156
53

THE VARIABILITY AND GEOMORPHOLOGY OF APPLING, CECIL, AND DAVIDSON SOILS ON SIDESLOPES IN THE VIRGINIA PIEDMONT

by

Michael Hoffman Genthner

Thesis submitted to the Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE
in
Crop and Soil Environmental Sciences

APPROVED:

W. L. Daniels, Chairman

James C. Baker
J. C. Baker

James B Campbell
J. B. Campbell

David J Parrish
D. J. Parrish

September, 1990
Blacksburg, Virginia

THE VARIABILITY AND GEOMORPHOLOGY OF APPLING, CECIL, AND DAVIDSON SOILS ON SIDESLOPES IN THE VIRGINIA PIEDMONT

by

Michael Hoffman Genthner

Committee Chairman: W. Lee Daniels

Crop and Soil Environmental Sciences

(ABSTRACT)

Delineations of Appling, Cecil, and Davidson soils were sampled on a grid pattern (4 to 9 m spacings), using a bucket auger, to determine their modal character and variability with regard to various chemical and morphological parameters. Delineations were located on south-southwest facing, 5 to 12% slopes, in gently rolling landscapes that typify the Virginia Piedmont. Appling soils had the thickest A horizons and sola and were highest in A horizon P but were lowest in A horizon pH, K, Ca, Mg, and organic matter and B horizon pH, P, K, Ca, and Mg. Cecil soils were highest in A and B horizon pH and in B horizon P, K, and Mg, but had the thinnest sola. Davidson soils were highest in A and B horizon Ca and in A horizon organic matter but were lowest in A horizon P. Soil variability was considerable at all sites, with A horizon thickness and pH and B horizon P and K varying the most over short distances. Subsequent to the grid sampling study, we dug soil pits in

areas in which approximately modal soil characteristics had been observed. Pit studies revealed negative effects of agriculture upon these soils; A horizons were high in clay, had high bulk densities, and had low organic matter contents. Predictably, tilth was poor. Pit studies also showed that locally supplied colluvial materials cover a significant portion of the upland Piedmont soilscape. Of 18 pedons studied, 12 appeared to be formed in colluvial materials. However, colluvium-derived soils were usually distinguished from their residual counterparts only by the presence of a stone line that roughly paralleled the present soil surface at depths of 0 to 2 m. Therefore, these colluvial inclusions should rarely affect soil interpretations for Appling, Cecil, and Davidson map units.

Acknowledgements

I would like to express sincere appreciation to my committee, Drs. W. Lee Daniels, James C. Baker, James B. Campbell, and David J. Parrish, whose patience, guidance and support were crucial to the preparation of this manuscript. I would also like to thank Dr. William J. Edmonds for his very helpful advice concerning the use of non-parametric statistical methods. This work was funded by subcontract #19X-27413C from the U.S. Department of Energy, let through Martin-Marietta Energy Systems, Inc.

I wish to express my gratitude to the following people for their valuable assistance with experimental site location, soil sampling, and laboratory and statistical analyses: Ron Alls, Jay Bell, David Ellinghausen, Steve Feldman, John Genthner, Katie Haering, Ren-Sheng Li, Steve Nagle, Hof Owen, Louise Price, Earl Reber, Jay Roberts, Dave Starner, Barry Stewart, Rob Wheeler, and the staff of the Virginia Tech Extension Soil Testing Lab.

I would also like to thank my fellow graduate students for their friendship and for the intellectual contributions they inevitably made to this thesis through countless exchanges of ideas, information, etc.

Finally, I would like thank my parents, Hank and Sara Genthner, and my lovely wife Mary for their love and encouragement.

"If we start from our human scale of existence and explore the content of the universe further and further, we finally arrive, both in the large and the small, at misty distances where first our senses and then even our concepts fail us."

Physicist Emil Weichert, from an address
to the Physics and Economics Society of
Konigsberg, East Prussia, 1896.

Table of Contents

INTRODUCTION

The Piedmont physiographic province is a gently rolling upland that extends from the Hudson River in southeastern New York State to Montgomery in central Alabama (Thornbury, 1965; Godfrey, 1980). It is the easternmost of four physiographic regions collectively referred to by Fenneman (1938) as the Appalachian Highlands. The Piedmont is bounded on the west by the Blue Ridge and Ridge and Valley provinces and to the east by the Atlantic Coastal Plain.

When viewed from the air, the Piedmont has the appearance of a vast plain that slopes gently to the east. This impression is deceptive, however; for once on the ground, the observer becomes aware of the highly dissected nature of the topography (Buol et al., 1973). Locally, relief varies from nearly flat to 100 m or more, the landsurface being most highly dissected near major streams. Elevations along the Piedmont's inner boundary range from 60 m in New Jersey to as much as 550 m in the Dahlonega Plateau of Georgia (Thornbury, 1965).

Numerous isolated low mountains punctuate the Piedmont surface; examples are Big Cobbler Mountain in Virginia, Kings Mountain and Brushy Mountain in North Carolina (Thornbury, 1965), and Pine and Stone Mountains in Georgia (Pirkle and Yoho, 1982). Though scattered throughout, these mountains or "inselbergs" (Kesel, 1974) are more numerous along the western margin of the province.

During the eighteenth and nineteenth centuries, the Piedmont's primal forests of chestnut, oak, hickory, and tulip poplar were cut down as settlers made way for fields of tobacco, corn, and cotton (Godfrey, 1980). However, the region's rolling landscape proved to be less than ideally suited for row crop agriculture. Soil erosion was a serious problem, and widespread degradation of much of the upland soils occurred. Langdale et al. (1985) attributed the erodibility of Southern soils to their low organic matter content, weak structure, and the low permeability of their high-clay subsoils. Godfrey (1980) reports that by 1800, "farmed out" land was already being abandoned, and Trimble (1974) has chronicled the depletion of Piedmont soils through the writings of mumerous contemporary observers, one of whom wrote in the 1830s that:

> ...the scratching farmer's cares and anxieties are only relieved by his land soon washing away. As that goes down the rivers he goes over the mountains.

Despite warnings, however, imprudent agricultural practices continued. Trimble (1974) identified the period from 1860 to 1920, a period of expanding cultivation of cotton and tobacco, as the period of greatest erosive land use in the southern Piedmont.

In this century, economic and social forces have combined to force the abandonment of much Piedmont farmland. It is estimated that south of the Potomac River 65 to 70% of the Piedmont is in a stage of secondary succession with only 25 to 30% of the land still being farmed. Indeed, row crop agriculture has declined in all but one county in the southern Piedmont since 1925 (Trimble, 1974; Godfrey,1980).

In the spring of 1985, researchers in the Departments of Agronomy (now Crop and Soil Environmental Sciences) and Agricultural Engineering undertook a project funded by Martin-Marietta Corporation who were under contract with the U.S. Department of Energy, to assess the biomass-producing potential of a number of herbaceous perennials using eroded Piedmont soils. Through the use of soil conserving planting techniques, we hoped to demonstrate the feasibility of producing a renewable energy source on these soils, without inducing the widespread soil loss that occurred in the past. As part of this project, a detailed study of selected "marginal" Piedmont soils was required.

In order to ensure the effective transfer of findings from the crops study, we sought to locate plots on soils that typified the highly weathered, clayey, eroded character of soils found over much of the Piedmont region. Thus, three soils common to the southern Piedmont, the Appling series (clayey, kaolinitic, thermic family of Typic Kanhapludults), the Cecil series (clayey, kaolinitic, thermic family of

Typic Kanhapludults), and the Davidson series (clayey, kaolinitic, thermic family of Rhodic Kandiudults) were chosen for establishment of the experimental plots. These three soils occur extensively throughout the Southern Piedmont region, and where they occur in Virginia, they are usually mapped as consociations. The primary purpose of the "marginal soils" study was to work in conjunction with the crops portion of the study in providing the necessary site/soil characterization data at the chosen experimental sites.

The research proposal originally submitted to my committee listed five objectives of this marginal-soils study:

(1) Provide a chemical, physical, and morphological characterization of soils on which biomass experimental plots are located.

(2) Investigate the chemical and morphological variabilty of experimental site soils.

(3) Characterize Appling, Cecil, and Davidson soils as they occur on south-southwest facing 9 to 12% slopes and relate morphology to landscape position.

(4) Determine whether our experimental site soils fit

the concept of the respective nominal series classifications.

(5) Locate and describe relatively undisturbed examples of Appling, Cecil, and Davidson series soils.

While the first four objectives were largely completed, the fifth was not, due to time constraints. The original research proposal did not anticipate some of the soil geomorphic findings that I chose to emphasize in completing this study. Neither was I familiar enough, at the study's inception, with any of the more sophisticated techniques available for quantifying soil spatial variability, and hence that phase of the study was perhaps less enlightening than it might have been.

This thesis is submitted to fulfill, in part, the requirements for a Master of Science degree in Crop and Soil Environmental Sciences, College of Agriculture and Life Sciences, Virginia Polytechnic Institute and State University. The thesis is comprised of four chapters. Chapter 1 will review literature pertinent to the study of Piedmont soils, to include a brief description of the geology and geomorphology of the Appalachian Piedmont. In addition to the site selection process, Chapter 2 will discuss differences among experimental site soils, as measured across a number of (largely) soil-test parameters.

These data should be helpful in explaining biomass yield differences among experimental sites and soil mapping units. Chapter 3 will discuss experimental site/soil characteristics revealed by in-depth studies involving the description and sampling of soil pits at each experimental site. This third chapter focuses on the possible effects of long-term slope instability and post-settlement erosion on soil physical and morphological characteristics. Chapter 4 examines the previously proposed hypothesis that Pleistocene climatic fluctuations caused mass wasting of the Piedmont landscape. Soil data will be examined for evidence of such mass wasting, and Piedmont soil formation will be discussed within the context of recent developments in the Piedmont geomorphic model.

CHAPTER 1: LITERATURE REVIEW

Geology of the Piedmont

The geology of the Piedmont is a highly complex mixture of metamorphic and igneous rocks with isolated outcrops of sedimentary rock. Rocks of primarily Precambrian age outcrop along the western margin of the Piedmont province, forming the spine of the Blue Ridge Mountains. Resting unconformably on this Precambrian basement rock, at the western margin of the Piedmont, is a thick, pelite-turbidite sequence of upper Precambrian age, known in Virginia as the Lynchburg Formation, in the Carolinas as the Ocoee Series, and in Georgia as the Great Smoky Group. Overlying the Lynchburg/Ocoee/Great Smoky sequence is the Catoctin Formation, volcanics of upper Precambrian age, and the Chilhowee Group, clastic rocks of lower Paleozoic age. The Lynchburg Formation thins rapidly to the north and west, disappearing in northern Virginia. Further north in southern Pennsylvania, the Catoctin Formation pinches out, and the Chilhowee rests unconformably on the Precambrian basement rock (Fisher, 1970).

Near the eastern margin of the Piedmont a thick accumulation of metamorphosed slates, turbidites, and volcanic rocks of Cambrian and Ordovician age crops out in a band known as the Carolina Slate Belt. Sedimentary rocks occur in a series of northeast-southwest trending troughs that extend from the southeastern tip of New York State to northern South Carolina. These relatively unmetamorphosed rocks of Triassic age are thought to have been deposited as sediments during an episode of continental rifting (Dott and Batten, 1980).

The study of Piedmont geology is made difficult by a general lack of hard-rock exposures. In most places, the Piedmont's crystalline rocks are covered by a thick mantle of saprolite (Fisher,1970). Saprolite is the friable, residual geologic material that results from the intense, long-term chemical weathering of bedrock (Overstreet et al., 1968). Saprolite retains the texture and structure of the original rock; but, because weathering leaves only the most resistant minerals unaltered, very different rocks may produce saprolites that appear quite similar (Overstreet et al., 1968).

The saprolite-rock interface roughly parallels the land surface except along major stream valleys, where saprolite has been removed by fluvial processes (Pavich, 1986). Costa and Cleaves (1984) have reported that, in the Maryland Piedmont, ephemeral and first-order streams flow on saprolite, while higher order streams flow on bedrock. Saprolite has also been shown to be thickest on highly metamorphosed rocks, those rocks high in plagioclase feldspars, and highly jointed and foliated rocks (Overstreet et al., 1968; Costa and Cleaves, 1984). Pavich (1985) reports an average thickness for saprolites on the Piedmont upland of 15 to 20 m. Overstreet et al. (1968) note that roadcuts in excess of 15 m thick often fail to expose unweathered rock, but that saprolite is generally less than 23 m thick in southeastern gold mines. Cleaves et al. (1970) report saprolite thicknesses of 12 to 24 m in a small forested watershed in Maryland. The maximum thickness reported for saprolite is 56 m, recorded in a well in Gaston County, North Carolina (Overstreet et al., 1968).

The transformation from rock to saprolite is essentially a constant volume process (Overstreet et al., 1968; Cleaves, 1974) in which alumina-poor primary minerals such as plagioclase and hornblende are dissolved and replaced with more alumina-rich secondary minerals such as kaolinite, gibbsite, and smectite (Cleaves, 1974). The most resistant minerals such as ilmenite, rutile, zircon, monazite, sillimanite, staurolite, epidote, and kyanite may be preserved; yet the etching of quartz grains shows that during this transformation there is a significant loss of silica (Overstreet et al., 1968). Accompanying this loss of weatherable minerals is a reduction in the specific gravity and an increase in the porosity (Overstreet et al., 1968; Cleaves 1974). Cleaves (1974) studied the formation of saprolite on mafic rocks of the Maryland Piedmont and found that 30 to 60% of the original rock mass was removed by percolating groundwater. Porosity increased from 5% in the unweathered rock to greater than 50% in the saprolite. As a consequence, saprolite plays a central role in the hydrology of the region. Pavich (1986) has noted that saprolite serves as a groundwater reservior and that groundwater transmission in the Piedmont occurs largely through lateral movement at the rock/saprolite interface.

Geomorphology of the Piedmont

Discussions of the origin of the Appalachian Piedmont surface have fueled nearly a century of debate among geomorphologists. Harvard geographer William Morris Davis (1909) attempted to explain the Piedmont's gently rolling ridge and ravine topography within the context of his now classic "geographical cycle" (the so-called Davisian system) of landscape development. According to Davis, landscapes evolved through an inevitable sequence of forms which began with the uplift of an undissected plain (Fig. 1.1a), proceeded to a stage of maximum development of relief through dissection of the plain by streams (Fig. 1.1b), and concluded with the gradual reduction of the topography, by lateral planation of streams, to a near plain or peneplain (Fig. 1.1c). These stages he referred to as "youth", "maturity", and "old age", respectively (Fig. 1.1d). Davis knew that his geographical cycle grossly oversimplified

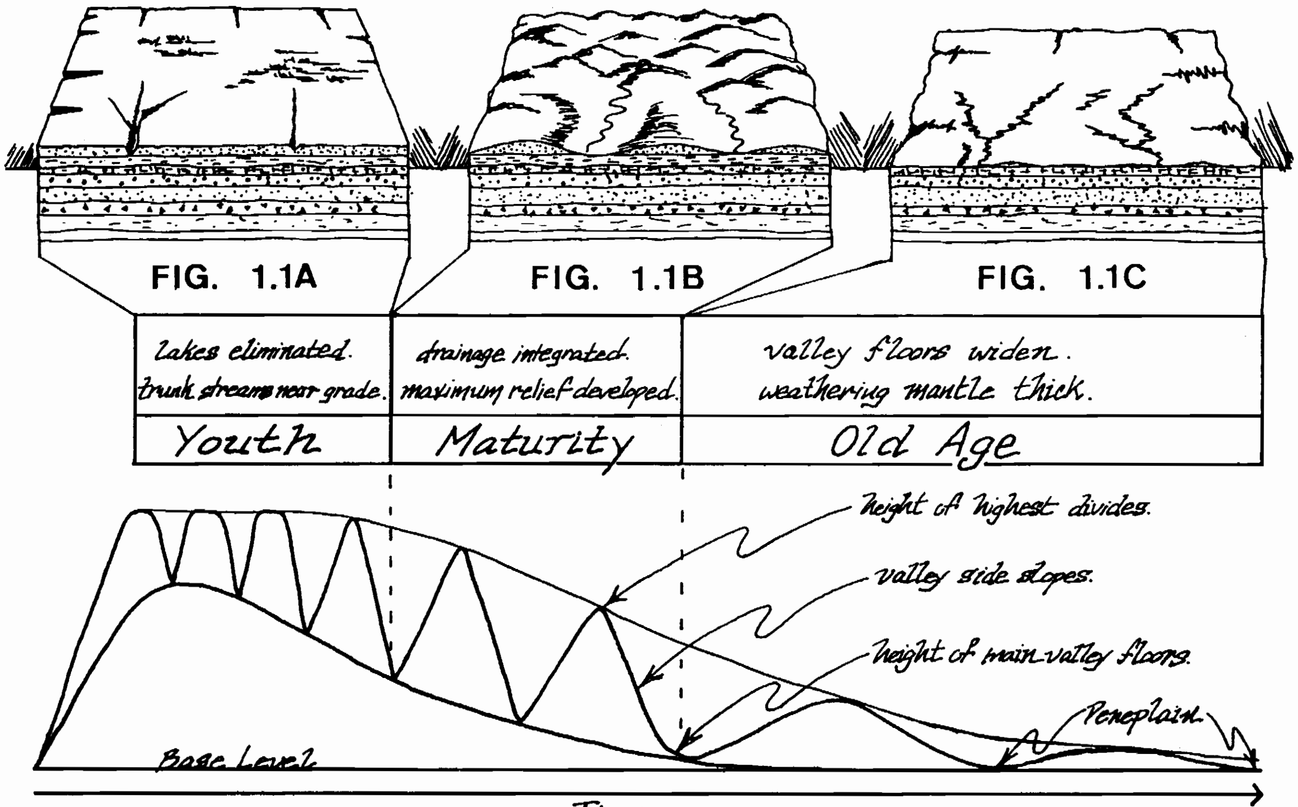


FIG. 1.1D *Davis' Geographical Cycle.*

adapted from: Selby (1985);
Pirkle & Yoho (1982).

landscape development, yet preferred to keep his model simple for pedagogical reasons (Selby, 1985). Though Davis' views on landscape development were immediately challenged by some, his ideas were widely accepted and adopted by many of his students and contemporaries (Higgins, 1975).

Alternative theories of landscape development were proposed by Walther Penck (von Engeln, 1942) and Lester C. King (1953). The dissemination of Penck's ideas suffered from both the lack of an English translation (he wrote in German) and his untimely death (Higgins, 1975). Where Davis' theories were aimed primarily at the study of landforms, Penck's theories were more concerned with the nature of diastrophism (crustal deformation) (von Engeln, 1942). While Davis' work stressed time as the overriding factor in landscape development, Penck believed diastrophism was the driving force in landscape development. Penck's ideas on hillslope development, while not widely accepted, nevertheless provoked considerable debate (von Engeln, 1948), and undoubtedly contributed to the quantitative revolution that overtook geomorphic study in the 1950s.

Lester King's system, despite his rejection of many of Davis' concepts, retains elements of the geographical cycle (Higgins, 1975). Both systems invoke short periods of rapid crustal uplift, followed by long periods of crustal stability during which the landscape is reduced to a plain of low relief. King envisioned his plain (pediplain) as resulting from coalescing pediments which enlarge as a result of headward erosion of scarps (Fig. 1.2). However, while Davis' peneplain could be rejuvenated by renewed crustal uplift, King's pediplain remained a plain of low relief until consumed by the receding scarp at its down-valley end. Flemal (1971) contends that King's system is open to many of the same criticisms leveled at the geographical cycle, and notes that the system has gained few followers outside those living in arid or semi-arid environments.

Most recently, there has been considerable support for the "dynamic equilibrium" approach to landscape analysis. This concept, while not itself a model of landscape development, relies on the the study of structure and process (Flemal, 1971) for interpretation of the landscape. Relief and form are related to spatial relationships rather than stages in evolutionary development (Hack, 1960). Such an approach is less deterministic and may reflect a growing late-twentieth century belief that nature is best understood in probabilistic terms (Higgins, 1975).

Others have attempted to reconcile the geographical cycle and equilibrium models. Schumm and Lichty (1965) contended that these two radically different approaches to landscape development might both have value, depending upon the scale of time and space being considered. While alternating periods of crustal instability and quiesence may

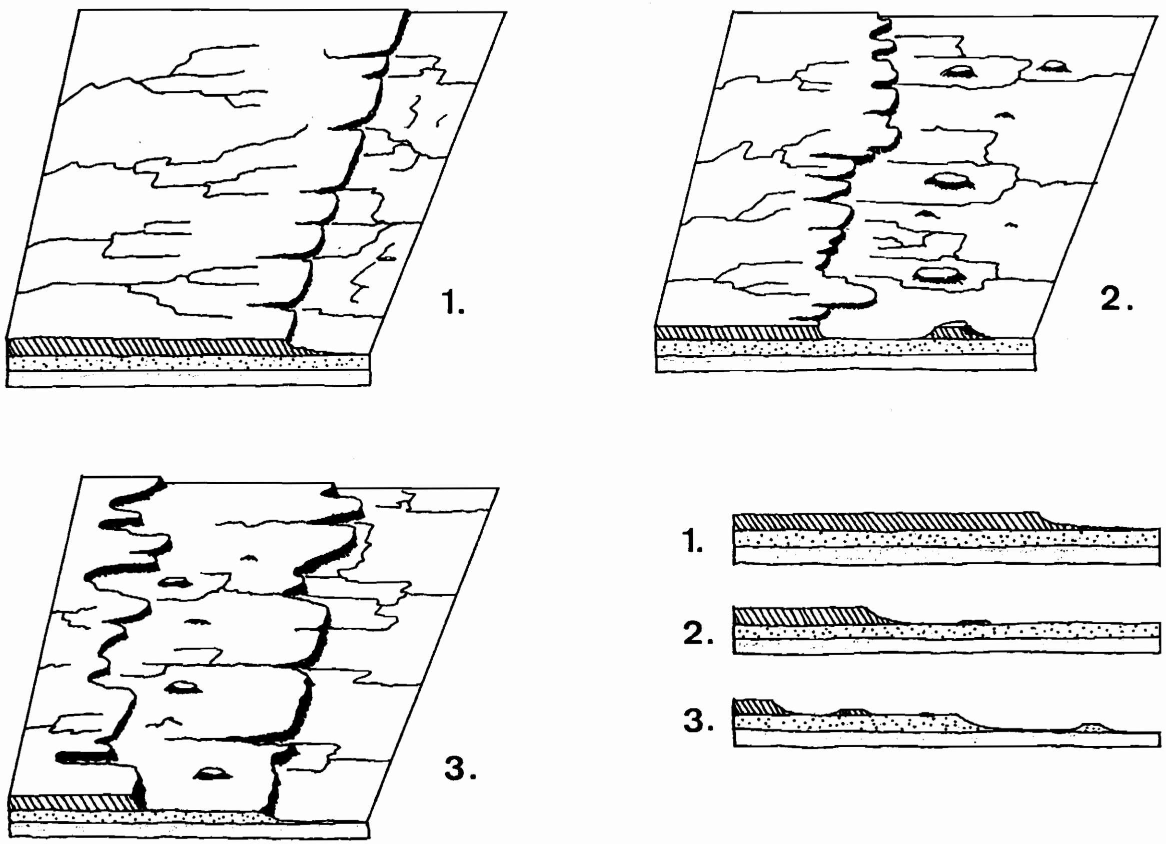


Fig. 1.2. Schematic Blocks Illustrating Lester C. King's "Pediplanation" Cycle. (adapted from Selby, 1985).

dominate landscape development on a macro scale in time and space (elements of the geographical cycle), localized factors such as lithology (a dynamic equilibrist's focus) may be more important in landform genesis over shorter distances and time periods.

As previously mentioned, the land surface of the Piedmont has been often interpreted as a peneplain or series of peneplains (Fenneman, 1938; Thornbury, 1965). Davis' contemporaries, McGee and Darton, both favored this interpretation of the Virginia Piedmont land surface (Davis, 1909). Davis noted Darton's belief that the Piedmont was actually a composite of two peneplains, the older thought to be of late Jurassic/early Cretaceous age (approximately 100 to 150 Ma B.P.), and the younger being a surface of Tertiary age (<65 Ma B.P.). The older peneplain was seen to be preserved in the heights of mountains along the Piedmont's western margin and in the surface buried beneath the largely Cretaceous-age sediments of the Atlantic Coastal Plain. To Davis, however, the deep regolith of the upland was incongruent with the narrow rockbound gorges of the larger streams. Thus, he concluded that the Piedmont surface was indeed a peneplain, but one that had been recently rejuvenated by crustal uplift.

Thornbury (1965) has questioned the existence of a planation surface buried beneath sediments of the Atlantic Coastal Plain. He notes that seismic profiles indicate 60 to

150 m of relief developed on the basement rock. Neither is there much evidence to support Johnson's (1931) contention that Piedmont drainage was superimposed from a cover of Cretaceous fluviomarine sediments (Costa and Cleaves, 1984). Costa and Cleaves note that deposits of Cretaceous sediments are absent west of the Fall Zone, and mineralogical studies of non-marine lower Cretaceous sediments indicate that the Piedmont's crystalline rocks were exposed and being eroded during this time. It should be noted, however, that Staheli (1976) has presented convincing evidence that drainage in the southeastern Georgia Piedmont was indeed superimposed from a cover of Cretaceous sediments.

An equilibrium model of Appalachian Piedmont morphogenesis has been proposed by Pavich (1985). Pavich supports Hack's belief that rather than being a Davisian peneplain, the Piedmont is a landscape in a state of dynamic equilibrium. Where Davis saw a landscape reduced to a near plain by long term erosion combined with crustal stability, Hack and Pavich believe the Piedmont's gently rolling ridge and ravine topography to be the equilibrium form resulting from the action of humid, temperate region erosion processes on a landscape undergoing long, slow uplift. Pavich (1986) suggests that this slow uplift is driven, largely, by the mass loss accompanying the conversion of hard rock to saprolite.

Costa and Cleaves (1984) applied Schumm and Lichty's

(1965) integrated approach to landscape analysis to the Maryland Piedmont and found evidence that both episodic erosion and local lithologic variability had contributed to landscape development there. As evidence that equilibrium processes were active it was noted that: (1) first and second order streams often displayed structural control while regional lithologic variability appeared to influence the location of third and fourth order stream channels; (2) locally, relief was often controlled by lithology, particularly where there existed sharp differences in rock type; (3) the thickness of saprolite was related to the mineralogy and degree of metamorphism of the underlying bedrock; and (4) mineral suites in the saprolite were closely tied to landscape position, with kaolinite and oxides predominating in drier upland sites and quartz, kaolinite, and smectite predominating in lower, wetter landscape positions.

Evidence for the occurrence of episodic erosion was found in (1) the general slope to the east of the Maryland Piedmont, with the land surface truncating non-carbonate rocks of varying lithologies, (2) the existence of large clastic deposits, apparently associated with erosional processes not presently active, and (3) the truncation of saprolite by modern drainage patterns, indicating that the upland areas might be more stable and thus older than valley sides or valley bottoms.

Soil Erosion and the Productivity of Piedmont Soils

European settlers began cultivating the Piedmont in the latter part of the 17th century. While native Americans had practiced some small-scale agriculture in the region, plantings had been confined primarily to floodplain areas of low relief and thus low erosivity (Trimble, 1974). With the arrival of Europeans, however, most of the prime bottomland was deeded to the aristocracy, leaving the more rolling uplands to be farmed by the common people (Godfrey, 1980). These farmers practiced a type of shifting agriculture, often growing tobacco for several years until the soil was depleted, and then planting the field to corn or abandoning it altogether (Trimble, 1974). This rapid clearing of forests had a profound effect on the hydrologic balance, increasing runoff and, consequently, erosion. Soil Conservation Service studies have shown that only 5% of the precipitation in a forest ecosystem runs off, while as much as 60% runs off in an agricultural system (Costa, 1975).

While the deleterious effects of row crop agriculture on soil and water quality were apparent to numerous observers, erosive land use continued unabated until the 1920s (Trimble, 1974). By that time, a combination of social and economic factors had begun to make cultivation of the Piedmont unprofitable. Farmers began to abandon the land "en masse", and much of the Piedmont was gradually reclaimed by second growth-forests.

Piedmont soils have been characterized as among the most eroded in the United States (Langdale et al., 1985). It has been estimated that the southern Piedmont from Virginia to Alabama has lost an average of 18 cm of soil due to accelerated erosion (Trimble, 1975). While it is generally acknowledged that agriculturally-accelerated soil erosion is undesirable, the true cost in terms of crop losses is difficult to quantify. Yield losses that might have resulted from culturally induced erosion of topsoil have been more than offset by increases in yield resulting from the use of synthetic fertilizers and better fertility management.

Latham (1940) grew cotton in fertilized plots of A, B, and C horizon material and found that yields were substantially reduced when grown on subsoil material. Manure additions were shown to substantially increase yields of cotton grown in B and C horizon material. Adams (1949) compared yields of cotton, corn, oats, and vetch on slightly eroded and severely eroded Cecil soils. Cotton yields were reduced by 38% on severely eroded soils, while corn, oat, and vetch yields were reduced by 40%, 34%, and 22%, respectively.

Langdale et al. (1979) studied corn yield reductions on Cecil and Starr soils. Corn trials over a period of three years showed a 42% decrease in grain yields on severely eroded soils as compared to relatively uneroded soils. When harvested for silage, yield losses were not as severe, though production did decline 15% on severely eroded land as compared to moderately eroded land. Similar drastic reductions in soybean yields were demonstrated by White et al. (1985) on Cecil and Pacolet soils. Thomas (1987) studied soybean yields on Cecil-Pacolet soils and found a slight but statistically non-significant reduction in yields on the severely eroded soils.

Several researchers have noted the confounding effect of landscape position on erosion and productivity studies (Stone et al., 1985; Daniels et al., 1985; Gilliam et al., 1985). As the most eroded soils are often associated with areas of divergent water flow, it becomes difficult to ascertain whether it is drought stress or indeed some negative characteristic of the exposed subsoil that limits crop yield. Daniels et al. (1985) showed that within areas mapped as Cecil, shoulders and side slopes were most severely eroded, while head and footslopes were least eroded. The authors suggested that perhaps extensive variability existed in these soils prior to the arrival of European settlers.

It is interesting to note that not all erosion/productivity studies have shown erosion to have a negative effect on subsequent crop yields. Stone et al. (1985) obtained their highest corn yields on moderately eroded soils as compared to slightly or severely eroded soils. The authors did note, however, that the relationship between yield and landscape position was stronger than the relationship between yield and erosion class.

The Taxonomy and Genesis of Piedmont Soils

The vast majority of southeastern soils have been classified as Ultisols (Buol et al., 1973), highly weathered soils with a low base status, formed in temperate regions under mixed hardwood/pine vegetation. Of these soils, Udults, Ultisols formed in humid environments are the most extensive (Soil Survey, 1987). Udults were mostly classified as either Red-Yellow Podzolic or Reddish-Brown Lateritic soils under the 1938 system of soil classification. The Udults are subdivided into seven great groups: Paleudults, Hapludults, Kandiudults, Kanhapludults, Rhodudults, Plinthudults, and Fragiudults (Soil Survey, 1987).

Paleudults are soils with a thick (often 150 to 200+cm) argillic horizon of predominately low-charge clay minerals. Native fertility of these soils is quite low, as is the organic matter content. Mineralogy is dominated by kaolinite, though lesser amounts of vermiculite, chlorite, gibbsite, goethite, and smectite may be present (Buol et al., 1973). Paleudults were mostly classified as Red-Yellow Podzolic soils in the 1938 classification system, although a few were classified as Reddish-Brown Calcitic soils or

Regosols (Soil Survey, 1987).

Hapludults are well-drained soils occurring in gently rolling to steep topography. They have been extensively mapped in Kentucky, Virginia, Tennessee, the Carolinas, Georgia, Alabama, and Arkansas (Buol et al., 1973). Hapludults are thinner and less highly weathered than Paleudults, though base status and organic matter content remain low. Argillic horizons are thin to moderately thick and typically strong brown to yellowish-red. Most are formed from acid rocks or sediments on moderate to steeply sloping surfaces of Pleistocene age or older (Soil Survey, 1987). The Hapludults were mostly classified as Red-Yellow or Gray-Brown Podzolic soils under the 1938 system of soil classification, although a few were classified as Lithosols, Regosols, and Planosols (Soil Survey, 1987).

Rhodudults are well drained soils formed on moderately to steeply sloping surfaces of mostly Pleistocene age (Buol et al., 1973). Argillic horizons in these soils are dark red and commonly contain weatherable minerals. Illuviation is generally not as evident in Rhodudults as it is in other Ultisols (Buol et al., 1973). These soils were classified as Reddish-Brown Lateritic soils under the 1938 system of soil classification (Soil Survey, 1987).

Fragiudults are Udults that have a fragipan in or below the argillic or kandic horizon. They are formed mainly in loamy textured soil materials, both transported and residual. These soils are commonly found on gentle slopes throughout the southeastern United States. Fragiudults were classified as either Planosols or Red-Yellow Podzolic soils under the 1938 system (Soil Survey, 1987).

Recently, the kandic subsurface horizon has been used to define the Kandiudult and Kanhapludult great groups of Ultisols. The kandic horizon is a subsurface horizon "significantly higher" in clay than the overlying horizon or horizons. The clay fraction is dominated by low-activity 1:1 type layer silicates, primarily kaolinite, and contains varying amounts of iron and aluminum oxy-hydroxides (Soil Survey, 1987). The reclassification of soils with respect to these new great groups is currently in progress. Eventually many soils presently classified as Paleudults and Hapludults will undoubtedly be reclassified as Kandiudults and Kanhapludults.

In addition to the Ultisols, lesser acreages of Alfisols, Inceptisols, and Entisols have been mapped in the Virginia Piedmont. Alfisols are mapped primarily in association with mafic and ultra-mafic parent materials, and rocks of Triassic age. Most of the Alfisols mapped belong to the Ultic subgroup, indicating that they have been subjected to intensive weathering. Inceptisols are commonly mapped on steep slopes and highly dissected uplands on the Piedmont. Inceptisols and Entisols are mapped on the floodplains (Lietzke, 1979).

Genesis of Cecil and Appling Soils

Fanning and Fanning, (1989) define podzolization as the process by which:

> "...organic matter is added at the soil surface as litter (Oi) and roots, which are typically very prolific in these soils in the lower O horizons (Oi and/or Oa). The decomposition (transformation) of the organic matter, probably mainly with fungi, produces mobile fulvic acids. Cheluviation of iron, aluminum, and other "metals" from upper horizons occurs, together with illuviation by some mechanism or mechanisms - for example, saturation of fulvic acids by iron and/or aluminum...in the B horizon or horizons."

Laterization, on the other hand, is essentially an opposing process whereby:

> "silica and bases are ... preferentially soluviated leaving Fe, Al, and Ti behind to form 'oxides' and forming minerals such as kaolinite as a result of leaching and complex mineral transformations. This assumes that the parent material is rich in weatherable minerals. Typically, soils called Latosols have been recognized over mafic rocks such as serpentinite or basalt."

