth of 136cm. At the 136cm depth paralithic contact with soft, weathered sandstone occurs and extends to a depth of 185cm where lithic contact with hard sandstone occurs. Figure 9 is a map of the research area.

Soil morphology for Pedon 2 is shown in Table 4. A diagnostic argillic horizon (27-136cm) occurs in the loess parent material and continues into the residual parent material. A soil horizon that exhibits fragic soil properties occurs at the boundary of the two parent materials in this pedon. Weak prismatic soil structure, blind pores, and brittleness appear in the Btx horizon (89-110cm). Although the Btx horizon exhibits fragic properties, the horizon lacks the 60% brittle bodies necessary for a diagnostic fragipan. The presence of fragic soil properties in this profile exhibits the contrast in the two materials that form the lithologic discontinuity.

Soil particle size analysis data for Pedon 2 appears in Table 5. A cumulative plot of particle size distribution appears in Figure 10. The difference in the proportions of particle size apparent in this pedon indicates that the upper horizons formed in loess while the lower horizons formed in residuum. The surface horizons including the upper argillic contain a high proportion of silt (silt loam textures) compared to the residual horizons (clay loam textures) lower in the profile (loess ~45-50% silt vs. residuum ~20% silt). In addition, the proportion of sand increases with increasing depth and clay content increases dramatically at the lithologic discontinuity (~17% clay in loess soil vs. ~28% clay in residuum soil). Although the high proportion of clay in the residual material could be the result of the maximum expression of the argillic the contrasting nature of the horizons above and below the discontinuity indicates that pedogenesis has occurred for differing duration within the two soil parent materials.

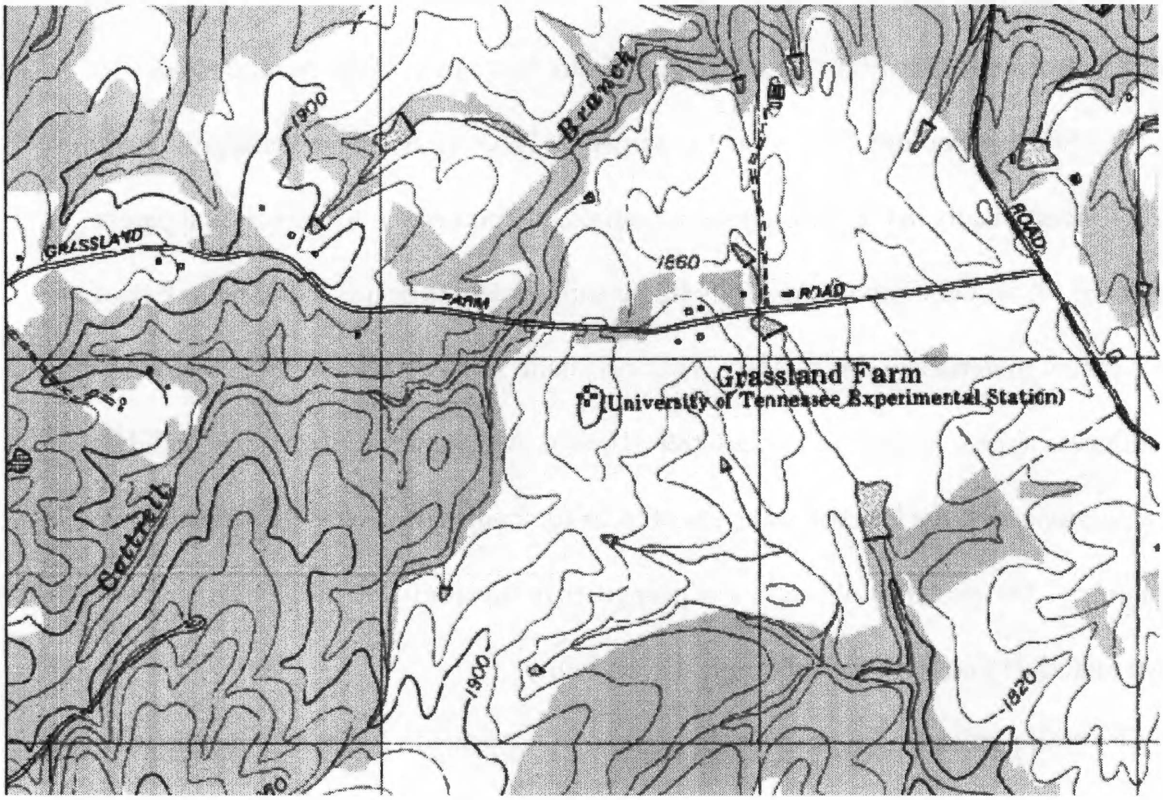

Figure 9: Map of location of Pedon 2. Formed in loess over sandstone residuum.

Table 4: Soil morphology data for Transported Pedon 2. Formed in loess over sandstone residuum

Horizons	Depth (cm)	Color	Texture[a]	Rupture Class & Structure[b]	Boundary[c]	Redoximorphic Features	Notes
Ap	0 to 11	10YR 3/3	SiL	friable: mo gr	A-smooth		
BA	11 to 27	10YR 5/4	SiL	friable: mo sbk	G-smooth		
Bt1	27 to 57	10YR 4/6	L	friable: mo sbk	C-smooth		
Bt2	57 to 73	10YR 5/6	L	friable: mo sbk	C-smooth		
Bt3	73 to 89	10YR 5/6	L	friable:mo sbk	C-smooth	Few medium very pale brown (10YR 7/4) mottles	
2Btx	89 to 110	10YR 5/6	L	firm: wk pr	C-wavy	Common Medium very pale brown (10YR 7/4),	Common medium yellowish red (5YR 5/6) mottles; 5 percent sandstone gravel; 20% of horizon consists of brittle zones
2Bt	110 to 136	7.5YR 5/8	CL	friable: mo sbk	A-smooth		Common medium yellowish red (5YR 5/8) mottles
2Cr	136 to 185						
2R	185+						

a: Si=silt, L=loam; CL=clay loam

b: mo=moderate; wk=weak; gr=granular; sbk=subangular blocky; pr=prismatic

c: A=abrupt; G=gradual; C=clear

Table 5: Total particle size analysis data for Transported Pedon 2. Includes calculated proportions.

		(TOTAL)			(SILT)		(SAND)					CFPS %	Silt/ Sand Ratio	Coarse Silt/ Fine Silt Ratio
	Depth (cm)	Clay (<.002)	Silt (.002-.05)	Sand (.05-2)	Fine (.002-.02)	Coarse (.02-.05)	Very Fine (.05-.10)	Fine (.10-.25)	Medium (.25-.50)	Coarse (.5-1)	Very Coarse (1-2)			
Ap	0 to 11	12.9	50.3	36.8	39.1	11.2	8.7	24.7	3.1	0.2	0.1	0.3835	1.3668	0.2864
BA	11 to 27	15.2	51	33.8	39.2	11.8	7.7	22.9	2.9	0.2	0.1	0.3609	1.5089	0.3010
Bt1	27 to 57	19.9	47.7	32.4	37.6	10.2	7.3	22	2.7	0.3	0.1	0.3658	1.4722	0.2713
Bt2	57 to 73	16.3	41.7	42	31.3	10.4	9.6	29.2	3	0.1	0.1	0.4636	0.9929	0.3323
Bt3	73 to 89	15.2	37.3	47.5	28.4	8.9	11.3	32.3	3.6	0.2	0.1	0.5142	0.7853	0.3134
2Btx	89 to 110	24.9	27.7	47.4	19.9	7.8	10.9	32.9	3.3	0.2	0.3	0.5832	0.5844	0.3920
2Bt	110 to 136	32.8	19.5	47.7	13.1	6.4	9.7	34.2	3.3	0.2	0.4	0.6533	0.4088	0.4885
2Cr	136 to 185													
2R	185+													

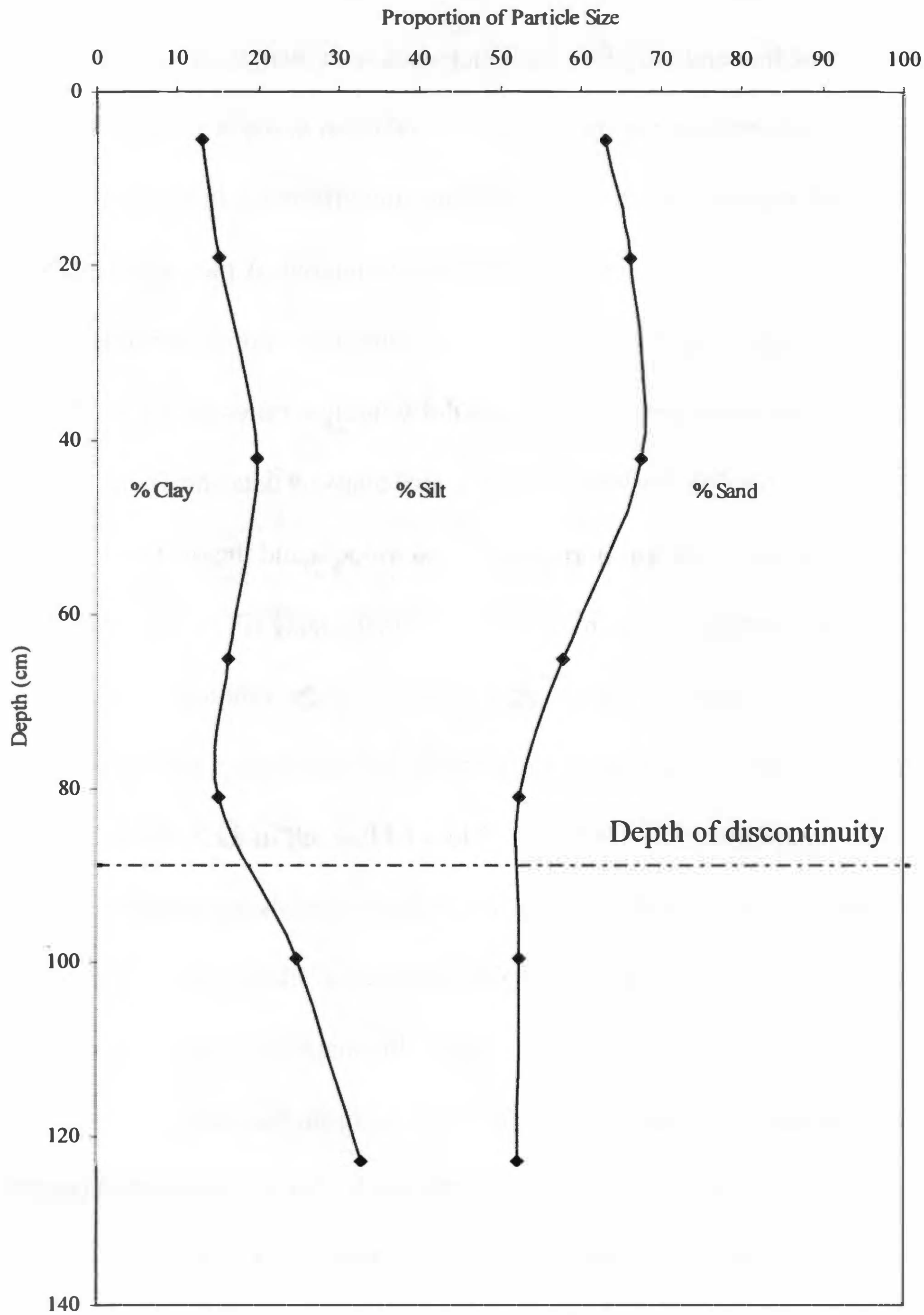

Figure 10: Particle size analysis plot for Pedon 2. Shows particle size distribution above and below lithologic discontinuity. Silt loam textures occur in the horizons formed from loess and clay loam textures occur in horizons formed from sandstone residuum.

Particle size distribution on a clay free basis for Pedon 2 is shown in Figure 11. Overall the proportion of fine and very fine sand increases with increasing depth and makes a much higher proportion of the particle size distribution in the horizon formed from the residual parent material. Such a shift reiterates the difference in particle size distribution that is a result of eolian versus residual parent material. A plot of the silt/sand ratio for Pedon 2 appears in Figure 12. Ratios of silt to sand in the upper horizons are 1.5:1 while the ratio in the lower depths is 0.5:1 resulting in three times the silt in the upper horizons versus the residual horizons. Particle size analysis data shows the high proportion of silt that occurs in the soil horizons formed in loess and the decrease of silt that occurs in the second residual parent material. Individual coarse silt to fine silt ratios for each horizon in Pedon 2 appear in the plot in Figure 13. At the lithologic discontinuity this ratio changes markedly as the particle size distribution reflects the properties of the soil parent material. High proportions of fine silt in the upper horizons indicate that the source of loess is a distant location as fine materials can travel farther than coarse materials. With increasing depth the ratio of coarse silt to fine silt becomes more consistent and moves closer to 1:1 indicating that this material formed in place.

Soil chemistry data for Pedon 2 appears in Table 6. From the partially organic surface horizon, percent organic carbon decreases with depth. An examination of percent free iron in a profile is used as an indicator of the relative duration of weathering experienced by soil parent material. The plot of free iron by depth appears in Figure 14. Percent free iron in Pedon 2 increases from around 1.5% in horizons formed in loess to around 3.5% in horizons formed in residual parent material. Such a difference further

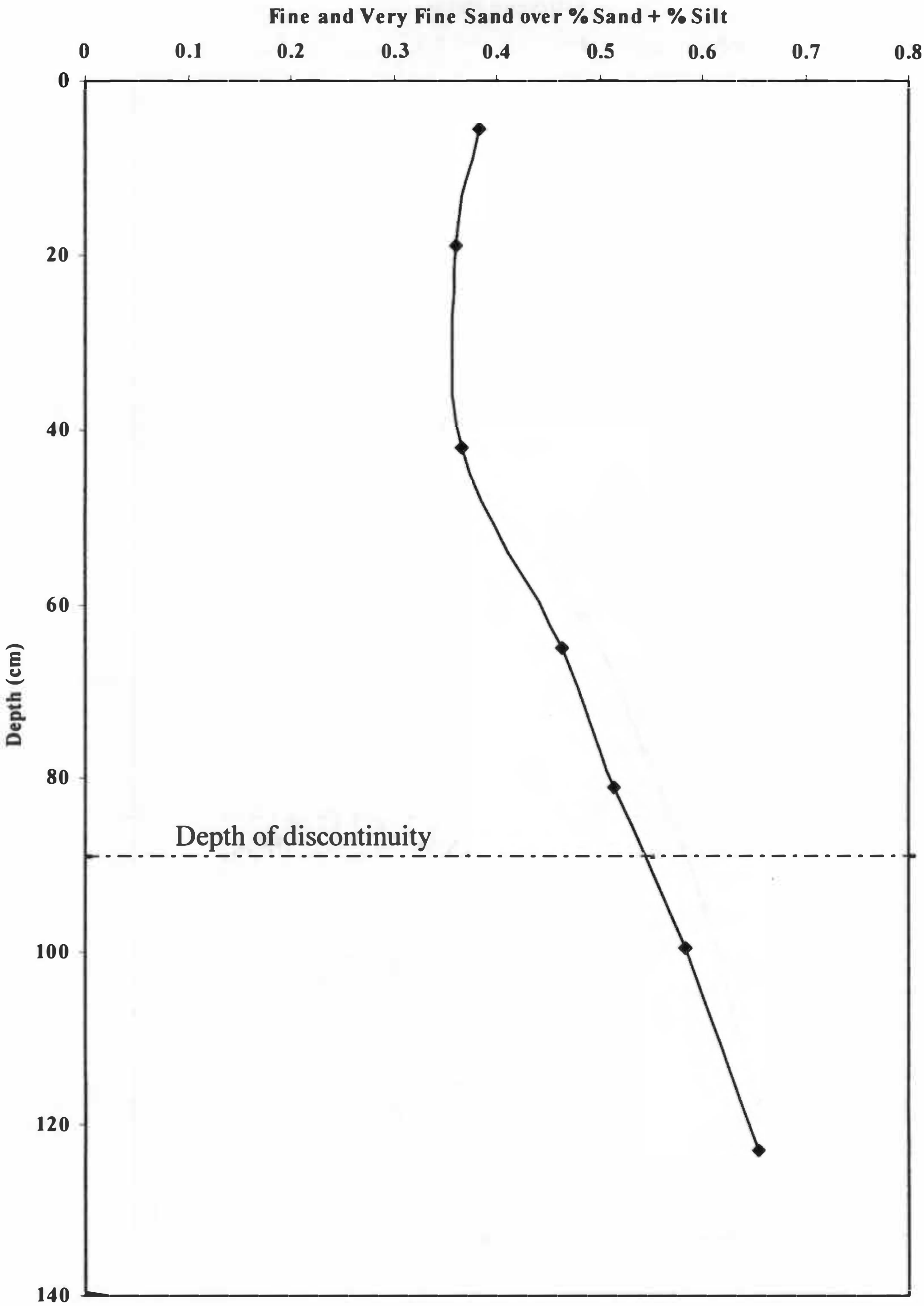

Figure 11: Clay free particle size analysis for Pedon 2. Shows difference above and below lithologic discontinuity.