Simonson (1950) discussed the conceptual development of the Red-Yellow Podzolic soil classification. It had been widely believed that these soils had formed through the podzolization of lateritic soil materials that had formed under a tropical climatic regime. Simonson rejected this model, noting that laterization was currently active in soils of the southeastern United States. Another concept considered Red-Yellow Podzolic soils as having formed in a "tension zone" between regions where podzolization and laterization were dominant soil forming processes. However, this concept was also rejected because Red-Yellow Podzolic soils have been recognized in tropical regions, which could not be considered tension zones. Simonson also found untenable the idea that Red-Yellow Podzolic argillic horizons are largely formed by the eluviation/illuviation of silicate clays. In his view, the A horizons that are typical of these soils were much too thin to account for the considerable clay bulge found in the B horizon(s). Simonson believed that the highest clay contents were frequently to be observed below the solum in the Red-Yellow Podzolic soils. He believed that clay distributions in these soils could best be explained through crystallization of clay minerals accompanying weathering of primary minerals contained in the bedrock. Concomitant with the formation of clay minerals deep in the profile was the destruction of clay minerals in the upper horizons (A and B) of the soil.

McCaleb (1959) studied Cecil, Appling, Durham, Wadesboro, Mayodan, and Granville series soils and found nothing to support the contention that formation of clays in the C horizon and their destruction in the A and B horizons were dominant processes in the genesis of Red-Yellow Podzolic soils. McCaleb argued that the formation of clay minerals occurred throughout the soil profile and that dimunition of clay in the A horizon(s) with respect to the B horizon(s) was attributable largely to physical translocation of clays through pores and channels. Soil color, whether red or yellow, was seen as dependent upon the quantity of weatherable minerals in the original parent rock. Color differences among Red-Yellow Podzolic soils were thought by White (1944) to be a function of the intensity of fracturing in the parent rock. Jointing allowed for the deep infiltration of water and oxygen into the parent rock, oxidizing the iron and leading to the development of the red color characteristic of soils such as the Cecil. Unjointed rock masses however, would tend to perch water for extended periods of time, thus preventing the intense oxidation of the soil material. The result would be the formation of yellow soils such as Appling or Louisburg.

Khalifa and Buol (1968) studied clay skins in a Cecil soil and found evidence that physical translocation of clay from the E horizon to the B horizon contributed significantly to the clay distribution observed in the soil profile. Pronounced clay skins were reported in both B and C horizons, with B horizon skins being thicker and more continuous. Fine clay (that fraction presumed to be most easily eluviated) was found to be highest in clay skins and in the Bt horizon bulk samples, and lowest in the E horizon. X-ray diffractograms of fine clay from Bt horizon clay skins displayed less sharply defined peaks as compared to diffractograms of fine clay from the CB or Bt bulk samples.

It was postulated that the relatively poor crystallinity of fine clay in Bt horizon clay skins might be due to the transient nature of clay skins in a zone where shrink/swell and biological activity appeared to rapidly incorporate illuvial material into the bulk soil. In the C horizon, pedoturbation was diminished. Clay skins would likely be more stable, thus allowing for the development of greater crystallinity of clay skin minerals.

The importance of eluvial/illuvial processes in the formation of Red-Yellow Podzolic soils was also stressed by Gibbs and Perkins (1966), who noted the presence of an E horizon in undisturbed examples of Cecil and Hayesville soils of Georgia. The authors stated their belief that kaolinite and gibbsite were precipitated from solution and were synthesized primarily within the solum. However, Pavich (in press) recently reported that no sandy, eluviated E horizons were found in numerous profiles weathered from quartzofeldspathic rocks in the northern Virginia Piedmont. He felt that the accumulation of clay in the B horizon could be attributed largely to "compaction and leaching of the underlying massive subsoil."

Characteristics of Cecil series soils.

Cecil soils are well-drained, upland soils formed in parent material derived from granite, granite gneiss, mica-gneiss, and mica-schist. These soils were reclassified in June, 1988 as clayey, kaolinitic, thermic Typic Kanhapludults in recognition of the dominance of the clay fraction by low activity minerals (Soil Survey, 1989). These soils were previously classified as clayey, kaolinitic, thermic Typic Hapludults and were earlier classified as Red-Yellow Podzolic soils (Rich et al., 1959) under the 1938 system of soil classification. The Cecil series is one of the most widely mapped in the Piedmont Region (Daniels et al., 1984). Over 4,000,000 ha have been mapped throughout Maryland, Virginia, North Carolina, South Carolina, Georgia, and Alabama (Soil Survey, 1989).

Cecil soils typically have red clay Bt horizons and light sandy loam A horizons (Rich et al., 1959), when they have not been removed by erosion. Solum thickness ranges from 100 to 150+ cm and depth to hard rock is greater than 200 cm. Cecil soils occur on slopes of 0 to 25%, with those on slopes of 2 to 15% being most common. Soils in the same family are the Appling, Bethlehem, Madison, Nankin, Pacolet, and Tumbleton series. Those in closely related families are the Aragon, Braddock, Cataula, Chestatee, Cullen, Georgeville, Hayesville, Herndon, Hiwassee, Hulett, Kolomoki, Mayodan, Mecklenburg, Spotsylvania, Tatum, and Wedowee series (Soil Survey, 1989).

The recently revised official series description for the Cecil series (Soil Survey, 1989) states the following concerning the distinction between the Cecil series and other soils in the same or closely related families:

> "Appling soils have a dominant hue of 7.5YR or yellower or where hue is 5YR, it has evident patterns of mottling in a subhorizon of the Bt or BC horizon. Aragon soils contain fragments of chert and have a cherty limestone C horizon. Bethlehem soils are moderately deep to weathered bedrock of sillimanite schist, phyllite schist, or mica schist. Braddock and Hayesville soils are mesic. Cataula soils have a fragipan. Chestatee soils contain more than 15%, by volume, of coarse fragments throughout the pedon. Cullen, Mayodan, Mecklenburg, and Tatum soils have mixed mineralogy. Georgeville and Herndon soils contain more than 30% silt. Hiwassee soils have rhodic colors to depths of 100 cm or more. Hulett, Nankin, Spotsylvania, and Wedowee soils have a Bt horizon in hue of 5YR or yellower. In addition, Nankin soils have C horizons of stratified marine sediments. Kolomoki soils are on stream terraces and have C horizons that are sandy. Madison and Pacolet soils have thinner sola. Tumbleton soils are on the Southern Coastal Plains uplands. With the exception of Hiwassee, none of the soils in the closely related families have kandic horizons."

A summary of data collected on eight Cecil pedons showed A horizon pH values of 4.2 to 5.4 (Rich et al., 1959). Values ranged from pH 4.0 to 5.8 in the B horizon. The pH of all C horizons sampled was near 5.0. The A horizon cation exchange capacities reported for the same eight pedons ranged 3.8 to 8.1 $\text{cmol}_c\ \text{kg}^{-1}$ and organic matter values ranged from 15 to 40 g kg^{-1}. Clay mineralogy of Cecil soils is dominated by kaolinite (Rich et al., 1959; Simonson, 1950; McCaleb, 1959; Gibbs and Perkins, 1966; Coleman et al., 1949).

Characteristics of Appling series soils.

Appling soils are well-drained, upland soils derived from granite, granite-gneiss, and coarse-grained sericite schist. These soils were reclassified in August, 1986 as clayey, kaolinitic, thermic Typic Kanhapludults in recognition of their low activity clays (Soil Survey, 1988). They were previously classified as clayey, kaolinitic, thermic Typic Hapludults and were earlier classified as Red-Yellow Podzolic soils under the 1938 system of soil classification (Rich et al., 1959). Appling soils are mapped extensively in the southern Piedmont from Virginia to Alabama (Soil Survey, 1988).

Appling soils typically have yellowish brown to strong brown Bt horizons and light yellowish brown to grayish A horizons. Mottling is common in the lower B horizon, with colors ranging from strong brown to red and yellow (Rich et al., 1959). Solum thickness ranges from 100 to more than 150 cm, and depth to bedrock ranges from 180 to 250 cm or more. Appling soils have been mapped on slopes of 0 to 15%. Soils in the same family are the Cecil, Madison, Nankin, and Pacolet series. Those in closely-related families are the Aragon, Braddock, Cataula, Chestatee, Cullen, Durham, Georgeville, Grover, Helena, Herndon, Hulett, Kolomoki, Mayodan, Nectar, Rion, Spotsylvania, Vance, and Wedowee series (Soil Survey, 1988).

The recently revised official series description for

Appling (Soil Survey, 1988) states the following concerning the distinctions between Appling and those competing soil series:

> "Aragon soils contain fragments of chert and have a cherty limestone C horizon. Braddock soils are mesic. Cataula soils have a fragipan. Cecil soils have a dominant hue of 5YR or redder; where hue is 5YR, evident patterns of mottling are absent in the Bt and BC horizon. Chestatee soils contain more than 15 percent, by volume, of coarse fragments throughout. Cullen, Helena, Mayodan and Vance soils have mixed mineralogy, and in addition Helena soils have low chroma mottles in the control section and Mayodan formed in Triassic age sediments. Durham, Grover and Rion soils are fine loamy. Georgeville and Herndon soils contain more than 30 percent silt. Hulett, Madison, Pacolet and Wedowee soils have thinner Bt horizons, and in addition Hulett and Madison soils contain more mica. Kolomoki and Nankin soils have C horizons of stratified marine sediments. Nectar soils have an R horizon of sandstone. Spotsylvania soils have a lithologic discontinuity with the upper horizons formed in marine sediments."

A summary of data collected for seven Appling pedons from Virginia, North Carolina, and South Carolina showed A horizon pH values ranging from 3.5 to 4.9 and pH values in the B horizon ranging from 4.3 to 5.7. A horizon CEC values ranged from 3.5 to 8.4 $\mathrm{cmol_c\ kg^{-1}}$ of soil. The mineral suite of Appling soils is dominated by kaolinite, although lesser amounts of vermiculite may also be present (Rich et al., 1959).

Genesis of Davidson Soils

Hardy and Rodrigues (1939) studied chemical and mineralogical transformations in a Davidson clay loam from Chatham County, North Carolina Piedmont. Mineralogical comparison of the unweathered parent rock (a fine grained diabase or basalt), the weathering crust of the parent rock, and a soil sample from the B horizon indicated an initial loss of bases and silica and the formation of gibbsite (laterization) as a primary weathering product. Formation of B horizon material was accompanied by a further loss of silica as well as the disappearance of much of the gibbsite, which was presumed to have undergone resilication into a secondary kaolinitic mineral, possibly halloysite. The clay fraction of the B horizon was composed of approximately 11% gibbsite, 58% kaolinite, and 22% Fe-oxides, with only trace amounts of quartz. It was proposed that this soil had undergone mild podzolization as evidenced by a slight accumulation of Fe-oxides in the Bt horizon.

These results are in general agreement with Cady (1950) who studied mineral alteration in a Davidson soil from Rowan County, North Carolina and reported that the initial products formed in the weathering of the diorite parent rock were gibbsite, chlorite, and allophane. More intensely weathered soil material showed the alteration of these minerals to kaolinite and Fe-oxides. Evidence for the illuviation of clay and sesquioxides was seen in clay films extending into the C horizon.

Davidson and Hiwassee series soils from North Carolina were studied by Nyun and McCaleb (1955). All profiles studied showed evidence of clay and sesquioxide translocation, indicating that some degree of podzolization had occurred. The fine texture of the soils studied was attributed to an abundance of easily weathered minerals in the parent rock and the lack of large-grained resistant minerals. The authors concurred with the earlier works of Hardy and Rodrigues (1939) and Cady (1950) concerning the formation of kaolinite in the Davidson soil, stating: "the increase of the kaolin-like mineral with depth is indicative of in-situ formation early in the cycle of weathering. The lower content of the surface is due to the subsequent destruction and movement to the B horizons." The authors concluded that the soils studied were sufficiently similar to Red-Yellow Podzolic soils to suggest their classification as intergrades to the Red-Yellow Podzolic soils.

England and Perkins (1959) studied three Reddish Brown Lateritic soils of Georgia. The clay fraction of these soils was dominated by kaolinite; vermiculite was secondary, while still lesser amounts of gibbsite, illite, goethite and quartz appeared. The authors noted the lack of an identifiable E horizon but noted that the AB horizon showed a decreased cation exchange capacity as compared to the horizons immediately above and below. This led to the conclusion that the AB horizon might be considered a weakly developed E horizon.

Perkins et al. (1971) studied a Davidson-like soil near Griffin, Georgia derived from a ferruginous sandstone. The authors found little morphological differentiation and greater than 12% free Fe on a whole-soil basis. It was proposed that the soil could justifiably be classified as an Oxisol, though Oxisols are not presently recognized in the continental United States.

Characteristics of Davidson series soils.

Davidson soils are deep, well drained, moderately permeable soils formed from rocks high in ferromagnesian minerals. Davidson series soils were recently reclassified as clayey, kaolinitic, thermic Rhodic Kandiudults in recognition of their low-activity clay composition (Soil Survey, 1989). These soils were previously classified as clayey, oxidic, thermic Rhodic Paleudults, and were still earlier classified as Reddish-Brown Lateritic soils under the 1938 system of soil classification.

Davidson soils have surface horizons that are dark reddish brown to dusky red. The B horizon is dark reddish brown to dark or dusky red, grading into a strong brown to dark reddish brown C horizon. Solum thicknesses are in excess of 150 cm, and the depth to bedrock is greater than 180 cm (Soil Survey, 1989). Davidson soils are found on slopes ranging up to 25%, though slopes are more commonly 2 to 15%. Only one soil, the Greenville series, is presently classified in the same family with Davidson. Those in closely related families are the Anniston, Coronaca, Cumberland, Decatur, Dyke, Gwinnett, Hiwassee, Nacogdoches, Rabun, and Rapidan series (Soil Survey, 1989).

The recently revised official series description for the Davidson series (Soil Survey, 1989) states the following concerning the distinction between the Davidson series and other soils in the same or closely related families:

> "Greenville soils formed in clayey marine sediments high in sand. Anniston soils have more than 35 percent silt in the control section and commonly contain chert or sandstone gravel and cobbles throughout. Coronaca and Cumberland soils have more than 35 percent base saturation. Decatur soils formed in old alluvium or residuum weathered from limestone and commonly contain fragments of chert. Dyke, Rabun and Rapidan soils occur in mesic temperature regimes and have thinner sola. Gwinnett soils have sola less than 100 cm thick. Hiwassee soils have more than a 20 percent decrease in clay from the maximum within 150 cm below the surface. Nacogdoches soils are dominated by tubular halloysite in the Bt horizon and have regoliths high in glauconite."

Soil Geomorphology

Piedmont soils have long been considered to be primarily residual, though numerous studies have suggested that perhaps this is an overgeneralization which obscures important factors in their genesis. Eargle (1940) studied erosion gullies in Spartansburg County, South Carolina and found organic deposits containing spruce/fir pollen buried under 6 m or more, of soil material. Supplementary observations gathered from borings indicated that 50% of the soils in an area "typical" of the South Carolina Piedmont were formed in transported materials.

Stone lines in some Georgia Piedmont soils are thought to mark discontinuities between former erosional surfaces and overlying colluvial deposits (Parizek and Woodruff, 1957). Many of these stone lines or "carpedoliths", when exposed, have been shown to slope less than the present surface, except uphill where they often bend sharply upward and are truncated by the present soil surface. The authors concluded that climatic fluctuations during the Pleistocene had precipitated a dramatic lowering of interstream divides, with the "carpedoliths" essentially preserving the form of the pre-Pleistocene topography.

Buried organic deposits of Pleistocene age, located in North and South Carolina, were analyzed by Whitehead and Barghoorn (1962). Pollen analyses indicated the mixing of both temperate and boreal plant species on the Pleistocene Piedmont. Citing climatic studies, which suggested a somewhat cooler and substantially wetter climate for the Piedmont region during periods of glacial advance, the authors proposed that saturation and frost action had triggered soil movement, burying organic sediments that had accumulated in shallow bogs. Evidence for two periods of colluvial deposition, separated by a period of soil formation, was found in the material overlying the organic deposits.

Recently, Whittecar (1985) has reported the widespread occurrence of colluvium in upland soils of the north-central Virginia Piedmont. While stopping short of assigning a periglacial origin to these deposits, the author did suggest that the work of Ciolkosz et al. (1979) and other authors previously mentioned would appear to support such a hypothesis.

Literature Cited

Adams, W.E. 1949. Loss of topsoil reduces crop yields. J. Soil and Water Cons. 4(3):130.

Alexander, L.T., S.B. Hendricks, and G.T. Faust. 1941. Occurrence of gibbsite in some soil forming materials. Soil Sci. Soc. Amer. Proc. 6:52-57.

Buol, S.W.,(ed.). 1973. Soils of the Southern States and Puerto Rico. Southern Coop. Series Bull. No. 174.

Cady, J.G. 1950. Rock weathering and soil formation in the North Carolina Piedmont region. Soil Sci. Soc. Amer. Proc. 15:337-342.

Ciolkosz, E.J., G.W. Peterson, R.L. Cunningham, and R.P. Matelski. 1979. Soils developed in colluvium in the Ridge and Valley area of Pennsylvania. Soil Sci. 128:153-162.

Cleaves, E.T., A.E. Godfrey, and O.P. Bricker. 1970. Geochemical balance of a small watershed and its geomorphic implications. Geol. Soc. Amer. Bull. 81:3015-3032.

Cleaves, E.T. 1974. Petrologic and chemical investigation of chemical weathering in mafic rocks, eastern Piedmont of Maryland. Maryland Geological Survey Report of Investigations No.25.

Coleman, N.T., M.L. Jackson, and A. Mehlich. 1949. Mineral composition of the clay fraction of several Coastal Plain, Piedmont, and mountain soils of North Carolina. Soil Sci. Soc. Amer. Proc. 13:81-85.

Costa, J.E. 1975. Effects of agriculture on erosion and sedimentation in the Piedmont province, Maryland. Geol. Soc. America Bull. 86:1281-1285.

Costa, J.E., and E.T. Cleaves. 1984. The Piedmont landscape of Maryland: a new look at an old problem. Earth Surface Processes and Landforms. 9:59-74.

Daniels, R.B., H.J. Kleiss, S.W. Buol, H.J. Byrd, and J.A. Phillips. 1984. Soil systems in North Carolina. Bulletin no. 467. North Carolina Agricultural Research Service. N.C.S.U. Raleigh, North Carolina.

Daniels, R.B., J.W. Gilliam, D.K. Cassel, and L.A. Nelson. 1985. Soil erosion class and landscape position in the North Carolina Piedmont. Soil Sci. Soc. Am. J. 49:991-995.

Davis, W.M. 1909. Geographical essays. D.W. Johnson (ed.). Ginn, Boston. Facscimile republication, 1954 by Dover Press.

Dott, R.H.,Jr. and R.L. Batten. 1981. Evolution of the earth. 3rd ed. McGraw-Hill, New York.

Eargle, D.H. 1940. The relations of soils and surfaces in the North Carolina Piedmont. Science. 91:337-338.

England, C.B., and H.F. Perkins. 1959. Characteristics of three Reddish-Brown Lateritic soils of Georgia. Soil Sci. 96:210-216.

Fanning, D.S. and M.C.B. Fanning. 1989. Soil: morphology, genesis, and classification. John Wiley and Sons, Inc., New York.

Fenneman, N.M. 1938. Physiography of the eastern United States. McGraw Hill, New York.

Fisher, F.W. 1970. The Piedmont. p.295-298. In Studies of Appalachian Geology: Central and Southern. Interscience Publishers.

Flemal, R.C. 1971. The attack on the Davisian system of geomorphology: a synopsis. Jour. Geol. Educ. 19:3-13.

Gibbs, J.A., and H.F. Perkins. 1966. Properties and genesis of the Hayesville and Cecil series of Georgia. Soil Sci. Soc. Amer. Proc. 30:256-260.

Gilliam, J.W., D.K. Cassel, R.B. Daniels, and J.R. Stone. 1985. Interrelationships among soil erosion, landscape position, and soil productivity in the North Carolina Piedmont. p.75-82. In Erosion and Soil Productivity: Proceedings of the National Symposium on Erosion and Soil Productivity. ASAE.

Godfrey, M.A. 1980. A Sierra Club naturalist's guide to the Piedmont. Sierra Club Books, San Francisco.

Hack, J.T. 1960. Interpretation of erosional topography in humid temperate regions. Am. Jour. Sci. 258-A:80-97.

Hardy, F., and G. Rodrigues. 1939. The genesis of Davidson clay loam. Soil Sci. 48:483-495.

Higgins, C.G. 1975. Theories of landscape development: a perspective. p.1-28. In W.N. Melhorn and R.C. Flemal (ed.) Theories of landform development. Publications in Geomorphology, Binghamton, N.Y.

Johnson. D.W. 1931. Stream sculture on the Atlantic Slope: a study in the evolution of Appalachian rivers. Columbia University Press, New York.

Kesel, R.H. 1974. Inselbergs on the Piedmont of Virginia, North Carolina, and South Carolina: types and characteristics. Southeastern Geology 16(1):1-30.

Khalifa, E.M., and S.W. Buol. 1968. Studies of clay skins in a Cecil (Typic Hapludult) soil: I. composition and genesis. Soil Sci. Soc. Amer. Proc. 32:857-861.

King, L.C. 1953. Canons of landscape evolution. Geol. Soc. Amer. Bull. 64:721-752.

Langdale, G.W., J.E. Box, Jr., R.A. Leonard, A.P. Barnett, and W.G. Fleming. 1979. Corn yield reduction on eroded southern Piedmont soils. J. Soil and Water Cons. 34(5):226-228.

Langdale, G.W., and W.D. Shrader. 1982. Soil erosion effects on soil productivity of cultivated cropland. pp. 41-51. IN B.L. Schmidt, R.R. Allmaras, J.V. Mannering, and R.I. Papendick (ed.). Determinants of soil loss tolerance. Amer. Soc. of Agron. Spec. Publ. No. 45. Madison, Wisconsin. 153 p.

Langdale, G.W., H.P. Denton, A.W. White, Jr., J.W. Gilliam, and W.W. Frye. 1985. Effects of soil erosion on crop productivity of Southern soils. In R.F. Follett and B.A. Stewart (ed.). Soil erosion and crop productivity. Amer. Soc. of Agron.

Latham, E.E. 1940. Relative productivity of the A horizon of the acid sandy loam and the B and C horizons exposed by erosion. J. Am. Soc. Agron. 32:950-954.

Lietzke, D.A. 1979. Guide to soil taxonomy and key to Virginia soils: Piedmont division. MA-218.

McCaleb, S.B. 1959. The genesis of the Red-Yellow Podzolic soils. Soil Sci. Soc. Amer. Proc. 23:164-168.

Nyun, M.A., and S.B. McCaleb. 1955. The Reddish-Brown Lateritic soils of the North Carolina Piedmont region: Davidson and Hiwassee series. Soil Sci. 80:27-41.

Overstreet, W.C., A.M. White, J.W. Whitlow, P.K. Theobald, D.W. Caldwell, and N.P. Cuppels. 1968. Fluvial monazite deposits in the southeastern United States. USGS Prof. Paper. 568, 85p.

Parizek, E.J. and J.F. Woodruff. 1957. Description and origin of stone layers in the soils of the southeastern United States. Jour. Geol. 65:24-34.

Pavich, M.J. 1985. Appalachian Piedmont morphogenesis: weathering, erosion and Cenozoic uplift. p.299-319. In M. Morisawa and J.T. Hack (ed.) Tectonic geomorphology. Proc. 15th Annu. Geomorphol. Symp. Ser., State University of New York, Binghamton.

Pavich, M.J. 1986. Processes and rates of saprolite production and erosion on a foliated granitic rock of the Virginia Piedmont. p.551-590. In S.M. Colman and D.P. Dethier (ed.) Rates of chemical weathering of rocks and minerals. Academic Press, Inc. Orlando, Florida.

Pavich, M.J., G.W. Leo, S.F. Obermeier, and J.R. Estabrook. 1989. Investigations of the characteristics, origin, and residence time of the upland residual mantle of the Piedmont of Fairfax County, Virginia. USGS Prof. Paper 1352, 58p.

Perkins, H.F., S.C. Tiwari, and K.H. Tan. 1971. Characterization and classification of a highly weathered soil of the southern Piedmont. Soil Sci. 111:119-123.

Pirkle, E.C. and W.H. Yoho. 1982. Natural landscapes of the United States. Kendall/Hunt Publishing Co. Dubuque, Iowa.

Rich, C.I., L.F. Seatz, and G.W. Kunze (ed.). 1959. Certain properties of selected Southeastern soils and mineralogical procedures for their study. Southern Coop. Series. Report of Cooperative Research under Southern Regional Project S-14.

Schumm, S.A., and R.W. Lichty. 1965. Time, space and causality in geomorphology. Am. Jour. Sci. 263:110-119.

Selby, M.J. 1985. Earth's changing surface. Oxford University Press, New York.

Simonson, R.W. 1950. Genesis and classification of Red-Yellow Podzolic soils. Soil Sci. Soc. Amer. Proc. 14:316-319.

Soil Survey Staff. 1987. Soil taxonomy. Agric Handb. no. 436. USDA. U.S. Government Printing Office. Washington, D.C.

Soil Survey Staff. 1988. Appling. Established Soil Series.

Soil Survey Staff. 1989. Cecil. Established Soil Series.

Soil Survey Staff. 1989. Davidson. Established Soil Series.

Staheli, A.C. 1976. Topographic expression of superimposed drainage on the Georgia Piedmont. Geol. Soc. Amer. Bull. 87:450-452.

Stone, J.R., J.W. Gilliam, D.K. Cassel, R.B. Daniels, L.A. Nelson, and H.J.Kleiss. 1985. Effect of erosion and landscape position on the productivity of Piedmont soils. Soil Sci. Soc. Am. J. 49:987-991.

Thomas, P.J. 1987. Characterization, classification, and productivity studies of Typic Hapludult mapping units from the Southern Piedmont of Virginia. M.S. thesis. Virginia Polytechnic Institute and State University, Blacksburg.

Thornbury, W.D. 1965. Regional geomorphology of the United States. John Wiley and Sons, New York.

Trimble, S.W. 1974. Man-induced soil erosion on the southern Piedmont. Soil Conservation Society of America, Ankeny, Ia.

Trimble, S.W. 1975. A volumetric estimate of man-induced soil erosion on the southern Piedmont: present and prospective technology for predicting sediment yields and sources. Houston, Texas. USDA Agricultural Research Service Pub. S-40.

von Engeln, O.D. 1942. Geomorphology. Macmillan, New York.

White, A.W., Jr., R.R. Bruce, A.W. Thomas, G.W. Langdale, and H.F. Perkins. 1985. Characterizing productivity of eroded soils in the southern Piedmont. p.83-95. In Erosion and soil productivity. Proceedings of the National Symposium on Erosion and Soil Productivity. ASAE.

White, W.A. 1944. Determining factors in the coloration of granite soils in the southeastern Piedmont. Am. Jour. Sci. 242:361-363.

Whitehead, D.R. and E.S. Barghoorn. 1962. Pollen analytical investigations of Pleistocene deposits from western North Carolina and South Carolina. Ecological Monographs. 32(4):347-369.

Whittecar, G.R. 1985. Stratigraphy and soil development in upland alluvium and colluvium, North Central Virginia Piedmont. Southeastern Geol. 26(2):117-129.

CHAPTER 2: A Study of Soil Variability in Appling, Cecil, and Davidson Mapping Units of the Virginia Piedmont.

Abstract

Several bodies of three commonly occurring Piedmont soils were intensively sampled and described as part of a study conducted to assess the biomass production potential of various grasses and legumes. Experimental plots were located in three counties in the Virginia Piedmont on Appling, Cecil, and Davidson soils. Twelve experimental sites, each consisting of 32, 4 x 6 m plots, were intensively characterized by describing and sampling the soil in one corner of each plot. Parameters measured included A horizon thickness and color, solum thickness and color, pH, P, K, Ca, and Mg of the A and B horizons, and A horizon organic matter content. Statistical comparisons were made of the differences across all parameters, both among sites within soils and among soils. Comparisons of experimental site soil characteristics among counties showed Lunenburg County soils (Appling map unit) to have the thickest A horizons and sola and the highest levels of extractable P in the A horizon; however, these soils registered lowest for all other parameters measured. Amelia County experimental site soils (Cecil map unit) were highest in A and B horizon pH, and B horizon P, K, and Mg, but had

the thinnest sola. Orange County experimental site soils (Davidson map unit) showed the highest levels of soil-test Ca in both A and B horizons, the highest levels of A horizon organic matter, but the lowest levels of extractable phosphorus. Short range soil variability was considerable at all experimental sites. Differences among counties (soil map units) usually accounted for the largest percentage of total variance across all soil parameters measured. However, A horizon thickness and pH, and B horizon P and K were highly variable over short distances; within block variability accounted for 68, 64, 45 and 82 percent of total variability across all experimental sites, respectively.

Introduction

Implicit in the attempts of soil scientists, geologists, and geographers to classify soils, model soil landscape relationships, and map soils is an acknowledgement of the heterogeneity of the soil cover. The development of the science of pedology, resulting from the pioneering efforts of such people as V.V. Dokuchaev, E.W. Hilgard, C.F. Marbut, and Hans Jenny, has been built upon the recognition of the fundamental role of various identifiable factors, both internal and external, in the development of soils. These factors interact in various combinations to produce a soil cover that is continuous yet anisotropic.

The increasing demand for information concerning useage and management of the soil resource has compelled pedologists to do more than merely ackowledge soil variability in qualitative terms. Those who have sought information concerning soil variability have often been hampered by a lack of quantitative data concerning the nature of soil heterogeneity (Beckett and Webster, 1971; Wilding and Drees, 1983). Indeed, the successful transfer of future agricultural, engineering, and environmental technologies is likely to depend, to some extent, upon our ability to quantify soil variability and thus predict soil behavior for a variety of applications.

The measurement and communication of information concerning soil spatial variability depends, in no small measure, upon the development of an effective sampling strategy. Soil fertility recommendations, for instance, are routinely based upon the analysis of a .5 to 1 kg sample which must represent, due to time and money constraints, several million kg of soil in the field (Donahue, 1985). Numerous methods of sampling soil landscapes have been employed, dependent upon the goals of a given study. Random sampling schemes have been employed by Edmonds et al.(1982) and Campbell and Edmonds (1984) to determine map-unit composition in a second-order soil survey. Alternatively, Powell and Springer (1965) and Steers and Hajek (1979) used randomly selected transects to study map unit composition.

Numerous other studies, usually those concerned with short-range spatial variability (Walker et al., 1968; Protz et al., 1968; Cameron et al., 1971; Norris, 1972; Campbell, 1977; Campbell, 1978) have found it advantageous to sample soils on a grid pattern. Webster (1977) has summarized commonly used techniques for sampling spatially variable populations.

Various approaches have been taken to statistically analyze soil spatial variability. Webster (1977) used a nested classification and sampling design to quantify soil variability. Such a design allows the researcher to compare variability at several levels (scales) and thus concentrate future efforts upon sampling at the level at which the greatest portion of the total variability is observed. Campbell (1979) has noted the limitations of such a sampling and analysis scheme, however, and has advocated the use of autocorrelation and semivariance to study soil variability as a function of distance (Campbell, 1977, 1978, 1979).

In the spring of 1985, researchers at Virginia Tech began a study to assess the biomass-producing potential of a number of herbaceous perennials. Twelve experimental sites were located in three Piedmont counties, on three common Southern Piedmont soils, the Appling and Cecil series (clayey, kaolinitic, thermic, family of Typic Kanhapludults) and the Davidson series (clayey, kaolinitic, thermic family of Rhodic Kandiudults). Since little was known about the magnitude and character of short-range variability in these soils, we decided to carry out an intensive sampling program at each of the twelve experimental sites. Our goal was to be able to state, with confidence, what soil differences existed (1) within an experimental site, (2) among experimental sites within a county (soil map unit), and (3) among counties (soil map units). It was expected that this detailed soil information would prove valuable in explaining biomass crop yield differences within and among experimental sites. This paper will focus on the results of statistical comparisons of soil differences at levels (1), (2), and (3), as stated above.

Materials and Methods

Three soils that occur widely in the southern Piedmont were chosen for the establishment of herbaceous energy crop plots. Experimental sites were located in Orange County, Virginia, on Davidson soils, in Amelia County, Virginia on Cecil soils, and in Lunenburg County, Virginia on Appling soils (Fig. 2.1). All experimental sites were located with assistance from Soil Conservation Service and Virginia Tech Soil Survey personnel. In order to study biomass production under what were expected to be marginal growing conditions, three experimental sites were located in each of the three counties on south or southwest facing slopes. An additional

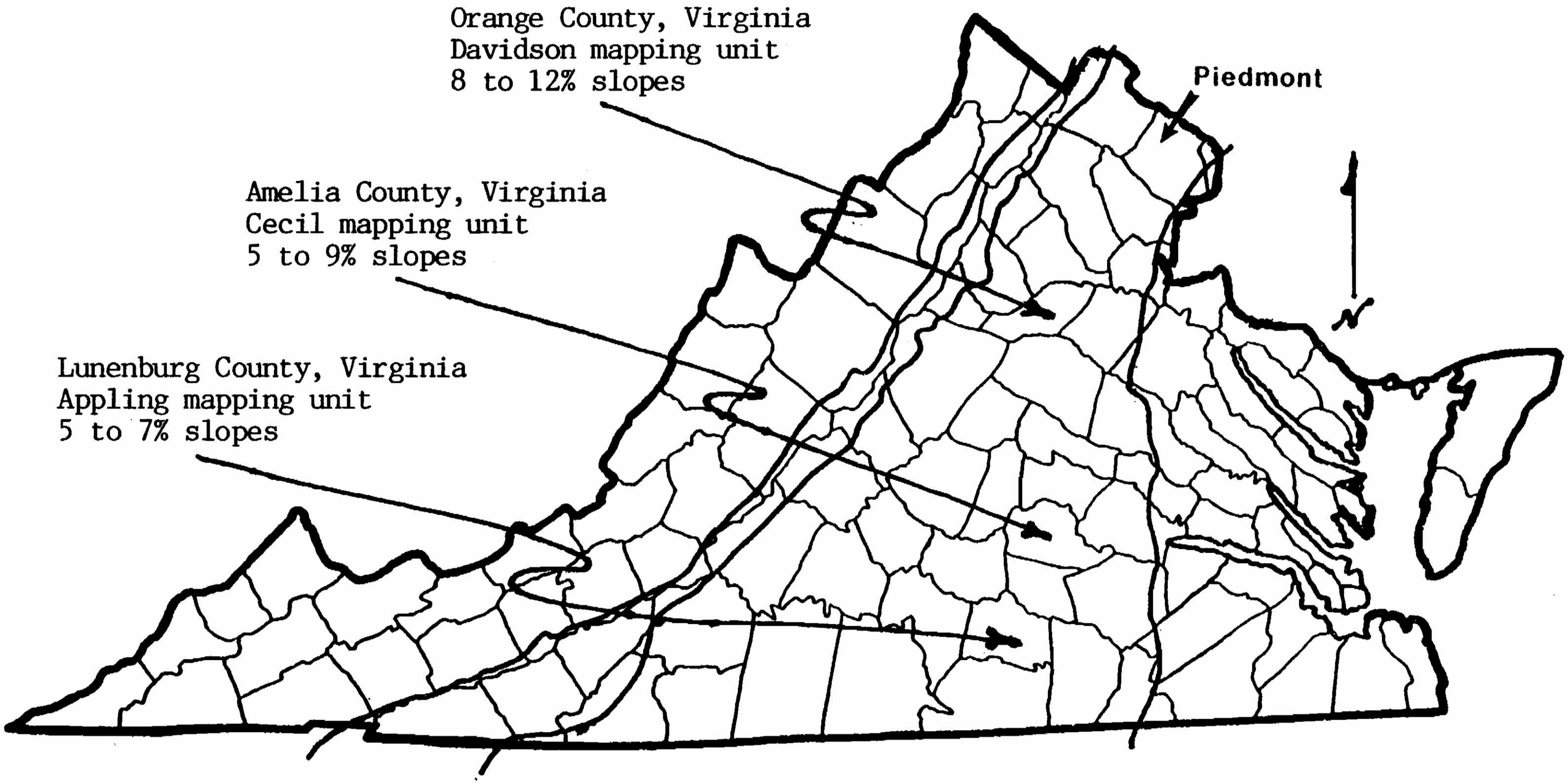


Fig. 2.1. Locations of biomass experimental sites.

three experimental sites were located on north slopes in Amelia County for the purpose of studying possible aspect effects on biomass yields. Slopes ranged from 5 to 7% in Lunenburg County, from 5 to 9% in Amelia County, and from 8 to 12% in Orange County.