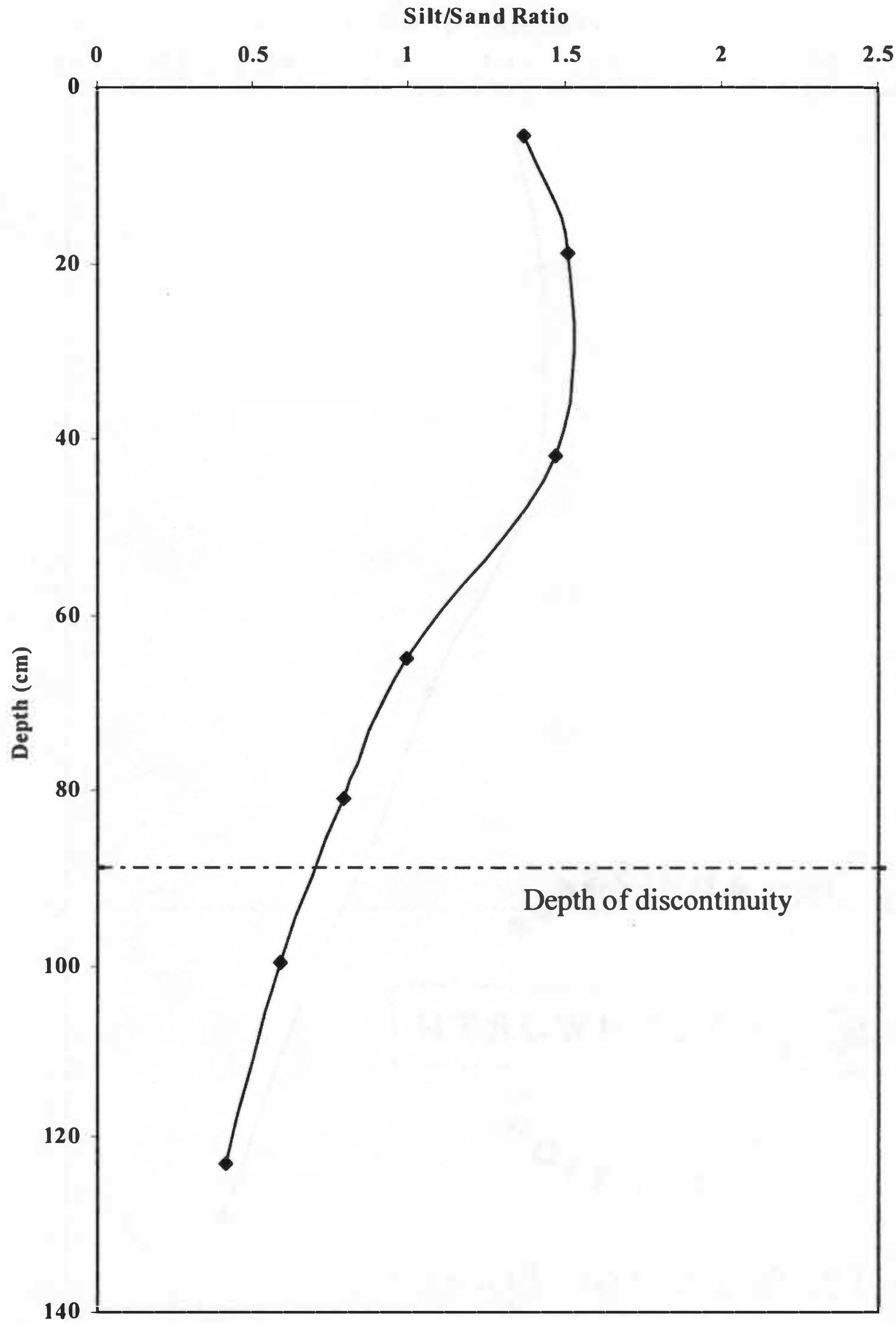

Figure 12: Ratio of silt to sand for Pedon 2. Shows difference above and below lithologic discontinuity.

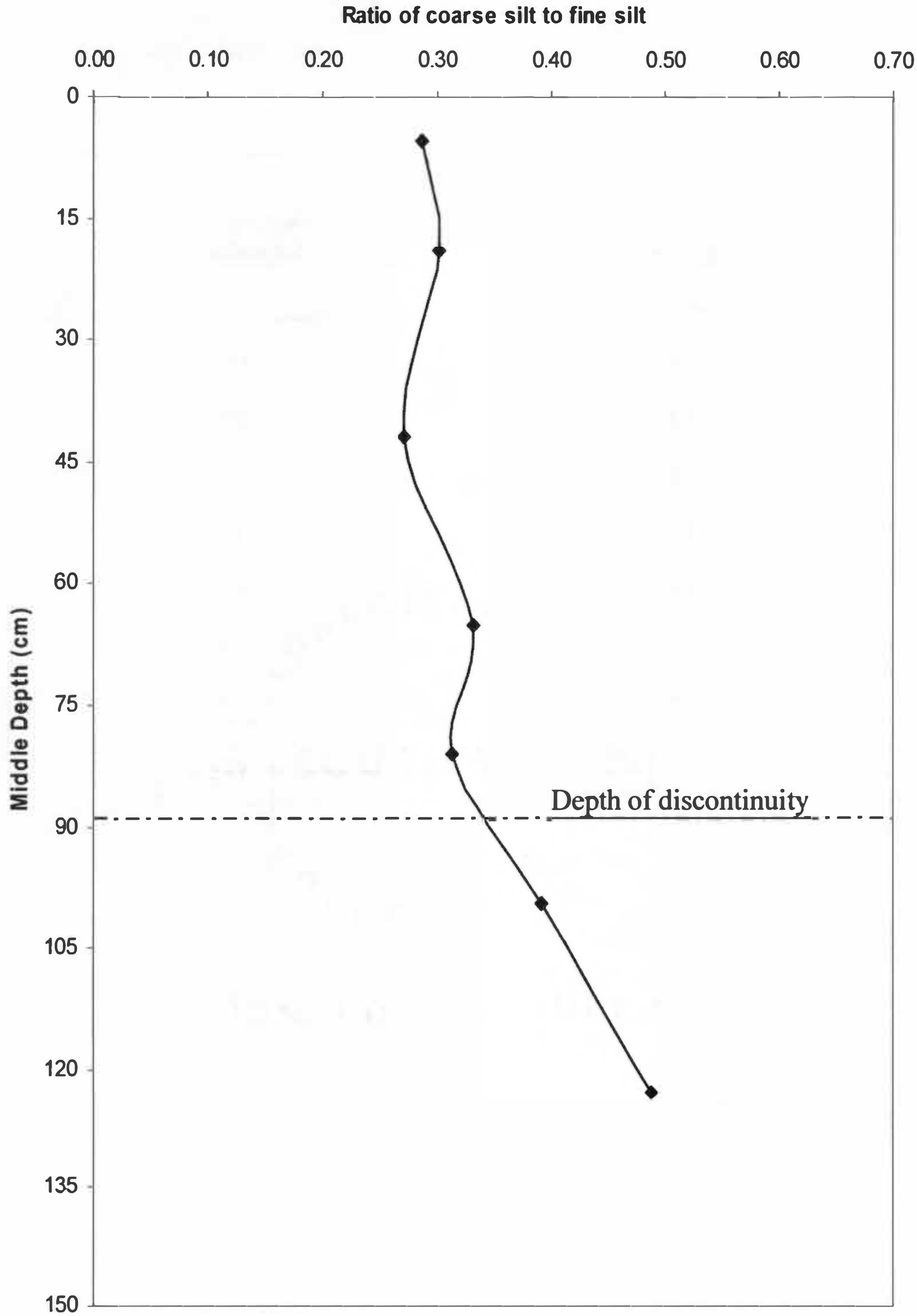

Figure 13: Plot of coarse silt to fine silt ratio for Pedon 2.

Table 6: Soil chemistry data for Transported Pedon 2. Formed in loess over residuum.

	Organic Carbon	Free Iron	CEC	CEC/clay	% Base Saturation	pH
	(Percent < 2mm)					(1:1)
Ap	3.29	1.1	13.0	1.01	100	5.6
BA	0.63	1.3	6.1	0.40	92	6.2
Bt1	0.36	1.6	7.3	0.37	73	5.5
Bt2	0.11	1.3	4.9	0.30	47	5.1
Bt3	0.06	1.4	4.3	0.28	84	4.9
2Btx	0.05	2.3	6.0	0.24	28	4.9
2Bt	0.12	3.5	8.0	0.24	14	4.9
Cr						

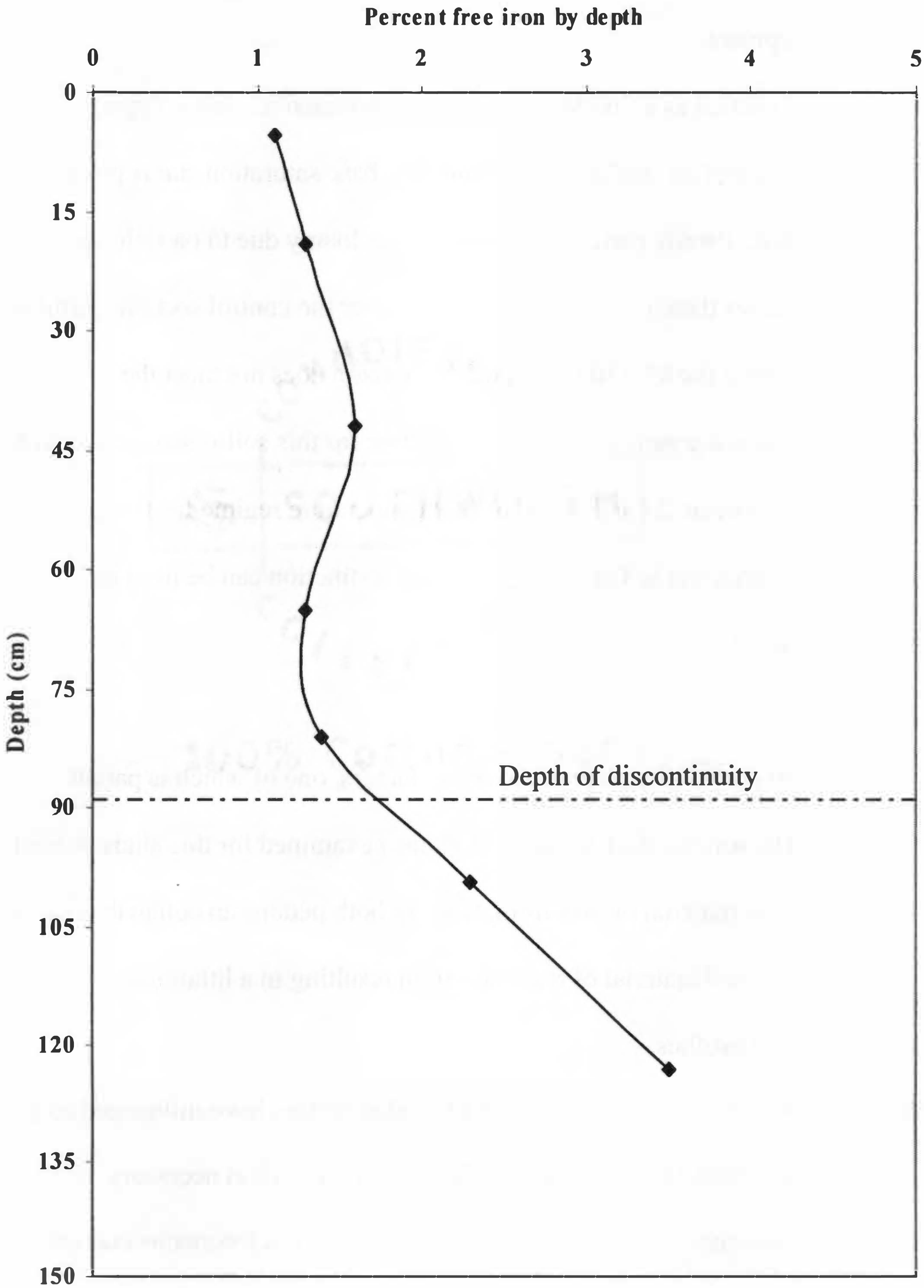

Figure 14: Plot of free iron by depth for Pedon 2. Indicatesd relative weathering.

supports the designation of two parent materials that have undergone different durations of pedogeneic development.

This soil is classified as a fine-loamy, siliceous, semiactive, mesic Typic Hapludult. The presence of an argillic horizon and low base saturation status places this soil in the order Ultisol. Family particle size class is fine loamy due to particle size distribution >15% coarser than 0.1mm and >18% clay over the control section. Although there is a fragic horizon at the 89-110 cm depth, the horizon does not meet the requirements for a diagnostic pan. The clay activity class for this soil is semiactive with the C.E.C./clay ratio between .24 and .40. The soil temperature regime for this pedon is mesic. The Great Group name is Typic since no other distinction can be used in classification at this level.

CONCLUSIONS

Soil formation occurs as a response to many factors, one of which is parent material of origin. The soils of the Cumberland Plateau examined for this study exhibit the effects of soil parent material on soil formation. In both pedons an eolian deposit of silt laden loess overlies soil material of residual origin resulting in a lithologic discontinuity in the soil profiles.

While Pedons 1 and 2 share a similar origin, other factors have influenced soil formation such that different family level classification of the soils is necessary. Both pedons contain horizons that exhibit fragic soil properties. Pedon 1 contains enough brittle bodies to make the fragipan in this pedon diagnostic. Pedon 2 contains a horizon that displays fragic properties but not to the degree to make the fragipan diagnostic in soil classification. Examination of silt/sand ratios for the two pedons may indicate possible causes for variation in the fragic nature of the pedons. The ratio of silt/sand in Pedon 1 is much higher than the silt/sand ratio of Pedon 2. This relatively higher proportion of silt for Pedon 1 may be sufficiently different from the particle size distribution for Pedon 2 to account for the degree of fragipan formation. The difference in chemical composition of the two parent materials may also play a role. A higher proportion of relatively unweathered silt in Pedon 1 translates into more carbonates that are potentially available to react with weathered oxides of the residual material. The residual material for the two pedons shows similarities in percentage of free iron. A strong contrast in chemical constituents of loess and residuum in Pedon 1 could account for the degree of formation of fragic soil properties. More available carbonates would mean more binding of particles leading to a more brittle nature than material composed of lesser carbonate concentration.

The cumulative plots of the ratios of coarse silt to fine silt for pedons 1 and 2 are nearly identical. Such a similarity indicates that the source of loess is likely from a location of some distance from the study site. The source must be far enough away to provide comparable conditions of deposition at the two sites. Figure 15 is a map showing the proximity of the individual sites to the probable loess source. Though Pedon 1 contains a higher proportion of silt overall, Pedon 2 contains a higher proportion of fine silt in upper horizons than does Pedon 1. This indicates that the source of loess is farther away from Pedon 2 than Pedon 1. This is confirmed when longitude for the study sites is considered. Pedon 2 is located 20 km to the southeast of Pedon 1. This difference in proximity to loess source has influenced soil properties, notably expression of fragic properties. The ratio of coarse silt to fine silt also indicates that deposition of loess

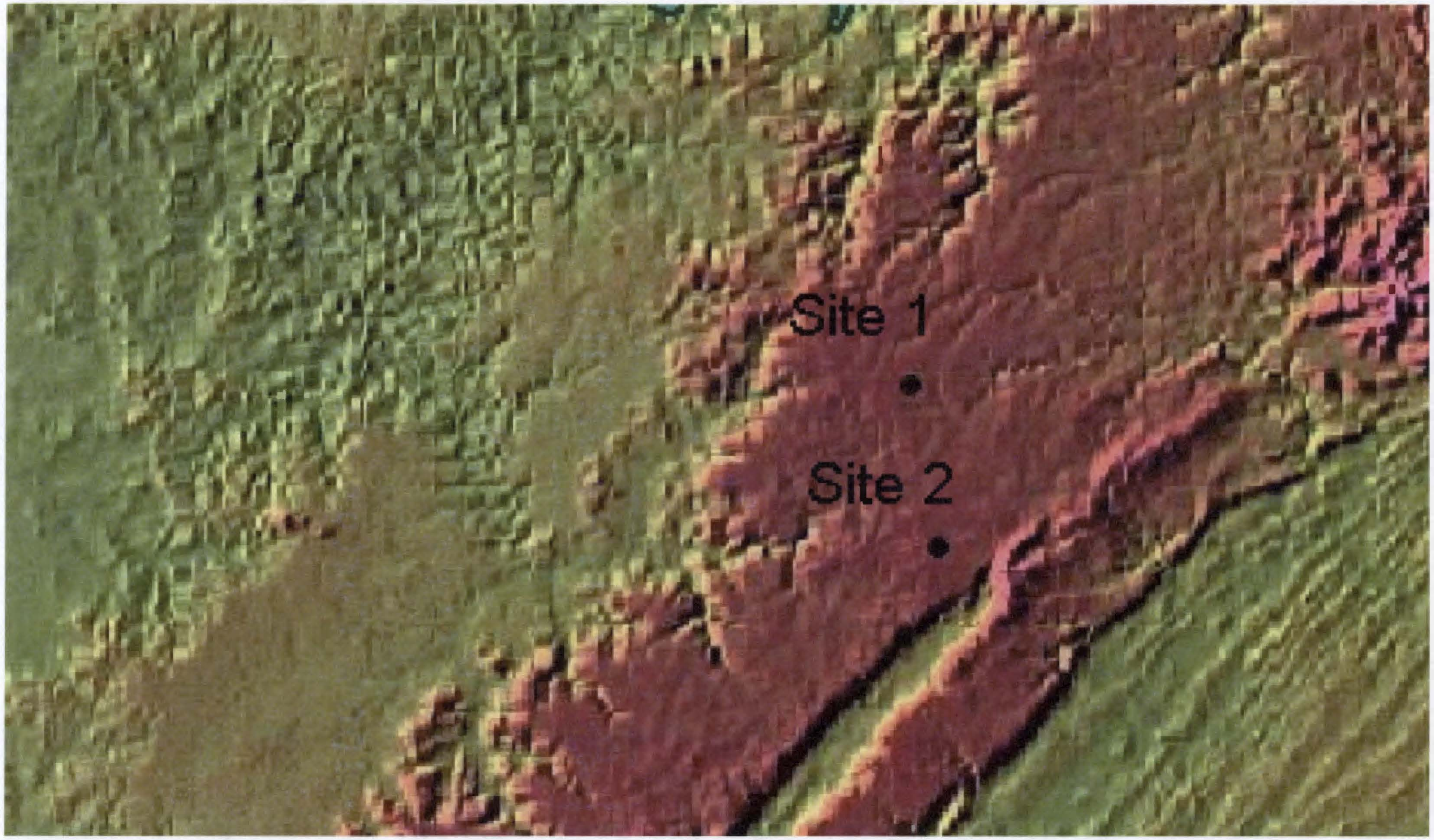

Figure 15: Location map showing proximity of sites to loess source.

occurred simultaneously for both sites and the duration of development for the two sites has been of similar extent.

In conclusion, soils on upland positions on landforms on the Cumberland Plateau of Tennessee form from two soil parent materials. A layer of loess covering sandstone residuum serves as the soil parent material in stable upland positions capable of maintaining loess coverage; that is on slopes where loess does not erode. Fragipan formation is both an indicator and a result of lithologic discontinuity in the pedons as the two pedons demonstrate fragic properties that reflect the degree of expression associated with the contrast of the two parent materials, chemically and physically.

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Part 3. Effect of pedogenesis on residual parent materials on the Cumberland Plateau of Tennessee

INTRODUCTION

Please refer to Part 2 of this manuscript for a complete introduction to the Cumberland Plateau of Tennessee. Soil formation is determined by the influence of the five soil forming factors: climate, topography, parent material, biota, and time. Soil properties are attributable to the effects of the individual soil forming factors. The effect of soil parent material on soil development appears in the unique characteristics indicative of the conditions of soil formation. The common soil types that appear on the Plateau are Hapludults and Dystrudepts (Springer and Elder, 1980). Hapludults appear in areas where pedogenesis has occurred while Dystrudepts persist in areas of limited pedogenic activity. Pennsylvanian age sandstones are the caprock of the Plateau and are the parent material for soils formed in residuum. The objective of this study is to analyze the effects of differing soil parent materials and slope on soil formation. Landscape position, relief and landform type as well as physical and chemical processes affect soil formation. The extent of these factors indicates the varying conditions and circumstances under which pedogenesis occurs.

LITERATURE REVIEW

Geology of the Sandstone Residuum

The geology of the Cumberland Plateau of Tennessee has its origins in the Paleozoic but has been affected by geomorphic factors since its deposition. The time period known as the Carboniferous occurring from about 345-280 million years ago reflected changes in Earth's Climatic fluctuations triggered by continental land building affected the deposits laid during those times. The strata appearing on the Cumberland

Plateau today reflect those fluctuations in the definitive properties the strata demonstrate. The strata deposited during the early Carboniferous in the Mississippian period (345-310 million years ago) are comprised of sediments of marine origin. Shallow, tropical seas persisted along the continental margins present at that time. The shallow waters were conducive to the development of expansive reef systems. As a result, the Mississippian aged stratigraphy present today contains a wealth of fossils of ancient, underwater plants and organisms within its layers of limestone and shale. The Pennsylvanian-aged sandstone capping much of the Cumberland Plateau is an invaluable tool in understanding both the events that led to its deposition as well as the conditions that have affected it since the time of deposition.

Much of the land that now makes up North America was located along the equator during the Late Carboniferous (Stanley, 1999). Such an equatorial position allowed for the development of extensive forest systems in tropical areas. Expansive areas covered in tropical swamps and bogs were filled with early seed-ferns and scale trees, the ancestors of modern forest species. At this time extreme temperature differences likely persisted among equatorial areas and polar areas, much like today. This was also likely the first time that a near continuous landmass existed from pole to pole on the Earth's surface. Land building occurred along the continental margin of North America (Sacks and Secor, 1990). Such a scenario would have had a pronounced influence on climatic conditions. The continuous landmass affected sea currents throughout the ocean, as there were resistant continental bodies to impede flow. In a similar way the prevailing winds of this time would have also been affected by the land surface. These factors combined with the effects of variances in the Earth's rotation and revolutions, the Milankovitch cycles, were an impetus to continental glaciations at this time. According to the Milankovitch cycles the orbit of the Earth about the sun alters in about 100,000 year intervals. Also the tilt of the Earth about its axis varies. This theory suggests that such a variance in orbit would have a pronounced effect on the amount of light reaching the Earth. The amount of solar radiation emitted onto the Earth's surface also affected glacial cycles.

Alternating periods of warming and cooling are apparent in the geologic record displayed in Pennsylvanian geology. Coal deposits are a major indicator of the varying conditions. In order for peaty material to accumulate, coal bogs must have been stable for extensive periods so that anoxic conditions were maintained at the bottoms of the bogs. Decomposition by oxygen and aerobic organisms would have destroyed the organic matter before it could begin to accumulate. Many of these swamps were positioned along coastal, delta areas. As glaciers crept over the North American continent, massive amounts of the material they scoured was collected and transported beneath the ice sheets. After a glacial maximum was reached, ice sheets would begin to recede. Ice dams held large volumes of glacial melt-water within the ice sheets. As these ice dams melted and broke away, surges of melt-water would flow from beneath, carrying massive amounts of sediment. These sediments were subsequently deposited in and covered the peat bogs that persisted at the stream deltas. While this general depositional scenario would result in alternating units of stratigraphy, the exact nature of the depositional environment of Pennsylvanian time is debatable. Alternate units of sandstone, shale and coal seams suggest that glacially influenced marine fluctuations dominated Pennsylvanian deposition (Churnet and Bergenback, 1986). The marginal marine interpretation suggests that sands intermittently deposited in barrier islands and tidal delta areas over and among slow moving backwater deposits of shale and mudstone. While there is evidence of a marginal marine environment as the depositional setting for Pennsylvanian sandstone, there is competing evidence for fluvial deposition as well. In the southern portion of the Plateau, stratigraphy is of fluvio-deltaic origin (Gray, 1980; Gastaldo, 1982). Plant remains found in coal seams and fossilized in overlying sandstone deposits support the notion that the area was indeed a deltaic- swamp or floodplain at intervals in Pennsylvanian time (Scott, 1979; Gastaldo, 1982). Miller and Jackson (1984) examined the Rockcastle Conglomerate formation of the northern Cumberland Plateau and found its depositional origin to be a braided stream deposit. Fluvial deposition is supported by lack of marine fossils present in Pennsylvanian stratigraphy (Churnet and Bergenback, 1986) and by the structural nature of the sandstone units. Sandstones are normally indicative of fast moving waters, capable of moving large, coarse sediments, while shale and mudstones are indicative of a slower moving depositional environment. The upper Pennsylvanian units found on the Cumberland Plateau are comprised of coarse-grained sands. Most lack the lateral accretion surfaces (point bar deposits) overlain by vertical accretion surfaces (shale and mudstone) that would indicate a meandering stream deposition (Churnet et al., 1985). Coarse-grained units dominate the upper Pennsylvanian. While overlying shale and mudstone units could have been removed by erosion of smaller streams, the general sequence of multi-layered sandstone suggests that braided streams were the dominant means of fluvial deposition. In a study of the central Appalachians, Meckel (1967) examined the Pottsville Conglomerate to determine the source of deposition. Meckel determined that the source for strata material was located to the southeast of the depositional basin. The distribution of coarse materials from the source indicates the direction of paleocurrents as smaller fragments are transported farther from their source than are larger sized fragments. Pennsylvanian sandstones display characteristics of both marine and fluvial depositional environments and were likely affected by both environments at the individual inception of their depositions throughout geologic time. The concept of diagenesis is an important component in the formation of sandstones. Sand is the product of weathering of quartz-bearing rocks resulting in crystalline grains of weathering resistant quartz. Sand grains are often the end-product of weathering as quartz is highly resistant to physical and chemical breakdown. This weathering is considered as the first component of diagenesis. The second component lies in the deposition and subsequent lithification of sand bodies. Given that the sand present on the Cumberland Plateau has undergone such an origin, soils formed in sandstone should exhibit properties inherited from and dependent on the diagenetic nature of Pennsylvanian sandstone.

Near the end of the Carboniferous, the area that is now the Cumberland Plateau was affected by an event known as the Allegheny Orogeny. According to plate-tectonic theory, Laurentia (North America) collided with Gondwanaland (Africa). As land building transpired the continents moved closer together. This collision caused the subduction of Laurentia beneath Gondwanaland (Sacks and Secor, 1990). This subduction resulted in an upheaval of surface materials. The intense pressure created by subduction caused much older rock units to be thrust to the surface creating the Appalachian Mountains as a result. Mafic intrusions appear along the margin of subduction as cracks in the Earth's surface were opened by continental collision. The many folds that appear in the Valley and Ridge province were also due to the Allegheny orogeny. The ridges that remain today resemble the stacking of a deck of cards as bedrock was pushed to the west by the movement of surface materials from the east. In addition to extensive folding, this event caused the strata of the Cumberland Plateau to be pushed up in an almost unbroken block. The thrust fault that makes up the eastern edge of the Plateau was likely the threshold for folding of the bedrock. Instead of folding, the Mississippian and Pennsylvanian strata were lifted up by the enormous pressure of moving continents to an elevation of roughly 2000 ft., about 1000 ft higher than surrounding geographic regions. The resulting landform is the plateau present today. It is assumed that most sedimentary deposits were laid down in a horizontal fashion at their inception (Stanley, 1999). While much of the Plateau remains relatively flat, the work of the Allegheny Orogeny impacted the terrain in a number of ways. The Sequatchie Valley, for example, is the result of water breaching and eroding away an anticline structure. Just a few miles away this same structure formed the Crab Orchard Mountains to the north of the valley. The Cumberland Mountains in the northeastern portion of the Plateau were created by an upward compaction of strata along the thrust fault of the Eastern escarpment. The area for this study is on a level terrain that is in many ways the preservation of an ancient landscape of the Late Carboniferous.

Although in consideration of the soil forming factors time alone is not directly responsible for soil formation, its importance for the development of soil is unquestionable. In order for any of the soil forming factors to have an effect, a suitable duration of time must transpire. Time zero for the development of soils on the Cumberland Plateau occurs at around the end of the Carboniferous, around 300 million years ago (Stanley, 1999). The sandstone residuum that comprises much of the soil parent material is subject to varying degrees of formative factors. The climate on Earth has changed many times since time zero. Environmental fluctuations between humidity and aridity and between warming and cooling cycles affect the development of soils.

The nature of the sandstone itself is a major determinant in the development of soil. Both physical and chemical changes occur as sands lithify into sandstone. Physically, gravity affects the architecture of a sand body. As gravity pulls downward on the mass, detrital sand grains compact to form a latticework of material (Pettijohn et al., 1972). Chemically, pores between grains are the medium for dissolution of quartz bearing minerals. Through diagenetic processes the sand materials weather to create a cement of quartz that fills the cavities and voids between sand particles. Silica and carbonate precipitates dominate most cement as sandstones are often cemented by quartz (SiO_2), a highly weathering resistant material, or by calcium carbonate (Pettijohn et al., 1972). Compaction of the sand body occurs with lithification to form a solid, nearly crystalline mass. The Pennsylvanian sandstone underlying the study site is composed of orthoquartzite (Churnet and Bergenback, 1986), a mineral that is highly resistant to weathering. In a study of the central Appalachians, Reed (2002) found lower units of Pennsylvanian stratigraphy to be quartz arenites, sandstones containing relatively high concentrations of alkaline material such as calcium carbonate. Reed (2002) reported that upper units were lithic arenites, sandstones derived from aluminous clay material (Pettijohn et al., 1972). In a study of total elemental concentrations of selected soils in the State of Tennessee, Ammons et al., (1997) examined a soil on the Cumberland Plateau formed in Pennsylvanian sandstone. Total aluminum (Al) concentrations in the subsoil BA and Bt horizons were over 35000 mg/kg with an upper limit of 39,444 mg/kg in the BA horizon. In addition, total calcium (Ca) concentrations for the Plateau profile descended with depth in the subsoil from 437 mg/kg in Bt1 to 183 mg/kg in Bt3. These findings would support the idea that upper Pennsylvanian units are indeed derived from aluminum bearing minerals rather than alkaline earth minerals. The depth of weathering fronts within sandstone residuum is affected by the porosity and permeability of the material. As a result, soil formation is somewhat limited to the range of weathering that occurs within the sandstone. As water percolates through parent material it both chemically and physically alters the minerals within the profile. Translocation of clay minerals, leaching of cations, and rearrangement of the soil architecture are components of soil formation that are dependent on the movement of water.

The landscape and associated landforms present on the Plateau are the result of both orogenic and climatic alterations of the original stratigraphy. The broad, uplifted surface of the Plateau has been dissected by numerous drainages. The elevation of the Plateau obstructs the movement of storm systems as weather moves from west to east, causing a great deal of rainfall. In places where the caprock is breached erosion is increased as more resistant rock is subjected to weathering. Differential weathering of bedrock created drainages and hollows. The variations that occur with higher relief landforms affect soil formation. Position on the landform is an important factor in soil genesis. Variance in slope, position on the slope, and slope aspect creates differing conditions for soil formation. On a landform with high slope, soil materials are likely going to be colluvial in origin whereas a soil on a relatively flat area may be of residual origin. However, on a landscape with a resistant parent material such as sandstone colluvial material on slopes may be limited by the lack of available weathered materials in the soils on a higher position on the slope. The relationship among these factors changes per site as different portions of the landscape are analyzed. Sandstone is a weathering resistant rock as evidenced by the armoring effect that sandstone geology applies on the landforms of Cumberland Plateau. Sandstone is resistant due to the cementation characteristics of the quartz minerals that compose its mass. This resistance to weathering limits the intensity and degree of pedogenic development in soils formed in sandstone residuum

MATERIALS AND METHODS

Site Description

In this study samples were taken from sites located on the Plateau and Grassland Agricultural Experiment Stations located near Crossville in Cumberland County, TN. These sites were selected to study the origins of parent material to determine how landscape positions affect soil formation.

Pedon 1 was located at 36°01'34.38" N latitude and 85°07'13.09" W longitude. The physiography for this site was a side slope with a soil slope of 9%. Elevation was 565 meters. Soil parent material at this site was hard, multicolored sandstone. Vegetative cover on this site is no-till crop residue.

Pedon 2 was located at 35° 50'29.3" N latitude and 85°03'43.2" W longitude. This soil is located at an elevation of 560 meters and on a side slope of 10% slope. Vegetative cover for this soil is fescue pasture.

The location of Pedon 3 was at 36°01'34.38" N latitude and 85°07'13.09" W longitude. The local physiography for this soil was a side slope location with a slope of

8%. Elevation at this site was 565 meters. Soil parent material in this pedon is residuum from multicolored sandstone. Land use for this pedon is no-till agriculture.

Pedon 4 lay at 36°01'12.68" N latitude and 85°07'36.97" W longitude. The physiography for this pedon was on a side slope along the side of a ridge at an elevation of 580 meters. Soil slope for this pedon was 3% and the vegetative cover for this pedon was mixed pasture. The parent material for this soil was hard sandstone bedrock.

The location of Pedon 5 was at 35° 50' 58"N latitude and 85° 04' 13"W longitude. This pedon lay on a side slope alongside a ridge. Soil slope is 3% with an elevation of 570 meters. The vegetative cover for this soil is mixed pasture.

The Rockcastle Conglomerate geologic formation underlay all locations and served as the residual soil parent material (Hardeman, 1966). This geologic unit was comprised of conglomeratic sandstone and sandstone that was gray to brown in color and fine to coarse grained in texture (Hardeman, 1966).

Field Methods and Sample Preparation

Sites were selected based on their locations on side slopes within the landscape. All pedons were sampled according to Soil Survey Division Staff Guidelines (1993), with samples taken from each horizon described. Horizons were described based on the properties present within the pedon. Field samples were air-dried, crushed and weighed according to Soil Survey Investigation Report No. 42, 1996. Samples are sieved to less than 2mm.

Laboratory Methods

All laboratory analyses were performed and the National Soil Science Laboratory in Lincoln, Nebraska. Particle size analysis was performed using the pipette method

(Kilmer and Alexander, 1949). Fractionation of sands into very coarse, coarse, medium, fine, and very fine was performed according to Gee and Bauder (1986).