The biomass production study employed a randomized complete block design, with each of eight treatments replicated four times for a total of 32 plots per site (Fig. 2.2). Following the establishment of the experimental plots, we undertook an intensive study of the soils at each site in order to document short-range soil variability and to identify obvious yield-limiting soil/site characteristics. This soil characterization study consisted of three stages. The first stage involved the plot-by-plot characterization of the soils at each of the 12 study sites. This was done by describing and sampling the soil in the lower right hand corner (as one faced uphill) of each plot with a 1.5-m bucket auger. Samples were taken from the A and B horizons and from the C horizon, when it could be sampled with the 1.5-m auger, and returned to the Virginia Tech Extension Soil Testing lab, where they were tested for Ca, Mg, K, P, pH, and A horizon organic matter (Donahue and Gettier, 1988).

This description and sampling scheme was carried out for each of 12 sites x 32 experimental plots for a total of 384 plots. The data generated in this phase of the study

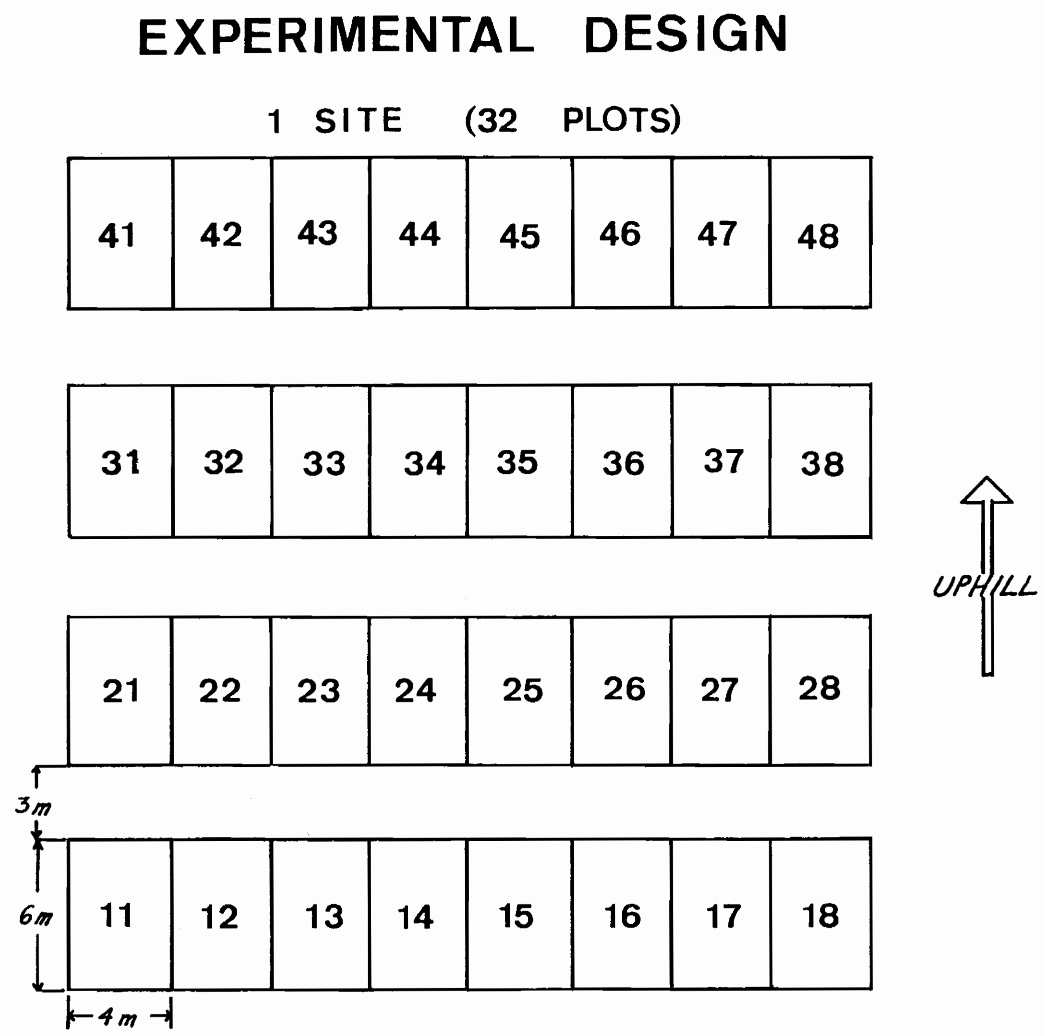


Fig. 2.2. Plot diagram showing layout of biomass experimental design. The numbers in the blocks were the designated plot numbers at all sites.

were later compiled and entered into a data array from which various statistical comparisons were made. Results will be discussed below.

The second stage of the soil characterization study involved pit excavation for observation of undisturbed soil morphology. Pit location was guided by the plot-by-plot observations recorded in the first phase of the study. Pits were located adjacent to plots which displayed approximately modal character for A horizon thickness, solum thickness, B horizon color, and soil horizon sequence. A total of 18 pits, four at the Lunenburg Co. sites (Appling map unit), six at the Orange Co. sites (Davidson map unit), and eight at the Amelia Co. sites (Cecil map unit) were described and sampled. The results of this phase of the study will be discussed in the Chapter 3 of this thesis.

The third stage of the soil characterization study was an attempt to determine how representative the soils at our experimental sites were of the surrounding soil landscape. This was accomplished by sampling randomly chosen bodies of soil mapped as either Appling, Cecil, or Davidson in the respective counties in which biomass experimental plots were located. As was the case with the biomass experimental plots, randomly chosen soil bodies were located on south-facing 5 to 12% slopes. These randomly chosen soil bodies were sampled and described using a 1.524 m bucket auger. Samples from the A, B and C horizons were submitted to the Virginia Tech Extension Soil Testing lab for Ca, Mg, K, P, pH, and organic matter (A horizon only) analysis, as previously cited.

Upon completion of the random sampling study, data were compiled and entered into a data array. Parameters included in this array were A horizon thickness, color, and organic matter content, B horizon color and solum thickness, and pH, P, K, Ca, and Mg content of the A and B horizons. No C horizon data were included in the array due to the large number of missing values (C horizons were often too deep to be sampled with a 1.5-m auger). Statistical analyses were conducted, by parameter, to determine whether significant differences existed: (1) among sites within a county (a single soil map unit), (2) between experimental site soils and randomly selected bodies of soil from the same map unit (within a county), (3) among experimental site soils by county (by soil map unit), and (4) among randomly selected bodies of soil by county (by soil map unit). Data were analyzed on the Virginia Tech computing system using SAS (1985). Preliminary investigations showed the data to be non-normally distributed for many of the measured parameters. Therefore, we chose to use non-parametric statistical methods. This entailed ranking all data and performing either a Wilcoxon rank sum test (comparison of two groups) or a Kruskal-Wallis rank sum test (comparison of three groups) to make comparisons (1), (2), (3), and (4) cited above.

An attempt was also made to apply autocorrelation and semivariance techniques to the analysis of soil variability. However, the results were inconclusive due to the incompatibility of the overall experimental design with such geostatistical analysis methods. Warrick et. al. (1986) noted that the application of geostatistical techniques to a small number of observations produce erratic results. The authors state that while "no exact minimum number of points is necessary" for the successful application of these techniques, "generally 100 points or so will suffice." In our case, we effectively sampled only eight points along a transect at intervals of 4 m (each experimental block consisted of eight plots 4 m wide, Fig. 2.2). Several attempts at using autocorrelation or semivariance techniques using this small number of sampling points did indeed produce "erratic" results. In addition, Campbell (1979) has noted that an optimal sampling interval for calculation of the autocorrelation function can only be established by trial and error. For these reasons, I decided that effective application of these geostatistical methods was not feasible and abandoned further attempts to use them.

Results and Discussion

Lunenburg County (Appling map unit).

The three Lunenburg county experimental sites were located on a single hillslope that had previously been mapped as Appling sandy loam, 7 to 15% slopes, eroded. The field had been in continuous row crop management for a number of years. Though it was our intention to locate plots on a single south facing delineation of Appling soils, subsequent study of the soils at these sites showed that we were not successful. While more will be said about this in the following chapter, it should be mentioned that the soils were too sandy to be correctly classified as Appling soils. In addition, a discontinuous pan, either a fragipan or a traffic pan, was described in some experimental plots. While its occurrence was noted, where obvious, the tendency of the pan to grade in and out and to seemingly soften following a good rain made consistent mapping of this feature impossible. However, both the sandy textures and the presence of the pan would tend to limit plant available water. This would likely have a serious effect on crop yields, particularly in a drought year.

Table 2.1 contains the results of the comparison of Lunenburg County experimental soils by individual parameters across all three sites. Site 2 had lower levels of K, Ca, and Mg in the A horizon and showed a trend of lower Ca and

Table 2.1. Comparison of Selected Soil Characteristics Among Sites Based on Kruskal-Wallis Rank Means.

APPLING MAPPING UNIT (Lunenburg Co.)

SITE	ACM**	ACDE	APH	AP	AK	ACA	AMG	AOM
1	36b* (32)#	31b (32)	47a (32)	57a (32)	55a (32)	56a (32)	55a (32)	47a (28)
2	66a (32)	60a (32)	45a (31)	54a (31)	31b (31)	33b (31)	32b (31)	47a (27)
3	42b (32)	55a (32)	49a (30)	29b (30)	55a (30)	52a (30)	55a (30)	35a (30)

	SOCM	BCDE	BPH	BP	BK	BCA	BMG
1	49ab (32)	43b (29)	58a (31)	43a (31)	45a (31)	41b (31)	44ab (31)
2	57a (32)	36b (31)	42ab (30)	49a (30)	43a (30)	38b (30)	36b (30)
3	39b (32)	60a (32)	37b (30)	46a (30)	51a (30)	59a (30)	58a (30)

* Mean ranks followed by different letters within a column by variable are significantly different, P = 0.05 (multiple comparisons based on Kruskal-Wallis mean ranks).
# values in parentheses indicate sample size.

**ACM = A-horizon thickness
ACDE = A-horizon color
APH = A-horizon pH
AK = A-horizon potassium
ACA = A-horizon calcium
AMG = A-horizon magnesium
AOM = A-horizon organic matter

SOCM = Solum thickness
BCDE = B-horizon color
BPH = B-horizon pH
BK = B-horizon potassium
BCA = B-horizon calcium
BMG = B-horizon magnesium

Mg in the B horizon as well (though not shown to differ significantly from site 1 in this respect). A horizon P was shown to be the lowest at site 3, probably reflecting its removal by soil erosion acting on higher topographic positions on the hillslope and its deposition lower in the landscape. This is supported by the finding that A horizons were thinnest in this same area on the slope, indicating that erosion processes were actively moving material from higher on the landscape and depositing it lower on the landscape. A horizon pH, A horizon organic matter content, B horizon K, and B horizon P were not shown to differ among sites.

The comparison of Lunenburg experimental site soils with randomly located bodies of Appling soil showed the experimental site soils to be generally inferior to randomly located bodies of Appling soil (Table 2.2). Experimental site soils were lower in A horizon K, Ca, Mg, and organic matter and B horizon K, Ca, and Mg. In addition, A horizons were thinner and B horizons more acidic at the experimental sites. Experimental site soils had thicker sola, though what effect this might have on plant growth is not certain. A horizon P levels were significantly higher at experimental sites in than randomly located soils.

Amelia County (Cecil map unit).

Amelia County experimental sites were located on both

Table 2.2. Comparison of Selected Soil Characteristics of Appling Series (Lunenburg Co.) Experimental Site Soils With Randomly Chosen Bodies of Appling Soil, Based on Wilcoxon Rank Sums. The P-Value is listed below each pair of comparisons.

	ACM**	ACDE	APH	AP	AK	ACA	AMG	AOM
PLOTS	59 (96)#	61 (96)	58 (93)	66 (93)	47 (93)	51 (93)	54 (93)	45 (85)
TRANSECTS	74 (28)	68 (28)	71 (28)	45 (28)	106 (28)	94 (28)	83 (28)	92 (28)
P-VALUE	.047	.242	.088	.006	.000	.000	.000	.000

	SOCM	BCDE	BPH	BP	BK	BCA	BMG
PLOTS	71 (96)	55 (92)	47 (91)	60 (91)	52 (91)	47 (91)	47 (91)
TRANSECTS	34 (28)	79 (28)	102 (28)	59 (28)	87 (28)	103 (28)	101 (28)
P-VALUE	.000	.000	.000	.912	.000	.000	.000

values in parentheses indicate sample size.

**ACM = A-horizon thickness
ACDE = A-horizon color
APH = A-horizon pH
AK = A-horizon potassium
ACA = A-horizon calcium
AMG = A-horizon magnesium
AOM = A-horizon organic matter

SOCM = Solum thickness
BCDE = B-horizon color
BPH = B-horizon pH
BK = B-horizon potassium
BCA = B-horizon calcium
BMG = B-horizon magnesium

north- and south-facing slopes on the Amelia Wildlife Management Area. All plots were located in open fields within sight of an antebellum farmhouse, indicating a likelihood that the soils has been farmed for perhaps 150 years or more. Though both north- and south-facing sites were sampled and described, only data from south facing sites were analyzed to insure that any aspect effects would not confound statistical analyses. Though intensive sampling did reveal some short range variability in soil parameters measured, nearly all soils fell within the allowable range in characteristics for either Cecil or the similar Pacolet soils.

A comparison of the three south-facing Amelia County sites (Table 2.3) showed that at least one site differed significantly in P, K, and Ca content and thickness of the A horizon, and B horizon K, Ca, Mg, and solum thickness. Differences in color of the A and B horizons were also noted. No differences among the three sites were found for A horizon pH, Mg or organic matter content. Neither were differences found in B horizon pH or P.

A comparison of Amelia experimental site soils with other randomly chosen, local bodies of soil mapped as Cecil (Table 2.4) showed randomly chosen soils to have thicker A horizons and sola, higher A horizon organic matter contents, and higher levels of A horizon K. Experimental site soils showed higher levels of P in both the A and B horizons. Soil

Table 2.3. **Comparison of selected soil characteristics among sites based on Kruskal-Wallis Rank Means.**

CECIL MAPPING UNIT (Amelia Co.)

SITE	ACM**	ACDE	APH	AP	AK	ACA	AMG	AOM
1	44ab* (32)#	35b (32)	34a (24)	44a (24)	42ab (24)	37b (24)	43a (24)	45a (23)
2	57a (29)	43b (29)	46a (28)	27b (28)	29b (28)	34b (28)	34a (28)	33a (25)
3	40b (32)	63a (32)	42a (29)	52a (29)	51a (29)	51a (29)	46a (29)	39a (29)

SITE	SOCM	BCDE	BPH	BP	BK	BCA	BMG
1	60a (31)	42ab (32)	43a (24)	35a (24)	30b (24)	30c (24)	50a (24)
2	44ab (29)	36b (26)	40a (29)	43a (29)	42ab (29)	49a (29)	33b (29)
3	36b (32)	55a (31)	36a (26)	41a (26)	47a (26)	39b (26)	39ab (26)

* Mean ranks followed by different letters within a column by variable are significantly different, P = 0.05 (multiple comparisons based on Kruskal-Wallis mean ranks).
# values in parentheses indicate sample size.

**ACM = A-horizon thickness
ACDE = A-horizon color
APH = A-horizon pH
AK = A-horizon potassium
ACA = A-horizon calcium
AMG = A-horizon magnesium
AOM = A-horizon organic matter

SOCM = Solum thickness
BCDE = B-horizon color
BPH = B-horizon pH
BK = B-horizon potassium
BCA = B-horizon calcium
BMG = B-horizon magnesium

Table 2.4. **Comparison of Selected Soil Characteristics of Cecil Series (Amelia Co.) Experimental Site Soils With Randomly Chosen Bodies of Cecil Soil, Based on Wilcoxon Rank Sums. P-values for each paired comparison are shown.**

	ACM**	ACDE	APH	AP	AK	ACA	AMG	AOM
PLOTS	54 (93)#	53 (69)	46 (69)	54 (69)	42 (69)	49 (69)	52 (69)	44 (69)
TRANSECTS	88 (31)	41 (29)	58 (29)	39 (29)	68 (29)	50 (29)	44 (29)	62 (29)
P-VALUE	.000	.042	.052	.014	.000	.935	.209	.006

	SOCM	BCDE	BPH	BP	BK	BCA	BMG
PLOTS	42 (69)	42 (69)	52 (69)	61 (69)	47 (69)	51 (69)	53 (69)
TRANSECTS	68 (29)	66 (29)	43 (29)	23 (29)	56 (29)	45 (29)	42 (29)
P-VALUE	.000	.000	.112	.000	.168	.321	.083

values in parentheses indicate sample size.

**ACM = A-horizon thickness
ACDE = A-horizon color
APH = A-horizon pH
AK = A-horizon potassium
ACA = A-horizon calcium
AMG = A-horizon magnesium
AOM = A-horizon organic matter

SOCM = Solum thickness
BCDE = B-horizon color
BPH = B-horizon pH
BK = B-horizon potassium
BCA = B-horizon calcium
BMG = B-horizon magnesium

Table 2.5. **Comparison of Selected Soil Characteristics Among Sites Based on Kruskal-Wallis Rank Means.**

DAVIDSON MAPPING UNIT (Orange Co.)

SITE	ACM**	ACDE	APH	AP	AK	ACA	AMG	AOM
1	38c* (32)#	47a (32)	57a (32)	77a (32)	74a (32)	47b (32)	36b (32)	17b (32)
2	58a (32)	53a (32)	17b (32)	35b (32)	29b (32)	26c (32)	35b (32)	60a (32)
3	48b (31)	44a (31)	70a (31)	32b (31)	40b (31)	72a (31)	74a (31)	68a (31)

	SOCM	BCDE	BPH	BP	BK	BCA	BMG
1	41b (31)	43a (32)	47b (32)	61a (32)	45a (32)	58a (32)	32b (32)
2	72a (32)	44a (31)	26c (31)	39b (31)	43a (31)	23b (31)	45ab (31)
3	22c (28)	44a (23)	64a (25)	31b (25)	46a (25)	53a (25)	59a (25)

* Mean ranks followed by different letters within a column by variable are significantly different, $P = 0.05$ (multiple comparisons based on Kruskal-Wallis mean ranks).
# values in parentheses indicate sample size.

**ACM = A-horizon thickness
ACDE = A-horizon color
APH = A-horizon pH
AK = A-horizon potassium
ACA = A-horizon calcium
AMG = A-horizon magnesium
AOM = A-horizon organic matter

SOCM = Solum thickness
BCDE = B-horizon color
BPH = B-horizon pH
BK = B-horizon potassium
BCA = B-horizon calcium
BMG = B-horizon magnesium

Table 2.6. Comparison of Selected Soil Characteristics of Davidson Series (Orange Co.) Experimental-Site Soils With Randomly Chosen Bodies of Davidson Soil, Based on Wilcoxon Rank Sums. P-values for each paired comparison are shown.

	ACM**	ACDE	APH	AP	AK	ACA	AMG	AOM
PLOTS	52 (85)#	54 (85)	49 (85)	53 (85)	56 (85)	55 (85)	57 (85)	52 (85)
TRANSECTS	65 (24)	59 (24)	77 (24)	64 (24)	52 (24)	54 (24)	49 (24)	67 (24)
P-VALUE	.083	.298	.000	.134	.586	.826	.279	.038

	SOCM	BCDE	BPH	BP	BK	BCA	BMG
PLOTS	54 (85)	50 (85)	50 (85)	55 (85)	55 (85)	54 (85)	52 (85)
TRANSECTS	49 (24)	74 (24)	71 (24)	55 (24)	59 (24)	59 (24)	66 (24)
P-VALUE	.283	.000	.005	.961	.953	.434	.047

values in parentheses indicate sample size.

**ACM = A-horizon thickness
ACDE = A-horizon color
APH = A-horizon pH
AK = A-horizon potassium
ACA = A-horizon calcium
AMG = A-horizon magnesium
AOM = A-horizon organic matter

SOCM = Solum thickness
BCDE = B-horizon color
BPH = B-horizon pH
BK = B-horizon potassium
BCA = B-horizon calcium
BMG = B-horizon magnesium

and B horizon pH of the experimental site soils was probably skewed by the very low values at site 2. Similarly, the lower A horizon organic matter content of the experimental site soils can probably be attributed to the very low test levels at site 1. While B horizon Mg was not dramatically lower at any one of the experimental sites, neither did the p-value of the pairwise comparison (.047) indicate very strong differences between experimental site soils and randomly chosen soils.

Comparison of soil properties by county (soil series).

Two data sets were available to look at differences between Appling, Cecil, and Davidson soils: (1) the plot-by-plot data from the experimental sites and (2) the data collected on the randomly chosen delineations of Appling, Cecil, and Davidson soils.

(1) Plot-by-plot data. Since experimental site soils represent only a small subset of the whole population of Appling, Cecil, and Davidson soils, and since the Lunenburg soils did not fit the range in characteristics ascribed to Appling soils, it would not be possible to make definitive statements about differences in these three common Piedmont soils, based on this data set alone. It would be more prudent to say that differences in one or more soil parameters measured may help to explain observed differences in species performance among counties (soil map unit).

A comparison of experimental site soils by map unit showed differences between at least two soils across all parameters measured (Table 2.7). Lunenburg County experimental site soils (Appling map unit) were found to have the thickest A horizons and sola as well as the highest levels of A horizon P. However, these soils were also shown to be lowest in A horizon pH, K, Ca, Mg, and organic matter and B horizon pH, P, K, Ca, and Mg. Amelia County experimental site soils (Cecil map unit) were shown to be highest both in A and B horizon pH and P, K, and Mg levels of the B horizon; however, they had the thinnest sola. Orange County experimental site soils (Davidson map unit) were highest in A and B horizon Ca and A horizon organic matter and were lowest in A horizon P. These comparisons among experimental site soils are represented graphically in Appendix A of this thesis.

Perhaps the most tangible piece of information to be gleaned from the analysis of variability in the experimental site soils is that short range variability is considerable for most of the parameters studied. Within a particular soil map unit (county), variance at the plot (within block) level accounted for a large percentage of the total variance for most parameters measured (Tables 2.8, 2.9 and 2.10). While this was less so at the Orange County experimental sites (Table 2.10) due to their being farther apart, variance at the lowest level of sampling still accounted for a

Table 2.7. **Comparison of Selected Soil Characteristics by Soil Map Unit (county) Based on Kruskal-Wallis Rank Means.**

SOIL	ACM**	ACDE	APH	AP	AK	ACA	AMG	AOM
Appling	176a* (96)#	48c (96)	114b (93)	202a (93)	48b (93)	48c (93)	47b (93)	45c (85)
Cecil	127b (93)	163b (93)	162a (81)	124b (81)	185a (81)	146b (81)	167a (81)	133b (77)
Davidson	126b (96)	218a (96)	134ab (96)	81c (96)	178a (96)	212a (96)	194a (96)	201a (96)

	SOCM	BCDE	BPH	BP	BK	BCA	BMG
Appling	187a (96)	50b (92)	55c (91)	83c (91)	114b (91)	48c (91)	46c (91)
Cecil	73c (92)	169a (89)	197a (79)	173a (79)	151a (79)	156b (79)	199a (79)
Davidson	158b (91)	188a (87)	148b (89)	140b (89)	127ab (89)	190a (89)	155b (89)

* Mean ranks followed by different letters within a column by variable are significantly different, P = 0.05 (multiple comparisons based on Kruskal-Wallis mean ranks).
# values in parentheses indicate sample size.

**ACM = A-horizon thickness
ACDE = A-horizon color
APH = A-horizon pH
AK = A-horizon potassium
ACA = A-horizon calcium
AMG = A-horizon magnesium
AOM = A-horizon organic matter

SOCM = Solum thickness
BCDE = B-horizon color
BPH = B-horizon pH
BK = B-horizon potassium
BCA = B-horizon calcium
BMG = B-horizon magnesium

Table 2.8. Source of Variance Across Selected Soil Chemical and Physical Characteristics (Ranked Data).

Appling Mapping Unit (Lunenburg Co.)
(experimental site soils)

Source of Variance	ACM**	ACDE	APH	AP	AK	ACA	AMG	AOM
	(percent of total variance)							
Sites	23	39	0	23	24	15	21	0
Blocks	15	30	0	18	21	23	26	22
Plots	62	31	100	59	55	62	53	78

	SOCM	BCDE	BPH	BP	BK	BCA	BMG	Avg.
Sites	0	17	0	0	0	11	10	12
Blocks	46	18	40	32	9	14	25	23
Plots	54	65	60	68	91	75	65	65

**ACM = A-horizon thickness
ACDE = A-horizon color
APH = A-horizon pH
AP = A-horizon phosphorus
AK = A-horizon potassium
ACA = A-horizon calcium
AMG = A-horizon magnesium
AOM = A-horizon organic matter

SOCM = solum thickness
BCDE = B-horizon color
BPH = B-horizon pH
BP = B-horizon phosphorus
BK = B-horizon potassium
BCA = B-horizon calcium
BMG = B-horizon magnesium

Table 2.9. Source of Variance Across Selected Soil Chemical and Physical Characteristics (Ranked Data).

Cecil Mapping Unit (Amelia Co.)
(experimental site soils)

Source of Variance	ACM**	ACDE	APH	AP	AK	ACA	AMG	AOM
	(percent of total variance)							
Sites	11	23	0	20	13	0	2	0
Blocks	14	29	1	4	0	14	9	16
Plots	75	48	99	76	87	86	89	84

	SOCM	BCDE	BPH	BP	BK	BCA	BMG	Avg.
Sites	9	5	0	0	10	10	16	8
Blocks	5	29	4	1	2	5	8	9
Plots	86	66	96	99	88	85	76	83

**ACM = A-horizon thickness
ACDE = A-horizon color
APH = A-horizon pH
AP = A-horizon phosphorus
AK = A-horizon potassium
ACA = A-horizon calcium
AMG = A-horizon magnesium
AOM = A-horizon organic matter

SOCM = solum thickness
BCDE = B-horizon color
BPH = B-horizon pH
BP = B-horizon phosphorus
BK = B-horizon potassium
BCA = B-horizon calcium
BMG = B-horizon magnesium

Table 2.10. Source of Variance Across Selected Soil Chemical and Physical Characteristics (Ranked Data).

Davidson Mapping Unit (Orange Co.)
(experimental site soils)

Source of Variance	ACM**	ACDE	APH	AP	AK	ACA	AMG	AOM
	(percent of total variance)							
Sites	8	0	70	69	57	48	36	76
Blocks	9	19	5	4	10	16	32	4
Plots	83	81	25	27	33	36	32	20

	SOCM	BCDE	BPH	BP	BK	BCA	BMG	Avg.
Sites	69	0	41	39	0	41	16	38
Blocks	1	5	14	5	30	25	33	14
Plots	30	95	45	56	70	34	51	48

**ACM = A-horizon thickness
ACDE = A-horizon color
APH = A-horizon pH
AP = A-horizon phosphorus
AK = A-horizon potassium
ACA = A-horizon calcium
AMG = A-horizon magnesium
AOM = A-horizon organic matter

SOCM = solum thickness
BCDE = B-horizon color
BPH = B-horizon pH
BP = B-horizon phosphorus
BK = B-horizon potassium
BCA = B-horizon calcium
BMG = B-horizon magnesium

substantial portion of the total. Even those parameters for which large differences existed from site to site, such as A horizon pH, A horizon phosphorus, and A horizon organic matter, showed considerable variability at the plot (within block) level. In every case, variance at the plot level accounted for at least 20%, and in many cases more than 50%, of the total variance at the Orange County sites. Even when experimental site soils data for the three counties were combined, plot (within block) variability remained the largest single component of total variability for A horizon thickness and pH and for B horizon P and K (Table 2.11). variance at the block (within site) level usually accounted for the smallest percentage of the total variance. These findings reaffirm notions of soil variability long recognized by crop and soil scientists and underscore the importance of sampling numerous points within a given field when retrieving soil samples for fertility analysis in yield correlation studies.

(2) Randomly chosen delineations data. The other data set upon which we may base statements about differences among Appling, Cecil, and Davidson soils was generated by sampling six to eight randomly chosen delineations of each soil. Statements about region-wide differences in these three common Piedmont soils may more reasonably be made using this data set rather than the plot-by-plot data, owing

Table 2.11. Source of Variance Across Selected Soil Chemical and Physical Characteristics (Ranked Data).

Appling, Cecil and Davidson Mapping Units Combined.
(experimental site soils)

Source of Variance	ACM**	ACDE	APH	AP	AK	ACA	AMG	AOM
	(percent of total variance)							
County	8	85	0	38	69	82	75	81
Sites	13	2	36	31	15	5	7	9
Blocks	11	4	0	4	3	2	6	2
Plots	68	9	64	27	13	10	13	8

	SOCM	BCDE	BPH	BP	BK	BCA	BMG
County	39	71	67	36	3	71	78
Sites	25	2	10	12	0	11	4
Blocks	7	5	3	7	15	6	7
Plots	29	22	20	45	82	12	11

**ACM = A-horizon thickness
ACDE = A-horizon color
APH = A-horizon pH
AP = A-horizon phosphorus
AK = A-horizon potassium
ACA = A-horizon calcium
AMG = A-horizon magnesium
AOM = A-horizon organic matter

SOCM = solum thickness
BCDE = B-horizon color
BPH = B-horizon pH
BP = B-horizon phosphorus
BK = B-horizon potassium
BCA = B-horizon calcium
BMG = B-horizon magnesium

to the greater geographic dispersal of sampling points among the randomly chosen delineations. However, some caution should still be observed. As previously stated, Appling, Cecil, and Davidson soils are mapped throughout the southern Piedmont. It is doubtful that the soils sampled adequately represent the total range of variability to be encountered in these three soils for each parameter measured. In addition, randomly sampled delineations from each soil series were confined to a single county. These factors raise some level of doubt as to universality of apparent differences between randomly chosen delineations of Appling, Cecil, and Davidson soils. These concerns extend in particular to the measured levels of chemical parameters. Consistently higher levels of one plant nutrient in one of the three soils may simply reflect more intensive fertility management among farmers in a particular geographic area. The confounding effect of county on soil characteristics (soil=county) could have been avoided by sampling delineations of Appling, Cecil, and Davidson soils in each of the three counties.

Despite these concerns, however, the random delineations data set is better suited to making statements about the differences in these three soils. Based on this data set, it was shown that Davidson soils had thinner A horizons than either Appling or Cecil soils, though solum thicknesses were not found to differ (Table 2.12). Soils

Table 2.12. Comparison of Selected Soil Characteristics by Soil Series (County) Based on Kruskal-Wallis Rank Means.

SOIL	ACM**	ACDE	APH	AP	AK	ACA	AMG	AOM
Appling	50a*	18c	38a	59a	27b	22b	24b	26b
Cecil	47a	46b	45a	32b	59a	48a	50a	41b
Davidson	30b	67a	48a	41b	41b	63a	57a	67a

	SOCM	BCDE	BPH	BP	BK	BCA	BMG
Appling	41a	21b	26b	42b	50a	28b	22b
Cecil	43a	51a	51a	29b	44ab	42b	54a
Davidson	45a	53a	51a	63a	33b	62a	53a

* Mean ranks followed by different letters within a column by variable are significantly different, P = 0.05 (multiple comparisons based on Kruskal-Wallis mean ranks).

values in parentheses indicate sample size.

**ACM = A-horizon thickness
ACDE = A-horizon color
APH = A-horizon pH
AK = A-horizon potassium
ACA = A-horizon calcium
AMG = A-horizon magnesium
AOM = A-horizon organic matter

SOCM = Solum thickness
BCDE = B-horizon color
BPH = B-horizon pH
BK = B-horizon potassium
BCA = B-horizon calcium
BMG = B-horizon magnesium

were clearly separated by A horizon color, though a significant B horizon color difference did not exist between Cecil and Davidson soils, reflecting the overlap in the allowable range in Munsell color for the two soil series. Only one parameter, A horizon pH, showed no difference among the three soils. Appling soils tested highest for A horizon P and B horizon K and they tested lowest for A horizon Ca and Mg and for B horizon pH and Mg. Cecil soils tested highest in A horizon K. Davidson soils tested highest in A horizon organic matter and in B horizon P and Ca.

As was the case for the experimental site soils, levels of extractable Ca and Mg were much lower in the Appling randomly chosen delineations when compared to Cecil and Davidson soils: The same was true for A horizon organic matter content. Once again, A horizon P levels were highest in these soils. These higher levels of A horizon P and the lower levels of Ca and Mg in both the A and B horizons of the randomly sampled Appling soils is consistent with the notion that Appling soils are formed from a parent material that is relatively low in weatherable minerals. Thus, although all three soils have a low native fertility, the Appling soil appears to be the least fertile of the three.

Summary and Conclusions

Of all experimental site soils, those at the Lunenburg

County experimental sites (Appling map unit) appeared to be the least favorable for plant growth. Their high sand content, the presence of a discontinous pan-like layer, and their low A horizon organic matter content would undoubtedly cause drought stress problems with these soils. In addition, fertility levels in these soils were the lowest measured. Lunenburg experimental site soils did register the highest levels of extractable P, presumably owing to their low Fe-oxide content. This higher level of A horizon P is not unimportant. Thomas (1987) found that soil P was the single best predictor of soybean yields on Cecil-Pacolet soils of the Virginia Piedmont. Therefore, these higher levels of A horizon P may help compensate for other less desirable characteristics of the Lunenburg County soils.

Orange County experimental site soils (Davidson map unit) showed the greatest degree of variability among experimental sites in both morphological and chemical parameters. This was attributable to their being more geographically dispersed, emphasizing local differences in parent material and the effects of differing management histories.

A comparison of all south-facing experimental sites showed Lunenburg County soils to have the thickest A-horizons and sola as well as the highest levels of extractable P. However, the lowest levels of all other parameters measured were registered at these sites. Amelia

County experimental site soils (Cecil map unit) showed the highest pH and the highest levels of B horizon P, K, and Mg. Amelia County soils also displayed the thinnest sola. Orange County expermental site soils were highest in A and B horizon Ca, A horizon organic matter and lowest in A horizon P.

Short-range variability was shown to be considerable at all experimental sites. Within a county (soil map unit), plot (within block) variability was never less than 20% of the total variability across all measured soil parameters. When experimental site soils data were analyzed in aggregate (Table 2.11), with experimental site soils data for all three counties combined, plot (within block) variability still accounted for at least 20% of the total variability encountered for A horizon thickness, solum thickness, and A horizon pH and P and B horizon color, pH, P, and K. A horizon thickness and pH and B horizon K were extremely variable over short distances, with within block (plot) variability accounting for 68, 64, and 82% of total variability, respectively.

Literature Cited

Beckett, P.H.T. and R. Webster. 1971. Soil variability: A review. Soils and Fertilitzers 34(1):1-15.

Cameron, D.R., M. Nyborg, J.A. Toogood and D.H. Laverty. 1971. Accuracy of field sampling for soil tests. Can. J. Soil Sci. 51:165-175.