Exchangeable bases were found using the ammonium acetate rapid distillation method according to Chapman (1965). Base saturation was determined mathematically as described by the Soil Survey Staff (1996). Total carbon was found using atomic combustion analysis. Since the pedons on the Plateau are not calcareous it was assumed that total carbon represented the organic carbon portion of the soil. Free iron is a useful indicator of weathering as iron bearing minerals are the product of weathering. Free iron was determined by the dithionate-citrate extraction method. A 1:1 pH was performed on each sample with H_2O (McLean, 1982). The culmination of field and laboratory data led to the classification of study pedons to the family level of soil taxonomy (Soil Taxonomy, 1999).

RESULTS AND DISCUSSION

Residual Site 1

The soil parent material for this site is sandstone residuum formed on a slope of 9%. This pedon extends to a depth of 66cm where lithic contact with the residual Pennsylvanian sandstone occurs. A location map for Pedon 1 appears in Figure 1.

Soil morphology data for Residual Pedon 1 appears in Table 1. This pedon contains a cambic diagnostic subsurface horizon. A cambic horizon was delineated based on a lack of illuviated clay and clay films and weakly developed structure. A transitional horizon designated BC is described at the 53-66 cm depth.

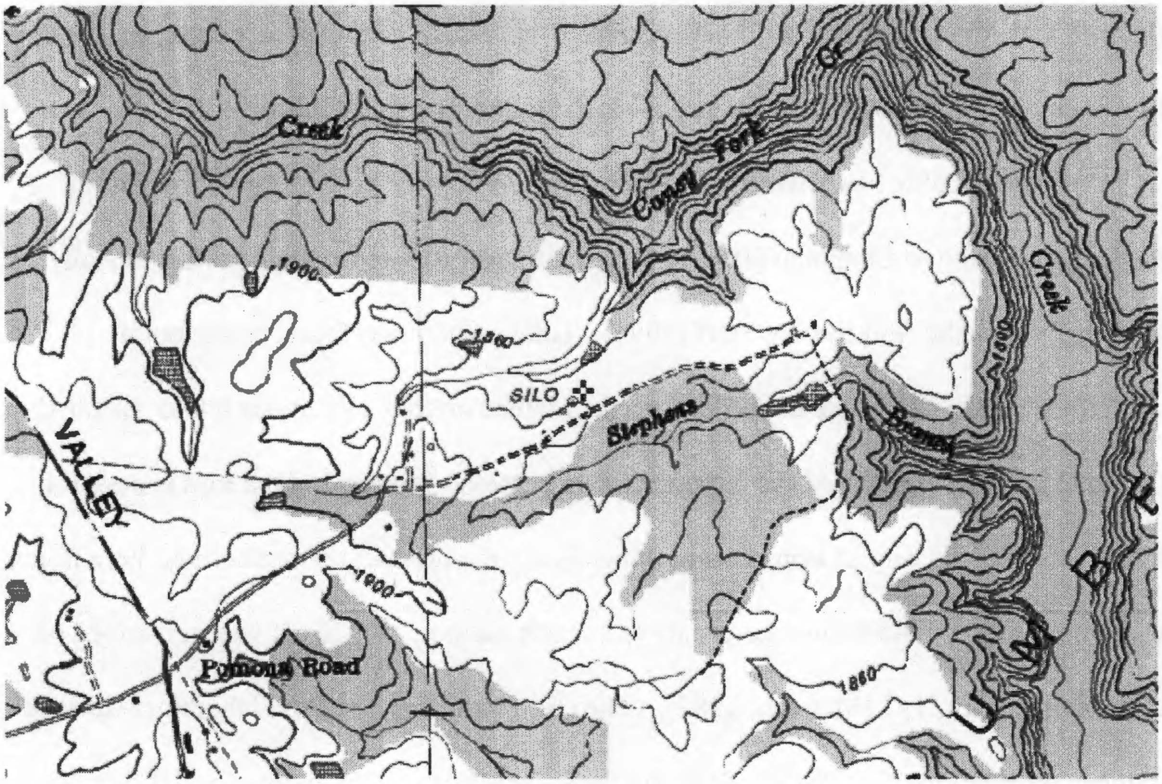

Figure 1: Location map for Residual Pedon 1. Formed in sandstone residuum.

Table 1: Soil morphology data for Residual Pedon 1. Formed in sandstone residuum.

Horizons	Depth (cm)	Color	Texture[a]	Rupture Class & Structure[b]	Boundary[c]	Redoximorphic Features	Notes
Ap	0 to 22	10YR 4/3	SL	friable:wk gr	A-smooth		
AB	22 to 38	10YR 4/3	SL	friable:wk sbk	C-smooth		
Bw	38 to 53	10YR 5/4	SL	friable:wk sbk	C-smooth		
BC	53 to 66	10YR 5/6	LS	friable:wk sbk	A-smooth		10 percent subrounded sandstone gravel; about ½ fragment volume soft, partially weathered
R	66+						

a: L=loam; SL=sandy loam; LS=loamy sand

b: wk=weak; gr=granular;
sbk=subangular blocky

c: A=abrupt; C=clear

This horizon marks the transition between the soil and the residual sandstone. This is evidenced by the loamy sand texture of the BC horizon and the presence of 10% sandstone gravels by volume in that horizon. Soil structure is weak subangular blocky through the profile except for the surface horizon that has weak granular structure.

Particle size analysis data for this pedon is shown in Table 2 with a cumulative plot of the distribution appearing in Figure 2. The percent clay for this soil decreases with increasing depth in the profile (14.6% in Ap to 8.8% in BC) while the proportion of sand increases (55.9% in Ap to 81.7% in BC). The percent sand is high enough for sandy loam textural designations in the upper horizons grading into loamy sand texture in the transitional BC horizon. Although there is an increase in clay from the Ap horizon to the AB, the increase does not meet the requirement for an argillic of 1.2 times more clay than the overlying horizon. The high proportion of sand in this soil combined with limited illuviation of clay indicates that weathering resistant sandstone is the soil parent material.

Soil chemistry data for Pedon 1 appears in Table 3. Organic carbon decreases with depth, a reflection of the organic matter portion of the surface horizon. The percent free iron is consistent throughout the profile indicating that the soils horizons have weathered for the same duration. Cation exchange capacity for this soil is low. Soil pH is low as well.

This soil is classified as a coarse-loamy, siliceous, semiactive, mesic Typic Dystrudept. This soil is of the order Inceptisol due to a lack of clay illuviation and weakly developed soil structure. Family particle size class is coarse-loamy since the particle size distribution >15% coarse than 0.1 mm and less than 18% clay through the control section. Mineralogy is siliceous since the soil is formed in sandstone residuum

Table 2: Total particle size analysis data for Residual Pedon 1. Formed in sandstone residuum

		(TOTAL)			(SILT)		(SAND)				
(mm)	Depth (cm)	Clay (<.002)	Silt (.002-.05)	Sand (.05-2)	Fine (.002-.02)	Coarse (.02-.05)	Very Fine (.05-.10)	Fine (.10-.25)	Medium (.25-.50)	Coarse (.5-1)	Very Coarse (1-2)
Ap	0 to 22	14.6	29.5	55.9	21.6	7.9	3.8	25.4	25.7	0.7	0.3
AB	22 to 38	15.4	30.7	53.9	23.1	7.6	3.7	25.9	23.6	0.6	0.1
Bw	38 to 53	12.2	19.8	68	14.1	5.7	3.1	24	38.8	1.8	0.3
BC	53 to 66	8.8	9.5	81.7	6.1	3.4	5.4	30.7	43.9	1.6	0.1
R	66+										

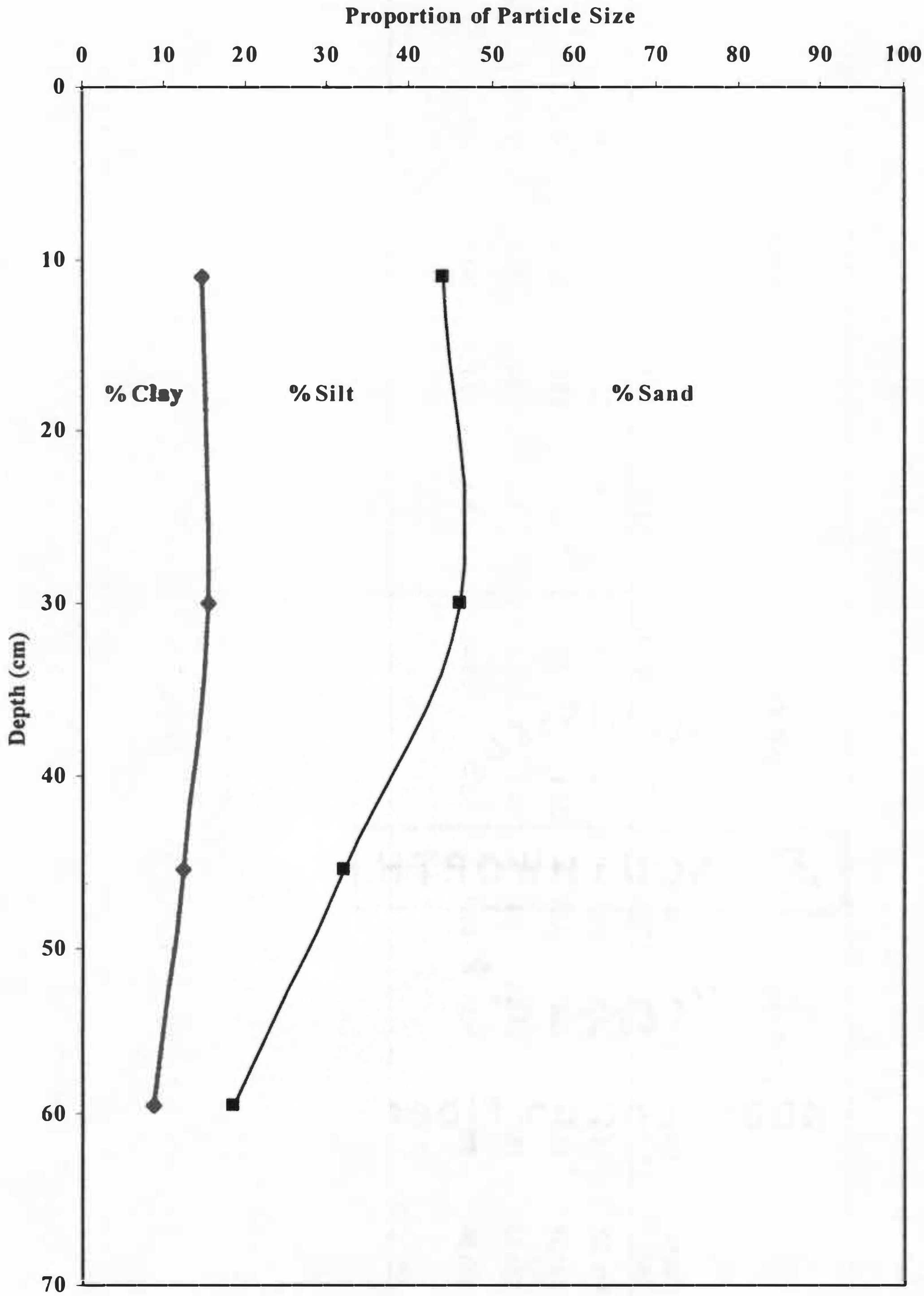

Figure 2: Particle size analysis plot for Residual Pedon 1. Formed in sandstone residuum.

Table 3: Soil chemistry data for Residual Pedon 1. Formed in sandstone residuum.

	Organic Carbon	Free Iron	CEC	CEC/clay	% Base Saturation	pH
	(Percent < 2mm)					(1:1)
Ap	1.05	1.3	6.7	0.46	64	5.4
AB	1.1	1.3	6.5	0.42	63	5.4
Bw	0.19	1.2	4.0	0.33	60	5.3
BC	0.08	1.0	2.8	0.32	100	5.0
R						

The cation exchange capacity to clay ratio gives a clay activity class of semiactive. Soil temperature on the Cumberland Plateau is in the mesic regime.

Residual sandstone parent material and landscape position are the most influential factors in the development of this soil. The lack of a developed argillic horizon and weak soil structure in this pedon reflects a limited development as does the presence of weathered sandstone gravels in the BC horizon. The shallow depth of this soil above lithic contact at 66cm also exhibits the limitations of soil formation in this pedon.

Pedogenesis has been limited by landscape position as well. This soil's side slope position on 9% slope has affected soil formation in a number of ways. First, the movement of water through a soil profile is a major impetus of pedogenic development. The sloping nature of this landscape position causes water movement to proceed down slope rather than percolating through the soil profile where it can facilitate both physical and chemical alteration of the soil parent material. This lack of percolation has limited soil formation. The erosion potential on this slope would also dictate a lack of loess on such a slope. Any loess deposited on this location has since washed away and has not been influential in soil formation. The resistant nature of the sandstone parent material coupled with side slope landscape position is determinant in soil formation.

Residual Site 2

The parent material in this pedon is hard, multicolored sandstone residuum. This pedon is on a slope of 10% and extends to a depth of 53cm where lithic contact with residual sandstone occurs. Paralithic contact with highly weathered, soft sandstone occurs from 41 to 53cm. A map of the research location of residual Pedon 2 appears in Figure 3.

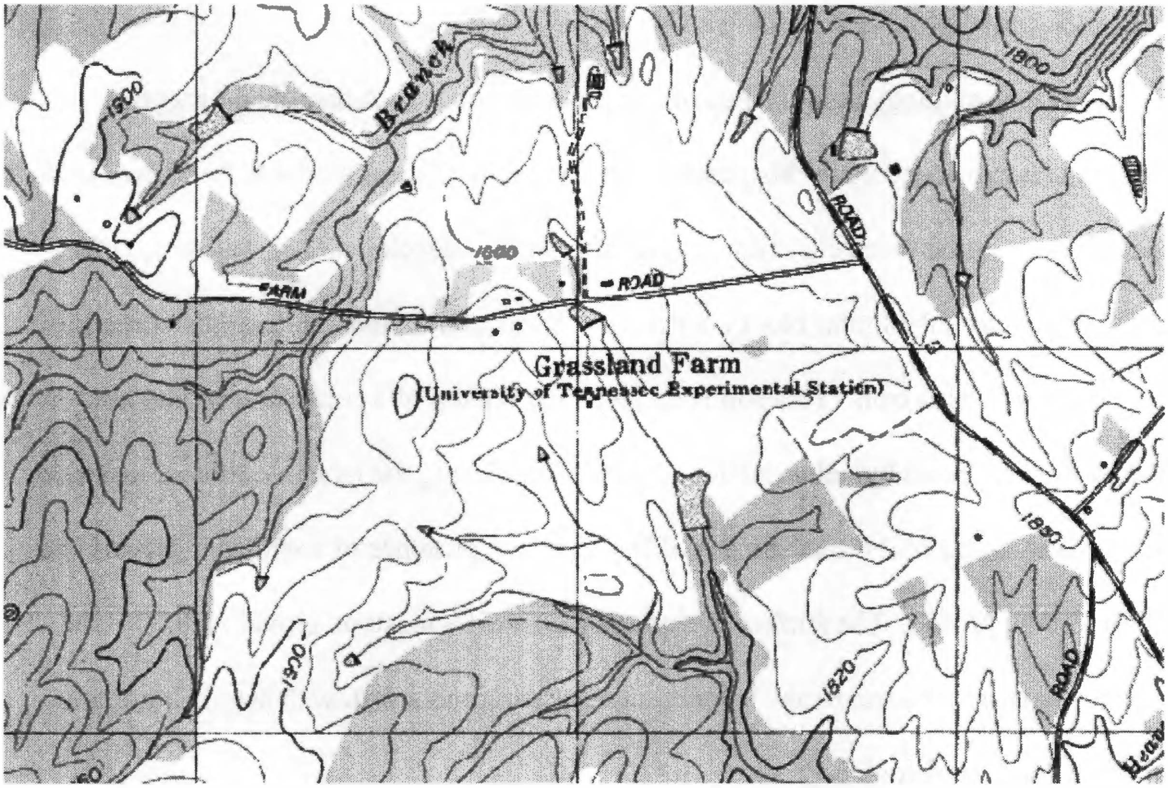

Figure 3: Location map for Residual Pedon 2. Formed in sandstone residuum.

Soil morphology data for Pedon 2 appears in Table 4. A cambic diagnostic subsurface horizon occurs in this pedon. The cambic horizon is distinguished based on a lack of illuviated clay and clay films along with weakly developed soil structure. Soil structure is weak subangular blocky for the Bw horizon and moderate granular structure in the surface Ap horizon. This soil is located near the top of a convex slope and is apparently unaffected by colluvial deposition. Considering the lack of colluvial influence the resistant nature of the sandstone is affirmed by the presence of weathered gravels and cobbles in the profile. The surface horizon contains 5% sandstone gravel while the Bw horizon contains 20% sandstone cobbles. This grades into a soft, weathered Cr horizon overlying hard sandstone bedrock.