Campbell, J.B. 1977. Variation of selected properties across a soil boundary. Soil Sci. Soc. Am. J. 41:578-582.

Campbell, J.B. 1978. Spatial variation of sand content and pH within single contiguous delineations of two soil mapping units. Soil Sci. Soc. Am. J. 42:460-464.

Campbell, J.B. 1979. Spatial variability of soils. Annals of the Association of American Geographers 69(4):544-556.

Campbell, J.B. and W.J. Edmonds. 1984. The missing geographic dimension to soil taxonomy. Annals of the Association of American Geographers 74(1):83-97.

Donahue, S.J. 1985. Soil testing. p.9.5-9.9. In W. Kroontje, R.R. Weil, J.C. Parker, and C.E. Zipper. Soils: A laboratory manual for introductory soil science. Burgess Publishing Company, Minneapolis, Minnesota.

Donahue, S.J. and S.W. Gettier. 1988. Laboratory procedures: soil testing and plant analysis laboratory. Virginia Cooperative Extension Service Publication 452-881.

Edmonds, W.J., S.S. Iyengar, L.W. Zelazny, M. Lentner, and C.D. Peacock. 1982. Variability in family differentia of soils in a second-order soil survey mapping unit. Soil Sci. Soc. Am. J. 46:88-93.

Norris, J.M. 1972. The application of multivariate analysis to soil studies. III. Soil variation. J. Soil Sci. 23:62-75.

Powell, J.C. and M.E. Springer. 1965. Composition and precision of classification of several mapping units of the Appling, Cecil, and Lloyd series in Walton County, Georgia. Soil Sci. Soc. Amer. Proc. 29:454-458.

Protz, R., E.W. Presant and R.W. Arnold. 1968. Establishment of the modal profile and measurement of variability within a soil landform unit. Can. J. Soil Sci. 48:7-19.

SAS. 1985. SAS user's guide: statistics. Version 5 edition. SAS Institute, Cary, North Carolina.

Steers, C.A. and B.F. Hajek. 1979. Determination of map unit composition by random selection of transects. Soil Sci. Soc. Am. J. 43:156-160.

Thomas, P.J. 1987. Characterization, classification, and productivity studies of Typic Hapludult mapping units from the Southern Piedmont of Virginia. M.S. thesis. Virginia Polytechnic Institute and State University, Blacksburg.

Walker, P.H., G.F. Hall and R. Protz. 1968. Relation between landform parameters and soil properties. Soil Sci. Soc. Amer. Proc. 32:101-104.

Webster, R. 1977. Quantiative and numerical methods in soil classification and survey. Oxford University Press, Oxford.

Warrick, A.W., D.E. Myers, and D.R. Nielsen. 1986. Geostatistical methods applied to soil science. In A. Klute (ed.) Methods of soil analysis. Part 1. 2nd ed. Agronomy 9:53-82.

Wilding, L.P. and L.R. Drees. 1983. Spatial variability and pedology. p.83-116. In L.P. Wilding, N.E. Smeck and G.F. Hall (ed). Pedogenesis and soil taxonomy: 1. Concepts and interactions. Elsevier Science Publishing Company Inc., New York.

CHAPTER 3: Physical, Chemical, and Morphological Characteristics of Soils of the Appling, Cecil, and Davidson Mapping Units on Sideslopes in the Virginia Piedmont.

Abstract

Selected examples of three soils common to the Southern Piedmont were intensively studied for differences and similarities in their morphology and chemical properties. All soils were located on 5 to 12% south-facing slopes in the Virginia Piedmont. Soils mapped as Appling in Lunenburg County, Virginia, were found not to fit their central concept, because they contained too little clay and showed evidence of having been derived from fluvial or marine sediments. Soils in Amelia County (Cecil map unit) and Orange County (Davidson map unit) were shown to fit the central concepts of their respective reference taxa more closely. All soils studied showed the effects of agricultural practices, which were manifested in the subsoil-like characteristics of the A horizons and in evidence of recent accretion of upslope materials. Evidence of a much older period of slope instability was recorded by the ubiquitous presence of stone lines at depths of 1 to 2 m in the soil profile. It was concluded that soils formed in locally derived colluvial materials may cover as much as one-half of the Virgina Piedmont landscape.

Introduction

Soils of the southeastern United States are predominantly classified as Ultisols (Buol et al., 1973). These soils are characterized by a B horizon that contains a significantly higher percentage of clay than the overlying horizon or horizons and a low native fertility (Soil Survey, 1987). Ultisols form in a variety of geologic materials ranging from Precambrian metamorphic rocks of the Blue Ridge and Piedmont regions to Quaternary-age sediments of stream valleys and the Atlantic Coastal Plain. Consequently, their topography of formation ranges from nearly flat terraces and broad interstream divides to highly mountainous areas. Elevations may therefore range from near sea level to more than 1500 m (Buol et al., 1973).

Three soils that are commonly mapped in the Southeast are the Appling, Cecil, and Davidson soils. Appling soils (clayey, kaolinitic, thermic Typic Kanhapludults) are characterized by a solum thickness of 1 m to more than 1.5 m and a reddish yellow to olive yellow Bt horizon that contains approximately 35 to 60% clay (Soil Survey, 1988). Cecil soils (clayey, kaolinitic, thermic Typic Kanhapludults) are characterized by a solum that ranges from 1 m to more than 1.5 m and a red Bt horizon that generally contains between 35 and 60% clay (Soil Survey, 1989). Davidson soils (clayey, kaolinitic, thermic Rhodic

Kandiudults) have a solum thickness of greater than 1.5 m and a red Bt horizon, and they generally contain between 40 and 75% clay in the control section (Soil Survey, 1989). Though differences exist among these three soils, they have similar use and management characteristics and are often associated geographically.

The numerous studies in which these and similar soils have been examined have produced a range of opinion as to the dominant processes involved in their genesis. The earlier classification of these soils as either Red-Yellow Podzolic soils (Appling and Cecil series) or Reddish-Brown Lateritic soils (Davidson series) drew a clear distinction between them based on parent material differences. Nyun and McCaleb (1955) stated that:

> "Reddish-Brown Lateritic and Red-Yellow Podzolic soils are the two great soil groups that occur most extensively in the Piedmont Plateau and Appalachian Mountain regions of the southeastern United States. The basic characteristics of the parent material differentiate lateritic and podzolic soils within this region".

Studies of Red-Yellow Podzolic soils have shown them to be associated with acid parent materials such as mica schists (Alexander et al., 1941; Rebertus and Buol, 1985), and granite gneisses and schists (Gibbs and Perkins, 1966; Calvert et al., 1980). Conversely, Reddish-Brown Lateritic soils have been shown to be formed from mafic rock types such as diabase (Hardy and Rodrigues, 1939; Alexander et al., 1941) and diorite gneiss and hornblende schist (England and Perkins, 1959).

This chapter will discuss morphological, chemical, and physical characteristics of a total of 18 pedons that were exposed and described at the various biomass experimental sites in Appling, Cecil, and Davidson mapping units. While the plot-by-plot study (previous chapter) had provided us with much information concerning the variability of soils at each experimental site, we still felt that we needed to more fully characterize a few typical soils. Therefore, we compiled the data from the plot-by-plot study and dug and described pits in areas where soils appeared "typical." While the geological/mineralogical data required for detailed soil genesis work were not gathered, considerable time was spent in the field observing and attempting to understand geomorphic influences on these soils. In addition, many observations were made concerning human influence on the chemical and morphological characteristics of these soils. This chapter describes methods used in characterizing these "typical" soils. Landscape characteristics of each experimental site will be discussed using soils and geomorphic data gathered during this study. In addition, data will be used to compare and contrast experimental site soils.

Materials and Methods

All biomass experimental sites were located in the spring of 1985 with help from Virginia Tech Soil Survey and USDA-SCS personnel. Our intent was to locate three study sites each, on south to southwest-facing delineations of Appling, Cecil, and Davidson soils. An additional three sites were to be located on north-facing slopes on Cecil soils. Appling study sites were located on 5 to 7% slopes in Lunenburg County; Cecil study sites were located on 5 to 9% slopes in Amelia County; and Davidson study sites were located on 8 to 12% slopes in Orange County. Biomass experimental plots were established in a randomized complete block design employing eight treatments replicated four times for a total of 32 plots per site. Shortly after the planting of biomass crops, we began an intensive study of soil and site characteristics at each study site. The first phase of the soils study involved the plot-by-plot sampling of the soils at each biomass experimental site. This process was described in Chapter 2. When these data were compiled for each site, we chose "typical" soils based on thickness of the A horizon, color of the B horizon, thickness of the solum, and sequence of horizons. Pits were then excavated next to plots where typical soils were described, and a full soil description was made.

Bulk samples of each horizon were returned to the laboratory, air-dried, and ground to pass through a 2 mm seive. Coarse fragments were weighed and their percentage on a soil weight basis was computed. Soil texture was determined by a modified pipette method (Day, 1965) following removal of organic matter by oxidation with H_2O_2 (Kunze and Dixon, 1986). Exchangeable cations were determined by 1 N NH_4OAc (pH 7.0) extraction (Thomas, 1982) and atomic absorption spectrophotometry. Soil pH was determined using a 1:1 soil:water suspension (McLean, 1982). Total acidity was determined by $BaCl_2$-TEA extraction, and exchangeable acidity was determined by KCl extraction (Thomas, 1982). Organic carbon was determined by a modified Walkley-Black procedure (Nelson and Sommers, 1982). Free Fe-oxides were determined by dithionite-citrate-bicarbonate (DCB) extraction (Olson and Ellis, 1982). Plant-available phosphorus was determined using a Mehlich-1 procedure (Nelson et al., 1953). Bulk density was determined by either the clod method or by taking intact cores (Blake and Hartge, 1986).

Results and Discussion

Lunenburg County (Appling map unit).

All three experimental sites were situated on a single south-facing hillslope, located approximately 670 m NE 86 degrees from the junction of State Routes 602 and 610, and approximately 1220 m NW 348 degrees from the junction of State Routes 602 and 603. The county soil survey showed two soils mapped in the field; Caroline sandy loam, 1 to 7% slopes, and Appling sandy loam, 7 to 15% slopes, eroded phase (McDaniel et al., 1981). The local topography is characterized by broad, nearly flat to gently rolling interstream divides. Elevation at the experimental sites is 135 m. Relief is roughly 20 m from the highest point on the interstream divide to Great Creek, the nearest perennial stream. The northern part of the county is drained by the Nottoway River and its tributaries; the southern part of the county is drained by the South Meherrin and the Meherrin Rivers and their tributaries.

An interesting feature of the Lunenburg County landscape is the occurrence of sizeable areas of sandy, apparently sedimentary deposits on nearly level portions of the highest interstream divides. Soils associated with these deposits were mapped as Caroline, a soil formed in sediments of supposed "fluviomarine" origins (McDaniel et al., 1981). These soils occur at an elevation of approximately 140 m in the vicinity of the biomass experimental sites, at about the same elevation in the community of Dundas 5.5 km to the northeast, and again at about 140 m in the town of Kenbridge 13 km to the northwest. Although these soils are found to occur at other elevations at other locations in the county, the approximate 140 m elevation appears to have some geomorphic significance. Fluviomarine sediments apparently related to a Miocene age marine transgression have been described at Tyson's Corner, Virginia at elevations of 140 to 150 m (Hack, 1975) and by Howard et al. (in press) at elevations of 100 to 135 m west of Richmond, Virginia. That the Lunenburg deposits might bear some relation to these Miocene deposits is only speculative; A hand auger inspection of several of the Lunenburg deposits showed them to be quite sandy, containing moderate amounts of clay (generally less than 35%) and only an occasional rounded quartz pebble. Not seen were the extensive cobble-rich deposits associated with other Fall Zone fluviomarine sediments in the vicinity of Richmond, Virginia. However, similar to fluviomarine deposits near Richmond, and like many upper Coastal Plain soils, the Lunenburg deposits did often display reticulate mottling in the subsoil. Whatever their exact origin, the presence of these deposits on the highest portions of the interstream divides points to a topographic inversion of the landscape. This phenomenon begins when stream channels are abandoned, either through stream capture or a rapid lowering of base level (the lowest elevation to which a stream channel can erode, ultimately sea level). Streams may subsequently erode the adjacent landscape, lowering the surrounding land surface and leaving portions of the former stream channel "high and dry." Evidence of this process is widespread on the Piedmont landscape.

Pedon L III-38 (Table 3.1) is an example of a soil thought to be formed in these elevated fluviomarine sediments. The pit was located high on the sideslope, near the upper extent of the experimental plots. The pit exposed a horizon described as a BA/Bw horizon that had some of the bleached appearance and brittleness associated with a fragipan, although this brittleness was highly variable even within the pit face. It is possible that the horizon had been more uniform and that chisel plowing had disrupted its continuity. Below this horizon, an argillic horizon was described to a depth of 84 cm with a BC horizon described below that to a depth of 116 cm. Both the Bt and BC horizons displayed weak subangular structure, but the most striking soil structural feature was the presence of very coarse plates within the subsoil horizons, particularly the BC and the C horizons. I believe these plates to be primarily a geologic feature as opposed to a pedogenic feature, as their strength of expression diminishes higher in the profile. They may be a relict feature related to shear stresses associated with sedimentary processes, although the nature of these processes is not understood.

A reticulate mottling pattern was strongly expressed in the BC and C horizons of pit III-38. The soil texture appeared to be non-homogeneous within the zone of mottling, with gleying seemingly associated with micro-regions of

Table 3.1. Morphological Characteristics of "Typical" Experimental Site Soils.

Horizon	Depth	Matrix Color	Texture	Structure	Consistence	Boundary	Comments
				Pedon L I-23			
Ap	0-12	2.5Y 4/4	sl	1fgr	mvfr	cs	
C	12-33	10YR 7/3	sl	o-m	mvfr	cw	
A\C	33-74	2.5Y 6/2	sl	o-m	mvfr	as	0-74 cm recent deposit.
Ab	74-86	2.5Y 4/4	sil	1fgr	mvfr	as	contains 60% silt.
Ab'	86-103	5Y 5/3	sl	1fgr/1f&msbk	mvfr	cs	
Eb	103-130	5Y 6/3	sl	1m&csbk	mvfr	cs	
Btb	130-180	2.5Y 6/4	sl	1f,m&csbk	mfr		
				Pedon L I-33			
Ap	0-24	2.5Y 5/4	ls	1fgr/1f&msbk	mvfr	as	
A1	24-40	2.5Y 7/4	ls	1m&csbk	mvfr	as	
A2	40-55	2.5Y 4/4	ls	1m&csbk	mvfr	as	
A3	55-71	10YR 6/6	ls	o-m	mvfr	gs	0-71 cm recent deposit.
E	71-88	2.5Y 7/2	sl	o-m	mvfr	gw	
EB	88-114	2.5Y 6/2	sl	1m&csbk	mfr	gw	
Bt	114-150	2.5Y 6/6	scl	2f&msbk	mfr	gw	
C	150-200	2.5Y 6/4	scl	o-m	mfr		
				Pedon L II-45			
Ap	0-22	10YR 5/4	ls	1fgr/1f,m&csbk	mvfr	cw	
E	22-40	2.5Y 6/4	s	1f,m&csbk	mvfr	cw	
EB	40-58	2.5Y 6/4	ls	1f,m&csbk	mfr	cs	
Bt1	58-86	2.5Y 5/4	sl	1f,m&csbk	mfr	cs	
Bt2	86-125	10YR 7/8	sl	1m&csbk	mfr	cs	
Bt3g	125-185	10YR 8/2	scl	1m&csbk	mfr	cs	stone line at 150 cm.
2Cg	185-200	7.5YR 7/0	scl	o-m	mvfr		
				Pedon L III-38			
Ap	0-27	10YR 6/4	ls	1msbk	mvfr	as	
BA\Bw	27-50	10YR 6/8	sl	o-m	mfr	cw	
Bt	50-84	10YR 6/8	sc	1f&msbk	mfr	cw	
BC	84-116	10YR 6/6	scl	1f&msbk	mfr	gw	reticulate mottling.
C	116-180	10YR 7/6	scl	o-m	mvfr		reticulate mottling.

higher clay content. However, no attempt was made to separate soil material by color so as to test the hypothesis that soil texture might somehow be related to micro-variations in soil redox conditions.

Pits L I-23 and L I-33 both showed what were apparently relatively recent additions of material to the soil profile. In pit L I-23, an Ap-C-A/C-Ab-Ab' sequence was described to a depth of 103 cm. The organic matter distribution in this profile (Pedon L I-23, Table 3.2) shows the Ab horizon to have, by far, the highest organic matter content (26.0 g kg^{-1}) and probably represents the pre-European-settlement soil surface. Curiously, the Ab horizon also contained an extraordinary amount of silt-sized material (61%). Because no such high-silt layer was noted anywhere else on the landscape, it is probable that the silt was deposited in slack-water as opposed to having an aeolian origin. This high-silt layer may indicate that this portion of the landscape, located as it was in the footslope position, was flooded at one time, perhaps by a nearby beaver pond or other feature. The material overlying the Ab horizon was much lower in both silt and organic matter and showed little horizon differentiation other than a slight melanization in some zones. This material was otherwise fairly homogeneous and was likely deposited since cultivation by European settlers began. Pit I-33 likewise showed considerable recent additions of material to the soil profile. Again, material

Table 3.2 Selected physical and chemical characteristics of "typical" experimental site soils.

Horizon	Depth	pH	Coarse frag.	Sand	Silt	Clay	Bulk dens.	Organic matter	Fe	P	Al	CEC	Base Satn.
	cm		%				Mg m^{-3}	g kg^{-1}		ppm	cmol kg^{-1}		%
Pedon L I-23													
Ap	0-12	5.4	1.4	75	18	7	1.60	9.6	2	44	0.25	5.45	16
C	12-33	5.8	0.8	83	13	4	1.76	5.3	1	43	0.25	5.35	7
A\C	33-74	5.5	0.1	77	16	7	1.76	7.5	2	10	0.45	4.14	4
Ab	74-86	5.2		31	61	9	1.34	26.0	4	15	1.05	9.70	2
Ab'	86-103	5.3	0.9	75	18	7	1.75	13.6	1	6	0.75	4.66	2
Eb	103-130	5.3	0.6	77	17	6	1.70	3.7	1	4	0.55	3.89	3
Btb	130-180	5.3	0.6	70	11	19	1.75	1.7	6	0	1.75	6.55	12
Pedon L I-33													
Ap	0-24	5.7		88	9	3	1.70		1		0.20	4.45	11
A1	24-40	5.9	1.1	87	9	4	1.74		2		0.15	2.73	12
A2	40-55	5.9	0.8	87	10	3	1.65		1	20	0.15	4.44	6
A3	55-71	5.4	1.4	75	21	4	1.68		2	7	0.35	2.89	3
E	71-88	5.5	0.9	74	20	6			2	3	0.35	2.29	4
EB	88-114	5.3	4.0	72	20	8			3	1	0.75	4.13	4
Bt	114-150	5.1	3.6	60	10	30			13	0	3.05	8.76	20
C	150-200	4.9	1.4	66	10	24			12	0	2.55	9.26	3
Pedon L II-45													
Ap	0-22	5.5	0.4	88	9	3	1.75	10.2	1	33	0.10	2.66	25
E	22-40	5.8	0.8	87	13	0	1.85	5.0	1	36	0.10	2.59	15
EB	40-58	6.0	0.5	76	17	7	1.77	3.4	2	12	0.10	3.87	13
Bt1	58-86	5.3	1.3	67	21	12	1.75	2.3	6	3	1.05	6.75	9
Bt2	86-125	5.4	3.7	75	11	14	1.94	1.1	6	0	1.65	5.71	13
Bt3g	125-185	5.0	21.2	64	15	21	1.85	1.0	10	0	2.45	9.59	9
2Cg	185-200	5.1	6.6	55	13	32		0.9	19	0	3.55	13.04	12
Pedon L III-38													
Ap	0-27	5.7	0.8	80	13	7	1.79		2	17	0.15	3.47	25
BA\Bw	27-50	4.9	1.0	66	19	15	1.87		7	4	1.15	2.86	30
Bt	50-84	5.0	0.8	53	9	38	1.71		21	0	2.65	9.59	19
BC	84-116	4.6	0.9	58	8	34	1.78		18	0	3.25	8.05	6
C	116-180	4.8	0.9	69	10	21	1.79		8	0	2.25	5.34	7

above the buried A horizons appeared quite homogeneous. Particle size data (Pedon L I-33, Table 3.2) showed only a slight coarsening upward above the EB horizon, indicating a common source for, and rapid deposition of, the material.

Evidence of much older local colluvial activity was found in pedon L II-45. While this pit did not have the thick, sandy capping of recently deposited material, it was shown to contain a stone line (Parizek and Woodruff, 1957; Ruhe, 1959) of angular to subangular vein quartz. This stone line occurred in what was described as the Bt3 horizon at a depth of 150 cm and approximately paralleled the present soil surface. Similar stone line morphology was described by Parizek and Woodruff (1957). The presence of this stone line can be noted in the high coarse fragment content (21.2%) of the Bt3g horizon (Pedon L II-45, Table 3.2). The mode of formation and the significance of these stone lines and the overlying colluvial deposits common to Southeastern soils has been debated, but some have seen them as evidence of more severe Pleistocene climatic conditions (Parizek and Woodruff, 1957; Whitehead and Barghoorn, 1962; Overstreet et al., 1968; Eargle, 1977; Costa and Cleaves, 1984; Whittecar, 1985). The subject of colluvial inclusions in presumed residual Piedmont soils will be discussed at length in the following chapter.

Though all pits were described as having a friable to very friable consistence throughout, bulk densities were found to be quite high in the surface horizons as well as the subsoils of all four pits. This can be ascribed to low A horizon organic matter contents and weak soil structure. Also noted were some apparent traffic compaction and weakly expressed fragic characteristics in some horizons. Though some brittleness was noted, soil moisture was high when the pits were described. How the consistence might have been affected by soil drying is uncertain, but these soils seemed to have the potential to become quite hard and massive when dry.

Available bases were predictably low in all four Lunenburg pits (Table 3.2). Pits L II-45 and L III-38 are Ultisols, as both contained an argillic horizon and a base saturation at a depth of 1.2 m below the top of the argillic, of less than 35%. Pit L I-33 was described as having an overthickened A horizon, an argillic horizon, and a base saturation of less than 35% in the chemical control section (1.8 m below the soil surface this time since the top of the argillic is more than 55 cm from the surface). Therefore, this soil is also classified as as Ultisol. Pit I-23 contained a buried soil and had less than 8% clay at depths between 20 and 50 cm from the soil surface. Therefore, it is classified as an Inceptisol rather than an Ultisol. Since there is no chemical control section at the order level in an Inceptisol, the selection of a horizon from which base saturation comparisons to the other three pits can be made is somewhat arbitrary. However, as with the other three soils, this soil was low in exchangeable cations, with the base saturation being considerably less than than 35% throughout the profile.

Soil pH ranged from 5.4 to 5.7 in the surface horizons of the four Lunenburg pits. The highest pH values in pits L I-23, L I-33, and L II-45 were measured just below the surface, at depths ranging from 12 to 55 cm. The highest pH measured in pit L III-38 was in the Ap horizon. Acidity tended to increase slightly in the lower horizons of these soils.

DCB-extractable Fe was quite low in the Lunenburg soils reflecting the quartzose character of the parent material. Fe contents were at a minimum in the surface horizons, rising to maxima of only 10 to 20 g kg^{-1} in those horizons where clay content was at a maximum. The low free Fe content of these soils is consistent with a lesser tendency for these and similar sandy, free-Fe-poor soils to fix large amounts of phosphorus fertilizers. Thus, despite the less desirable agricultural characteristics of these soils (very low base saturations and low water holding capacity), phosphorus deficiencies are unlikely to be a problem in crops grown on these and similar soils. This group would include many soils of the Atlantic Coastal Plain.

Amelia County

Six experimental sites were established on both north and south-facing slopes within the Amelia Wildlife Management Area (AWMA). South-facing sites were located on a single hillslope, approximately 3400 m, NE 82 degrees from the junction of State Routes 651 and 616, and approximately 1725 m, NE 22 degrees from the junction of State Routes 652 and 616. Slopes ranged from 7 to 9%. Soils on the hillslope and on most of the surrounding landscape have been mapped as Cecil (Soil Survey in progress). The AWMA is bounded on the north by the Appomattox River, a moderately sized, gently flowing stream typical of the Virginia Piedmont.

The topography within the AWMA, despite the area's close proximity to the Appomattox River, can be characterized as gently rolling. Slopes are generally less than 10%, with steeper slopes occurring only near perennial streams. Thus the topography is typical of much of the county and indeed, is typical of much of the southern Piedmont as a whole. Elevations at the experimental sites range from approximately 80 to 85 m. The Appomattox River flows at an elevation of approximately 60 m. Maximum relief is approximately 30 m from a highest point within the AWMA to the river.

As was the case in Lunenburg County, there was evidence of topographic inversion in the vicinity of the AWMA. A deposit of well-rounded quartzite cobbles caps a slight knoll in the northeast corner of the AWMA, at an elevation of 90 m. The well-sorted character of the deposit points to its probable origin as a channel deposit. This implies, of course, that the high point on the present day landscape was, at some time in the past, the low point on the landscape. Since the present day Appomattox River flows at an elevation of about 60 meters in the vicinity of the AWMA, it is apparent that, locally, base level has been lowered approximately 30 m since deposition of the cobble deposit. Howard et al. (in press) assigned an early Pleistocene (1.6 Ma B.P.) age to similar deposits located at an elevation of 30 m above the grade of the James River in the vicinity of Bon Air, west of Richmond, Virginia. Assuming that the rate of downcutting in the James River has been roughly equal to that in the Appomattox River, which is a tributary of the James and joins it at a point southeast of Richmond near Hopewell, Virginia, we can estimate the age of the cobbly deposit on the AWMA to be roughly 1.6 Ma. Further, if we assume that pre-Pleistocene relief in the vicinity of the AWMA was similar to that which presently exists, we can calculate an average Pleistocene erosion rate of roughly 19 m Ma^{-1}. This is very nearly the maximum late-Tertiary through Pleistocene Piedmont erosion rate of 20 m Ma^{-1} calculated by Pavich (1989) using Be^{10} dating techniques.

The value of speculating about the rate of long-term erosion within the vicinity of the AWMA lies in the possible insight gained into the ages of the geomorphic surface and the associated soils. As mentioned earlier, elevations in the vicinity of the experimental plots range from 80 to 85 m, somewhat below the elevation (90 m) of the cobble deposit to the northeast. Thus, if estimates of the age of this deposit are correct, the age of the geomorphic surface and the soils formed on it postdate the early Pleistocene. This contrasts with frequent characterizations of the Piedmont upland as a Miocene age surface (e.g., Costa and Cleaves, 1984).

Eight soil pits were dug and described at the AWMA in the fall of 1986 and the spring of 1987. Four of the pits were dug adjacent to south-facing experimental plots and four were dug adjacent to north-facing plots. I knew prior to pit excavation that soils at the AWMA were, in part, likely formed in some type of transported material. During auger sampling, I found that, in some areas of the experimental plots, a soil auger would not penetrate to full depth, indicating the probable presence of a stone line (Ruhe, 1959). When soil pits were finally dug, and soils could be viewed in greater detail, it became apparent that sideslope soils at the AWMA fell into two basic categories: those with shallow to moderately deep sola that appeared to have formed essentially in place (AS III-15, AN I-31, AN II-41 and AN III-21) and those that appeared to have formed in local colluvial/local alluvial material (AS I-12, AS

II-38, AS III-28 and AN I-18). Tables 3.3 and 3.4 provide summary morphological, chemical, and physical characterization data for these eight pits.

Of those pits excavated in soils putatively formed from transported materials, two (AS I-12 and AN I-18) exposed stone lines which contained a considerable number of rounded quartzite cobbles. Ireland et al. (1939) argued for a subsurface origin for the stone lines commonly observed in Southeastern soils. According to their model, stone lines form as a creeping soil mass shears off fragments of resistant rock (commonly vein quartz) that protrude into the base of the creeping mass. The rock fragments are dragged along the base of the mass, distributing them and giving the stone line its characteristic linear form (Figure 3.1). Parizek and Woodruff (1957) rejected this subsurface model, proposing instead that these stone lines, or "carpedoliths" as they preferred to call them, had formed as a lag deposit on an actively eroding surface. In their view, erosion processes were responsible for preferentially removing finer materials over time, thus concentrating coarser materials at the land surface (Figure 3.2a). The stone line was subsequently buried when a change in some factor in the erosional/depositional regime created a condition on the landscape in which deposition of fine-grained sediments occurred where formerly these sediments were removed from the landscape (Figure 3.2b). The presence of rounded, highly

Table 3.3. Morphological Characteristics of "Typical" Experimental Site Soils.

Horizon	Depth	Matrix Color	Texture	Structure	Consistence	Boundary	Comments
Pedon AS I-12							
Ap	0-21	5YR 3/4	scl	1mpr/1msbk	mfi	as	
Bt	21-60	2.5YR 4/6	cl	2mpr/2m&csbk	mfi	ci	
CB	60-80	7.5YR 5/8	cl	1m&csbk	mfr	cs	
2C	80-116	10YR 5/6	scl	o-m	mfr	cw	stone line at 100 cm.
3C1	116-175	7.5YR 5/8	cl	o-m	mfr	cw	
3C2	175-195	10YR 5/8	sl	o-m	mvfr		
Pedon AS II-38							
Ap	0-20	5YR 5/6	scl	1fgr/1f,m&csbk	mfr	as	
Bt	20-50	5YR 5/6	cl	1cpr/2f,m&csbk	mfi	cw	
CB	50-72	5YR 6/8	cl	1cpr/1f,m&csbk	mfr	as	
2C1	72-124	2.5YR 4/8	scl	o-m	mvfr	cw	
3C2	124-145	7.5YR 5/8	sl	o-m	mvfr	cw	
3C3	145-175	10YR 8/3	sl	o-m	mvfr		
Pedon AS III-15							
Ap	0-15	2.5YR 4/6	scl	2f&mgr	mfr	cs	
Bt1	15-45	2.5YR 4/8	c	3mpr/2f&msbk	mfi	cs	
Bt2	45-60	5YR 6/8	c	1m&csbk	mfi	gs	
BC	60-89	5YR 6/8	cl	1msbk	mfr	gw	solum thickness: 89 cm.
C	89-150	5YR 7/8	sl	o-m	mvfr		
Pedon AS III-28							
Ap	0-20	5YR 4/6	sl	1fgr/1f&msbk	mfr	cs	
Bt1	20-70	5YR 5/6	l	2f,m&csbk	mfi	cs	
Bt2	70-100	5YR 5/6	cl	2f,m&csbk	mfr	cs	
Bt3	100-130	2.5YR 4/6	cl	2f,m&csbk	mfr	cs	
2Bt4	130-155	2.5YR 4/8	c	2f&msbk	mfr	cs	
2C	155-208	2.5YR 4/8	scl	o-m	mvfr		

Table 3.3 (cont'd.). Morphological Characteristics of "Typical" Experimental Site Soils.

Horizon	Depth	Matrix Color	Texture	Structure	Consistence	Boundary	Comments
				Pedon AN I-18			
Ap	0-14	5YR 5/4	scl	1fg/1f,m&csbk	mfr	as	
ABp	14-27	5YR 4/6	scl	3vcpr/2f&msbk,abk	mfr	as	
Bt1	27-52	2.5YR 4/8	c	3vcpr/2f&msbk,abk	mfr	cs	
Bt2	52-75	2.5YR 4/8	c	3vcpr/2f&msbk,pl	mfr	cs	
BC1	75-89	2.5YR 4/8	cl	0-m	mfr	cw	
2BC2	89-110	7.5YR 6/8	scl	o-m	mvfr	gs	stone line at 100 cm.
2BC3g	110-150	7.5YR 6/8	c	o-m	mfr	dw	
2BC4	150-192	10YR 7/6	c	0-m	mvfr		
				Pedon AN I-31			
Ap	0-20	5YR 5/6	cl	1f,m&csbk	mfr	as	
Bt1	20-45	2.5YR 5/6	c	2csbk/2f&msbk	mfr	gw	
Bt2	45-85	2.5YR 4/8	c	2vcpl/2f&mpl	mfr	db	solum thickness: 85 cm.
C	85-150	10YR 5/8	scl	o-m	mvfr		
				Pedon AN II-41			
Ap	0-19	5YR 4/6	cl	1fgr/1f&msbk	mfr	as	
Bt	19-42	2.5YR 4/8	c	1f,m&csbk	mfr	cw	
BC	42-52	2.5YR 4/8	cl	1f,m&csbk	mfr	cb	solum thickness: 52 cm.
C	52-150	2.5YR 4/6	scl	o-m	mvfr		
				Pedon AN III-21			
Ap	0-24	5YR 4/6	sil	1fgr/1f,m&csbk	mvfr	as	
Bt	24-50	2.5YR 4/6	c	2cpr/2f,m&csbk	mfi	gw	
BC	50-74	2.5YR 5/8	c	2f&mpl	mfr	gw	solum thickness: 74 cm.
C1	74-100	10YR 5/8	sc	2vf,f&mpl	mvfr	gw	
C2	100-150	10YR 4/6	scl	o-m			

Table 3.4 Selected physical and chemical characteristics of "typical" experimental site soils.

Horizon	Depth	pH	Coarse frag.	Sand	Silt	Clay	Bulk dens.	Organic matter	Fe	P	Al	CEC	Base Satn.
	cm		%				$Mg\ m^{-3}$	$g\ kg^{-1}$		ppm	$cmol\ kg^{-1}$		%
Pedon AS I-12													
Ap	0-21	5.9	3.3	47	27	26	1.53	17.0	21	17	0.10	9.65	48
Bt	21-60	6.5	1.1	31	31	38	1.58	4.5	37	0	0.10	11.24	43
CB	60-80	6.4	0.1	29	29	42	1.45	2.8	45	0	0.20	12.66	39
2C1	80-116	6.0	5.2	49	26	25	1.67	2.2	27	0	0.10	8.17	32
3C2	116-175	5.4	4.5	41	27	32		1.7	55	0	0.15	11.72	20
3C3	175-195	5.3	20.6	65	22	13		0.8	75	2	0.10	12.43	15
Pedon AS II-38													
Ap	0-20	5.7	4.6	56	23	21	1.57		19	11	0.10	11.10	30
Bt	20-50	6.3	2.8	32	32	36	1.61		32	1	0.25	13.41	41
CB	50-72	6.3	0.5	41	28	31	1.63		33	0	0.10	11.61	40
2C1	72-124	5.7	1.2	59	10	31			30	0	0.15	9.87	31
3C2	124-145	5.4	0.4	74	18	8			45	1	1.35	11.18	27
3C3	145-175	5.3	0.4	72	21	7			19	2	1.65	8.22	27
Pedon AS III-15													
Ap	0-15	6.0	2.1	47	23	30	1.62			21	0.05	13.32	43
Bt1	15-45	6.2	0.3	21	30	49	1.42			3	0.30	16.88	38
Bt2	45-60	6.0	0.0	32	28	40	1.35		54	1	0.15	12.43	41
BC	60-89	5.5	0.0	42	28	30	1.21		42	2	0.55	9.18	35
C	89-150	5.3	0.1	72	19	9	1.28		31	2	0.85	7.57	21
Pedon AS III-28													
Ap	0-20	6.1	2.0	57	24	19	1.69		18	12	0.25	10.36	35
Bt1	20-70	6.2	0.1	36	40	24	1.69		20	2	0.35	9.65	34
Bt2	70-100	5.8	0.2	34	33	33	1.66		26	1	0.45	11.65	35
Bt3	100-130	5.5	0.6	35	32	33	1.64		30	1	0.55	11.13	34
2Bt4	130-155	5.4	0.2	37	21	42	1.49		41	2	0.95	13.73	25
2C	155-208	5.3	7.6	46	24	30			42	2	1.95	9.38	22

Table 3.4 (cont'd.) Selected physical and chemical characteristics of "typical" experimental site soils.