Particle size analysis data for Residual Pedon 2 appears in Table 5. A cumulative plot of particle size distribution appears in Figure 4. The clay content for this pedon decreases from 16.9% in the surface Ap horizon to 11.8% clay in the Bw horizon. This decrease in clay indicates that illuvial translocation of clay in this soil has been limited. . The proportion of sand increases with increasing depth from around 38% in the Ap to around 52% in the Bw horizon. Soil texture in the surface horizon is loam while the Bw has a sandy loam texture. This increase in the proportion of sand reflects a sandstone parent material for this pedon as sand percentage increases near paralithic and lithic contact with residual material that occurs below the cambic horizon.

Table 4: Soil morphology data for Residual Pedon 2. Formed in sandstone residuum.

Horizons	Depth (cm)	Color	Texture[a]	Rupture Class & Structure[b]	Boundary[c]	Redoximorphic Features	Notes
Ap	0 to 22	10YR 4/4	L	friable:mo gr	A-smooth		Common fine roots; 5% sandstone gravel
Bw	22 to 41	10YR 5/6	Cobbly SL	friable:wk sbk	A-wavy		Common fine roots; 20% sandstone cobbles
Cr	41 to 53						
R	53+						

a: L=loam; SL=sandy loam

b: mo=moderate; wk=weak; gr=granular; sbk=subangular blocky

c: A=abrupt

Table 5: Total particle size analysis data for Residual Pedon 2. Formed in sandstone residuum.

		(TOTAL)			(SILT)		(SAND)				
(mm)	Depth (cm)	Clay (<.002)	Silt (.002-.05)	Sand (.05-2)	Fine (.002-.02)	Coarse (.02-.05)	Very Fine (.05-.10)	Fine (.10-.25)	Medium (.25-.50)	Coarse (0.5-1)	Very Coarse (1-2)
Ap	0 to 22	16.9	45.2	37.9	32.8	12.4	14.6	21.6	1.3	0.3	0.1
Bw	22 to 41	11.8	35.9	52.3	26.1	9.8	14.4	32.1	3.7	1.5	0.6
Cr	41 to 53										
R	53+										

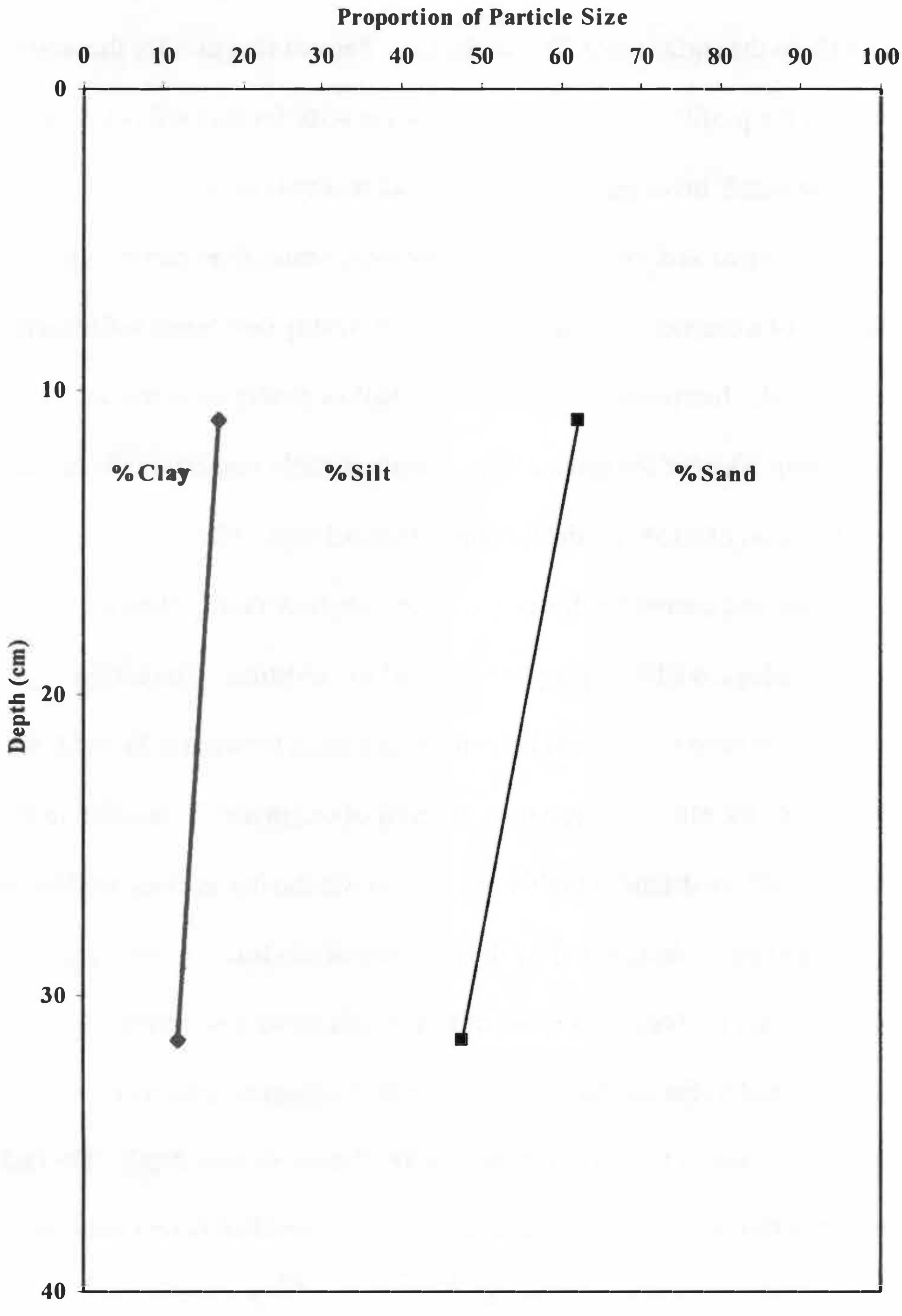

Figure 4: Particle size analysis plot for Residual Pedon 2. Formed in sandstone residuum.

Soil chemistry data for Pedon 2 appears in Table 6. Organic carbon decreases as expected from 1.44% in the surface to 0.25% in the Bw. Percent free iron for this soil is consistent throughout the profile. The cation exchange capacity for this soil is low as a result of a lack clay minerals involved in exchange. Soil acidity is high.

This soil is classified as a shallow, loamy, siliceous, semiactive, mesic Typic Dystrudept. The lack of a diagnostic argillic horizon and weakly developed soil structure places this soil in the order Inceptisol. This soil has a shallow family class due to paralithic contact within 50cm of the soil surface. Family particle size class is loamy due to particle size distribution of >15% particles coarser than 0.1 mm. There is no distinction between fine and coarse for this pedon since a shallow family class is designated. The mineralogy is siliceous for soils formed in sandstone. The cation exchange capacity to clay ratio for this soil is semiactive, falling between 0.24 and 0.40.

This soil exhibits the effects of its parent material of origin and its position in the landscape. Pennsylvanian sandstone is highly resistant to weathering as evidenced by the shallowness of this soil over residuum and by the presence of sandstone gravels and cobbles throughout the soil profile. As a result of this resistance to weathering soil formation has been limited to the top 50cm of this pedon. Pedogenic movement of clay does not appear in this pedon as the clay content actually decreases with depth. The lack of well developed structure also indicates the resistance of the residual parent material.

Table 6: Soil chemistry data for Residual Pedon 2. Formed in sandstone residuum.

	Organic Carbon	Free Iron	CEC	CEC/clay	% Base Saturation	pH
	(Percent < 2mm)					(1:1)
Ap	1.05	1.3	6.7	0.46	64	5.4
AB	1.1	1.3	6.5	0.42	63	5.4
Bw	0.19	1.2	4.0	0.33	60	5.3
BC	0.08	1.0	2.8	0.32	100	5.0
R						

Soil slope has also affected pedogenesis. The amount of water available to facilitate pedogenic processes is limited by slope. At this site water moves down slope at a rate that exceeds the rate of water percolating through the profile. The absence of loess at this location suggests that this landform is steep enough that any loess deposited has since eroded away.

Residual Site 3

Soil parent material at this site is Pennsylvanian sandstone. Pedon 3 lies on a side slope of 8% and extends to a depth of 89cm where lithic contact with hard sandstone bedrock occurs. A map showing the landscape position of Pedon 3 appears in Figure 5.

Soil morphology data for this pedon appears in Table 7. A cambic diagnostic subsurface horizon occurs from 38 to 89cm. The cambic horizon is distinguished by horizon development but with a lack of eluvial/illuvial clay accumulation and weakly developed soil structure. Soil structure is weak subangular blocky in the cambic horizon with moderate granular structure in the Ap. The BC horizon contains 10% sandstone gravel by volume. Sandstone gravels just above lithic contact suggests residual soil development.

Table 8 contains particle size analysis data for Pedon 3 with a cumulative plot of particle size appearing in Figure 6. The lack of an argillic horizon is confirmed by this data as clay decreases with increasing depth. Though there is a clay bulge in the lower depths of this pedon, this increase in clay is attributed to differential composition of the sandstone. Pockets of clay-rich shale material within the residuum at this site contribute to the clay content in the BC horizon. The proportion of sand increases from a minimum

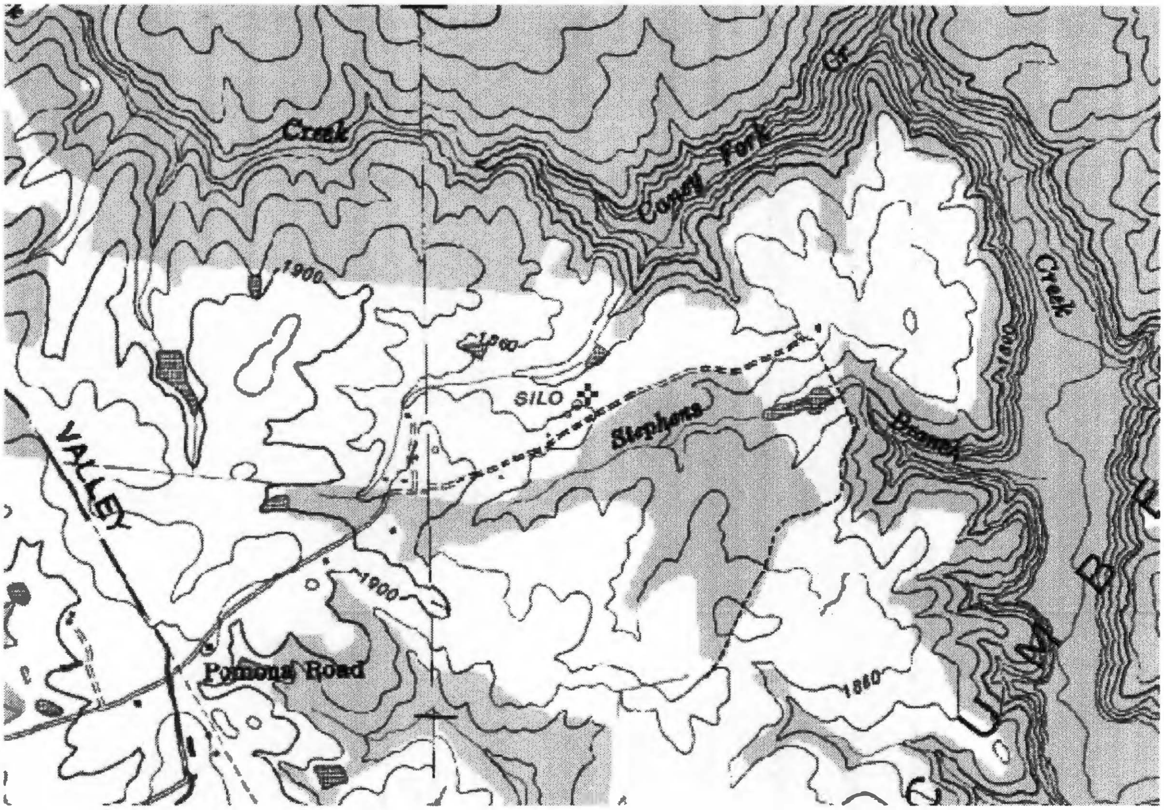

Figure 5: Location map for Residual Pedon 3. Formed in sandstone residuum.

Table 7: Soil morphology data for Residual Pedon 3. Formed in sandstone residuum.

Horizons	Depth (cm)	Color	Texture[a]	Rupture Class & Structure[b]	Boundary[c]	Redoximorphic Features	Notes
Ap	0 to 23	10YR 4/3	SL	friable:mo gr	A-smooth		Common very fine roots
AB	23 to 38	10YR 4/4	SL	friable:wk sbk	C-smooth		Few very fine roots
Bw1	38 to 47	10YR 5/6	LS	friable:wk sbk	C-smooth		
Bw2	47 to 59	10YR 5/6	LS	friable:wk sbk	C-smooth		Common faint brownish yellow (10YR 6/6) mottles
Bw3	59 to 66	10YR 5/6	LS	friable:wk sbk	A-smooth		Few faint brownish yellow (10YR 6/6) mottles
BC	66 to 89	10YR 6/8	LS	friable:wk sbk	A-smooth		Few distinct strong brown (7.5YR 5/8) mottles; 10% sandstone gravel
R	89+						

a: SL=sandy loam; LS=loamy sand

b: mo=moderate; wk=weak; gr=granular; sbk=subangular blocky

c: A=abrupt; C=clear

Table 8: Total particle size analysis data for Residual Pedon 3. Formed in sandstone residuum.

		(TOTAL)			(SILT)		(SAND)				
(mm)	Depth (cm)	Clay (<.002)	Silt (.002-.05)	Sand (.05-2)	Fine (.002-.02)	Coarse (.02-.05)	Very Fine (.05-.10)	Fine (.10-.25)	Medium (.25-.50)	Coarse (.5-1)	Very Coarse (1-2)
Ap	0 to 23	14.5	27.7	57.8	20.8	6.9	4.0	27.6	25.7	0.5	TR
AB	23 to 38	12.6	26.6	60.8	20.1	6.5	4.1	29.5	26.7	0.3	0.2
Bw1	38 to 47	8.8	19.5	71.7	13.8	5.7	4.8	34.8	31.4	0.6	0.1
Bw2	47 to 59	5.5	12.4	82.1	8.3	4.1	6.1	39.4	35.6	0.7	0.3
Bw3	59 to 66	11.8	8.3	79.9	5.4	2.9	5.1	37.7	36.4	0.6	0.1
BC	66 to 89	17.9	9.1	73.0	6.2	2.9	3.9	33.7	34.2	1.0	0.2
R	89+										

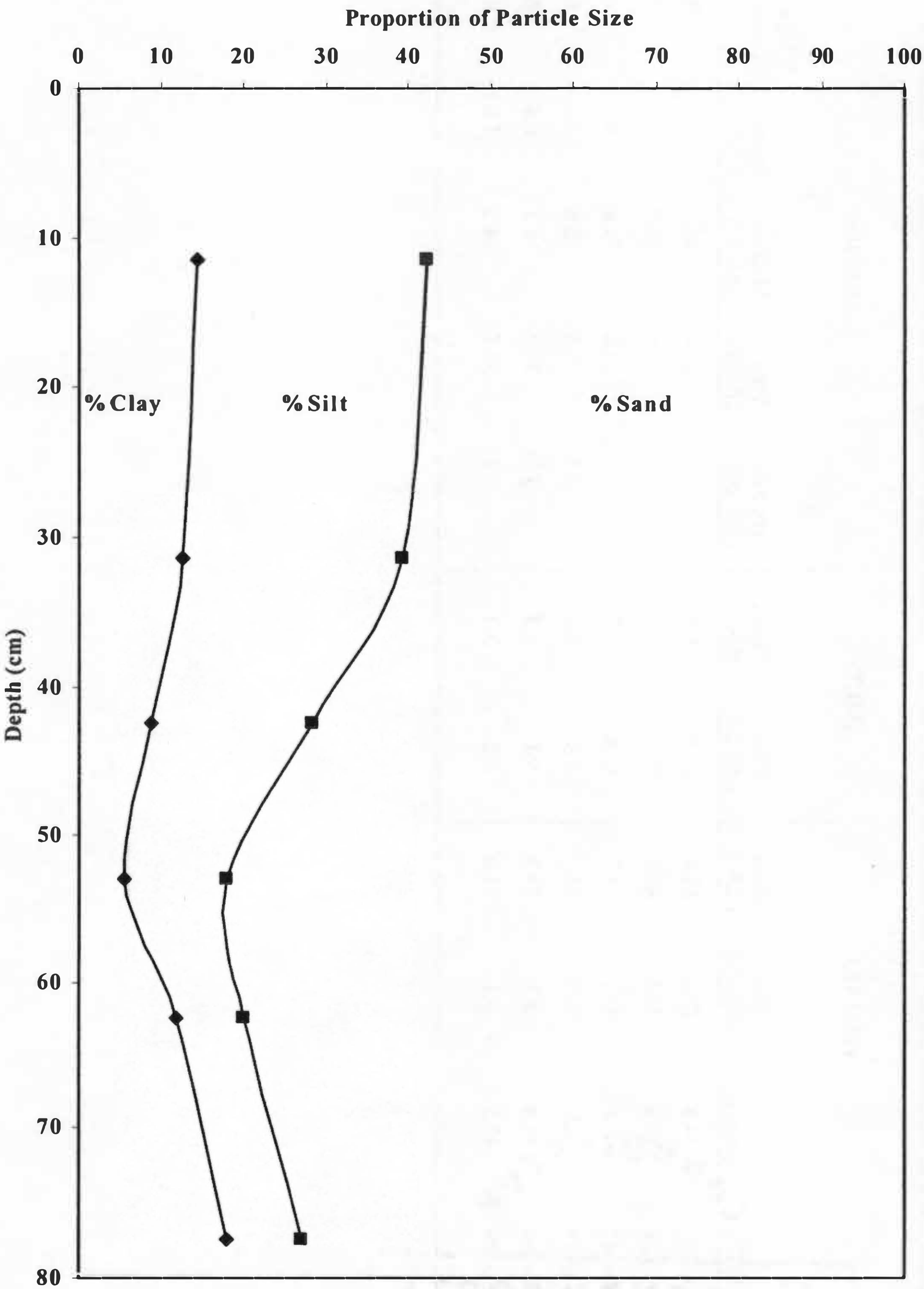

Figure 6: Particle size analysis plot for Residual Pedon 3. Formed in sandstone residuum.

of around 58% in the surface horizon to a maximum of around 82% in the Bw2 horizon then drops off to 73% in the BC.