Horizon	Depth	pH	Coarse frag.	Sand	Silt	Clay	Bulk dens.	Organic matter	Fe	P	Al	CEC	Base Satn.
	cm		%				$Mg\ m^{-3}$	$g\ kg^{-1}$		ppm	$cmol\ kg^{-1}$		%
Pedon AN I-18													
Ap	0-14	6.5	8.9	50	26	24	1.70	10.9	21	28	0.05	12.11	61
ABp	0-27	6.8	3.8	46	24	30	1.76		26	8	0.05	8.19	51
Bt1	27-52	5.6	0.4	32	20	48	1.55	3.6	46	3	0.25	11.17	43
Bt2	52-75	5.6	0.1	21	30	49	1.49	2.5	47	3	0.25	10.75	39
BC1	75-89	5.4	0.2	42	21	37	1.56	0.4	32	2	0.95	7.83	26
2BC2	89-110	5.4	50.6	61	19	20	1.77	0.4	11	2	1.05	4.43	15
2BC3g	110-150	4.9	2.2	41	15	44	1.57	0.4	28	2	1.95	9.74	18
2BC4	150-192	5.4	0.4	40	17	43		0.4	42	2	1.65	10.66	18
Pedon AN I-31													
Ap	0-20	6.2	5.9	51	27	22	1.76		17	11	0.05	8.56	49
Bt1	20-45	5.9	0.5	29	21	50	1.51		37	4	0.10	11.45	41
Bt2	45-85	5.3	0.2	30	21	49	1.44		44	2	0.65	13.23	32
C	85-150	5.1	0.3	53	27	20	1.45		25	2	2.45	9.18	18
Pedon AN II-41													
Ap	0-19	6.4	7.4	42	23	35	1.67		36	13	0.25	12.29	50
Bt	19-42	5.7	1.6	32	22	46	1.45		49	2	0.10	11.89	43
BC	42-52	5.7	0.2	41	20	39	1.44		46	2	0.25	11.79	39
C	52-150	5.3	2.3	60	16	24	1.45		33	2	0.65	8.51	39
Pedon AN III-21													
Ap	0-24	5.6	5.7	47	18	35	1.71		23	12	0.20	9.11	39
Bt	24-50	5.6	1.4	25	18	57	1.44		54	2	0.35	12.74	38
BC	50-74	4.9	3.8	29	13	58	1.41		55	1	2.55	12.52	16
C1	74-100	5.0	0.5	46	17	37	1.40		53	2	3.45	11.21	8
C2	100-150	5.3	0.5	53	18	29	1.44		48	1	2.65	8.77	7

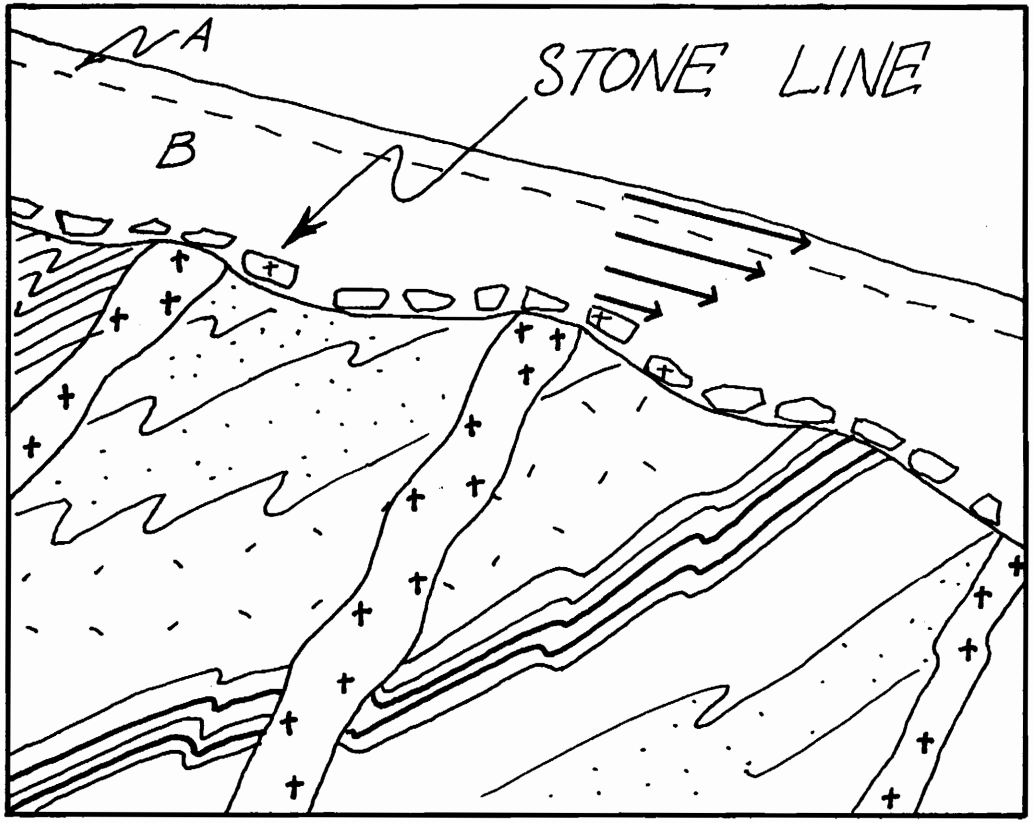
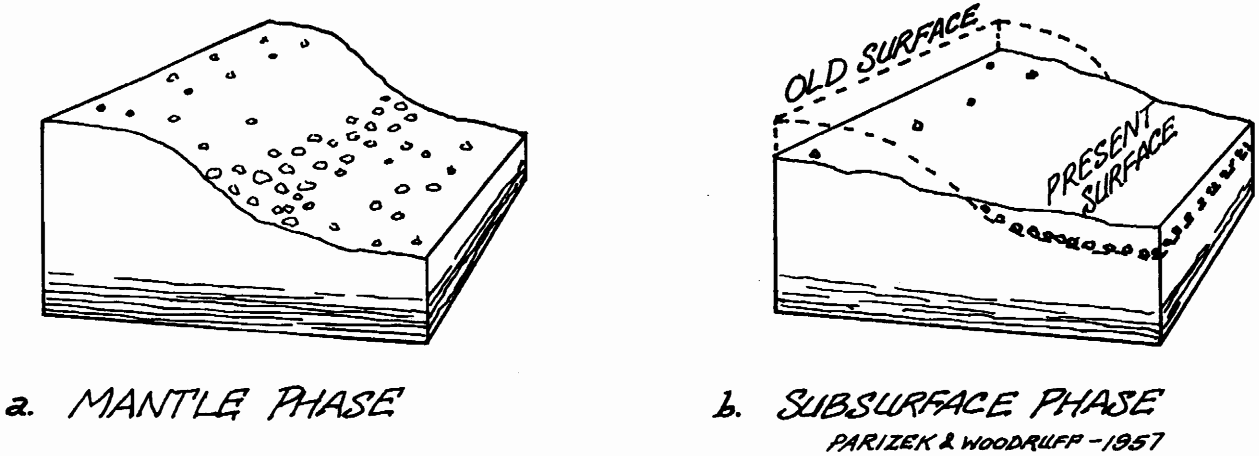


Fig. 3.1. Subsurface model of stone line formation (Ireland et al., 1939).



a. MANTLE PHASE

b. SUBSURFACE PHASE

PARIZEK & WOODRUFF -1957

Fig. 3.2. Two-stage model of stone line development, showing erosional or "mantle" phase followed by depositional or "subsurface" phase (Parizek and Woodruff, 1957).

water worn rock in the Amelia stone lines supports the view that stone lines are not simply quartz stringer fragments that have become detached and dragged along the base of a moving soil mass, as envisioned by Ireland et al. (1939). The frequent presence of water worn-cobbles in these stone lines can most logically be explained by the following series of events: (1) transport and deposition of the quartzite cobbles by a perenniel stream; (2) downwasting of the landscape and topographic inversion followed/accompanied by (3) the reworking of the rounded cobbles into lower "residual" portions of the landscape by colluvial/alluvial action; (4) the mixing of the rounded quartzite cobbles with angular detrital vein quartz fragments on an actively eroding upland surface; and (5) burial of the mixed angular vein quartz and rounded quartzite cobbles by earthy materials.

It is worth noting that all of the rounded cobbles found in the stone line of pit AS I-12 showed a greater degree of weathering than the cobbles contained in the deposit in the northeastern corner of the AWMA. This would indicate that the stone line cobbles are remnants of an older deposit, and they could have been deposited in their present location only by local colluvial/local alluvial action, since they presently sit lower on the landscape (85 m vs. 90 m) than the relatively less weathered cobble deposit to the northeast.

It is somewhat curious that those soils that did appear to have formed in place displayed such shallow sola and yet displayed clay distributions associated with argillic and kandic horizons (Figure 3.3). Pedons AN I-31, AN II-41, AN III-21, and AS III-15 all had sola less than 1 m thick. The solum thickness of Cecil soils ranges from 1 to 1.5 m. While it is quite possible that these soils have been truncated by post-settlement erosion (Trimble, 1974), the problem becomes one of explaining the removal of the pre-settlement topsoil and perhaps a portion of the argillic/kandic horizon while maintaining a clay distibution that satisfies the criteria for the identification of a kandic or argillic horizon.

The clay "bulge" characteristic of Ultisols was thought by Simonson (1950) to be formed by the destruction of clay that had formed deep in the soil profile. McCaleb (1959) argued that the increased clay content of the argillic horizon was largely attributable to physical translocation of clay-sized materials through pores and channels. Whatever the mechanism, it is widely believed that 10^4 years are required to form an Ultisol with its attendant clay bulge (Soil Taxonomy, 1987). If these soils have indeed been subject to considerable post-settlement erosion, as seems likely, the clay bulge measured in these truncated soils must be attributable to other processes. Miller (1983) has suggested that, while eluviation and illuviation are dominant processes in producing the clay bulge

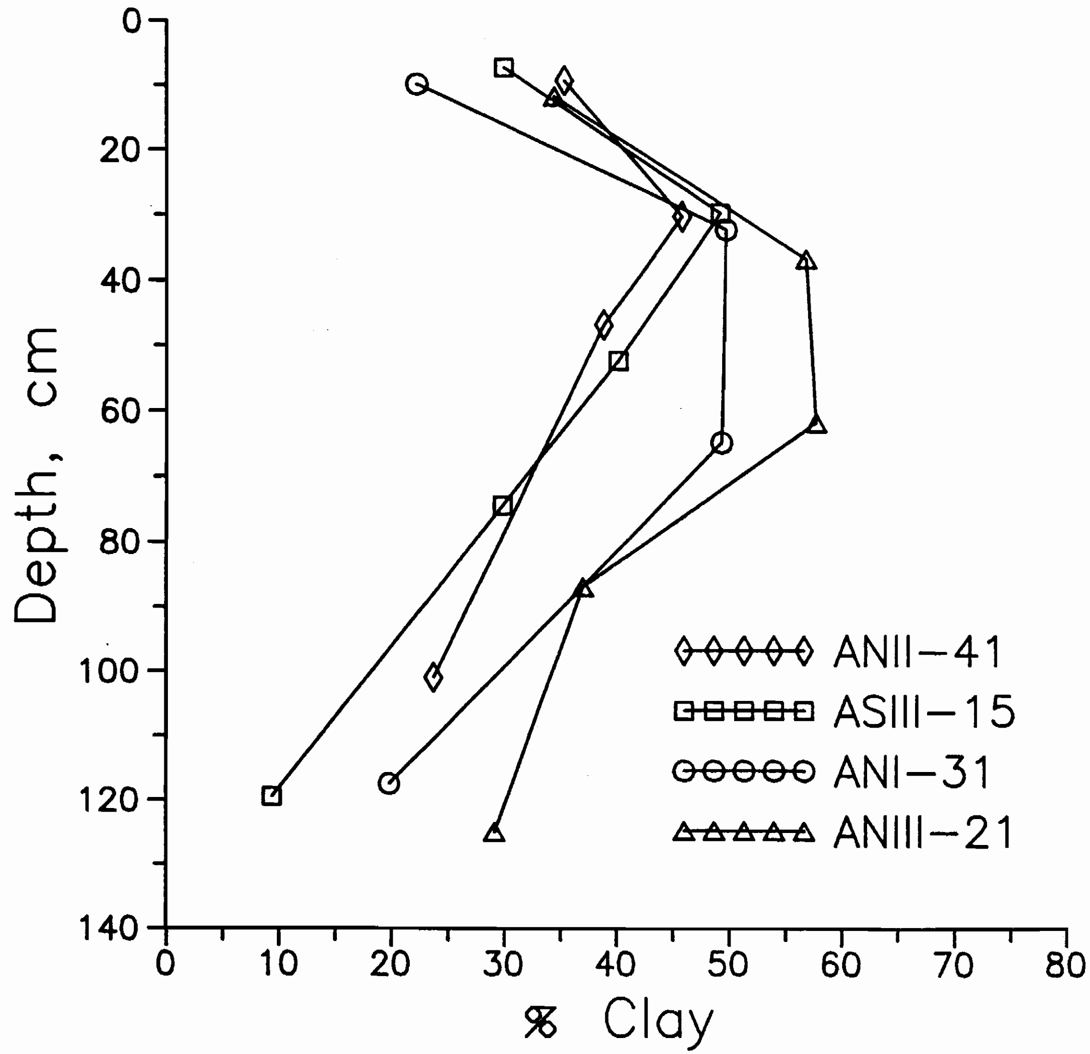


Fig. 3.3. Distribution of clay vs. depth in selected Amelia County pedons, Cecil mapping unit.

characteristic of Ultisols, differential erosion and transport of A horizon clay (elutriation) might, in some cases, contribute to a similar clay distribution. If one accepts the premise that argillic/kandic horizons require considerable time to form, then some selective erosion of clay-sized material by sheet wash may be one explanation for the observed clay distribution. Research by Daniels et al. (1983) suggests another possibility. Their work showed that rapid adjustments occurred in clay distributions of humid temperate region Ultisols when these soils were cleared for pasture. Pasture B horizons were deeper than their forest counterparts, and clay curves revealed a tendency for clay to accumulate at the B horizon/C horizon contact under pasture vegetation. Therefore the observed differences in A and B horizon clay contents in the Amelia soils may be attributable to rapid eluviation/illuviation of clay-sized material over a less than 300 years.

Another characteristic of these soils, undoubtedly related to post-settlement agricultural practices, is a high Ap horizon bulk density. With erosion of the original A horizon material, denser, high-clay B horizon material has gradually and increasingly been incorporated into the plow layer. Further, repeated plowing tends to destroy soil structure and reduce porosity through mechanical disruption, compaction, and oxidation of organic matter (Brady, 1974). The combined effects account for plow-layer bulk densities that are often the highest measured in the entire soil profile (Table 3.4). The practical implications of this condition are a surface layer that allows less water infiltration, has reduced aeration, and has less plant-available water. The establishment of a perennial crop, such as those planted in the biomass study, should have a remedial effect on surface horizon bulk density by adding organic matter and reducing the need for tillage.

Seven of eight Amelia pedons had the combination of clay distribution and low base saturation (<35%) required for classification as Ultisols. The eighth (Pedon AN II-41), while meeting clay distribution requirements for the argillic/kandic horizon description, had a base saturation at a depth of 1.2 m below the top of the Bt horizon of 39%, placing it just outside the range for classification as an Ultisol. All eight Amelia pedons had the 2.5YR to 5YR colors in the B horizon and the textures required of Cecil soils (AS III-28 did contain slightly more silt than is allowed for Cecil). The only criterion not consistently satisfied for classification as Cecil soils was solum thickness. Cecil soils must have a solum between 100 cm and 150 cm thick. Pits AS III-28 and AN I-18 (both of which were apparently formed in transported materials) met this requirement but, the others did not. Pacolet soils have sola from 50 to 100 cm thick and thus it would appear that the remaining six pedons should be classified as Pacolet. However, Cecil and

Pacolet are similar soils; and, to some extent the measurement of solum thickness involves subjective judgement. Thus, the reported failure of these soils to meet the solum thickness requirement for classification as Cecil soils should not be of great concern. These two soils probably occur in the same map unit over much of the Virginia Piedmont.

Orange County

Three biomass experimental sites were located on two private farms and on the Northern Piedmont Research Station at Orange, Virginia. Two pits were located on the Research Station approximately 1900 m, SW 200 degrees from the junction of Route 20 east and Route 15, and approximately 1550 m, NW 344 degrees from the junction of Route 638 and Route 647. Two pits were located on the Sedwick farm approximately 2900 m, NE 8 degrees from the intersection of Route 639 and Route 15 and approximately 1750 m, NE 35 degrees from the junction of Route 652 and Route 616. Two more pits were located on the Taylor farm approximately 800 m, NW 300 degrees from the junction of Route 612 and Route 20, and approximately 3650 m, NE 32 degrees from the junction of Route 638 and Route 647. The county soil survey shows soils at all sites to be Davidson clay loam, 7 to 15 percent slopes, severely eroded (Carter et al., 1971). The topography in the vicinity of the experimental plots ranges from gently rolling to steep. Local relief ranges up to 75 m or more. Unlike the topography in Amelia or Lunenburg Counties, prominent ridges mark the landscape. Elevations generally range from about 60 to 150 m, but several ridges in the southwestern part of the county rise to an elevation of over 300 m. Three rivers, the Rapidan, the North Anna, and the Rivanna, drain the county (Carter et al., 1971).

As was the case in Lunenburg and Amelia Counties, it was apparent that local colluvial/local alluvial activity contributed significantly to the formation of these soils. At all three sites, there appeared evidence of such activity, both ancient and more recent. At least one pedon (O I-22) showed evidence of at least two periods or episodes of sedimentation. Tables 3.5 and 3.6 provide summary morphological, physical, and chemical data for the six Orange County pedons studied in detail.

Stone lines were described in Orange County pits O I-22, O II-33, and O III-13. Pit O I-48, while not containing an obvious stone line, did contain an occasional rounded quartz pebble indicating some alluvial influence. Another pit, O II-18, could have been formed entirely in place; but, it was noted that, in probing the pit floor with a bucket auger, an obstruction was encountered that roughly paralleled the soil surface at a depth of 260 cm. While this could have been bedrock, no saprolite was observed above the obstruction to mark the usual transition from soil material

Table 3.5. Morphological Characteristics of "Typical" Experimental Site Soils.

Horizon	Depth	Matrix Color	Texture	Structure	Consistence	Boundary	Comments
				Pedon O I-22			
Ap	0-20	2.5YR 4/4	sicl	2mpr/1f,m&csbk	mfr	as	
BA	20-38	2.5YR 5/6	sic	2mpr/2f,m&csbk	mfr	cs	
Bt1	38-57	2.5YR 5/8	c	2mpr/2f,m&csbk	mfr	cs	
2Bt2	57-90	2.5YR 5/6	c	2mpr/2f,m&csbk	mfr	cs	stone line at 60 cm.
2Bt3	90-123	2.5YR 4/8	c	2mpr/2csbk,f&msbk	mfr	cs	low chroma mottling.
3Bt4	123-150	10R 4/8	c	2f,m&csbk	mfr	cs	stone line at 125 cm.
3BC	150-170	10R 4/8	c	1m&csbk	mfr	cs	
3C	170-200	10R 4/8	c	o-m	mfr		
				Pedon O I-48			
Ap	0-16	10R 4/6	c	3cpr/2f&mabk	mfr	cs	
BA	16-42	10R 4/6	c	3cpr/2f&msbk	mfr	cs	
Bt1	42-79	7.5YR 6/8	c	3cpr/3m&csbk	mfr	cs	
Bt2	79-110	10R 4/6	sic	3cpr/3m&csbk	mfr	cs	
2Bt3	110-140	10R 4/8	c	3f,m&csbk	mfr		
							rounded quartz pebbles.
				Pedon O II-18			
Ap	0-23	2.5YR 3/6	sic	3mpr/2f,m&csbk	mfr	as	
Bt1	23-60	2.5YR 4/6	c	2mpr/2f,m&csbk	mfr	cs	
Bt2	60-96	2.5YR 4/6	c	2f,m&csbk,abk	mfr	cs	
Bt3	96-150	2.5YR 4/6	c	2f,m&csbk,abk	mfr	cs	
Bt4	150-260	2.5YR 4/6	c	1f,m&csbk	mfr		stone line(?) at 260 cm.
				Pedon O II-33			
Ap1	0-10	5YR 4/6	sicl	2fgr/2f&msbk	mfr	as	
Ap2	10-28	5YR 4/6	sicl	1f,m&csbk	mfr	as	
Bt1	28-62	2.5YR 4/6	c	2cpr	mfr	cs	
Bt2	62-100	2.5YR 4/8	c	2cpr/2f,m&csbk	mfr	cw	
Bt3	100-110	2.5YR 4/6	c	2f&msbk,abk	mfr	cw	
2Bt4	110-140	2.5YR 4/4	c	2f&msbk,abk	mfr	cw	stone line at 150 cm.
2Bt5	140-220	2.5YR 4/8	c	1f,m&csbk	mfr	c	
2BC	220-250	2.5YR 4/6	c	1f&msbk	mvfr	c	
2C	250-300	5YR 5/6	sic	1f,m&csbk	mfr		

Table 3.5 (cont'd.). Morphological Characteristics of "Typical" Experimental Site Soils.

Horizon	Depth	Matrix Color	Texture	Structure	Consistence	Boundary	Comments
				Pedon O III-13			
Ap1	0-9	2.5YR 3/6	sic	2cpr/2f&msbk	mfr	cs	
Ap2	9-24	2.5YR 3/6	sicl	2cpr/2f,m&csbk	mfr	cs	
BA	24-61	2.5YR 3/6	gsicl	1f,m&csbk	mfr	cs	
Bt1	61-109	2.5YR 4/6	gsicl	2f,m&csbk	mfr	cs	30% rock fragments.
2Bt2	109-126	2.5YR 5/8	sicl	1f,m&csbk	mfr	cs	
2Bt3	126-151	2.5YR 5/8	sic	1f,m&csbk	mfr	cs	
2C	151-175	10YR 6/8	sil	o-m	mfr		
				Pedon O III-48			
Ap	0-26	2.5YR 3/6	sic	2cpr/2f,m&csbk	mfr	cs	
Bt	26-57	2.5YR 4/8	sic	2vcpr/2f,m&csbk	mfr	gw	
CB	57-94	2.5YR 4/6	sic	1f,m&csbk	mfr	gw	
C	94-150	10YR 6/8	sicl	o-m	mvfr		

Table 3.6 Selected physical and chemical characteristics of "typical" experimental site soils.

Horizon	Depth	pH	Coarse frag.	Sand	Silt	Clay	Bulk dens.	Organic matter	Fe	P	Al	CEC	Base Satn.
	cm		------------	%	------------		$Mg\ m^{-3}$	--$g\ kg^{-1}$--		ppm	--$cmol\ kg^{-1}$--		%
Pedon O I-22													
Ap	0-20	6.1	2.3	16	46	38	1.69	8.6	67	41	0.10	14.30	36
BA	20-38	6.5	4.0	17	40	43	1.62	2.0	66	7	0.05	12.40	42
Bt1	38-57	6.7	10.0	19	30	51	1.59	0.9	72	5	0.05	12.97	49
2Bt2	57-90	5.7	10.3	17	25	58	1.56	0.8	92	5	0.05	15.16	40
2Bt3	90-123	4.6	2.9	23	29	48	1.65	0.1	54	5	3.95	13.14	11
3Bt4	123-150	4.4	12.1	16	23	61		0.9	84	2	6.75	17.21	9
3BC	150-170	4.4	6.1	18	29	53		0.4	80	2	10.25	20.98	8
3C	170-200	4.4	0.5	7	33	60		0.6	162	4	11.15	25.31	6
Pedon O I-48													
Ap	0-16	5.7	3.2	8	27	65	1.59		102	9	0.05	17.28	44
BA	16-42	5.3	0.7	5	31	64	1.48		128	2	0.25	14.23	31
Bt1	42-79	5.0	2.2	6	29	65	1.50		82	2	1.55	15.49	11
Bt2	79-110	5.0	2.0	7	45	48	1.50		121	2	2.65	15.64	8
2Bt3	110-140	4.9	8.1	14	28	58	1.58		105	2	5.75	16.71	7
Pedon O II-18													
Ap	0-23	5.5	1.7	8	44	48	1.59		93	17	0.10	18.39	37
Bt1	23-60	5.5	0.2	4	27	69	1.49		108	2	0.85	17.37	30
Bt2	60-96	5.0	0.2	4	30	66	1.52		102	2	2.85	14.81	14
Bt3	96-150	5.1	2.6	5	29	66	1.53		102	2	3.65	15.25	9
Bt4	150-260	4.9	0.4	5	30	65			107	2	3.65	16.11	7
Pedon O II-33													
Ap1	0-10	6.0	3.5	11	57	32	1.61		77	46	0.10	18.47	44
Ap2	10-28	5.8	10.1						77	7	0.20	13.79	29
Bt1	28-62	5.8	0.5	5	39	56	1.50		90	4	0.20	14.73	38
Bt2	62-100	5.3	0.1	4	31	65	1.55		97	2	2.15	16.97	24
Bt3	100-110	5.3	0.3	6	31	63	1.53		101	2	2.80	16.98	14
2Bt4	110-140	5.2	48.6	8	30	62	1.50		99	2	2.85	14.61	14
2Bt5	140-220	4.9	0.1	12	34	54			94	2	2.65	15.43	11
2BC	220-250	5.0	4.1	16	33	51			93	4	3.05	13.44	7
2C	250-300	4.9	0.0	3	52	45			105	3	3.95	14.33	6

Table 3.6 (cont'd.) Selected physical and chemical characteristics of "typical" experimental site soils.

Horizon	Depth	pH	Coarse frag.	Sand	Silt	Clay	Bulk dens.	Organic matter	Fe	P	Al	CEC	Base Satn.
	cm		%				$Mg\ m^{-3}$	$g\ kg^{-1}$		ppm	$cmol\ kg^{-1}$		%
							Pedon O III-13						
Ap1	0-9	6.2	1.0	10	46	44	1.38	41.4	97	19	0.10	24.53	46
Ap2	9-24	6.4	10.3	10	50	40	1.53	18.2	98	6	0.10	19.84	45
BA	24-61	6.6	22.2	10	56	34	1.59	4.2	93	4	0.05	17.14	33
Bt1	61-109	6.6	29.2	11	50	39	1.57	2.2	88	2	0.05	16.42	41
2Bt2	109-126	6.7	1.6	10	51	39	1.50	1.0	104	2	0.05	17.69	44
2Bt3	126-151	6.6	1.2	7	48	45		1.1	111	2	0.05	15.75	47
2C	151-175	6.5	2.1	11	71	18		0.8	119	5	0.05	14.67	39
							Pedon O III-48						
Ap	0-26	6.4	8.7	10	41	49	1.56		93	13	0.05	18.25	49
Bt	26-57	6.7	0.8	8	42	50	1.49		101	2	0.05	16.68	40
CB	57-94	5.9	0.0	14	46	40	1.37		105	2	0.05	15.88	34
C	94-150	6.0	0.1	11	62	27	1.17		110	3	0.75	14.41	24

to hard rock. As was the case in Amelia County, the only soil with truly residual characteristics had a relatively shallow solum thickness of 57 cm (O III-48). The residual character of the subsoil was confirmed by the presence of a nearly intact quartz stringer that could be traced to within 60 cm of the soil surface.

As compared to the anomalous Amelia County soils, clay distributions in the Orange County soils were more typical of what one would expect to find in a highly eroded Ultisol (Figure 3.4). Pits O I-48, O III-13, and O III-48 were shown to have clay maxima in or very near the surface horizon, indicating truncation by post-settlement erosion. The two pits at site II contained considerably lower percentages of clay in the surface than they did with depth, indicating that they were less eroded. The Davidson soils, as a whole, were higher in clay than either the Amelia or Lunenburg County soils.

As was the case with the Amelia County soils, the high clay content of the surface horizon had a negative effect on tilth, particularly when combined with a low organic matter content. Bulk densities of the surface horizons at sites I (Pedons O I-22 and O I-48) and II (Pedons O II-18 and O II-33) ranged from 1.59 to 1.69 Mg m^{-3} (Table 3.6). An organic matter content of less than 10 g kg^{-1} was measured in pit O I-22. By contrast, the organic matter content measured in pit O III-13 was over 40 g kg^{-1}, and the

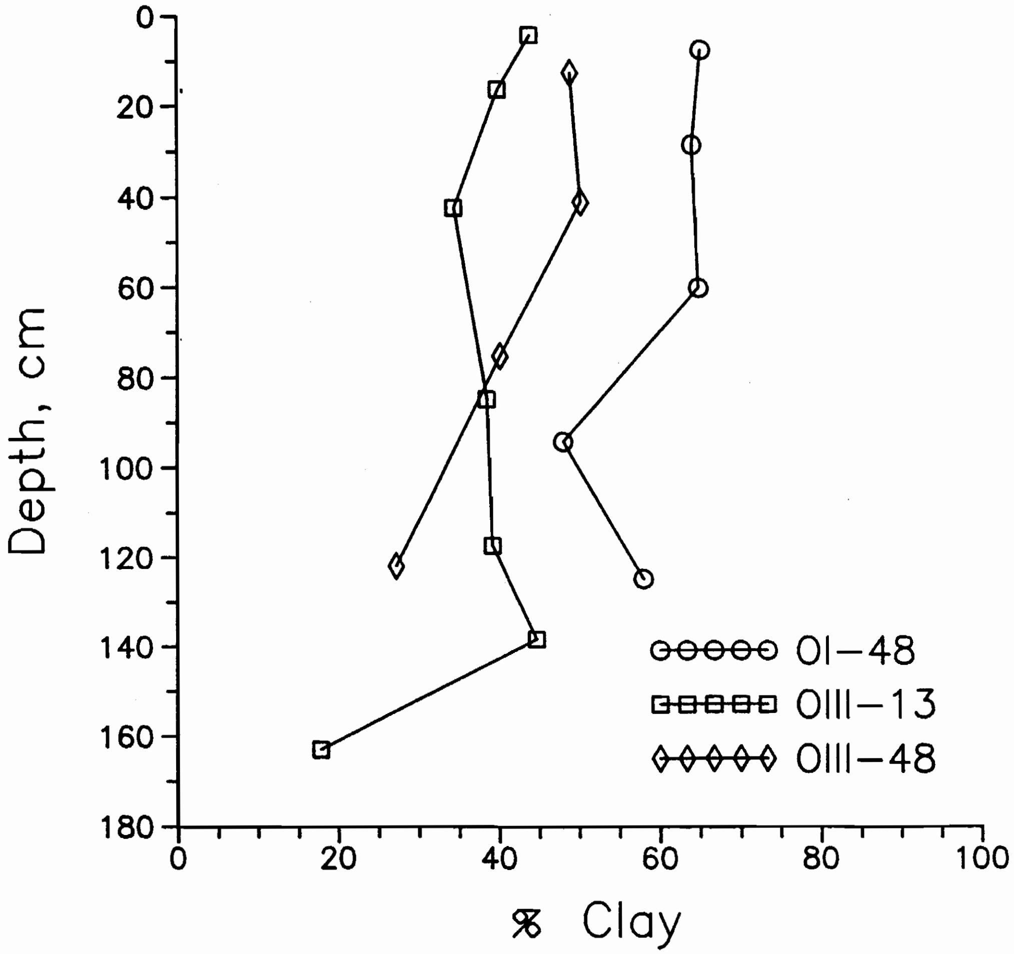


Fig. 3.4. Distribution of clay vs. depth in selected Orange County pedons, Davidson mapping unit.

corresponding bulk density in the surface horizon measured 1.38 Mg m^{-3}. The more favorable physical characteristics of the plow layer at site III were strongly evident when these pits were described in July of 1987. During this period, Orange County was experiencing an extended drought and it appeared that biomass crops at sites I and II were under considerable stress. To compound the problem, the surface layers at these two sites were severly puddled and would have impeded water infiltration. The plants at site III, however, appeared to be under less stress; and, while it is not known for certain that the physical condition of the surface was a factor, it seems likely. The soils at site III had been under pasture before establishment of the biomass experimental plots, whereas soils at the other two sites were in cropped fields. This undoubtedly explains the better physical condition of the soils at site III.

The pH of the Orange County soils was generally highest in the surface and decreased with depth. This trend was most marked in the soils at site I, where high levels of KCl-extractable Al were measured in the lower horizons. Those soils that did not show a marked decrease in pH with depth (O III-13 and O III-48) had very low levels of KCl-extractable Al. No attempt was made to determine the source of the KCl-extractable Al, and thus the significance of the wide range of extractable levels found in these soils can only be speculated upon. As noted by Barnhisel and

Bertsch (1982), Al extracted by a neutral salt solution may be attributable to a number of sources, including "true" exchange sites, hydroxy-polymeric interlayers, clay mineral structures, and dissolution of gibbsite or non-crystalline phases. However, one thing that was noted at the time the pits were dug and described was that the sola at site III contained a considerable quantity of weathered greenstone pebbles that were not seen at the other two Orange County sites. Alexander et al. (1941) reported that resilication of gibbsite to form kaolinite occurred in close proximity to an actively weathering rock surface in Davidson soils of North Carolina. It is possible that an abundance of weatherable minerals in the solum might be forcing the resilication of Al-oxides and the formation of kaolinite, thereby "tying up" the Al in a less KCl-extractable form. A study comparing the clay mineralogy of the Orange County soils would probably have helped to resolve this question.

Base saturation, like soil pH, was highest at or near the surface and decreased with depth. Cation exchange capacity was slightly higher in these soils than in the soils of the two other counties, but the abundance of KCl-extractable Al in these soils, particularly in the lower horizons, kept base saturations from being higher than those measured in Amelia or Lunenburg Counties.

Free Fe was in abundance in the Orange County soils, with concentrations in the C horizons commonly exceeding 100 g kg^{-1} soil. By contrast, the highest concentrations measured in the C horizons of Lunenburg soils were in the range of 15 to 20 g Fe kg^{-1} soil and concentrations in Amelia County soils were generally less than 50 g Fe kg^{-1} soil. In all three soils, there appeared to be a correlation between clay content and free Fe, though the strength of this relationship was not measured.

Summary and Conclusions

The considerable post-settlement erosion chronicled by Trimble (1974) was very much in evidence at all biomass experimental sites, although the effects of this erosion were manifested in somewhat different ways at each site. Erosion at the Lunenburg sites was apparent in the overthickened, undifferentiated, sandy cappings that overlie soils in the footslope landscape positions. Surface soils in Orange County were characterized by high-clay contents, blocky structure, and 2.5YR colors consistent with the removal of the pre-agricultural A horizon. Surface soils at the Amelia County experimental sites often displayed shallow sola, blocky structure, and colors characteristic of the subsoil. Yet, despite evidence of severe erosion and profile truncation at the Amelia County sites, a distinct clay bulge remained. It has been suggested that, in some cases, sheet erosion might be capable of selective removal of clay-sized material from a surface horizon, creating a clay distribution in the profile approximating that caused by eluvial and illuvial processes. However, it has also been shown that rapid redistribution of clay by eluvial/illuvial processes occurs when forested soils are cleared for agriculture; and, thus, this may provide a more plausible explanation for the observed clay distributions.