Soil chemistry data for Pedon 3 appears in Table 9. Organic carbon decreases regularly with depth. The maximum in the Ap horizon is attributable to the organic fraction of that horizon. Free iron data is consistent with depth, ranging from 0.8 to 1.2% except for the BC horizon containing 2.1% free iron. Cation exchange capacity for Pedon 3 is low as is soil pH.

This soil is classified as a coarse-loamy, siliceous, semiactive, mesic Typic Dystrudept. Weak pedogenic development of horizons, color and structure places this soil in the order Inceptisol. Limited pedogenesis is evidenced by the lack of an argillic horizon and poorly developed soil structure. The lack of pedogenic soil formation is likely attributable to the characteristics of the sandstone residuum and to slope of the landform. Family particle size class is coarse-loamy since the particle size distribution is >15% coarser than 0.1mm and <18% clay in the control section. Quartz-rich mineralogy places this soil in the siliceous mineralogy class. A C.E.C./clay ratio between 0.24 and 0.40 indicates a semiactive clay activity class. Soil temperature at this elevation is of the mesic regime.

The effect of soil parent material is again evident in Pedon 3. Quartz minerals serve as a major component of sandstone. The crystalline nature of these minerals allows for very limited alteration by weathering. As a result of this resistance to weathering, depth of soil formation in this pedon is determined by the resistance of the underlying sandstone to pedogenic processes. Soil slope has also affected soil formation for this pedon. The translocation of clay and oxides is limited by the amount of water moving

Table 9: Soil chemistry data for Residual Pedon 3. Formed in sandstone residuum.

	Organic Carbon	Free Iron	CEC	CEC/clay	% Base Saturation	pH
	(Percent < 2mm)					(1:1)
Ap	0.95	1.2	5.9	0.41	71	6.0
AB	0.22	1.1	4.2	0.33	67	5.5
Bw1	0.14	0.9	2.7	0.31	48	5.1
Bw2	0.05	0.8	1.3	0.24	54	5.0
Bw3	0.03	1.2	2.7	0.23	37	4.9
BC	0.05	2.1	3.6	0.20	42	4.8
R						

through the soil profile. Due to the slope of 8%, water moves laterally over the surface of this pedon down slope rather that percolating through the profile. Prolonged alteration by water movement is not possible so processes dependent on percolation are limited. Soil formation is determined by the resistance of the soil parent material to weathering and the side slope position of this pedon.

Residual Site 4

Soil parent material for this site is again Pennsylvanian sandstone residuum on a slope of 3%. This soil is described to a depth of 79cm where lithic contact occurs. A location map of Residual Pedon 4 appears in Figure 7.

Soil morphological data for Residual Pedon 4 appears in Table 10. A cambic diagnostic subsurface horizon is described from 27 to 44cm. Lack of illuvial clay and limited soil structural development warrants a cambic designation. Soil structure is weak subangular blocky throughout the profile below the surface Ap horizon that exhibits moderate granular structure. Below the cambic horizon lie two transitional horizons. These horizons mark the transition from sandstone residuum into soil horizons. Sandstone cobbles appear in 30% of the BC2 horizon apparently weathered from the residual material. Since this site location is not suitable for colluvial deposition the occurrence of cobbles suggests that this pedon formed from pedogenic alteration of the underlying sandstone residuum.

Soil particle size analysis data appears in Table 11 with a cumulative plot of particle size distribution appearing in Figure 8. The decreasing clay content that prompted a cambic diagnostic horizon designation appears in this data. The influence of the sandstone bedrock also appears in this data. Surface horizons of this pedon have loam

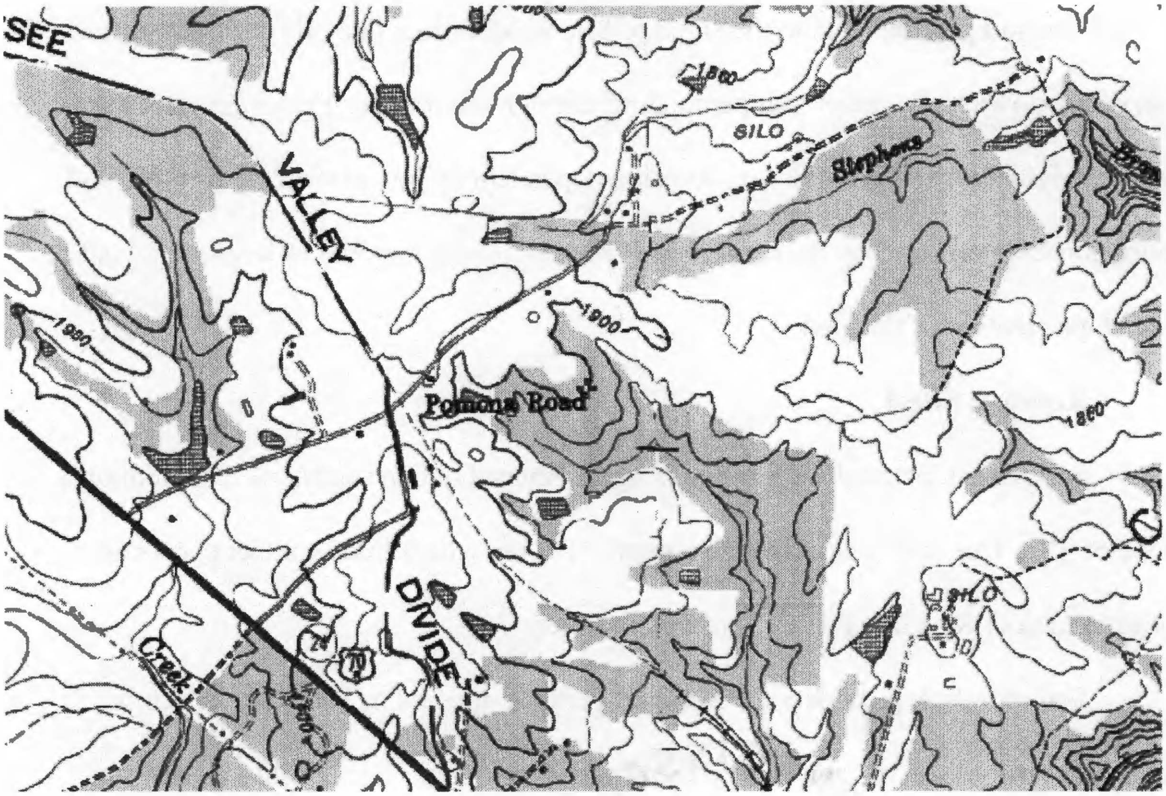

Figure 7: Location map for Residual Pedon 4. Formed in sandstone residuum.

Table 10: Soil morphology data for Residual Pedon 4. Formed in sandstone residuum.

Horizons	Depth (cm)	Color	Texture[a]	Rupture Class & Structure[b]	Boundary[c]	Redoximorphic Features	Notes
Ap1	0 to 15	10YR 4/3	L	friable:wk gr	C-smooth		Common very fine and fine roots
Ap2	15 to 27	10YR 4/3	L	friable:wk sbk	A-smooth		Common fine roots between peds
Bw	27 to 44	10YR 5/4	L	friable:mo sbk	G-smooth		Common fine roots between peds
BC1	44 to 64	10YR 5/6	SL	friable:wk sbk	G-smooth		Common fine roots between peds
BC2	64 to 79	10YR 5/8	Cobbly LS	friable:wk sbk	A-smooth		Common distinct pale brown (10YR 6/3) mottles and few distinct brown (10YR 4/3) mottles; 30% sandstone cobbles
R	79+						

a: L=loam; SL=sandy loam; LS=loamy sand
b: wk=weak; mo=moderate; gr=granular; sbk=subangular blocky
c: C=clear; A=abrupt, G=gradual

Table 11: Total particle size analysis data for Residual Pedon 4. Formed in sandstone residuum.

		(TOTAL)			(SILT)		(SAND)				
(mm)	Depth (cm)	Clay (<.002)	Silt (.002-.05)	Sand (.05-2)	Fine (.002-.02)	Coarse (.02-.05)	Very Fine (.05-.10)	Fine (.10-.25)	Medium (.25-.50)	Coarse (.5-1)	Very Coarse (1-2)
Ap1	7.5	18.7	42.7	38.6	32	10.7	5.0	21.5	11.7	0.3	0.1
Ap2	21	18.8	43.4	37.8	33.2	10.2	4.7	20.9	12.0	0.2	TR
Bw	35.5	16.8	40.8	42.4	30.9	9.9	5.2	23.8	13.1	0.2	0.1
BC1	54	9.4	30.7	59.9	21.9	8.8	6.4	32.3	20.6	0.3	0.3
BC2	71.5	11.3	15.7	73	10.1	5.6	5.7	37.6	29.1	0.6	TR
R											

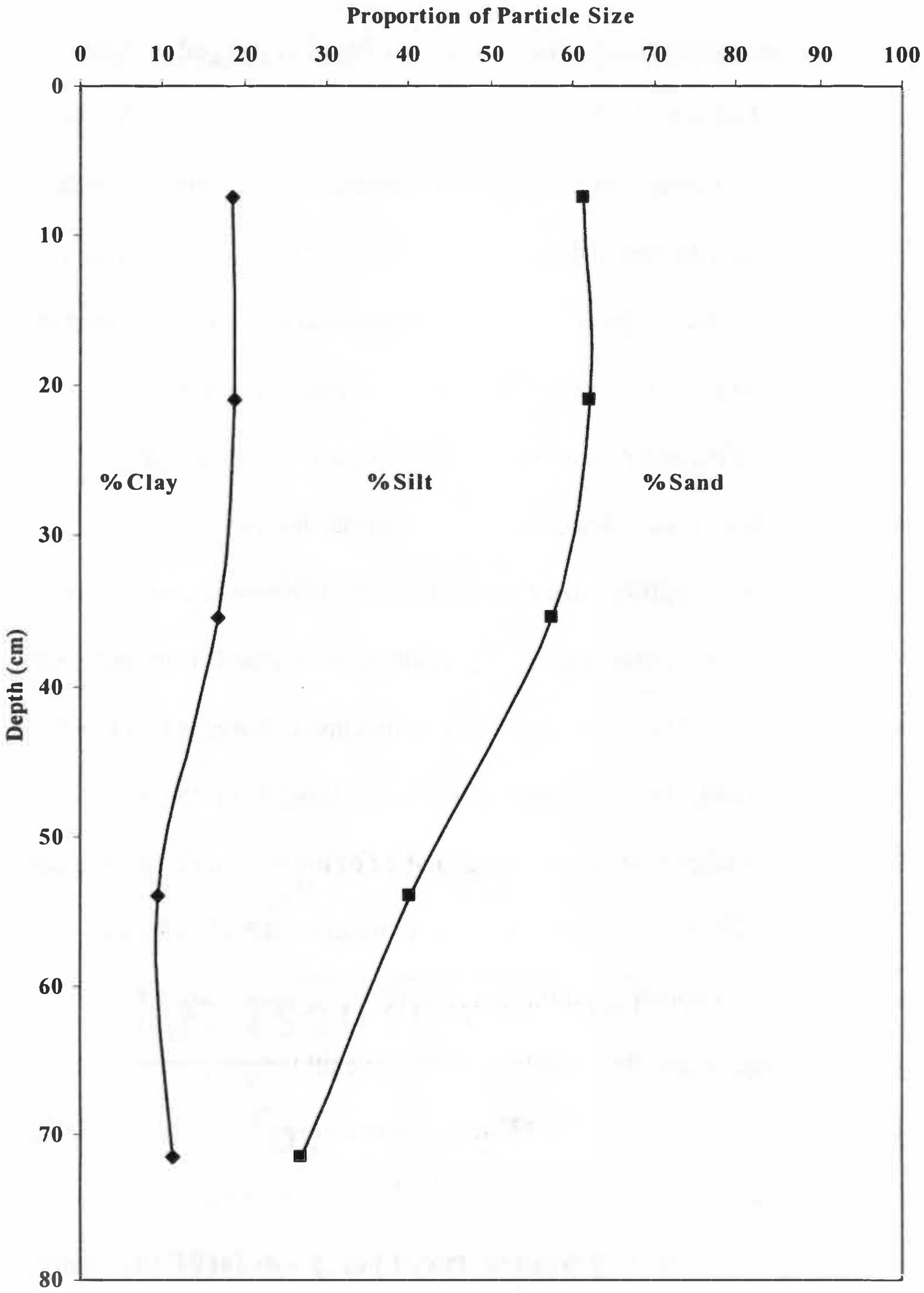

Figure 8: Particle size analysis plot for Residual Pedon 4. Formed in sandstone residuum.

textures while underlying transitional BC1 and BC2 horizons have coarser sandy loam and loamy sand textures, respectively. The proportion of sand in this pedon increases with depth from around 39% in the Ap1 horizon to around 73% sand in the BC2 horizon. This indicates that this soil formed in place from the weathering of sandstone residuum.

Soil chemistry data for Pedon 4 appears in Table 12. Organic carbon content decreases regularly with depth. The percent free iron is consistent with depth ranging from 1.0% to 1.5%. Cation exchange capacity is low and this soil is acidic.

This soil is classified as a coarse-loamy, siliceous, active, mesic Typic Dystrudept. The presence of a cambic diagnostic subsurface horizon places this soil in the order Inceptisol. Family particle size class in the control section is coarse-loamy due to a particle size distribution containing >15% particles coarser than 0.1mm and <18% clay. Mineralogy for this soil is siliceous. Clay activity class is active with a C.E.C./clay ratio between 0.40 and 0.60. The soil temperature regime is mesic for this elevation.

Soil formation is highly influenced by the nature of the sandstone bedrock serving as soil parent material. The resistance of sandstone to weathering and pedogenic alteration appears in the morphology of this soil. Sandy subsurface textures, transitional horizons, the appearance of sandstone cobbles, and an overall low proportion of clay suggest that the sandstone residuum is highly resistant to change.

Landscape position for this soil has influenced soil formation as well. Though this soil sits on a rather flat surface (3%), the nature of that surface on the landform is such that soil formation has been affected by it. This pedon lies on the edge of an upland, table-like landform. Given that the sandstone caprock covering the Cumberland Plateau

Table 12: Soil chemistry data for Residual Pedon 4. Formed in sandstone residuum.

	Organic Carbon	Free Iron	CEC	CEC/clay	% Base Saturation	pH
	(Percent < 2mm)					(1:1)
Ap1	1.35	1.4	8.6	0.46	88	5.8
Ap2	1.28	1.5	8.5	0.45	84	5.8
Bw	0.25	1.4	6.0	0.36	50	5.1
BC1	0.12	1.0	3.3	0.35	36	4.9
BC2	0.06	1.3	5.1	0.45	73	5.0
R						

exhibits topography influenced by the weathering resistant nature of the rock, this pedons location on the very edge of such a landform has limited pedogenic development. Since the slope of this landform occurs just below this site location the armoring effect of the residual soil parent material is apparent both in the topography and in the soil formed on it.

Residual Site 5

Soil parent material at this site is residuum composed of hard Pennsylvanian age sandstone. This pedon extends to a depth of 51cm where lithic contact with hard sandstone bedrock occurs. A map showing the location and landscape position of Pedon 5 appears in Figure 9.

Soil morphological data for Residual Pedon 5 appears in Table 13. A diagnostic cambic horizon is described from 10 to 51cm, the depth lithic contact occurs. Soil structure in this pedon is weak subangular blocky except for the surface horizon that has moderate granular structure. Of particular interest is the depth to bedrock. This is a shallow soil formed over hard sandstone. The shallow depth reflects the resistant nature of the sandstone residuum as soil formation is limited to this range.