Clay contents were highest in the Orange County soils, and lowest in the Lunenburg County soils, with intermediate amounts of clay being measured in the Amelia County soils. While clay content is often taken to be a relative index of soil age, parent material differences best explain the differences in clay content in these soils. Orange County soils have formed from greenstone, a rock with abundant weatherable minerals. The relatively low clay content of the Lunenburg County soils can be attributed to their having formed from more siliceous materials low in weatherable minerals. Differences in Fe content between the three counties can be attributed to differences in weatherable mineral content of the parent material, as well. Common greenstone constituents such as chlorite, epidote, biotite, and hornblende (Chesterman, 1978), contain an abundance of Fe, which is released upon weathering to form Fe-oxyhydroxides and oxides (Schwertmann and Taylor, 1977). At the other extreme, Lunenburg soils contained relatively little DCB-extractable Fe, consistent with their formation from parent materials low in weatherable minerals.

Extractable Al contents were somewhat more difficult to explain. Soils in Lunenburg and Amelia contained relatively low amounts of KCl-extractable Al, though Al did increase somewhat in the lower B and the C horizons at Lunenburg. The amount of extractable Al in Orange County soils ranged from quite low at site III, to intermediate at site II to high at site I. Differences between the Orange County sites could be attributable to parent material variabilty or differing degrees of parent material weathering. However, one possible explanation for the large differences in extractable Al is that an abundance of weatherable minerals in the sola of site III soils might be causing the resilication of Al to form kaolinite, thus tying up Al in a less extractable form.

The high clay surface horizons of the more eroded Orange and Amelia County soils showed the potential to become dense and indurated. This was particularly noticeable in fields where tillage had reduced soil organic matter levels and caused surface compaction. This condition appears to be alleviated by the establishment of a sod cover, which eliminates tillage-related compaction and increases soil organic matter levels. High bulk densities were measured in Lunenburg County soils, as well, owing to low organic matter contents and weak soil structure. However, given the sandy, friable nature of the Lunenburg plow layer, this is thought to be less problematic. Of greater concern in the Lunenburg experimental site soils was a discontinuous horizon, which displayed some of the characteristics of a fragipan. This horizon, in combination with the sandy soil textures, might have severely limited the plant-available water holding capacity of these soils.

After digging and describing numerous pits in these three common Piedmont soils, it is apparent that soils formed from locally derived, transported material are a significant component of the upland Piedmont landscape. Though this finding was not a total surprise, given the frequent mention of such deposits in the literature (Ireland et al., 1939; Parizek and Woodruff, 1957; Overstreet et al., 1968; Eargle, 1977; Whittecar, 1985), we were not wholly convinced of their ubiquitous nature until pits provided a view of the undisturbed soil.

The importance of recognizing the presence of these colluvial materials is largely academic. We found no evidence that upland soils formed in colluvial materials were fundamentally different from those that appeared to be residual. The data showed that such characteristics as soil color, texture, CEC, etc., did not vary substantially between colluvial and residual soils. In those soils that were formed in colluvial materials, there were no substantive differences in soil properties across discontinuities. It would appear that the combination of highly pre-weathered colluvial parent materials, the local source of parent materials for both residual and colluvial soils, and post-depositional pedogenesis have ensured the relative homogenity of the soil cover. While possible differences in solum thickness may exist between colluvial and residual soils, we lacked sufficient data to make such a determination.

It is unfortunate that the plot-by-plot observations made in the first phase of the study were of little use in determining the extent to which transported materials blanket the landscape. It became clear, as the study progressed, that discriminating between stone lines and quartz stringers or isolated rock fragments was impossible. In addition, it was not possible to assess coarse fragment contents or to view such features as cross-bedding or horizon boundary topography, all of which were important in the pit study to identify soils formed in locally transported materials. Thus, neither the plot-by-plot observations nor the transects were particularly helpful in quantifying the transported component of these soils. The soil pits were not randomly chosen, and therefore the possibility exists that the characteristics of these pits apply to only a relatively small portion of the landscape. However, this is not very likely, as we were surprised to find evidence of transported materials in most of the pedons we examined.

Literature Cited

Alexander, L.T., S.B. Hendricks, and G.T. Faust. 1941. Occurrence of gibbsite in some soil forming materials. Soil Sci. Soc. Amer. Proc. 6:52-57.

Barnhisel, R. and P.M. Bertsch. 1982. Aluminum. In A.L. Page (ed.) Methods of soil analysis. Part 2. 2nd ed. Agronomy 9:275-300.

Blake, G.R. and K.H. Hartge. 1986. Bulk density. In A. Klute (ed.) Methods of soil analysis. Part 1. 2nd ed. Agronomy 9:363-375.

Brady, N.C. 1974. The nature and properties of soils. 8th ed. Macmillan Publishing Co., Inc., New York.

Buol, S.W.,(ed.). 1973. Soils of the Southern States and Puerto Rico. Southern Coop. Series Bull. No. 174.

Cady, J.G. 1950. Rock weathering and soil formation in the North Carolina Piedmont region. Soil Sci. Soc. Amer. Proc. 15:337-342.

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

Carter, J.B., J.W. Wills, and W.E. Cummins. 1971. Soil survey of Orange County, Virginia. USDA-SCS, U.S. Government Printing Office, Washington, D.C.

Chesterman, C.W. 1978. The Audubon field guide to North American rocks and minerals. Alfred Knopf, New York.

Costa, J.E., and E.T. Cleaves. 1984. The Piedmont landscape of Maryland: a new look at an old problem. Earth Surface Processes and Landforms. 9:59-74.

Daniels, W.L., D.F. Amos, and J.C. Baker. 1983. The influence of forest and pasture on the genesis of a humid temperate-region Ultisol. Soil Sci. Soc. Am. J. 47:560-566.

Day, P.R. 1965. Particle fractionation and particle-size analysis. In C.A. Black (ed.) Methods of soil analysis. Part 1. Physical and mineralogical properties, including statistics of measurment and sampling. Agronomy 9:545-567.

Eargle, D.H. 1977. Piedmont Pleistocene soils of the Spartanburg area, South Carolina. Geologic Notes, South Carolina Division of Geology. 21(2):57-74.

England, C.B., and H.F. Perkins. 1959. Characteristics of three Reddish-Brown Lateritic soils of Georgia. Soil Sci. 96:210-216.

Gibbs, J.A., and H.F. Perkins. 1966. Properties and genesis of the Hayesville and Cecil series of Georgia. Soil Sci. Soc. Amer. Proc. 30:256-260.

Hack, J.T. 1975. Dynamic equilibrium and landscape evolution. p.87-102. In W.N. Melhorn and R.C. Flemal (ed.) Theories of landform development. Publications in Geomorphology, Binghamton, N.Y.

Hardy, F., and Rodrigues, G. 1939. The genesis of Davidson clay loam. Soil Sci. 48:483-495.

Howard, J.L., D.F. Amos, and W.L. Daniels. In press. Alluvial soil chronosequence in the Inner Coastal Plain, Central Virginia.

Ireland, H.A., C.F.S. Sharpe, and D.H. Eargle. 1939. Principles of gully erosion in the Piedmont of South Carolina. U.S. Dept. Agr. Tech. Bull. 633. 143 p.

Kunze, G.W. and J.B. Dixon. 1986. Pretreatment for mineralogical analysis. In A. Klute (ed.) Methods of soil analysis. Part 1. 2nd ed. Agronomy 9:91-100.

McCaleb, S.B. 1959. The genesis of the Red-Yellow Podzolic soils. Soil Sci. Soc. Amer. Proc. 23:164-168.

McDaniel, J.C., H.L. Gillispie, and J. Ali. 1981. Soil survey of Lunenburg County, Virginia. USDA-SCS, U.S. Government Printing Office, Washington, D.C.

McLean, E.O. 1982. Soil pH and lime requirement. In A.L. Page (ed.) Methods of soil analysis. Part 2. 2nd ed. Agronomy 9:199-224.

Miller, B.J. 1983. Ultisols. p. 283-323. In L.P Wilding, N.E. Smeck and G.F. Hall. Pedogenesis and soil taxonomy. II. The soil orders. Elsevier Science Publishing Company Inc., New York.

Nelson, D.W. and L.E. Sommers. 1982. Total carbon, organic carbon, and organic matter. In A.L. Page (ed.) Methods of soil analysis. Part 2. 2nd ed. Agronomy 9:539-579.

Nelson, W.L., A. Mehlich, and E. Winters. 1953. The development, evaluation, and use of soil tests for phosphorus availability. Agronomy 4:153:188.

Nyun, M.A., and S.B. McCaleb. 1955. The Reddish-Brown Lateritic soils of the North Carolina Piedmont region: Davidson and Hiwassee series. Soil Sci. 80:27-41.

Olson, R.V. and R. Ellis, Jr. 1982. Iron. In Methods of soil analysis. Part 2. 2nd ed. Agronomy 9:301:312.

Overstreet, W.C., A.M. White, J.W. Whitlow, P.K. Theobald, D.W. Caldwell, and N.P. Cuppels. 1968. Fluvial monazite deposits in the southeastern United States. USGS Prof. Paper. 568, 85p.

Parizek, E.J. and J.F. Woodruff. 1957. Description and origin of stone layers in the soils of the southeastern United States. Jour. Geol. 65:24-34.

Pavich, M.J. 1989. Regolith residence time and the concept of surface age of the Piedmont "peneplain". In T.W. Gardner and W.D. Sevon (ed.) Appalachian geomorphology. Geomorphology, 2:181-196.

Rebertus, R.A. and S.W. Buol. 1985. Iron distribution in a developmental sequence of soils from mica gneiss and schist. Soil Sci. Soc. Am. J. 49:713-720.

Ruhe, R.V. 1959. Stone lines in soils. Soil Sci. 87:223-231.

Schwertmann, U. and R.M. Taylor. 1977. Iron oxides. p.145-180. In J.B. Dixon and S.B. Weed (ed.) Minerals in soil environments. SSSA, Madison WI.

Simonson, R.W. 1950. Genesis and classification of Red-Yellow Podzolic soils. Soil Sci. Soc. Amer. Proc. 14:316-319.

Soil Survey Staff. 1987. Soil taxonomy. Agric Handb. no. 436. USDA. U.S. Government Printing Office. Washington, D.C.

Soil Survey Staff. 1988. Appling. Established Soil Series.

Soil Survey Staff. 1989. Cecil. Established Soil Series.

Soil Survey Staff. 1989. Davidson. Established Soil Series.

Thomas, G.W. 1982. Exchangeable cations. In A.L. Page (ed.) Methods of soil analysis. Part 2. 2nd ed. Agronomy 9:159-165.

Trimble, S.W. 1974. Man-induced soil erosion on the southern Piedmont. Soil Conservation Society of America, Ankeny, Ia.

Whitehead, D.R. and E.S. Barghoorn. 1962. Pollen analytical investigations of Pleistocene deposits from western North Carolina and South Carolina. Ecological Monographs. 32(4):347-369.

Whittecar, G.R. 1985. Stratigraphy and soil development in upland alluvium and colluvium, North Central Virginia Piedmont. Southeastern Geol. 26(2):117-129.

CHAPTER 4: The Occurrence of Colluvial Deposits in Upland Soils of the Virginia Piedmont.

Abstract

A study of several randomly selected bodies of three common upland Virginia Piedmont soils revealed that a significant portion of the soil landscape was covered with transported materials. All study sites were located on 5 to 12% slopes in areas that typify the gently rolling topography of much of the Virginia Piedmont. While the origin and thus the significance of these transported materials is open to speculation, we believe that many of the deposits are the product of Pleistocene slope instability. Though the deposits seemed to bear some relationship to the present topography, they were found to extend well up the backslope into convex upward portions of the landscape. The stone lines were always approximately parallel to the present soil surface, and slope deposits were rarely as much as 2 m thick. This indicates that the deposits postdate or perhaps formed concurrently with the development of the present topography. Soils formed in transported materials were shown not to differ in character from those soils formed wholly in residual materials. This is attributable to the presence over most of the Piedmont landscape of a thick blanket of highly-weathered saprolites,

which may act as a source for near "ready-made" soil materials.

Introduction

Though soils of the Southern Piedmont are assumed to have formed largely in residuum, a portion of the landscape is known to be covered with transported material (Daniels et al., 1984). The occurrence of colluvial deposits on steep sideslopes bordering perennial streams is well documented (Overstreet et al., 1968; Costa and Cleaves, 1984; Pavich, 1986). These poorly sorted deposits commonly override recent alluvial deposits (Pavich, 1986) and may contain modern artifacts (Overstreet et al., 1968). Thus, local colluviation appears to be active. Such slope movements are presumably a response to the undercutting of stream banks and are undoubtedly facilitated by frequent saturation of the regolith in proximity to those streams. These materials predictably show little soil profile development.

Colluvial deposits are also a recognized feature in more mountainous regions of the southern Piedmont. In Virginia, colluvial soil series such as Appomattox, Braddock, Dyke, Meadowville, Starr, and Tate have been mapped in areas of higher relief. These soils show varying degrees of profile development; some deposits are apparently quite old, while others show minimal development and can be assumed to be relatively young, particularly when found at the base of one of the numerous inselbergs that dot the Piedmont landscape. These deposits are, in all probability, an equilibrium feature of the Piedmont landscape, the product of slow creep and slope failures caused by catastrophic storms.

However, at least a portion of Piedmont colluvial deposits described in the literature (Ireland et al., 1939; Parizek and Woodruff, 1957; Overstreet et al., 1968; Eargle, 1977; Costa and Cleaves, 1984; Whittecar, 1985) occur in upland areas of minimal relief, where catastrophic slope failures are highly unlikely, and where soil creep is of questionable importance (Parizek and Woodruff, 1956). These deposits are typically fine-grained and commonly contain stone lines (Parizek and Woodruff, 1957; Ruhe, 1959) of angular vein quartz fragments at their base. In a few localities, late-Pleistocene organic materials have been found buried under such deposits, leading to speculation that Pleistocene climatic fluctuations triggered widespread slope instability in the southeastern United States (Parizek and Woodruff, 1957; Eargle, 1977). Recent intensive studies of three commonly mapped Piedmont soils have suggested that transported materials cover a significant portion of the gently sloping Piedmont upland of Virginia. My goal was to describe the geographic distribution of these transported materials and the morphological characteristics of the soils formed in them. In so doing, I hoped to use soils data to suggest a source for these transported materials and to examine the relationship between soil development and landscape evolution on the Piedmont.

Materials and Methods

Three soils commonly mapped in the southern Piedmont, the Appling series (clayey, kaolinitic, thermic family of Typic Kanhapludults), the Cecil series (clayey, kaolinitic, thermic family of Typic Kanhapludults), and the Davidson series (clayey, oxidic, thermic family of Rhodic Paleudults), were chosen for study. Cecil and Appling series soils are of large extent in the southeastern United States, and are mapped from Virginia to Alabama (Soil Survey, 1988; Soil Survey, 1989). Davidson series soils have been mapped throughout the region, as well, and are of moderate extent (Soil Survey, 1989). The Virginia Piedmont has extensive areas in which these three soils are mapped as consociations, and we sought to locate our study sites within those areas.

We located our Appling study sites in Lunenburg County, Virginia, where Appling soils were mapped on approximately 25% of the landscape (McDaniel et al., 1981). In this county, Appling soils are commonly associated with somewhat-redder Cecil and Madison soils and in some areas are found to be associated with Caroline soils (clayey, mixed, thermic family of Typic Paleudults), a soil formed in sediments of supposed fluviomarine origin. Saprolite at our study sites had a granitic character but, since no undisturbed examples were observed, bedrock type could not be confirmed.

Cecil study sites were located on the Amelia Wildlife Management Area (AWMA) in Amelia County, Virginia. Amelia County is currently being mapped, and therefore no total acreage estimates are yet available. However, large acreages of Cecil soils have been mapped, particularly in the northern part of the county. Saprolite on the AWMA is weathered from a feldspathic gneiss.

The Davidson study sites were located on two private farms and on the Northern Piedmont Research Station at Orange, Virginia. Davidson soils have been mapped on 13% of the landscape in Orange County and are associated with outcrops of Catoctin greenstone.

Study Site Selection Criteria

The primary purpose of our soils work was to provide a morphological, chemical, and physical characterization of the soils at each of 12 biomass experimental sites. Study sites were located on each of the three soils with the aid of SCS and Virginia Tech Soil Survey personnel. In each case, considerable effort was made to locate uniform soil bodies that closely fit the central concept of the chosen soil series. Twelve study sites, three in Lunenburg County (Appling map unit) on south-facing, 5 to 9% slopes, three in Orange County (Davidson map unit) on south-facing, 7 to 11% slopes, and six in Amelia County (Cecil map unit), three on south-facing and three on north-facing 5 to 9% slopes, were marked off and planted early in the summer of 1985. Simultaneously we began sampling soils at each study site by boring a hole in the lower left corner of each plot with a 1.5 m bucket auger, describing the soils morphologically, and sampling the major horizons for chemical analysis. The biomass study employed a randomized complete block design with eight treatments and four blocks per site. Thus, we described and sampled a total of 32 auger observations per site in an area of slightly less than 1100 m^2. This intensive sampling scheme allowed us to look at short-range variability in these three soils and to describe with confidence the modal characteristics of the soils at each site. The results of this phase of the study are discussed in the second chapter of this thesis.

The morphological observations were compiled by site, and on the basis of four characteristics, (1) thickness of the A-horizon, (2) thickness of the solum, (3) color of the argillic horizon, and (4) sequence of horizons described, we chose one to two typical pedons per experimental site for further study. Once the typical pedons were located, pits were excavated adjacent to them to a depth of 1.5 to 2 m.

Pits were described according to standard Soil Survey (1984) procedures. Each horizon was sampled and returned to the lab for further analysis.

Methods of Sample Analysis

Bulk samples of each horizon were returned to the laboratory, air dried, and ground to pass through a 2-mm sieve. Coarse fragments (>2 mm) were weighed, and their percentage of the whole soil was computed. Soil texture was determined by a modified pipette method (Gee and Bauder, 1986). Exchangeable cations were determined by 1N NH_4OAc (pH 7.0) extraction and atomic absorption spectrophotometry. Effective cation exchange capacity was calculated as the sum of basic cations plus 1 N KCl extractable Al. Percent base saturation was calculated as the sum of the basic cations divided by the total exchangeable cations (basic cations plus 1 N KCl-extractable Al). Soil pH was determined using a 1:1 soil:water suspension. Total acidity was determined by $BaCl_2$-Triethanolamine (TEA) extraction. Exchangeable Al was determined by 1 N KCl extraction and titration to pH 7 with 0.1N NaOH (Thomas, 1982). Organic carbon was determined by the Walkley-Black method (Nelson and Sommers, 1982). Free Fe-oxides were determined by dithionite-citrate-bicarbonate (DCB) extraction (Olson and Ellis, 1982). Plant-available phosphorus was determined using a Mehlich-1 procedure (Nelson et al., 1953). Bulk density was determined by the clod method (Blake and Hartge, 1986).

Results and Discussion

For the purposes of this paper, I use "colluvium" as a general term to describe the range of non-fluvial, transported materials described here and in the literature. I intend the term to describe "weathered material transported by gravity" (Whitten & Brooks, 1972), but I assume that water, whether pore water, ice, or surface runoff, may have had some role in sediment transport. I acknowledge that these colluvial deposits of the Southern Piedmont display a range in characteristics that may reflect somewhat different mechanisms of movement. Some prefer to use the term "local alluvium" or "hillslope sediments" (McCracken et al., 1987) to describe the deposits to which I refer. However, I feel that little evidence exists to make a clear genetic distinction between deposits described as "local alluvium" or "hillslope sediments" and those deposits occurring in Piedmont soils historically described as colluvial.

Appling, Cecil, and Davidson series soils were chosen for study due to their extensive occurrence throughout the southern Piedmont. Where these soils occur in Virginia, they are often mapped as consociations and are dominant over large portions of the landscape. Thus, they are typical examples of the common red-yellow Piedmont soil. It is commonly presumed that all three of these soils are formed in residuum.

A total of 18 pits were excavated, described and sampled among the three soil map units (three counties). Pits were located on backslopes (Ruhe, 1960) in areas typical of the southern Piedmont's gently rolling landscape. The morphology, chemistry, and physical characterization of these pits has been discussed in detail in Chapter 3 of this thesis. What I wish to focus on in this chapter is the evidence for and implications of colluviation in these soil landscapes. Of the 18 pedons, 12 appear to have formed in colluvium. These findings are in line with other studies that have shown that, locally, 50% or more of the Piedmont landscape bears a cover of transported materials (Eargle, 1940; Parizek and Woodruff, 1957; Whittecar, 1985; McCracken et al., 1987).

Lunenburg County Soils (Appling Mapping Unit).

At the Lunenburg County study sites, Appling soils were intermixed with Caroline soils, which are a Typic Paleudult formed in fluviomarine sediments (McDaniel et al., 1981). After careful study of numerous pedons we concluded that the soils on these sites may more closely fit the central concept of Caroline soils than that of Appling soils. These soils commonly had gray mottles in the subsoil and contained crushable siliceous nodules in the argillic horizon; both are characteristics of Caroline soils (McDaniel et al., 1981). In addition, some pedons displayed a prominent reticulate mottling pattern, which one often associates with sedimentary deposits of considerable age.

In addition to the possibility that these soils were formed in fluvial deposits, soils at the Lunenburg County sites showed evidence of at least two more recent periods of sedimentation. Pedon L I-23 (Chapter 3, Tables 3.1 and 3.2) was one of two pits containing buried A horizons. The organic matter content of the Ab horizon was considerably higher than that of the present surface horizon (26.0 g kg^{-1} vs. 9.6 g kg^{-1}). Since it is not likely that buried organic material would remain long in the profile of a well-drained upland Piedmont soil, this suggests burial of the Ab horizon by post-settlement erosion. Due to the inherent difficulties in dating soil organic carbon (Matthews, 1985), no attempt was made at dating the deposition.

Orange County Soils (Davidson Mapping Unit).

Davidson soils were studied at three sites in the vicinity of Orange, Virginia; two pits were located on Virginia Tech's Northern Piedmont Research Station, and four more pits were located on private farms. Davidson soils are mapped in a 3 km-wide band that closely coincides with an outcrop of Catoctin greenstone. Relief is generally more pronounced in Orange County than in either Amelia County or Lunenburg County, with slopes of 25% or more being common.

Of the six Davidson pedons studied, five were marked by evident stone lines composed of angular to subangular vein quartz and unweathered to highly weathered greenstone pebbles and cobbles. Typically, the transported materials overlying the stone lines were well-sorted, though in two pits, O I-22 and O III-13, stonelines were more diffuse.

Pits at two locations exposed massive stone lines primarily composed of unweathered, angular cobbles of greenstone at depths in excess of 100 cm. When encountered during excavation, these stone lines were first assumed to be simply shattered pieces of bedrock at the regolith/bedrock interface. However, persistent digging showed the rock layer to be only one stone thick. The soil material underlying the unweathered greenstone was highly weathered and similar in appearance to the material overlying the stone line. This fact is illustrated by the data for pedon O II-33 (Chapter 3, Tables 3.5 and 3.6). The stoneline containing the large pieces of greenstone is apparent in the 2Bt4 horizon with its nearly 49% coarse fragment content. It is apparent from the textural data, the free Fe content, and the CEC data that the material above the stoneline and the material below the stoneline are much the same. The only differences noted are the increasing base saturation and pH, and the slight decrease in free Fe associated with pedogenic processes and fertilization in the upper soil horizons.

One pit at the Virginia Tech Station (pedon O I-22) contained two stone lines, indicating two periods of deposition separated by a period of erosion. Another pit at the same location (O I-48) contained an occasional rounded pebble along with sub-angular gravel, indicating an alluvial influence on the soil parent material.

Amelia County Soils (Cecil Mapping Unit).

Cecil pedons were located on the Amelia Wildlife Management Area (AWMA), Amelia County, Virginia. The AWMA is situated in the north-central portion of Amelia County and is bounded on the north and east by the Appomattox River. Pedons were located on both north- and south-facing slopes approximately 0.5 to 1 km from the river. Though hard rock exposures were not seen in the immediate vicinity of the pits, saprolite in the pits had a gneissic character. The topography was gently rolling; slopes were generally 2 to 7% with slopes of greater than 10% restricted to areas bordering the Appomattox River.

Rounded quartz and quartzite cobbles were scattered over much of the soil surface within the AWMA. Howard et al. (in press) studied late-Miocene fluvial terrace remnants west of Richmond, Virginia, and suggested a late-Miocene age for the surface cobbles at the AWMA based upon a weathering rind thicknesses similar to those that the authors had studied (J.L. Howard, personal communication). However, even those Amelia experimental site soils formed in material that was clearly transported showed none of the characteristics (e.g.s fining upward sequences, basal gravel deposits at the sediment/residuum contact, etc.) that one would associate with alluvial deposits. Thus, the scattered Miocene age cobbles appear to be only a lag surface deposit and not coarse fragments in an intact, thick, alluvial terrace deposit.

Of the eight pedons studied, four contained stone lines at depths between 70 and 200 cm (see Chapter 3, Tables 3.3 and 3.4). A fifth pit appeared to contain a stone line at a depth of 20 cm, but at this shallow depth a cultural origin is possible. The stone lines were usually only one stone thick and composed of angular and subangular vein quartz fragments with an occasional rounded quartz or quartzite cobble. These cobbles were identical in their lithology and degree of weathering to those scattered upon the surface, and their presence in stone lines seems to say that: (1) stone lines at the AWMA formed as a lag deposit on an eroding surface (Parizek & Woodruff, 1957), and (2) that deposits overlying these stone lines are of post-Miocene age (assuming the age tentatively assigned to the scattered surface cobbles is correct).

As mentioned in the previous chapter, those soils that did appear to be formed in truly residual material typically were shallow and underdeveloped. Profile truncation can probably be attributed to post-settlement erosion (Trimble, 1974). Shallow, truncated sola were occasionally found near to those formed in transported materials, which raises the possibility that transported materials once blanketed the entire landscape but are gradually being removed by both natural and culturally accelerated erosion processes.

Noting that "detailed investigations of landscapes where gravel or stones are available as a marker usually show a thin mantle of sediment overlying a stone line on slopes up to 20% or more", Daniels et al. (1986) have posed the following question concerning the genesis of these upland deposits and their significance and relationship to those processes that have formed the Piedmont landscape: "Is active (present day) deposition on the landscape confined to only the concave areas or does it also occur on the linear slopes above the concave areas?"

The scenario seemingly depicted by the recurring residuum-stoneline-colluvium sequence that we observed is that of profile truncation and lag gravel concentration at the soil surface by erosion processes followed by deposition (Parizek and Woodruff, 1957). It is possible (as Daniels et al. have suggested) that erosion and deposition are active on constantly shifting portions of the landscape and that deposits of similar character are presently forming. The evidence for recent deposition in the Lunenburg County soils, despite the probability that cultivation had at least accelerated sedimentation, could support such a scenario. Similarly, the lack of a distinct clay bulge and the weak structure in the BA and 2Bt2/2Bt3 horizons of pedon O III-13 could be taken as evidence of more recent deposition. It should be noted, however, that no significant amount of organic matter is present in the Orange III-13 subsoil; this seems to indicate that sedimentation was not very recent. Either sufficient time has passed for the oxidation of any buried organic matter, or the former soil surface was rapidly stripped and buried before any organic matter accumulated on the stripped surface.

For the most part, however, material overlying stonelines showed strong pedogenic development (homogeneity of color, characteristic Bt horizon clay distributions, and moderate to strong structure); this may indicate that a considerable period time has elapsed since deposition ended and pedogenesis began. Material under stone lines was always massive and free of organic material, indicating that enough time had elapsed since deposition of the overlying materials for the obliteration of any pedogenic development in the underlying materials. However, exactly what these observations tell us about the age of these deposits and the soils formed in them is subject to some debate. The structure and characteristic clay distribution of an Ultisol argillic/kandic horizon is usually thought to require perhaps tens of thousands of years to develop (Soil Taxonomy, 1987). However, the time required to develop these characteristics in highly weathered, high-clay material like that blanketing the Piedmont landscape may be considerably shorter than conventionally thought. If this is the case, looking for the development of Ultisol characteristics may be of little value in attempting to date these deposits.

Other questions concern the mode of sediment transport and whether late-Pleistocene climatic conditions might actually have triggered slope movement as has been suggested by some (Parizek & Woodruff, 1957; Eargle, 1977). It is possible that the well-sorted character of many of these deposits may give some clue as to their origin. The predominance of fines could indicate gradual accumulation by slope wash, a process that has been accelerated through cultivation but that certainly operates on all but the gentlest of slopes in humid regions, even under forest cover. However, as previously noted, hard rock is rare on the Piedmont; and, thus, many slope deposits, regardless of the mode of deposition, are likely to be stone poor. Therefore, it is also possible that the well-sorted character of the slope deposits may mask their origins.

Eargle (1940, 1977) and Whitehead and Barghoorn (1962) speculated that increased frost action during the late Pleistocene was responsible for slope instability. Under this scenario, slope movement would presumably have been effected by solifluction or perhaps frost heaving and the growth of needle ice (Selby, 1985). Though large gaps exist in our understanding of the Pleistocene climate of the southeastern U.S., there is some evidence for a considerably cooler climate in the region during the Late-Pleistocene (Whitehead and Barghoorn, 1962; Sirkin et al., 1977). However, no direct evidence has been found that a true periglacial climate existed in the southern Piedmont as it apparently did south of the ice border in Pennsylvania (Ciolkosz et al., 1979) and at higher altitudes in the southern Appalachians (Clark, 1968, Clark and Ciolkosz, 1988). Thus, if periglacial mechanisms were responsible for slope movements in the southern Piedmont, their effects were probably somewhat subdued.

I feel that the question of whether episodic mass movement during the late Pleistocene did blanket the Piedmont landscape with a layer of colluvium might best be resolved by examination of the work of Eargle (1940, 1977) and Overstreet et al., (1968). These workers were able to locate Wisconsinan-age organic deposits buried in saturated zones overlain by as much as 6 m or more, of colluvium. Carbon-14 dating of the material collected by Whitehead and Barghoorn (1962) from two localities in the North Carolina/South Carolina Piedmont yielded an age of greater than 35 ka. While the particular deposits that these workers described were found in third-order stream valleys, and not on the convex, upland portions of the landscape that I studied, I think it quite possible that these organic deposits are related to those that I described. What is particularly relevant to our study is that the soils burying these organic deposits had been mapped as Cecil and Appling and similar soils (Ireland et al., 1939) before their colluvial origin was known. Thus, it is possible that the deposits which I described in the upland soils may represent the feather edge of similar and more massive deposits lower in the watershed.

Eargle (1977) and Overstreet et al. (1968) detailed the locations of several of the Pleistocene organic deposits that they described in the vicinity of Spartanburg, South Carolina. According to these workers, the buried Pleistocene organic deposits are a characteristic feature of the Piedmont landscape, though they do not pinpoint the location of any such deposits outside the Spartanburg study area. It is significant and relevant to this study that these deposits were commonly found to be buried under soils that had been mapped as Cecil and Appling (Eargle, 1977). After carefully reading the literature, I believe that if these deposits are indeed a characteristic feature of the Virginia Piedmont landscape, they are most likely to be found in the vicinity of the springheads (Figure 4.1) that mark the landscape transition from the U-shaped swales of the upland

THE PIEDMONT SOILSCAPE

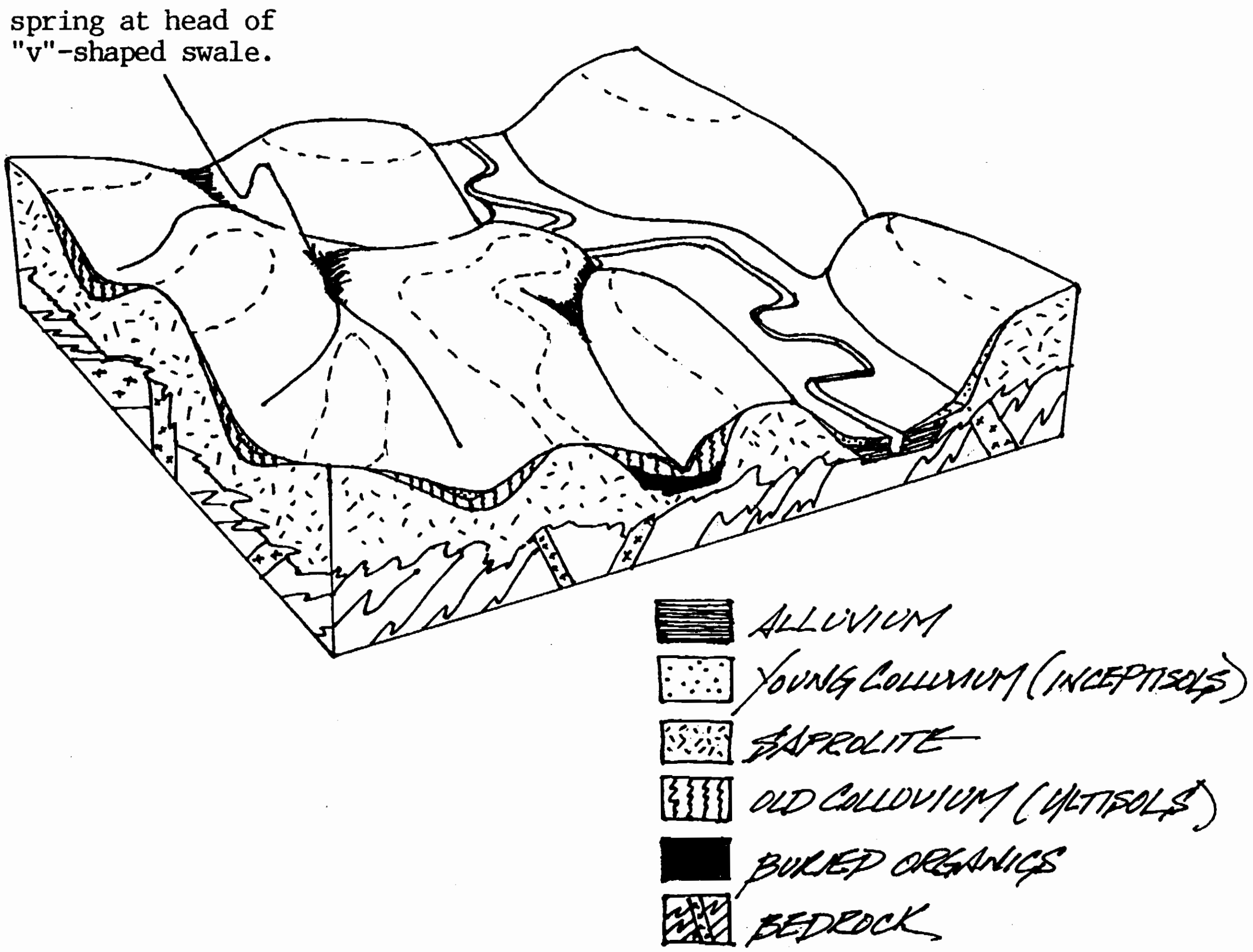


Fig. 4.1. Block Diagram of the Piedmont Soilscape Showing Relationship Between Landscape Position and Transported Materials.

to the V-shaped channels of the intermittent and perennial streams (Pavich, 1986). The preservation of these deposits over any considerable period of time would require their being saturated by groundwater to prevent oxidation. The identification of Pleistocene deposits similar to those described by Eargle (1977), at other locations in the Piedmont would make a strong case for Pleistocene climate-driven, mass wasting of the Piedmont landscape and would indicate that the lowering of the Piedmont surface has, at times, been episodic.

During recent work in the southwestern Virginia coalfields, we were alerted to the presence of relatively well-preserved organic materials buried under large colluvial deposits in the heads of steeply sloping hollows. One such sample yielded a C^{14} date of 39.8 +/- .2 ka. It is perhaps coincidental that the ages of these deposits are so similar; catastrophic storms have very recently triggered slope failures on steeper slopes in the southern Appalachians (Williams and Guy, 1973; Kochel et al., 1982), and the coalfield deposits may be the result of such storms. However, I feel that the closeness of the ages of these deposits bears further scrutiny. What is needed are more dated organic deposits at other locations in the southeastern U.S. Recent refinements in C^{14} analysis techniques allow the dating of materials as old as 100 ka. In addition, other isotopic dating methods exist, and floral and faunal assemblages could further be used to help date deposits.

The possibility that colluvial deposits on the southern Piedmont record periods of slope instability has broad implications for studies in soil genesis, soil mineralogy, and geomorphology. The fact that these colluvial materials occur as inclusions in such commonly mapped "residual" soils as Appling, Davidson, and Cecil blurs the distinction between "residual" soils and those more traditionally thought of as "colluvial". While distinguishing between colluvium and residuum is perhaps only important when certain use-limiting characteristics of soils need to be identitfied, ignoring the widespread presence of these Piedmont hillslope deposits does obscure the importance of erosional/sedimentary processes in the genesis of these soils.

Chapter 4 of the Soil Survey Manual (1984) notes that "the term residuum is used when the properties of the soil indicate that it has been derived from the rock like that which underlies it and when evidence is lacking that it has been modified by movement." From this perspective, then, there is perhaps little reason to attempt to separate pedons that show evidence of movement from those that appear entirely residual. As was noted in Chapter 3 of this thesis, there is little, apart from the presence of the ubiquitous stone line, to distinguish these upland soils formed in transported material from the associated residual soils. Indeed, when stone lines are lacking, deciding whether a soil is "residual" or "colluvial" often becomes impossible. Both residual and colluvial soils have clay loam to clay argillic horizons and similar coarse fragment contents in the upper solum; thus, such things as tillage response and water holding capacity should be similar in both soils. Particle-size distributions show no radical changes across the boundary between colluvial and residual material; therefore, perching of water is not a problem. (One pedon, O I-22, Appendix D., did show some chroma 3 mottling in the 2Bt3 horizon, but this was the only evidence I saw to indicate that water might be perching above a discontinuity.) Colluvial materials did not show compaction, and stone lines were usually not vey thick; thus, root penetration should not be restricted. In summary, nowhere did I see evidence to suggest that these colluvial inclusions should be managed differently from their colluvial counterparts. This is fortunate, for the two classes of soils are so intermixed on the landscape as to make separation impractical.

These findings should not be surprising given the highly weathered nature of Piedmont parent material. Several studies have shown that the most significant mineral transformations occur within a few centimeters of the rock/saprolite interface and not within the solum (Cleaves et al., 1970; Costa and Cleaves, 1984; Pavich, 1986). Wysocki et al. (1988) recently stressed the importance of these deep weathering processes in maintaining a reservoir of pre-weathered soil material. I agree with Wysocki's contention that the availability of this material may significantly shorten the amount of time required to develop the kaolinitic mineralogy, highly oxidized colors, and well-developed argillic horizon that are normally associated with "old" Ultisols.

Pavich (1989) recently proposed the use of Be^{10} inventories as a tool for dating geomorphic surfaces. His work seems to show that the residence time of the typical upland Piedmont regolith may be on the order of 1 to 5 Ma. If we take 10 to 20 m as the average thickness of the upland Piedmont regolith and 1 m as the thickness of typical upland Piedmont solum, and if we assume that regolith production, solum formation, and erosion are in approximate equilibrium, as has been advocated by Pavich (1985, 1986), we can hypothesize a residence time of between 50 and 500 ka for the upper 1 m of the regolith or the solum. Viewed in this context, the typical Cecil profile appears to be much younger than many have thought (e.g. Lee, 1955, p 21.)

Summary and Conclusions

A signicant portion of the upland Piedmont soil landscape is covered by colluvial sediments. This study has shown that soils formed in these materials account for as much as 50% of the area of some Appling, Cecil, and Davidson map units located on backslopes in the Virginia Piedmont. Data from Georgia, South Carolina, and North Carolina suggest that the 50% figure may be applicable to the whole of the southern Piedmont. While the colluvial origin of much soil material becomes difficult to dispute when many soils contain distinct stone lines, there seems to be little reason for soil mappers and interpreters to be concerned with the presence of these colluvial inclusions. Those soils formed in colluvial materials can only be differentiated from their truly residual counterparts by the subsoil presence of a thin band of angular to subangular rock fragments (usually vein quartz) that roughly parallels the present soil surface.

The age and geomorphic significance of these colluvial deposits can only be speculated upon. However, indirect evidence seems to indicate that Pleistocene climatic fluctuations induced slope instability, leading to widespread stripping of the landscape. However, the possibility that these deposits are an equilibrium feature of the Piedmont landscape, as some have suggested, cannot be ruled out. The question of the origin of these colluvial deposits might be resolved through the location of buried organic deposits similar to those located in the South Carolina Piedmont by other workers.

One of the inescapable conclusions to be drawn from this study is that the Piedmont is not simply an ancient, static landscape draped with a mantle of highly weathered, residual soils. Whether one believes that the present day Piedmont landscape has been more influenced by episodic processes or by equilibrium processes, the widespread evidence for topographic inversion and the abundance of transported materials on supposedly residual portions of the upland provide ample evidence of a dynamic Piedmont landscape.

Literature Cited

Blake, G.R. and K.H. Hartge. 1986. Bulk density. In A. Klute (ed.) Methods of soil analysis. Part 1. 2nd ed. Agronomy 9:363-375.

Ciolkosz, E.J., G.W. Peterson, R.L. Cunningham, and R.P. Matelski. 1979. Soils developed in colluvium in the Ridge and Valley area of Pennsylvania. Soil Sci. 128:153-162.

Clark, G.M. 1968. Sorted patterned ground: new Appalachian localities south of the glacial border. Science 161:355-356.

Clark, G.M. and E.J. Ciolkosz. 1988. Periglacial geomorphology of the Appalachian Highlands and Interior Highlands south of the glacial border-a review. Geomorphology 1:191-220.

Cleaves, E.T., A.E. Godfrey, and O.P. Bricker. 1970. Geochemical balance of a small watershed and its geomorphic implications. Geol. Soc. Amer. Bull. 81:3015-3032.

Costa, J.E., and E.T. Cleaves. 1984. The Piedmont landscape of Maryland: a new look at an old problem. Earth Surface Processes and Landforms. 9:59-74.

Daniels, R.B., H.J. Kleiss, S.W. Buol, H.J. Byrd, and J.A. Phillips. 1984. Soil systems in North Carolina. Bulletin no. 467. North Carolina Agricultural Research Service. N.C.S.U. Raleigh, North Carolina.

Daniels, R.B., D.K. Cassel, and J.W. Gilliam. 1986. Reply to "comments on 'soil erosion class and landscape position'." Soil Sci. Soc. Am. J. 50:1375-1376.

Eargle, D.H. 1940. The relations of soils and surfaces in the North Carolina Piedmont. Science. 91:337-338.

Eargle, D.H. 1977. Piedmont Pleistocene soils of the Spartanburg area, South Carolina. Geologic Notes, South Carolina Division of Geology. 21(2):57-74.

Gee, G.W. and J.W. Bauder. 1986. Particle-size analysis. In A. Klute (ed.) Methods of soil analysis. Part 1. 2nd ed. Agronomy 9:383-411.

Howard, J.L., D.F. Amos, and W.L. Daniels. In press. Alluvial soil chronosequence in the Inner Coastal Plain, Central Virginia.

Ireland, H.A., C.F.S. Sharpe, and D.H. Eargle. 1939. Principles of gully erosion in the Piedmont of South Carolina. U.S. Dept. Agr. Tech. Bull. 633. 143 p.

Kochel, R.C., R.A. Johnson, and S. Valastro, Jr. 1982. Repeated episodes of Holocene debris avalanching in central Virginia (abs.) Geol. Soc. America Abstracts with Programs. v.14, p.31.

Lee, W.D. 1955. The soils of North Carolina. North Carolina Agric. Exp. Stn. Tech. Bul. No. 115.

Matthews, J.A. .1985. Radiocarbon dating of surface and buried soils: principles, problems, and prospects. p. 269-288. In K.S. Richards, R.R. Arnett, and S. Ellis (eds.) Geomorphology and soils. George Allen and Unwin (Publishers) LTD, London.

McCracken, R.J., R.B. Daniels, and W.E. Fulcher. 1987. Soils, landforms and vegetation in a virgin North Carolina Piedmont woods. p. 228. In Agronomy abstracts. ASA, Madison, WI.

McDaniel, J.C., H.L. Gillispie, and J. Ali. 1981. Soil survey of Lunenburg County, Virginia. USDA-SCS, U.S. Government Printing Office, Washington, D.C.

Nelson, D.W. and L.E. Sommers. 1982. Total carbon, organic carbon, and organic matter. In A.L. Page (ed.) Methods of soil analysis. Part 2. 2nd ed. Agronomy 9:539-579.

Nelson, W.L., A. Mehlich, and E. Winters. 1953. The development, evaluation, and use of soil tests for phosphorus availability. Agronomy 4:153:188.

Olson, R.V. and R. Ellis, Jr. 1982. Iron. In Methods of soil analysis. Part 2. 2nd ed. Agronomy 9:301:312.

Overstreet, W.C., A.M. White, J.W. Whitlow, P.K. Theobald, D.W. Caldwell, and N.P. Cuppels. 1968. Fluvial monazite deposits in the southeastern United States. USGS Prof. Paper. 568, 85p.

Parizek, E.J. and J.F. Woodruff. 1956. Apparent absence of soil creep in the east Georgia Piedmont. Geol. Soc. Amer. Bull. 67:1111-1116.

Parizek, E.J. and J.F. Woodruff. 1957. Description and origin of stone layers in the soils of the southeastern United States. Jour. Geol. 65:24-34.

Pavich, M.J. 1985. Appalachian Piedmont morphogenesis: weathering, erosion, and Cenozoic uplift. p.299-319. In M. Morisawa and J.T. Hack (ed.) Tectonic Geomorphology. Proc. 15th Annu. Geomorphol. Symp. Ser., State University of New York, Binghamton.

Pavich, M.J. 1986. Processes and rates of saprolite production and erosion on a foliated granitic rock of the Virginia Piedmont. p.551-590. In S.M. Colman and D.P. Dethier (ed.) Rates of chemical weathering of rocks and minerals. Academic Press, Inc. Orlando, Florida.

Pavich, M.J. 1989. Regolith residence time and the concept of surface age of the Piedmont "peneplain". In T.W. Gardner and W.D. Sevon (ed.) Appalachian geomorphology. Geomorphology, 2:181-196.

Pavich, M.J., G.W. Leo, S.F. Obermeier, and J.R. Estabrook. 1989. Investigations of the characteristics, origin, and residence time of the upland residual mantle of the Piedmont of Fairfax County, Virginia. USGS Prof. Paper 1352, 58 p.

Ruhe, R.V. 1959. Stone lines in soils. Soil Sci. 87:223-231.

Selby, M.J. 1985. Earth's changing surface. Oxford University Press, New York.

Sirkin, L.A., C.S. Denny, and M. Rubin. 1977. Late Pleistocene environment of the central Delmarva Peninsula, Delaware-Maryland. Geol. Soc. Amer. Bull. 88:139-142.

Soil Survey Staff. 1984. Soil survey manual. U.S. Government Printing Office, Washington D.C.

Soil Survey Staff. 1987. Soil taxonomy. Agric Handb. no. 436. USDA. U.S. Government Printing Office. Washington, D.C.

Soil Survey Staff. 1988. Appling. Established Soil Series.

Soil Survey Staff. 1989. Cecil. Established Soil Series.

Soil Survey Staff. 1989. Davidson. Established Soil Series.

Thomas, G.W. 1982. Exchangeable cations. In A.L. Page (ed.) Methods of soil analysis. Part 2. 2nd ed. Agronomy 9:159-165.

Trimble, S.W. 1974. Man-induced soil erosion on the southern Piedmont. Soil Conservation Society of America, Ankeny, Ia.

Whitehead, D.R. and E.S. Barghoorn. 1962. Pollen analytical investigations of Pleistocene deposits from western North Carolina and South Carolina. Ecological Monographs. 32(4):347-369.

Whittecar, G.R. 1985. Stratigraphy and soil development in upland alluvium and colluvium, North Central Virginia Piedmont. Southeastern Geol. 26(2):117-129.

Whitten, D.G.A. and J.R.V. Brooks. 1972. The Penguin dictionary of geology. Penguin Books Limited, Harmondsworth, Middlesex, England.

Williams, G.P. and H.P. Guy. 1973. Erosional and depositional aspects of Hurricane Camille in Virginia, 1969. U.S. Geological Survey Professional Paper 804, 80 p.

Wysocki, D.A., D.A. Lietzke, and L.W. Zelazny. 1988. Effects of parent material weathering on chemical and mineralogical properties of selected Hapludults in the Virginia Piedmont. Soil Sci. Soc. Am. J. 52:196-203.

CHAPTER 5: Summary

The purpose of this chapter is to summarize the findings of this study of marginal Piedmont soils. Since the first-stated objective, to "provide a chemical, physical, and morphological characterization of the soils at biomass experimental sites", was met by investigating the other stated objectives, I will begin this discussion with the second objective. As stated in the Introduction, the fifth objective, to "locate and describe relatively undisturbed (uneroded) examples of Appling, Cecil, and Davidson soils", was not met due to time constraints. Therefore, I will restate objectives (2), (3), and (4) of the study and follow each with a summary of our findings pertaining to that objective.

(2) Investigate the chemical, physical, and morphological variability of experimental site soils. In this phase of our marginal soils investigation, we used ANOVA to compare soil variability as measured by selected soil morphological and chemical parameters. In order to get some feel for the spatial component of soil variability, I treated the soils data gathered through plot-by-plot sampling as a nested design with three levels of classification: (1) plots (within blocks), (2) blocks (within sites), and (3) sites (within soil map units or

counties). While the use of geostatistical tools such as autocorrelation or semivariance might have provided more quantitative information concerning the nature of soil variability, I was not familiar with such techniques at the inception of this study. In any event, treating the plot-by-plot data as a nested- classification problem does provide an acceptable, if somewhat crude, method for analyzing soil variability. The results of this analysis may provide some insight into differences in species performance within a given site or from one site to another.

The major finding of this phase of the study was that short-range variability of the experimental site soils was considerable. In every case, variability at the plot level accounted for at least 20% and often more than 50% of the total variability measured for each parameter across all experimental sites within a county (soil map unit). Even when experimental sites were more geographically dispersed, as was the case in Orange County (Davidson map unit), variability at the plot level remained the single largest component of the total variability for many of the soil parameters measured including A horizon thickness, A and B horizon color, and B horizon pH, P, K, and Mg. Where all three experimental sites had been located in the same mapping unit, as was the case in both Amelia and Lunenburg Counties, plot variability accounted for the largest percentage of the total variability measured across most soil parameters. The short-range variability of A horizon pH was extreme; plot (within block) variability accounted for essentially all of the variability in Lunenburg (Appling map unit) and Amelia Counties (Cecil map unit) soils.

(3) Characterize Appling, Cecil, and Davidson soils as they occur on south-southwest facing 9 to 12% slopes and relate morphology to landscape position. We feel that two separate phases of our marginal soils study actually contributed to our characterization efforts. Firstly, we selected and sampled soils in a number of randomly chosen delineations of each of these three soils and found that Lunenburg County soils (Appling map unit) tested lowest in A horizon Ca, Mg, and organic matter content and B horizon pH and Mg. However, Lunenburg soils tested highest in A horizon P, presumably due to their low Fe-oxide content. Amelia County soils (Cecil map unit) were highest in A horizon K. Orange County soils (Davidson map unit) were highest in A horizon organic matter and B horizon P and Ca and measured lowest in A horizon thickness and B horizon K. In general, Lunenburg County soils, apart from their higher levels of A horizon P, were inferior to the soils in Amelia and Orange Counties. This is presumably attributable to the tendency for Appling soils to form from parent materials low in weatherable minerals.

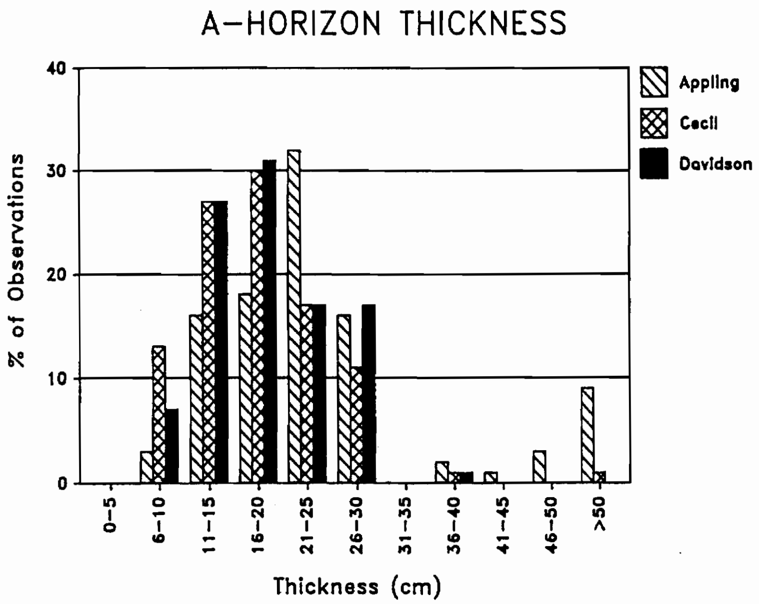
We also gained considerable knowledge of these soils from the total of 18 pits that we described in these three soils. Perhaps the most significant finding was that, as often as not, soils on upland sideslopes are formed in colluvium. These soils are quite similar in most respects to truly residual soils but often contain a stone line of angular to subangular vein quartz fragments at the base of the solum. Some of the stonelines we encountered, however, contained numerous water-worn pebbles and cobbles, indicating that these stonelines once formed a surface pavement that was subsequently buried by colluvial activity. A local source for these colluvial materials is likely, given their similarity to residual materials. In addition, the relatively uniform thickness of the sideslopes' colluvial covering (from 0 to 2m) indicates that deposits likely formed in relation to the present topography. Since there is evidence that the Piedmont surface is being lowered at a rate of between 2 and 20 m Ma^{-1}, these deposits, and thus the soils formed in them, probably date from no earlier than the late Pleistocene.

<u>(4) Determine whether our experimental site soils fit the series concepts of the soils for which their respective mapping units (consociations) were named.</u> This determination is thought to be important for the effective transfer of information from the biomass study to other locations in the southern Piedmont. While it is my opinion that soil

differences between the classic red-yellow upland Piedmont soils probably affect crop yields less than factors such as rainfall and effective fertility management, we did attempt in a qualitative way to determine whether these soils did indeed fit the concept of the soil series for which the map units were named. While no attempt was made to correlate all 384 experimental-plot pedons described, we felt confident that soils at both the Amelia (Cecil map unit) and Orange County (Davidson map unit) sites represented reasonable examples of soils of their respective map units. However, Lunenburg County soils consistently contained too little clay to fit the concept of Appling soils, though in other parameters such as solum thickness, CEC, color, and depth to bedrock, these soils were quite similar to Appling soils.

While the objectives of the study were perhaps somewhat vague, I feel that we have done an adequate job of characterizing Appling, Cecil, and Davidson soils as they occur on sideslopes in the Virginia Piedmont. Due to time constraints, some aspects of the soil characterization study may have suffered. In particular, the reader may be curious about the absence of mineralogical data. I would point out, however, that these three soils have been the subject of numerous studies, and undoubtedly literally thousands of pedons have been correlated during the course of numerous soil surveys; consequently, such characteristics of these soils as mineralogy and parent materials have long been established. Therefore, I chose to spend my time in the field familiarizing myself with these soils in their natural landscape settings. During the course of some 70 days spent in the field, I attempted to develop an accurate picture of the essential elements of these soil landscapes. As a result, I feel confident that the observations contained in this thesis, particularly in regard to the colluvial origin of soil parent materials on sideslopes, can be applied to the whole of the Piedmont landscape.

APPENDIX A: Graphs of Distributions of Soil Test Data Across All Experimental Sites by Soil Mapping Unit.



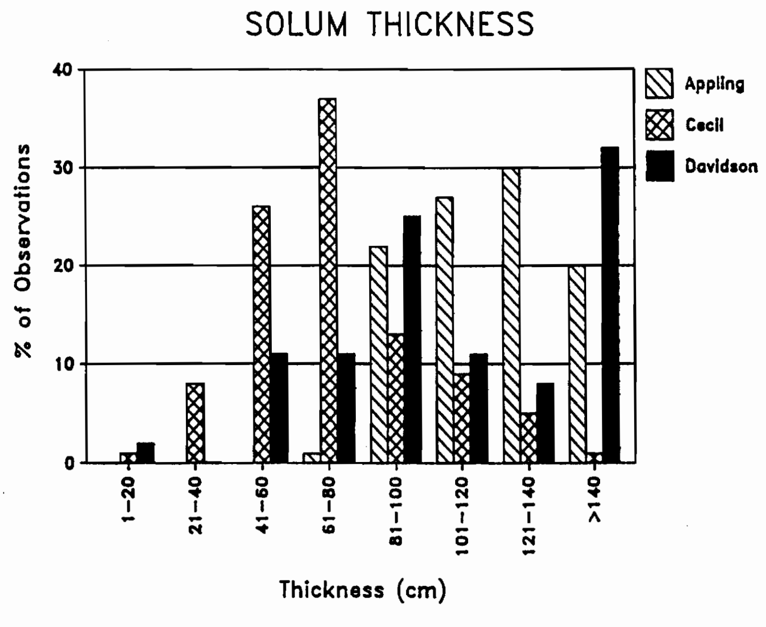
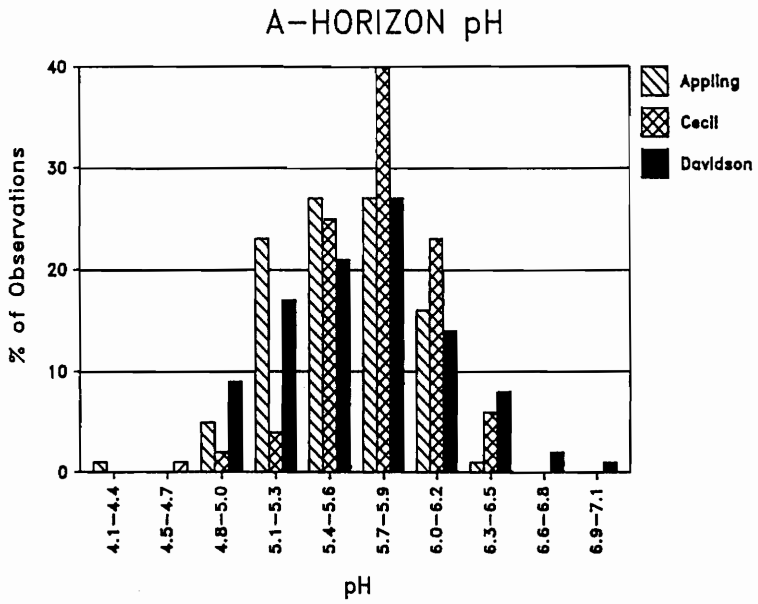


Fig. A.1. A horizon and solum thickness across all experimental sites by soil mapping unit.



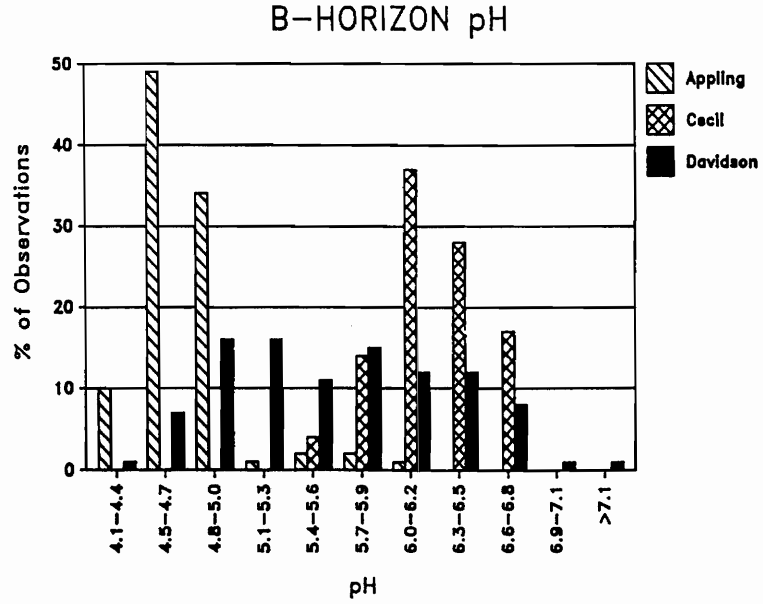
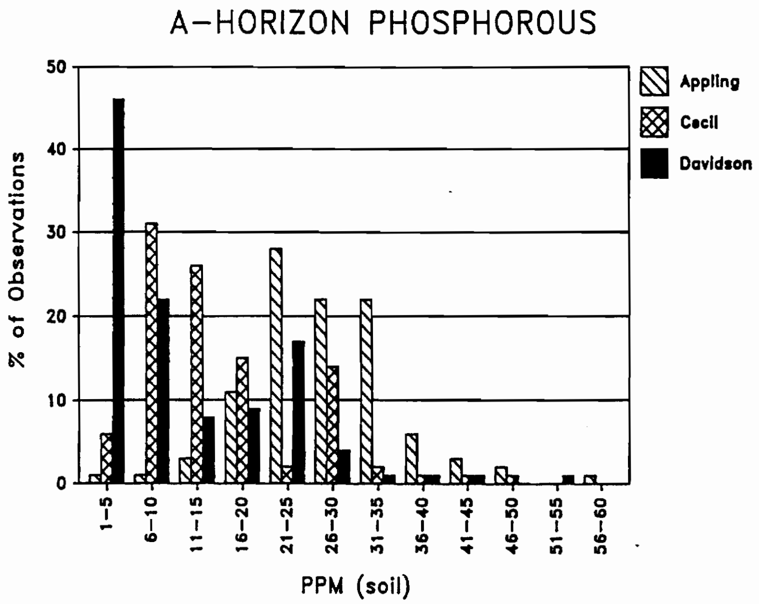


Fig. A.2. A and B horizon pH across all experimental sites by soil mapping unit.



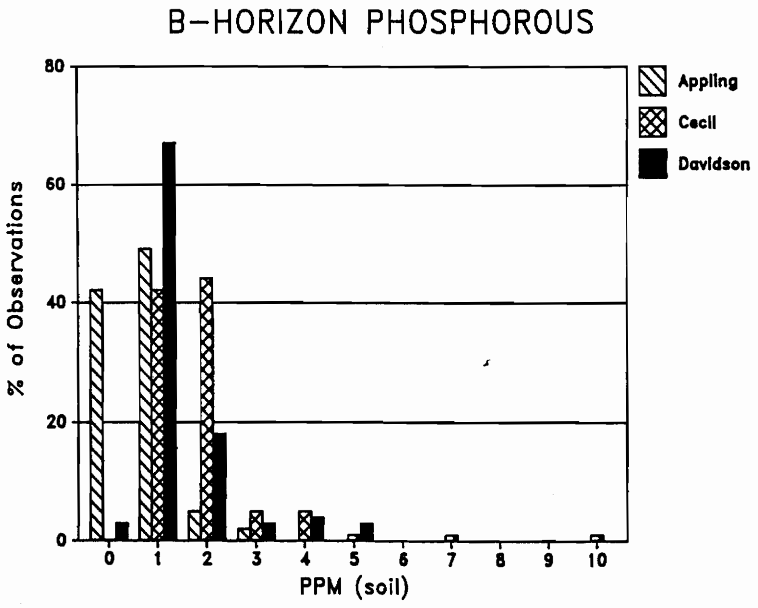
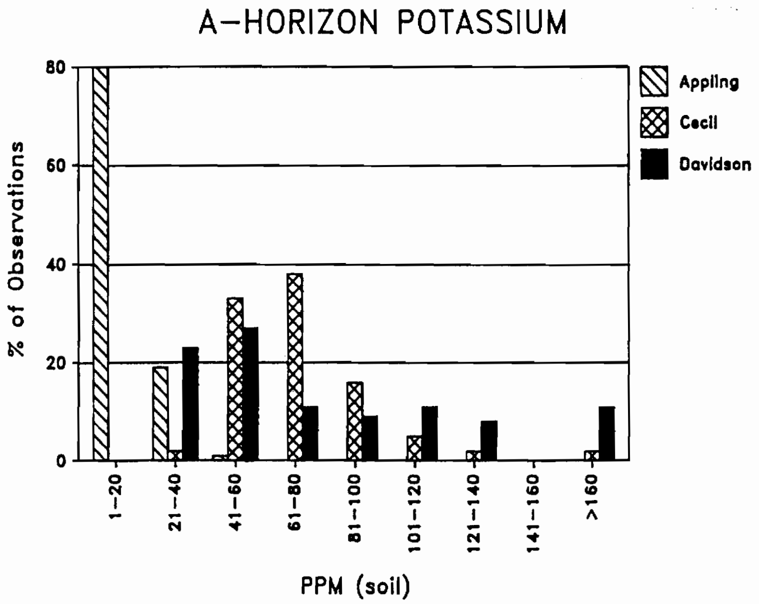


Fig. A.3. A and B horizon phosphorous across all experimental sites by soil mapping unit.



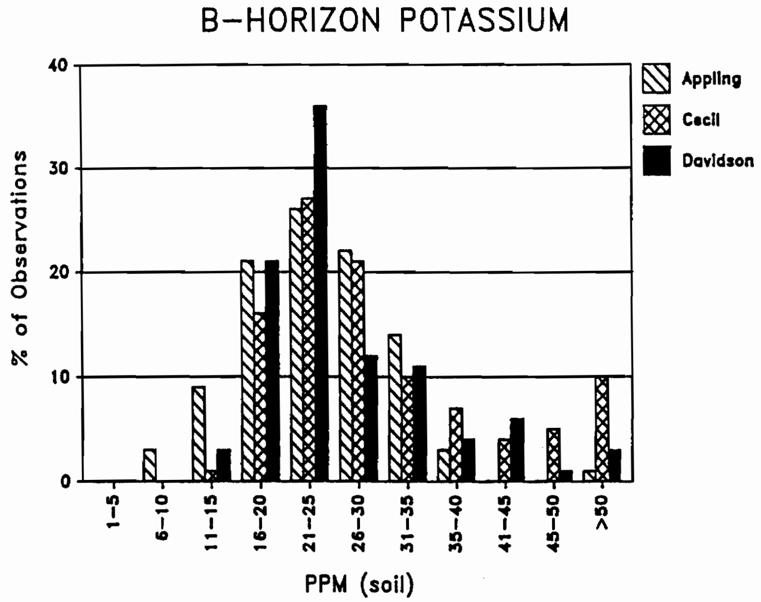


Fig. A.4. A and B horizon potassium across all experimental sites by soil mapping unit.

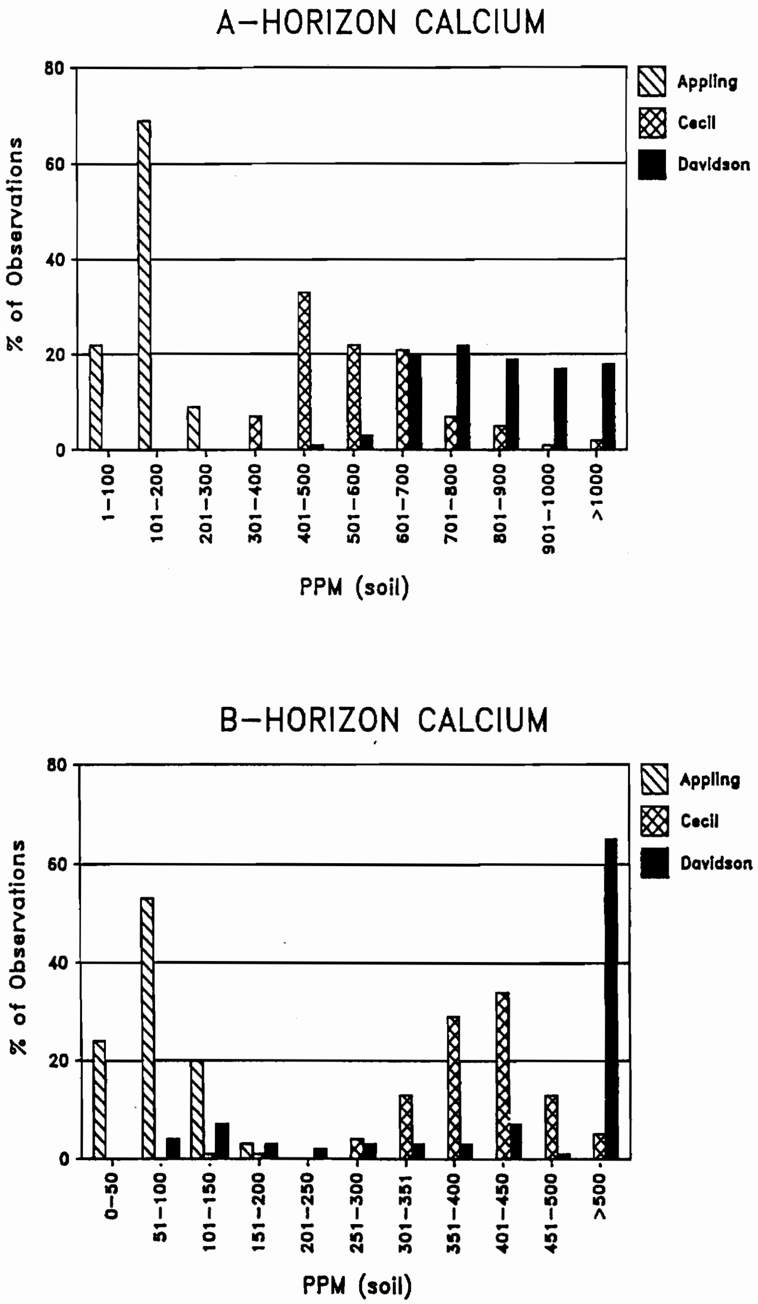
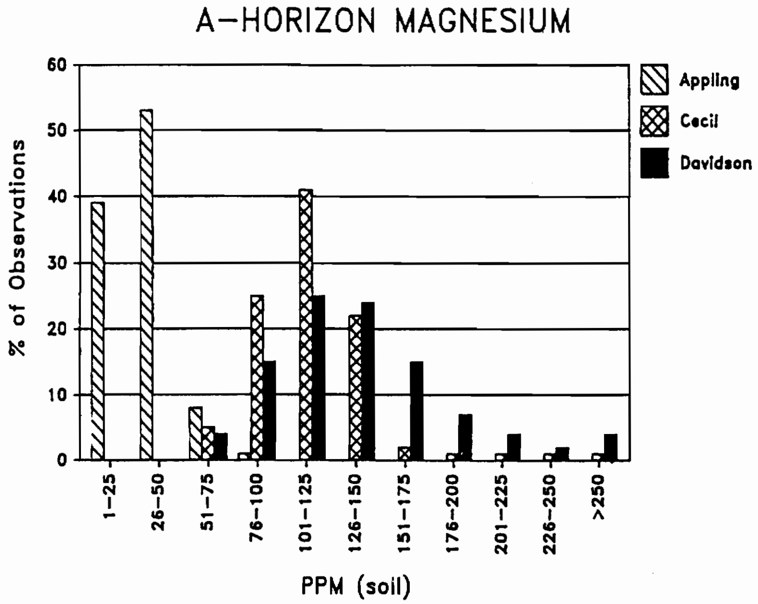


Fig. A.5. A and B horizon calcium across all experimental sites by soil mapping unit.