Particle size analysis data for appears in Table 14 and in Figure 10. A decrease in clay content suggests limited pedogenic translocation of clay downward through the profile. This data supports the designation of a cambic diagnostic horizon. The sand fraction in this pedon is of note. In previously examined pedons the amount of sand increases with depth, so much that loamy sand textures occurred near lithic contact. In Pedon 5 the consistency of sand percentages in this pedon perhaps indicates that this soil formed in sandstone influenced by a more varied chemical and physical composition than

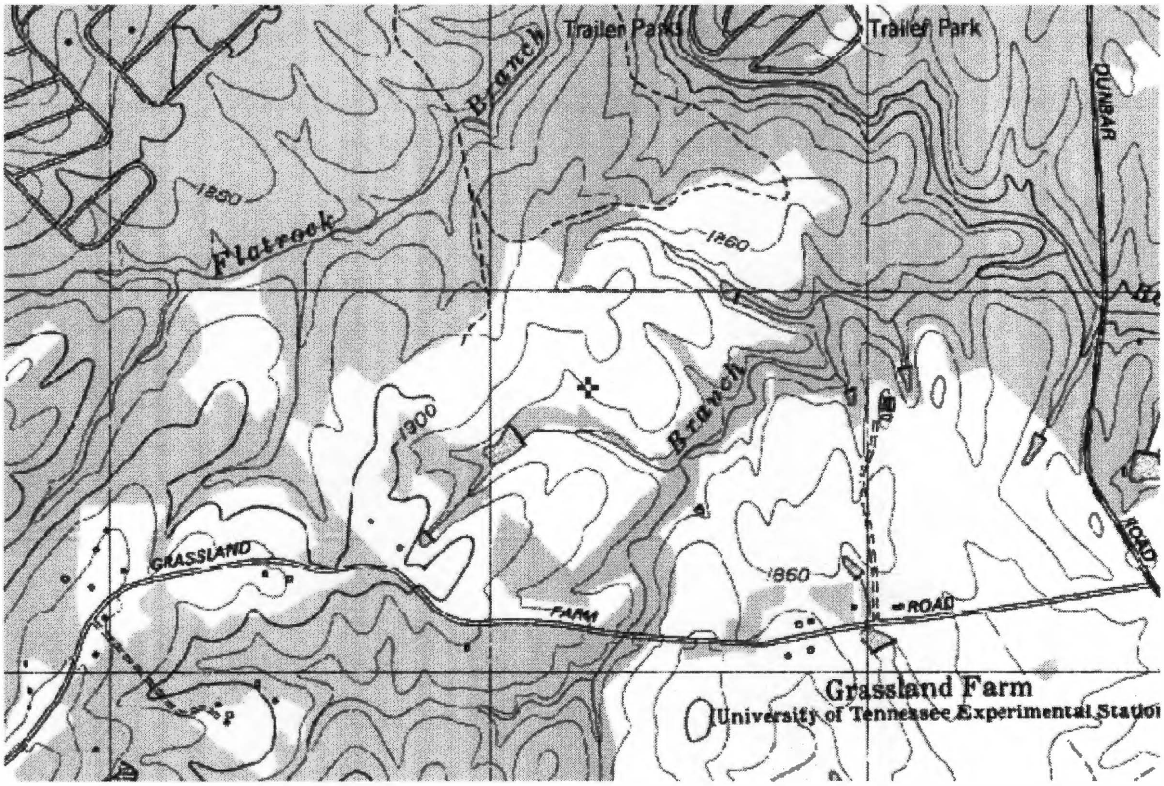

Figure 9: Location map for Residual Pedon 5. Formed in sandstone residuum.

Table13: Soil morphology data for Residual Pedon 5. Formed in sandstone residuum.

Horizons	Depth (cm)	Color	Texture[a]	Rupture Class & Structure[b]	Boundary[c]	Redoximorphic Features	Notes
Ap	0 to 10	10YR 4/3	L	friable:mo gr	A-smooth		Common very fine and fine roots throughout
Bw1	10 to 30	10YR 4/4	L	friable:wk sbk	C-smooth		Common very fine and fine roots between peds
Bw2	30 to 51	10YR 5/4	L	friable:wk sbk	A-smooth		Common fine roots between peds
R	51+						

a: L=loam

b : mo=moderate; wk=weak; gr=granular; sbk=subangular blocky

c: A=abrupt; C=clear

Table 14: Particle size analysis data for Residual Pedon 5. Formed in sandstone residuum.

		(TOTAL)			(SILT)		(SAND)				
(mm)	Depth (cm)	Clay (<.002)	Silt (.002-.05)	Sand (.05-2)	Fine (.002-.02)	Coarse (.02-.05)	Very Fine (.05-.10)	Fine (.10-.25)	Medium (.25-.50)	Coarse (.5-1)	Very Coarse (1-2)
Ap	0 to 10	15.7	40.7	43.6	30.1	10.6	4.1	23.9	15.3	0.2	0.1
Bwl	10 to 30	16.8	42.2	41.0	31.9	10.3	4.0	22.8	13.9	0.2	0.1
Bw2	30 to 51	14.3	42.0	43.7	31.0	11.0	4.2	24.5	14.8	0.2	TR
R	51+										

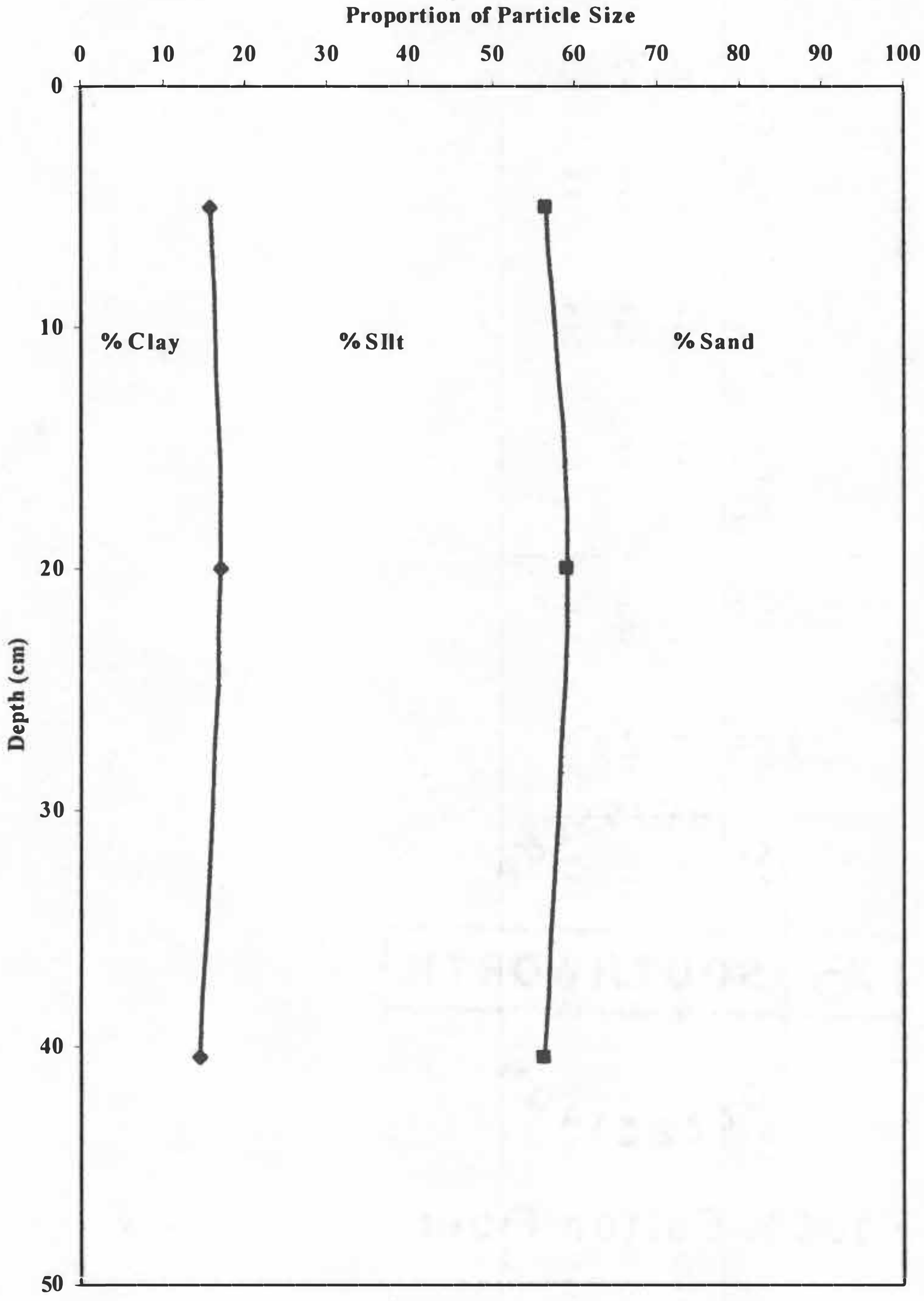

Figure 10: Particle size analysis plot for Residual Pedon 5. Formed in sandstone residuum.

the parent material of pedons that contain much higher proportions of sand within their lower soil horizons. This differential composition is related to the conglomeritic formation of the bedrock. As a conglomerate, sandstones formed in this manner contain materials interbedded in the matrix of the material. The overall low proportion of sand in this pedon suggests such an influential material, perhaps siltstone, has affected soil formation.

Soil chemistry data for Pedon 5 appears in Table 15. The percentage of organic carbon decreases regularly with depth as expected from the influence of organic matter in the surface horizon. Free iron is consistent throughout the profile, only varying from 1.2% to 1.4%. Cation exchange capacity for this soil is low and it is acidic.

This soil is classified as a coarse-loamy, siliceous, semiactive, mesic Typic Dystrudept. The lack of expression of eluvial/illuvial clay movement along with a weakly developed soil structure place this soil in the order Inceptisol. Family particle size class is coarse-loamy as >15% of the particle size distribution is coarser than 0.1mm and contains <18% clay in the control section. Quartz-rich residual soil parent material makes the mineralogy class siliceous. The C.E.C./clay ratio falls between 0.24 and 0.40 resulting in a semiactive clay activity class designation. The soil temperature regime for this elevation is mesic.

The influence of the underlying geology is evident in the morphological properties of this soil. The shallow depth to lithic contact suggests that this parent material is very resistant to weathering. However, this pedon does not contain the proportion of sand apparent in the other examined pedons formed in residuum. This difference in particle size distribution indicates an influential residual parent material that

Table 15: Soil chemistry data for Residual Pedon 5. Formed in sandstone residuum.

	Organic Carbon	Free Iron	CEC	CEC/clay	% Base Saturation	pH
	(Percent < 2mm)					(1:1)
Ap	3.98	1.2	14.3	0.91	64	5.1
Bw1	0.67	1.4	7.1	0.42	65	5.3
Bw2	0.28	1.2	5.5	0.38	76	5.6
R						

is conglomeritic, containing various portions of physically and chemically contrasting materials. Soil slope has influenced soil formation as well. This pedon lies on a side slope, albeit on a flattened portion of it. Movement of water above and below the pedon has not been such that pedogenic development can occur. This coupled with the weathering resistant character of the soil parent material has determined soil formation.

CONCLUSIONS

Soil formation on the Cumberland Plateau is influenced by a number of factors. In the pedons examined soil parent material and landscape position seemed to most influence soil formation. Sandstone residuum serves as the parent material for the pedons described in this chapter. Differences in the morphological expression of soil properties reflect differences in the physical and chemical characteristics of the sandstone itself as different pedons exhibited variation in the proportion of sand within their horizons as well as differences in clay content and soil color, texture, and structure.

Landscape position influences soil formation in the examined pedons. Much of the Cumberland Plateau is covered in silty mantle of loess. In the pedons examined in this study, soil slopes are steep enough that any loess deposited has since been removed by erosion. High slopes also translate into limitations of the water available for facilitation of pedogenic processes. A lack of stability resulting from slope limits pedogenesis. Two of the residual soils (Pedons 4 and 5) occur on flatter slopes, however their respective landscape positions dictate limited pedogenic development. Pedon 4 lies on the edge of an upland, table-like landform. This position on the edge of an armoring landform overlies material that is resistant to weathering. Pedon 5 occurs on a sort of bench in the middle of a side slope. Though soil slopes are between 8% and 10%, the colluvial influence on soil formation is limited. The resistant nature of the sandstone material results in a lack of material available for movement down slope.

The weathering resistant nature of the sandstone is also evident. The increased proportions of sand with increasing depth indicate that pedogenesis is limited by the depth of weathering possible in each of the described pedons. Soil textures reflect the influence of parent material. Transitional horizons grading from sandy loam to loamy sand textures also affirm this influence. Lithic contact occurs at relatively shallow depths in these pedons, further exhibition of the resilient characteristics of the underlying bedrock.

Soil formation on the Cumberland Plateau is related to the influence of soil parent material, landscape position, and the soil slope. This influence is apparent in the soils formed on residual Pennsylvanian sandstone. Soils in the inception of their development persist on parent materials that resist the alteration of weathering. Each of the above stated factors determines soil formation in a unique way. The combined influence of these factors must be considered in conjunction, however, as their individual characteristics rely on characteristics of the other factors.

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APPENDICIES

Appendix A. Profile Description for Transported Pedon 1

Landscape Position: Upland
Parent Material Sequence: Loess over Pennsylvanian Sandstone Residuum
Elevation: 590 meters
Slope: 3%
Natural Drainage Class: Moderately Well Drained
Location: 36° 01' 08"N
85° 07' 47"W
Classification: fine-loamy, siliceous, semiactive, mesic Typic Fragiudult

Apl 0 to 12 cm; brown (10YR 4/3) silt loam; moderate medium granular structure; friable; many very fine and fine roots in mat at top of horizon; few fine interstitial and tubular pores; clear smooth boundary.

Ap2 12 to 25 cm; brown (10YR 4/3) silt loam; weak coarse granular structure; friable; common very fine and fine roots between peds; few fine interstitial and tubular pores; abrupt smooth boundary.

Bt 25 to 48 cm; yellowish brown (10YR 5/4) silt loam; moderate medium subangular Blocky structure; friable; common very fine roots between peds; common fine And medium tubular pores; gradual smooth boundary.

Btx 48 to 66 cm; yellowish brown (10YR 5/4) silt loam; common medium prominent Light gray (2.5Y 7/2) mottles; weak very coarse subangular blocky structure Parting to weak medium subangular blocky; firm; few very fine roots between Peds; common medium tubular pores; few faint clay films on vertical faces of Peds; gradual wavy boundary. About 40% of horizon is occupied by more Massive and brittle bodies.

2Btx 66 to 94 cm; strong brown (7.5YR 4/6) clay loam; common medium prominent brownish yellow (10YR 6/6), common medium prominent olive yellow (2.5Y 6/8), and common fine prominent red (2.5YR 5/8) mottles; weak coarse prismatic structure parting to strong medium subangular blocky; firm; common medium and coarse discontinuous tubular pores; common distinct clay films on vertical and horizontal faces of peds; gradual wavy boundary. About 60% brittle peds with structureless vertical seams 1-3 cm wide occupying about 10% of horizon. Vertical seams are 2.5Y 5/4 in color and have loam textures and are more friable than surrounding matrix.

2Bt1 94 to 132 cm; strong brown (7.5YR 5/6) clay loam; common medium distinct brownish yellow (10YR 6/6), common medium prominent red (2.5 YR 5/8), and common medium distinct brownish yellow (10YR 6/8) mottles; moderate medium subangular blocky structure; friable; few fine and medium tubular pores; few distinct clay films throughout; gradual smooth boundary.

2Bt2 132 to 155 cm; strong brown (7.5YR 5/6) clay loam; common medium distinct brownish yellow (10YR 6/6) and common fine prominent red (2.5YR 5/8) mottles; weak medium subangular blocky structure; friable; few distinct clay films throughout; gradual smooth boundary.

2Cr 155+ cm.
Soft multicolored sandstone and interbedded shale bedrock.

Supplementary Data for Transported Pedon 1

	Depth (cm)	Total N	Dith-Cit Extractable Al	Mn	NH4OAc Ext. Bases Ca	Mg	Na	K	Sum	CaCl2 pH
Ap1	0 to 12	0.108	0.4	0.1	7	0.3	0.2	0.3	7.8	5.7
Ap2	12 to 25	0.098	0.4	0.1	5.8	0.4	0.3	0.4	6.9	5.6
Bt	25 to 48	0.035	0.4	0.1	2.1	0.3	0.3	0.3	3	4.3
Btx	48 to 66	0.019	0.4	0.1	0.8	0.2	0.3	0.3	1.6	4.1
2Btx	66 to 94	0.033	0.8	0.1	2.8	0.2	0.3	0.2	3.5	4
2Bt1	94 to 132	0.046	0.8	0.1	0.1	0.2	0.2	0.3	0.9	4
2Bt2	132 to 155		0.7	0.1	2.5	0.2	0.3	0.2	3.1	4
2Cr	155+									

		Bulk Density 1/3 Bar	Oven Dry	Water Content 1/3 Bar	15 Bar	Acidity	Extr. Al
Ap1	0 to 12	1.57	1.61	19.2	7.5	5.4	
Ap2	12 to 25	1.62	1.67	18.4	7.3	5.3	
Bt	25 to 48	1.61	1.66	18.9	7.8	6.8	3.3
Btx	48 to 66	1.72	1.74	17.3	6.8	6.5	4.4
2Btx	66 to 94	1.67	1.71	19.5	13	11.7	
2Bt1	94 to 132	1.57	1.62	23.2	16.3	12.6	
2Bt2	132 to 155	1.62	1.65	21.6	16.6	12.3	
2Cr	155+						

Appendix B. Profile Description for Transported Pedon 2

Landscape Position: Upland
Parent Material: Loess over Pennsylvanian Sandstone Residuum
Elevation: 579 meters
Slope: 3%
Natural Drainage Class: Well Drained
Location: 35° 50' 30.5" N
85° 04' 02.5" W
Classification: fine-loamy, siliceous, semiactive, mesic Typic Hapludult

Ap 0 to 11 cm; dark brown (10YR 3/3) loam; moderate medium granular structure; abrupt smooth boundary.

BA 11 to 27 cm; yellowish brown (10YR 5/4) loam; moderate medium subangular blocky structure; gradual smooth boundary.

Bt1 27 to 57 cm; dark yellowish brown (10YR 4/6) loam; moderate medium subangular blocky structure; 5 percent patchy faint clay films; clear smooth boundary.

Bt2 57 to 73 cm; yellowish brown (10YR 5/6) loam; moderate medium subangular blocky structure; 5 percent patchy faint clay films; clear smooth boundary.

Bt3 73 to 89 cm; yellowish brown (10YR 5/6) loam; 1 percent medium distinct very pale brown (10YR 7/4) mottles; moderate medium subangular blocky structure; 5 percent patchy faint clay films; clear smooth boundary.

Btx 89 to 110 cm; yellowish brown (10YR 5/6) loam; 10 percent medium prominent yellowish red (5YR 5/6) and 15 percent medium prominent very pale brown (10YR 7/4) mottles; weak medium prismatic parting to weak medium subangular blocky structure; 5 percent patchy faint clay films in root channels and/or pores; 5 percent 2- to 75-millimeter sandstone fragments; clear wavy boundary. 20% of this horizon consists of brittle zones.

2Bt 110 to 136 cm; strong brown (7.5YR 5/8) clay loam; 15 percent medium distinct yellowish red (5YR 5/8) mottles; moderate medium subangular blocky structure; 15 percent patchy distinct clay films on faces of peds and in pores; abrupt smooth boundary.

2Cr 136 to 185 cm; Soft weathered interbedded sandstone and shale.

2R 185 cm; Hard interbedded sandstone and shale.

Supplementary Data for Transported Pedon 2

	Depth (cm)	Total N	Dith-Cit Extractable Al	Dith-Cit Extractable Mn	NH4OAc Ext. Bases Ca	NH4OAc Ext. Bases Mg	NH4OAc Ext. Bases Na	NH4OAc Ext. Bases K	NH4OAc Ext. Bases Sum	CaCl2 pH
Ap	0 to 11	0.273	0.4	0.1	12.8	1.1	0.4	0.7	15	5.4
BA	11 to 27	0.067	0.3	0.1	4.7	0.3	0.3	0.3	5.6	6.2
Bt1	27 to 57	0.047	0.4	0.1	4.2	0.5	0.3	0.3	5.3	4.7
Bt2	57 to 73	0.029	0.3	0.1	1.4	0.1	0.4	0.4	2.3	4.2
Bt3	73 to 89	0.015	0.3	0.1	3	0.1	0.3	0.2	3.6	4.1
Btx	89 to 110	0.023	0.5	0.1	0.4	0.4	0.7	0.2	1.7	4
2Bt	110 to 136		0.7	0.1	0.3	0.3	0.3	0.2	1.1	4
2Cr	136 to 185									
2R	185+									

		Bulk Density 1/3 Bar	Bulk Density Oven Dry	Water Content 1/3 Bar	Water Content 15 Bar	Acidity	Extr. Al
Ap	0 to 11	1.09	1.17	36.1	9.4	8.4	
BA	11 to 27	1.51	1.54	19.7	6.3	3.4	
Bt1	27 to 57	1.55	1.6	18.6	8.6	5.1	
Bt2	57 to 73	1.74	1.76	15.8	6.4	4.7	
Bt3	73 to 89	1.77	1.79	14.2	6	4.7	5
Btx	89 to 110	1.75	1.78	16.5	10.1	7.5	6.6
2Bt	110 to 136	1.61	1.64	21.1	13.8	10	3.6
2Cr	136 to 185						
2R	185+						

Appendix C. Profile Description for Residual Pedon 1

Landscape Position: Side Slope
Parent Material Sequence: Pennsylvanian Sandstone Residuum
Elevation: 565 meters
Slope: 9%
Natural Drainage Class: Well Drained
Location: 36° 01' 28" N
85° 07' 13" W
Classification: coarse-loamy, siliceous, semiactive, mesic Typic Dystrudept

Ap 0 to 22 centimeters; brown (10YR 4/3) loam; weak medium granular structure; friable.

AB 22 to 38 centimeters; brown (10YR 4/3) loam; weak medium subangular blocky structure;friable.

Bw 38 to 53 centimeters; yellowish brown (10YR 5/4) loam; weak medium and coarse subangular blocky structure; friable.

BC 53 to 66 centimeters; yellowish brown (10YR 5/6) sandy loam; weak coarse subangular blocky structure; friable; 10 percent subrounded 2- to 75-millimeter sandstone fragments. Lab sample # 97P02434. About one half fragment volume are soft, partially weathered.

R 66 centimeters; Hard Sandstone bedrock

Supplementary Data for Residual Pedon 1

	Depth (cm)	Total N	Dith-Cit Extractable Al	Dith-Cit Extractable Mn	NH4OAc Ext. Bases Ca	NH4OAc Ext. Bases Mg	NH4OAc Ext. Bases Na	NH4OAc Ext. Bases K	Sum	CaCl2 pH
Ap	0 to 22	0.093	0.4	0.1	3.3	0.3	0.3	0.4	4.3	4.8
AB	22 to 38	0.096	0.4	0.1	3.2	0.3	0.3	0.3	4.1	4.8
Bw	38 to 53	0.024	0.3	0.1	1.6	0.2	0.3	0.3	2.4	4.5
BC	53 to 66	0.016	0.3	0.1	3.2	0.2	0.3	0.2	3.9	4.2

	Depth (cm)	Bulk Density 1/3 Bar	Bulk Density Oven Dry	Water Content 1/3 Bar	Water Content 15 Bar	Acidity	Extr. Al
Ap	0 to 22				6.6	6.7	
AB	22 to 38	1.66	1.68	14.5	6.7	6.6	
Bw	38 to 53	1.6	1.64	15.4	5.3	2.4	
BC	53 to 66	1.74	1.77	13.1	3.7	2.7	

Appendix D. Profile Description for Residual Pedon 2

Landscape Position: Side slope
Parent Material Sequence: Pennsylvanian Sandstone Residuum
Elevation: 560 meters
Slope: 10%
Natural Drainage Class: Well Drained
Location: 35°50’29.3” N
85°03’43.2” W
Classification: shallow, loamy, siliceous, semiactive mesic Typic Dystrudept

Ap 0 to 22 centimeters; dark yellowish brown (10YR 4/4) loam; moderate medium granular structure; common fine roots; 5 percent 2- to 75-millimeter sandstone fragments; abrupt smooth boundary.

Bw 22 to 41 centimeters; yellowish brown (10YR 5/6) cobbly loam; weak fine subangular blocky structure; common fine roots; 20 percent 75- to 250-millimeter sandstone fragments; abrupt wavy boundary.

Cr 41 to 53 centimeters; abrupt smooth boundary. Highly weathered soft multicolored sandstone.

R 53 centimeters.. Hard multicolored sandstone.

Supplementary Data for Residual Pedon 2

	Depth	Total	Dith-Cit Extractable		NH4OAc Ext. Bases					CaCl2
	(cm)	N	Al	Mn	Ca	Mg	Na	K	Sum	pH
Ap	0 to 22	0.15	0.4	0.1	7.7	0.2	0.3	0.2	8.4	5.5
Bw	22 to 41	0.04	0.3	0.1	3.1	0.1	0.7	0.2	4.1	5.3
Cr	41 to 53									
R	53+									

	Depth	Bulk Density		Water Content		Acidity	Extr. Al
	(cm)	1/3 Bar	Oven Dry	1/3 Bar	15 Bar		
Ap	0 to 22	1.49	1.58	24.9	7.5	5.3	0.1
Bw	22 to 41	1.59	1.63	17.8	4.9	2.9	0.3
Cr	41 to 53						
R	53+						

Appendix E. Profile Description for Residual Pedon 3

Landscape Position: Side slope
Parent Material Sequence: Pennsylvanian Sandstone Residuum
Elevation: 565 meters
Slope: 8%
Natural Drainage Class: Well Drained
Location: 36° 01' 28"N
85° 07' 13"W
Classification: coarse-loamy, siliceous, semiactive mesic Typic Dystrudept

Ap 0 to 23 centimeters; brown (10YR 4/3) loam; moderate fine granular structure; friable; common very fine roots throughout; abrupt smooth boundary.

AB 23 to 38 centimeters; dark yellowish brown (10YR 4/4) loam; weak medium and coarse subangular blocky structure; friable; few very fine roots throughout; common fine interstitial and tubular pores; clear smooth boundary.

Bw1 38 to 47 centimeters; yellowish brown (10YR 5/6) sandy loam; weak medium subangular blocky structure; friable; common fine interstitial and tubular pores; clear smooth boundary.

Bw2 47 to 59 centimeters; yellowish brown (10YR 5/6) sandy loam; 10 percent medium faint brownish yellow (10YR 6/6) mottles; weak medium subangular blocky structure; friable; common fine interstitial and tubular pores; clear smooth boundary.

Bw3 59 to 66 centimeters; yellowish brown (10YR 5/6) sandy loam; 1 percent medium faint brownish yellow (10YR 6/6) mottles; weak fine and medium subangular blocky structure; friable; abrupt smooth boundary.

Bw4 66 to 89 centimeters; brownish yellow (10YR 6/8) sandy loam; 1 percent fine distinct strong brown (7.5YR 5/8) mottles; weak medium subangular blocky structure; friable; 10 percent subrounded 2- to 75-millimeter sandstone fragments; abrupt smooth boundary. Faint clay films lining pores and some faces might be evident under magnification. About one half of the fragments are soft or partially weathered.

R 89 centimeters. Hard Sandstone bedrock.

Supplementary Data for Residual Pedon 3

	Depth (cm)	Total N	Dith-Cit Extractable Al	Mn	NH4OAc Ext. Bases Ca	Mg	Na	K	Sum	CaCl2 pH
Ap	0 to 23	0.084	0.4	0.1	3.4	0.3	0.2	0.3	4.2	5.3
AB	23 to 38	0.041	0.3	0.1	2	0.3	0.2	0.3	2.8	4.7
Bw1	38 to 47	0.014	0.2	0.1	0.7	0.2	0.2	0.2	1.3	4.4
Bw2	47 to 59	0.006	0.2	0.1	0.2	0.1	0.2	0.2	0.7	4.3
Bw3	59 to 66	0.006	0.3	0.1	0.3	0.2	0.3	0.2	1	4.2
Bw4	66 to 89	0.021	0.4	0.1	0.7	0.2	0.2	0.4	1.5	4.2
R	89+									

	Depth (cm)	Bulk Density 1/3 Bar	Oven Dry	Water Content 1/3 Bar	15 Bar	Acidity	Extr. Al
Ap	0 to 23	0	0	0	6.4	4.9	
AB	23 to 38	1.7	1.72	13.5	5.1	3.7	
Bw1	38 to 47	1.65	1.65	9.2	3.6	2.9	
Bw2	47 to 59	1.62	1.63	7.1	2.2	1.8	
Bw3	59 to 66	1.77	1.77	10.4	4.6	3.7	
Bw4	66 to 89	1.72	1.74	13.1	8	5.3	
R	89+						

Appendix F. Profile Description for Residual Pedon 4.

Landscape Position: Side slope
Parent Material Sequence: Pennsylvanian Sandstone Residuum
Elevation: 580 meters
Slope: 3%
Natural Drainage Class: Well Drained
Location: 36° 01' 06"N
85° 07' 37"W
Classification: coarse-loamy, siliceous, semiactive, mesic Typic Dystrudept

Ap1 0 to 15 centimeters; brown (10YR 4/3) loam; moderate medium granular structure; friable; common very fine and fine roots throughout; clear smooth boundary.

Ap2 15 to 27 centimeters; brown (10YR 4/3) loam; weak coarse subangular blocky structure; friable; common fine roots between peds; abrupt smooth boundary.

Bw 27 to 44 centimeters; yellowish brown (10YR 5/4) loam; moderate medium subangular blocky structure; friable; common fine roots between peds; gradual smooth boundary.

BC1 44 to 64 centimeters; yellowish brown (10YR 5/6) sandy loam; weak coarse subangular blocky structure; friable; common fine roots between peds; gradual smooth boundary.

BC2 64 to 79 centimeters; yellowish brown (10YR 5/8) cobbly sandy loam; 1 percent fine distinct brown (10YR 4/3) and 10 percent medium distinct pale brown (10YR 6/3) mottles; weak coarse subangular blocky structure; friable; 30 percent subangular 75- to 250-millimeter sandstone fragments.

R 79 centimeters. Hard sandstone bedrock.

Supplementary Data for Residual Pedon 4

	Depth (cm)	Total N	Dith-Cit Extractable Al	Dith-Cit Extractable Mn	NH4OAc Ext. Bases Ca	NH4OAc Ext. Bases Mg	NH4OAc Ext. Bases Na	NH4OAc Ext. Bases K	NH4OAc Ext. Bases Sum	CaCl2 pH
Ap1	0-15	0.121	0.4	0.1	6.6	0.3	0.2	0.5	7.6	5.5
Ap2	15-27	0.123	0.4	0.1	6.2	0.3	0.3	0.3	7.1	5.3
Bw	27-44	0.04	0.4	0.1	2.2	0.2	0.3	0.3	3	4.4
BC1	44-64	0.032	0.3	0.1	0.7	0.1	0.2	0.2	1.2	4.2
BC2	64-79	0.017	0.3	0.1	3.2	0.1	0.2	0.2	3.7	4.2
R	79+									

	Depth (cm)	Bulk Density 1/3 Bar	Bulk Density Oven Dry	Water Content 1/3 Bar	Water Content 15 Bar	Acidity	Extr. Al
Ap1	0-15	1.64	1.7	19.3	8.2	7.3	
Ap2	15-27	1.61	1.66	18.2	8.2	7.2	
Bw	27-44	1.66	1.69	16.7	7	7.9	
BC1	44-64	1.8	1.81	12	4.1	3.9	
BC2	64-79	1.89	1.9	9.4	5	4.5	
R	79+						

Appendix G. Profile Description for Residual Pedon 5.

Landscape Position: Side slope
Parent Material Sequence: Pennsylvanian Sandstone Residuum
Elevation: 570 meters
Slope: 4%
Natural Drainage Class: Well Drained
Location: 35°50'44" N
85°03'55.8" W
Classification: coarse-loamy, siliceous, semiactive, mesic Typic Dystrudept

Ap1 0 to 14 centimeters; dark yellowish brown (10YR 4/4) loam; moderate fine granular structure; common fine roots and common medium roots; fine cylindrical yellowish red (5YR 4/6) masses of oxidized iron; clear smooth boundary.

Ap2 14 to 29 centimeters; brown (10YR 4/3) loam; moderate fine and medium subangular blocky structure; common fine roots; clear smooth boundary.

Bw1 29 to 43 centimeters; yellowish brown (10YR 5/4) loam; moderate fine and medium subangular blocky structure; common fine roots; gradual smooth boundary.

Bw2 43 to 58 centimeters; yellowish brown (10YR 5/4) loam; weak medium subangular blocky structure; gradual smooth boundary.

BC 58 to 79 centimeters; light olive brown (2.5Y 5/6) sandy loam; 10 percent fine distinct brownish yellow (10YR 6/6) mottles; weak medium subangular blocky structure; abrupt smooth boundary.

R 79 centimeters. Hard sandstone bedrock.

Supplementary Data for Residual Pedon 5

	Depth (cm)	Total N	Dith-Cit Extractable Al	Mn	NH4OAc Ext. Bases Ca	Mg	Na	K	Sum	CaCl2 pH
Ap	0 to 10	0.358	0.4	0.1	6.4	0.9	0.4	1.5	9.2	4.8
Bw1	10 to 30	0.085	0.4	0.1	3	0.2	0.2	1.2	4.6	4.6
Bw2	30 to 51	0.035	0.3	0.1	3.1	TR	0.4	0.7	4.2	4.8
R	51+									

	Depth (cm)	Bulk Density 1/3 Bar	Oven Dry	Water Content 1/3 Bar	15 Bar	Acidity	Extr. Al
Ap	0 to 10	1.48	1.44	23.3	9.2	14.1	0.4
Bw1	10 to 30	1.39	1.44	17.8	7.3	6.7	1.4
Bw2	30 to 51	1.63	1.65	13.6	5.9	4.9	0.9
R	51+						

VITA

Edward Gaither Arnold was born June 26, 1980, in Shelbyville, Tennessee. He lived in Shelbyville until 1998 when he entered the University of Tennessee at Knoxville. After receiving a Bachelor of Science degree in Environmental and Soil Science, he continued his education at the University of Tennessee as a graduate assistant working towards a Master of Science degree in Environmental and Soil Science.