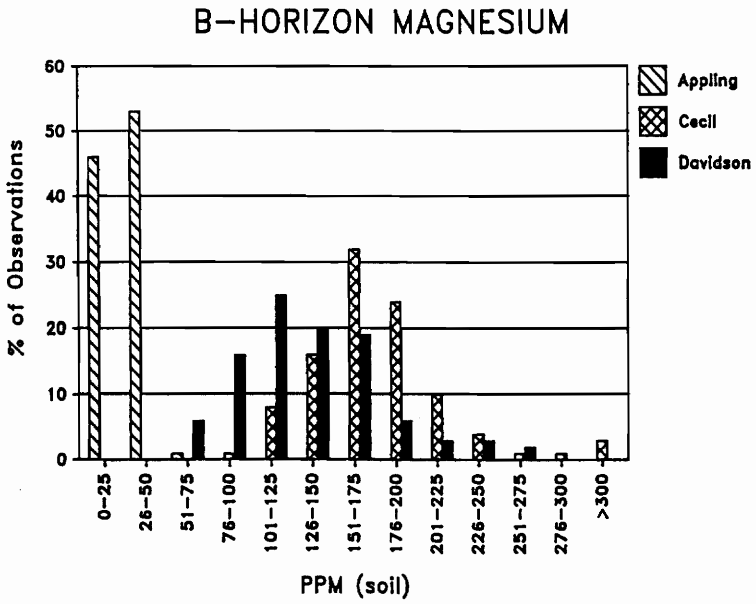


Fig. A.6. A and B horizon magnesium across all experimental sites by soil mapping unit.

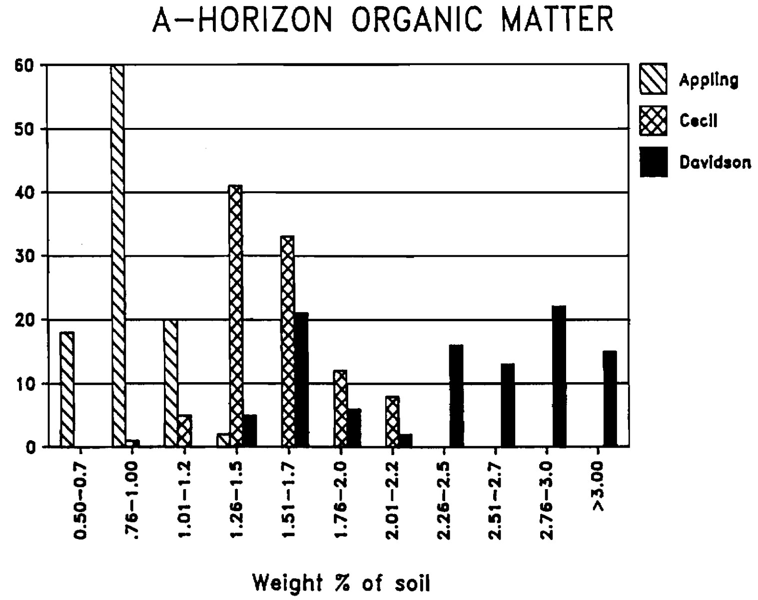


Fig. A.7. A horizon organic matter across all experimental sites by soil mapping unit.

APPENDIX B: Pedon Descriptions of Typical Experimental Site Soils.

Table B.1 -Profile description of pedon L I-23.

Soil Mapping Unit: Appling sandy loam (clayey, kaolinitic, thermic family of Typic Kanhapludults), 7 to 15% slopes, eroded.

Location: Forksville, Va. quadrangle; Wilkerson Farm; approximately 670 m, NE 72 degrees from the junction of Route 602 and Route 610; approximately 1220 m, NW 348 degrees from the junction of Route 602 and Route 603.

Vegetation: Corn, soybeans and tobacco.

Parent Material: Granite and granite gneiss.

Landscape Position: Upland footslope.

Elevation: 135 m.

Relief: 20 m.

Slope: 6%.

Sampled By: Mike Genthner, 7/10/87.

Ap -- 0 to 12 cm; olive brown (2.5Y 4/4) sandy loam; weak fine granular structure; very friable; common very fine and few fine roots; common very fine tubular and irregular pores; strongly acid; clear smooth boundary.

C -- 12 to 23 cm; very pale brown (10YR 7/3) sandy loam; massive; very friable; few very fine, fine and medium roots; common very fine and fine, tubular and irregular pores; moderately acid; clear wavy boundary.

A/C -- 33 to 74 cm; light brownish gray (2.5Y 6/2) and pale yellow (2.5Y 8/3) sandy loam; massive; very friable; few very fine, fine and medium roots; many fine and medium oblique tubular pores; few fine charcoal fragments; strongly acid; abrupt smooth boundary.

Ab -- 74 to 86 cm; olive brown (2.5Y 4/4) and olive yellow (2.5Y 6/6) silt loam; weak fine granular structure; very friable; few very fine, fine and medium roots; many fine and medium oblique and horizontal tubular pores; strongly acid; abrupt smooth boundary.

Ab' -- 86 to 103 cm; olive (5Y 5/3) sandy loam; weak fine granular and fine and medium subangular blocky structure;

Table B.1 -Continued.

very friable; common fine and few medium oblique tubular pores; strongly acid; clear smooth boundary.

Eb -- 103 to 130 cm; pale olive (5Y 6/3) sandy loam; massive to weak medium and coarse subangular blocky structure; very friable; common, very fine, fine and medium oblique tubular pores; strongly acid; clear smooth boundary.

Btb -- 130 to 180 cm; mottled, light yellowish brown (2.5Y 6/4), olive yellow (2.5Y 6/6) and very pale brown (10YR 8/3) sandy loam; weak fine, medium and coarse, subulangular blocky structure; friable; common fine and very fine oblique tubular pores; strongly acid.

Table B.2 -Profile description of pedon L I-33.

Soil Mapping Unit: Appling sandy loam (clayey, kaolinitic, thermic family of Typic Kanhapludults), 7 to 15% slopes, eroded.

Location: Forksville, Va. quadrangle; Wilkerson farm; approximately 670 m, NE 72 degrees from the junction of Route 602 and Route 610; approximately 1220 m, NW 348 degrees from the junction of Route 602 and Route 603.

Vegetation: Corn, soybeans and tobacco.

Parent Material: Granite and granite gneiss.

Landscape Position: Upland sideslope.

Elevation: 135 m.

Relief: 20 m.

Slope: 7%.

Sampled By: Mike Genthner and W. Lee Daniels, 4/12/87.

Ap -- 0 to 24 cm; light olive brown (2.5Y 5/4) loamy sand; weak fine granular and fine and medium subangular blocky structure; very friable; many very fine and medium roots; moderately acid; abrupt smooth boundary.

A1 -- 24 to 40 cm; pale yellow (2.5Y 7/4) loamy sand; weak medium and coarse subangular blocky structure; very friable; many very fine and medium roots; moderately acid; abrupt smooth boundary.

A2 -- 40 to 55 cm; olive brown (2.5Y 4/4) loamy sand; weak medium and coarse subangular blocky structure; very friable; few fine and very fine roots; moderately acid; abrupt smooth boundary.

A3 -- 55 to 71 cm; dark grayish brown (10YR 6/6) loamy sand; massive; very friable; few fine and very fine roots; strongly acid; gradual smooth boundary.

E -- 71 to 88 cm; light gray (2.5Y 7/2) sandy loam; massive; very friable; strongly acid; gradual wavy boundary.

EB -- 88 to 114 cm; light brownish gray (2.5Y 6/2) sandy loam; weak medium and coarse subangular blocky structure;

Table B.2 -Continued.

friable; strongly acid; gradual wavy boundary.

Bt -- 114 to 150 cm; olive yellow (2.5Y 6/6) sandy clay loam; weak to moderate fine and medium subangular blocky structure; friable; strongly acid; gradual wavy boundary.

C -- 150 to 200 cm; light yellowish brown (2.5Y 6/4) sandy clay loam; massive; very strongly acid; friable.

Table B.3 -Profile description of pedon L II-45.

Soil Mapping Unit: Appling sandy loam (clayey, kaolinitic, thermic family of Typic Kanhapludults), 7 to 15% slopes, eroded.

Location: Forksville, Va. quadrangle. Wilkerson Farm. approximately 670 m, NE 72 degrees from the junction of Route 602 and Route 610; approximately 1220 m, NW 348 degrees from the junction of Route 602 and Route 603.

Vegetation: Corn, soybeans and tobacco.

Parent Material: Granite and granite gneiss.

Landscape Position: Upland sideslope.

Elevation: 135 m.

Relief: 20 m.

Slope: 7%.

Sampled By: Mike Genthner, 7/10/87.

Ap -- 0 to 22 cm; yellowish brown (10YR 5/4) loamy sand; weak fine granular and fine, medium and coarse subangular blocky structure; very friable; common very fine and fine roots; common very fine and fine and few medium tubular pores; strongly acid; clear wavy boundary.

E -- 22 to 40 cm; light yellowish brown (2.5Y 6/4) sand; weak, fine, medium and coarse subangular blocky structure; very friable; common very fine and few fine roots; common very fine and fine and few medium tubular pores; moderately acid; clear wavy boundary.

EB -- 40 to 58 cm; light yellowish brown (2.5Y 6/4) loamy sand; weak, fine, medium and coarse subangular blocky structure; friable; few very fine and fine roots; common very fine and fine vesicular and common medium, tubular pores; moderately acid; clear smooth boundary.

Bt1 -- 58 to 86 cm; light olive brown (2.5Y 5/4) sandy loam; common fine to medium, faint, very pale brown (10YR 7/3) mottles; weak, fine, medium and coarse subangular blocky structure; friable; few very fine roots; common fine, very fine and few medium vesicular and tubular pores; strongly acid; clear smooth boundary.

Table B.4 -Continued.

Bt2 -- 86 to 125 cm; yellow (10YR 7/8) sandy loam; common, fine to medium, faint brown (10YR 5/3) and many fine to medium, distinct reddish yellow (7.5YR 7/8) mottles; weak, medium and coarse subangular blocky structure; friable; few, very fine roots; common, very fine vesicular and tubular pores; strongly acid; clear smooth boundary.

Bt3g -- 125 to 185 cm; mottled, white (10YR 8/2), brownish yellow (10YR 6/6) and strong brown (7.5YR 5/8) sandy clay loam; weak medium and coarse subangular blocky structure; friable; common very fine vesicular and tubular pores; very strongly acid; clear smooth boundary.

2Cg -- 185 to 200 cm; mottled light gray (7.5YR 7/0), brownish yellow (10YR 6/8) and red (2.5YR 4/8) sandy clay loam; massive; very friable; strongly acid.

Table B.4 -Profile description of pedon L III-38.

Soil Mapping Unit: Appling sandy loam (clayey, kaolinitic, thermic family of Typic Kanhapludults), 7 to 15% slopes, eroded.

Location: Forksville, Va. quadrangle; Wilkerson farm; approximately 670 m, NE 72 degrees from the junction of Route 602 and Route 610; approximately 1220 m, NW 348 degrees from the junction of Route 602 and Route 603.

Vegetation: Corn, soybeans and tobacco.

Parent Material: Granite and granite gneiss.

Landscape Position: Upland sideslope.

Elevation: 135 m.

Relief: 20 m.

Slope: 7%.

Sampled By: Mike Genthner and W. Lee Daniels, 4/12/87.

Ap -- 0 to 27 cm; light yellowish brown (10YR 6/4) loamy sand; weak medium subangular blocky structure; very friable; common very fine, fine, and medium roots; moderately acid; abrupt smooth boundary.

BA/Bw -- 27 to 50 cm; brownish yellow (10YR 6/8) sandy loam; few fine and medium very pale brown (10YR 8/3) mottles; massive; friable; few very fine, fine, and medium roots; very strongly acid; clear wavy boundary.

Bt -- 50 to 84 cm; brownish yellow (10YR 6/8) sandy clay; weak fine to medium subangular blocky structure; friable; few, fine to medium, distinct red (2.5YR 4/8) mottles; few, fine and very fine roots; very strongly acid; clear wavy boundary.

BC -- 84 to 116 cm; brownish yellow (10YR 6/6) sandy clay loam; common medium and coarse faint yellow (10YR 7/8), many medium prominent red (10R 4/8) and common fine and medium distinct light gray (10YR 7/2) reticulate mottles; weak fine and medium subangular blocky structure; friable; few very fine roots; very strongly acid; gradual wavy boundary.

Table B.4 -Continued.

C -- 116 to 275 cm; mottled yellow (10YR 7/6), light gray (10YR 7/2) and red (10R 4/8) sandy clay loam; massive; very friable; very strongly acid.

Table B.5 -Profile description of pedon AS I-12.

Soil Mapping Unit: Cecil loam (clayey, kaolinitic, thermic family of Typic Kanhapludults), 7 to 15% slopes, eroded.

Location: Chula quadrangle; Amelia Wildlife Management Area; 3400 m, NE 82 degrees from the junction of Route 651 and Route 616; 1730 m, NE 22 degrees from the junction of Route 652 and Route 616, Amelia County, Virginia.

Vegetation: Corn and small grains.

Parent Material: Mica gneiss and schist.

Elevation: 80 m.

Relief: 25 m.

Slope: 9%.

Sampled by: Barry Stewart, W. Lee Daniels, and Mike Genthner, 9/16/86.

Ap -- 0 to 21 cm. dark reddish brown (5YR 3/4) sandy clay loam; weak, medium prismatic structure parting to weak, medium subangular blocky structure; slightly hard (dry), firm (moist) and sticky (wet); common fine roots; common fine to medium pores; approximately 2% disoriented sub-rounded gravel; moderately acid; abrupt smooth boundary.

Bt -- 21 to 60 cm. red (2.5YR 4/6) clay loam; moderate, medium to coarse prismatic structure parting to medium and coarse subangular blocky structure; hard (dry), firm (moist), and sticky (wet); few fine roots; common fine and medium vertical tubular and irregular pores; few fine mica flakes; slightly acid; clear irregular boundary.

CB -- 60 to 80 cm. strong brown (7.5YR 5/8) clay loam with red (2.5YR 4/6) clay flows; weak, medium and coarse subangular blocky structure; friable (moist), slightly sticky (wet); few fine and medium roots; common, fine to medium vertical tubular and irregular pores; many fine mica flakes; slightly acid; clear smooth boundary .

2C1 -- 80 to 116 cm; yellowish brown (10YR 5/6) sandy clay loam; reddish yellow (7.5YR 6/8) root channels, red (2.5YR 4/6) 1-5 mm thick clay flows; massive; friable

Table B.5 -Continued.

(moist), slightly sticky (wet); few, fine roots; few, fine tubular pores; common fine mica flakes; 5% rounded vein quartz and quartzite gravel; moderately acid; clear wavy boundary.

3C2 -- 116 to 175 cm; strong brown (7.5YR 5/8) clay loam; reddish yellow (2.5YR 5/8) clay films; massive; friable (moist), slightly sticky (wet); few, fine roots; few, fine tubular pores; common fine mica flakes; 5% rounded vein quartz and quartzite gravel; strongly acid; clear wavy boundary.

3C2 -- 175 to 195 cm; yellowish brown (10YR 5/8) sandy loam; massive; very friable; common fine mica flakes; 20% rounded vein quartz and quartzite gravel; strongly acid.

Table B.6 -Profile description of pedon AS II-38.

Soil Mapping Unit: Cecil loam (clayey, kaolinitic, thermic family of Typic Kanhapludults), 7 to 15% slopes, eroded.

Location: Chula, Va. quadrangle; Amelia Wildlife Management Area; 3400 m, NE 83 degrees from the junction of Route 651 and Route 616; 1750 m, NE 26 degrees from the junction of Route 652 and Route 616, Amelia County, Virginia.

Vegetation: Corn and small grains.

Parent Material: Mica gneiss and mica schist.

Landscape Position: Upland sideslope.

Elevation: 80 m.

Relief: 25 m.

Slope: 9%.

Sampled By: M.H. Genthner, W.L. Daniels, and B.S. Stewart, 9/16/86.

Ap -- 0 to 20 cm; reddish yellow (5YR 5/6) sandy clay loam; weak fine granular and fine, medium, and coarse subangular blocky structure; slightly hard (dry), friable (moist) and slightly sticky (wet); common fine and very fine roots; few very fine and fine tubular pores; few subrounded pebbles; moderately acid; abrupt smooth boundary.

Bt -- 20 to 50 cm; yellowish red (5YR 5/6) clay loam; reddish brown (5YR 4/4) coatings on faces of peds; weak coarse prismatic structure parting to weak and moderate fine, medium, and coarse subangular blocky; hard (dry), firm (moist) and sticky (wet); few very fine vertical roots; very few fine tubular vertical pores; angular quartz fragments; slightly acid; clear wavy boundary.

CB -- 50 to 72 cm; olive yellow (5Y 6/8) and brownish yellow (10YR 6/8) clay loam; red (2.5YR 4/8) and yellowish red (5YR 5/8) coatings on faces of peds; weak coarse prismatic structure parting to weak fine, medium, and coarse subangular blocky; slightly hard (dry), friable (moist) and slightly sticky (wet); few very fine vertical roots; few very fine tubular vertical pores; few fine flakes of mica; slightly acid; abrupt smooth boundary.

Table B.6 -Continued.

2C1 -- 72 to 124 cm red (2.5YR 4/8) sandy clay loam; yellowish red (5YR 4/6) clay flows; massive; very friable (moist), slightly sticky (wet); few very fine vertical pores; many fine flakes of mica; compact in place; common fine angular quartz pebbles at top of horizon; moderately acid; clear wavy boundary.

3C2 -- 124 to 145 cm; banded, strong brown (7.5YR 5/8) brownish yellow (10YR 6/8), very pale brown (10YR 8/4) and light red (2.5YR 6/8) sandy loam; massive; very friable (moist) slightly sticky; many, fine flakes of mica; strongly acid.

3C3 -- 145 to 175 cm; banded, very pale brown (10YR 8/3), yellowish red (5YR 5/8), very pale brown (10YR 7/3), and brownish yellow (10YR 6/8) sandy loam; massive; very friable; many fine flakes of mica; strongly acid.

Table B.7 -Profile description of pedon AS III-15.

Soil Mapping Unit: Cecil loam (clayey, kaolinitic, thermic family of Typic Kanhapludults), 7 to 15% slopes, eroded.

Location: Chula, Va. quadrangle; Amelia Wildlife Management Area; 3465 m, NE 84 degrees from the junction of Route 651 and Route 616; 1760 m, NE 35 degrees from the junction of Route 652 and Route 616.

Vegetation: Corn and small grains.

Parent Material: mica gneiss and mica schist.

Landscape position: Upland sideslope.

Elevation: 79 m.

Relief: 25 m.

Slope: 8%.

Sampled By: Mike Genthner, 6/12/87.

Ap -- 0 to 15 cm; red (2.5YR 4/6) sandy clay loam; moderate fine and medium granular structure; friable, slightly sticky, slightly plastic; common very fine and fine roots; few fine irregular pores; moderately acid; clear smooth boundary.

Bt1 -- 15 to 45 cm; red (2.5YR 4/8) clay; strong medium prismatic structure parting to moderate fine and medium subangular blocky structure; firm, sticky, plastic; few very fine and fine roots; few fine irregular pores; slightly acid; clear smooth boundary.

Bt2 -- 45 to 60 cm; reddish yellow (5YR 6/8) clay; common medium distinct pink (5YR 8/3) mottles; weak medium and coarse subangular blocky structure; firm, sticky, plastic; few very fine and fine roots; few very fine mica flakes; moderately acid; gradual smooth boundary.

BC -- 60 to 89 cm; reddish yellow (5YR 6/8) clay loam; common medium and coarse distinct pink (5YR 8/3) and common fine prominent black (7.5YR 2.5/1) mottles; weak medium subangular blocky structure; friable, sticky, plastic; few very fine and fine roots; common very fine mica flakes; strongly acid; gradual wavy boundary;

Table B.7 -Continued.

C -- 89 to 150 cm; reddish yellow (5YR 7/8) sandy loam; common medium distinct red (2.5YR 7/8) very pale brown (10YR 7/3) mottles; massive; very friable, slightly sticky, non-plastic; few very fine and fine roots; many fine mica flakes; strongly acid.

Table B.8 -Profile description of pedon AS III-28.

Soil Mapping Unit: Cecil loam (clayey, kaolinitic, thermic family of Typic Kanhapludults), 7 to 15% slopes, eroded.

Location: Chula, Va. quadrangle; Amelia Wildlife Management Area; 3465 m, NE 84 degrees from the junction of Route 651 and Route 616; 1760 m, NE 35 degrees from the junction of Route 652 and Route 616, Amelia County, Virginia.

Vegetation: Corn and small grains.

Parent Material: Mica gneiss and mica schist.

Landscape Position: Upland sideslope.

Elevation: 80 m.

Relief: 25 m.

Slope: 9%.

Sampled By: Mike Genthner, 6/12/87.

Ap -- 0 to 20 cm; yellowish red (5YR 4/6) sandy loam; weak very fine and fine granular and weak fine and medium subangular blocky structure; friable; common very fine and few fine roots; few fine tubular pores; few fine flakes of mica; slightly acid; clear smooth boundary.

Bt1 -- 20 to 70 cm; yellowish red (5YR 5/6) loam; weak and moderate fine, medium, and coarse subangular blocky structure; firm; few fine and very fine roots; many very fine and common fine tubular pores; few fine flakes of mica; slightly acid; clear smooth boundary.

Bt2 -- 70 to 100 cm; yellowish red (5YR 5/6) clay loam; moderate coarse subangular blocky structure parting to moderate fine, medium, and coarse subangular blocky and fine and medium angular blocky; friable; few fine and very fine roots; few fine flakes of mica; moderately acid; clear smooth boundary.

Bt3 -- 100 to 130 cm; red (2.5YR 4/6) clay loam; moderate coarse subangular blocky structure parting to medium and fine subangular and fine angular blocky; friable; few fine and very fine roots; few fine flakes of mica; strongly acid; clear smooth boundary.

Table B.8 -Continued.

2Bt4 -- 130 to 155 cm; red (2.5YR 4/8) clay; moderate medium subangular blocky structure parting to moderate fine and medium subangular and fine angular blocky; friable; few very fine roots; few fine flakes of mica; strongly acid; clear smooth boundary.

2C -- 155 to 208 cm; red (2.5YR 4/8) sandy clay loam; massive; very friable; common fine flakes of mica; strongly acid.

Table B.9 -Profile description for pedon AN I-18.

Soil Mapping Unit: Cecil loam (clayey, kaolinitic, thermic family of Typic Kanhapludults), 2 to 7% slopes, eroded.

Location: Chula, Va. quadrangle; Amelia Wildlife Management Area; 3070 m, NE 67 degrees from the junction of Route 651 and Route 616; 2280 m NE 10 degrees from the junction of Route 652 and Route 616, Amelia County, Virginia.

Vegetation: Corn and small grains.

Parent Material: Mica gneiss and mica schist.

Landscape Position: Upland sideslope.

Elevation: 80 m.

Relief: 25 m.

Slope: 5%.

Sampled By: Mike Genthner, 7/1/87.

Ap -- 0 to 14 cm; reddish brown (5YR 5/4) sandy clay loam; weak fine granular and weak fine, medium, and coarse subangular blocky structure; friable; common very fine and fine and few medium roots; common fine tubular pores; few fine flakes of mica; slightly acid; abrupt smooth boundary.

ABp -- 14 to 27 cm; mottled yellowish red (5YR 4/6) and red (2.5YR 4/6) sandy clay loam; strong very coarse prismatic structure parting to moderate fine, medium and coarse subangular blocky and moderate fine and medium angular blocky; friable; few very fine and fine roots; common very fine and fine random and irregular vesicular and tubular pores; neutral; abrupt smooth boundary.

Bt1 -- 27 to 52 cm; red (2.5YR 4/8) clay; few fine to medium prominent brownish yellow (10YR 6/8) mottles; strong very coarse prismatic structure parting to moderate fine, medium, and coarse and moderate fine and medium angular blocky; friable; common very fine and fine roots; common very fine and few fine random and common fine irregular pores; moderately acid; clear smooth boundary.

Bt2 -- 52 to 75 cm; red (2.5YR 4/8) clay; common medium

Table B.9 -Continued.

distinct yellowish red (5YR 5/8) mottles; strong very coarse prismatic structure parting to moderate fine, medium, and coarse subangular blocky and moderate medium to coarse platy structure parting to moderate fine to medium platy; friable; common very fine horizontal and common very fine and fine roots; common very fine random and common fine irregular pores; moderately acid; clear smooth boundary.

BC1 -- 75 to 89 cm; red (2.5YR 4/8) clay loam; common medium distinct brownish yellow (10YR 6/8) mottles; massive; friable; strongly acid; clear wavy boundary.

2BC2 -- 89 to 110 cm; mottled reddish yellow (7.5YR 6/8), red (2.5YR 4/8) and very pale brown (10YR 7/4) sandy clay loam; massive; very friable; approximately 50% coarse fragments; strongly acid; gradual smooth boundary.

2BC3g -- 110 to 150 cm; mottled reddish yellow (7.5YR 6/8), red (2.5YR 4/8), brownish yellow (10YR 6/8) and white (N 8/0) clay; massive; friable; very strongly acid; diffuse wavy boundary.

2BC4 -- 150 to 192 cm; mottled yellow (10YR 7/6) and red (2.5YR 4/8) clay; massive; very friable; strongly acid.

Table B.10-Profile description of pedon AN I-31.

Soil Mapping Unit: Cecil loam (clayey, kaolinitic, thermic family of Typic Kanhapludults), 2 to 7% slopes, eroded.

Location: Chula, Va. quadrangle; Amelia Wildlife Management Area; 3070 m, NE 67 degrees from the junction of Route 651 and Route 616; 2280 m, NE 10 degrees from the junction of Route 652 and Route 616, Amelia County, Virginia.

Vegetation: Corn and small grains.

Parent Material: Mica gneiss and mica schist.

Landscape Position: Upland sideslope.

Elevation: 80 m.

Relief: 25 m.

Slope: 5%.

Sampled By: Mike Genthner, 7/1/87.

Ap -- 0 to 20 cm; yellowish red (5YR 5/6) clay loam; weak fine, medium, and coarse subangular blocky structure; friable; many very fine and common fine roots; slightly acid; abrupt smooth boundary.

Bt1 -- 20 to 45 cm; red (2.5YR 5/6) clay; moderate coarse subangular blocky structure parting to moderate fine and medium subangular blocky; friable; few very fine and fine roots; few fine irregular and common very fine random tubular pores; moderately acid; gradual wavy boundary.

Bt2 -- 45 to 85 cm; red (2.5YR 4/8) clay; moderate very coarse platy structure parting to fine and medium platy; friable; few very fine and fine roots; common very fine random tubular and few fine irregular pores; moderately acid; diffuse broken boundary.

C -- 85 to 150 cm; mottled yellowish brown (10YR 5/8), yellow (10YR 8/8), very pale brown (10YR 8/3) and red (2.5YR 4/8) sandy clay loam saprolite; massive; very friable; strongly acid.

Table B.11-Profile description of pedon AN II-41.

Soil Mapping Unit: Cecil loam (clayey, kaolinitic, thermic family of Typic Kanhapludults), 2 to 7% slopes, eroded.

Location: Chula, Va. quadrangle; Amelia Wildlife Management Area; 3070 m, NE 70 degrees from the junction of Route 651 and Route 616; 2130 m, NE 13 degrees from the junction of Route 652 and Route 616, Amelia County, Virginia.

Vegetation: Corn and small grains.

Parent Material: Mica gneiss and mica schist.

Landscape Position: Upland sideslope.

Elevation: 84 m.

Relief: 25 m.

Slope: 5%.

Sampled By: Mike Genthner, 7/1/87.

Ap -- 0 to 19 cm; yellowish red (5YR 4/6) clay loam; weak fine granular and weak fine and medium subangular blocky structure; friable; common fine and medium roots; common fine and very fine irregular pores; common fine flakes of mica; slightly acid; abrupt smooth boundary.

Bt -- 19 to 42 cm; red (2.5YR 4/8) clay; weak fine, medium, and coarse subangular blocky structure; friable; few fine and medium roots; few very fine and fine pores; many fine flakes of mica; moderately acid; clear wavy boundary.

BC -- 42 to 52 cm; red (2.5YR 4/8) clay loam; weak fine, medium, and coarse subangular blocky structure; friable; few very fine and fine pores; many fine flakes of mica; moderately acid; clear broken boundary.

C -- 52 to 150 cm; mottled red (2.5YR 4/6), reddish yellow (7.5YR 7/8), very pale brown (10YR 8/3), and black (10YR 8/1) sandy clay loam; massive; very friable; few very fine roots; few very fine pores; many very fine flakes of mica; strongly acid.

Table B.12-Profile desciption of pedon AN III-21.

Soil Mapping Unit: Cecil loam (clayey, kaolinitic, thermic family of Typic Kanhapludults), 2 to 7% slopes, eroded.

Location: Chula, Va. quadrangle; Amelia Wildlife Management Area; 3130 m, NE 74 degrees from the junction of Route 651 and Route 616; 1975 m, NE 18 degrees from the junction of Route 652 and Route 616, Amelia County, Virginia.

Vegetation: Corn and small grains.

Parent Material: Mica gneiss and mica schist.

Landscape Position: Upland sideslope.

Elevation: 90 m.

Relief: 25 m.

Slope: 5%.

Sampled By: Mike Genthner, 7/1/87.

Ap -- 0 to 24 cm; yellowish red (5YR 4/6) silt loam; weak coarse subangular blocky structure parting to weak fine, medium, and coarse subangular blocky and weak fine granular; very friable; common fine and very fine and few medium roots; many fine and very fine vertical pores; moderately acid; abrupt smooth boundary.

Bt -- 24 to 50 cm; red (2.5YR 4/6) clay; moderate coarse prismatic structure parting to moderate fine, medium, and coarse subangular blocky and moderate medium platy; firm; few fine and common very fine roots; few fine and very fine vertical and many very fine horizontal pores; moderately acid; gradual wavy boundary.

BC -- 50 to 74 cm; red (2.5YR 5/8) clay; few fine and medium distinct yellow (10YR 6/8) mottles; moderate fine and medium platy structure; firm; few very fine roots; few fine and very fine horizontal pores; very strongly acid; gradual wavy boundary.

C1 -- 74 to 100 cm; yellowish brown (10YR 5/8) sandy clay; common fine to medium distinct yellow (10YR 8/6) mottles; moderate very fine to medium platy structure; friable; few very fine and common very fine horizontal and vertical

Table B.12-Continued.

irregular pores; very strongly acid; gradual wavy boundary.

C2 -- 100 to 150 cm; mottled dark yellowish brown (10YR 4/6), yellow (10YR 7/8), black (10YR 2/1), reddish yellow (5YR 7/8), and red (2.5YR 5/8) sandy clay loam; massive; very friable; common very fine and few fine irregular pores; strongly acid.

Table B.13-Profile description of pedon O I-22.

Soil Mapping Unit: Davidson clay (clayey, kaolinitic, thermic family of Rhodic Kandiudults), 7 to 15% slopes, severely eroded.

Location: Orange, Va. quadrangle. Northern Piedmont Research Station (VPI). 1885 m, SW 200 degrees from the junction of Route 20 (east) and Route 15; 1550 m, NW 344 degrees from the junction of Route 638 and Route 647.

Vegetation: Cropped.

Parent Material: Greenstone.

Landscape Position: Upland sideslope.

Elevation: 150 m.

Relief: 25 m.

Slope: 9%.

Sampled By: Mike Genthner - 7/30/87.

Ap -- 0 to 20 cm; reddish brown (2.5YR 4/4) silty clay loam; moderate medium prismatic structure parting to weak, fine, medium and coarse subangular blocky and weak fine and medium angular blocky structure; friable, sticky, slightly plastic; common very fine to medium vertical roots; few fine to medium vertical, irregular pores; 2% greenstone and quartz gravel; slightly acid; abrupt smooth boundary.

BA -- 20 to 38 cm; red (2.5YR 5/6) silty clay; moderate medium prismatic structure parting to moderate fine, medium and coarse subangular blocky structure; friable, sticky, plastic; 5% greenstone and quartz gravel; few very fine and medium roots; few very fine and medium pores; slightly acid; clear smooth boundary .

Bt1 -- 38 to 57 cm; red (2.5YR 4/8) clay; moderate medium prismatic structure parting to moderate, fine, medium and coarse subangular blocky structure; friable, sticky, plastic; few very fine and fine roots; common very fine and fine and few medium irregular and tubular pores; 10 % greenstone and quartz gravel; neutral; clear smooth boundary.

Table B.13-Continued.

2Bt2 -- 57 to 90 cm; red (2.5YR 5/6), strong brown (7.5YR 5/8), black (7.5YR 2/0) and yellow (10YR 7/8) clay; moderate medium prismatic structure parting to moderate fine, medium and coarse subangular blocky and moderate fine angular blocky structure; friable, sticky, plastic; few very fine and fine roots; common very fine to fine and few medium irregular pores; 10% greenstone and quartz gravel; moderately acid; clear smooth boundary.

2Bt3 -- 90 to 123 cm; mottled very pale brown (10YR 7/3), red (10R 4/6) and red (2.5YR 4/8) clay; moderate medium prismatic structure parting to moderate coarse subangular blocky and moderate fine and medium angular blocky structure; friable, sticky, plastic; common very fine and fine and few medium irregular pores; 3% gravel; very strongly acid; clear smooth boundary.

3Bt4 -- 123 to 150 cm; red (10R 4/8) clay; many fine and medium distinct yellow (10YR 7/8) and very pale brown (10YR 8/3) mottles; moderate coarse subangular blocky structure parting to moderate fine and medium subangular blocky structure and moderate fine and medium angular blocky structure; friable, sticky, plastic; 12% gravel; extremely acid; clear smooth boundary.

3BC -- 150 to 170 cm; mottled red (10R 4/8), yellow (10YR 7/8) and very pale brown (10YR 8/3) clay; weak medium and coarse subangular blocky structure; friable, sticky, plastic; 6% gravel; extremely acid; clear smooth boundary.

3C -- 170 to 200 cm; mottled red (10YR 4/8), yellow (10YR 7/8) and very pale brown (10YR 8/3) clay; massive; friable, sticky, plastic; less than 1% gravel; extremely acid.

Table B.14-Profile description of pedon O I-48.

Soil Mapping Unit: Davidson clay (clayey, kaolinitic, thermic family of Rhodic Kandiudults), 7 to 15% slopes, severely eroded.

Location: Orange, Va. quadrangle. Northern Piedmont Research Station (VPI). 1885 m, SW 200 degrees from the junction of Route 20 (east) and Route 15; 1550 m, NW 344 degrees from the junction of Route 638 and Route 647.

Vegetation: Cropped.

Parent Material: Greenstone.

Landscape Position: Upland sideslope.

Elevation: 150 m.

Relief: 25 m.

Slope: 9%.

Sampled By: Mike Genthner - 7/30/87.

Ap -- 0 to 16 cm; red (10R 4/6) clay; strong coarse prismatic parting to moderate fine and medium angular blocky and subangular blocky structure; friable; common very fine roots; common very fine and fine irregular pores; moderately acid; clear smooth boundary.

BA -- 16 to 42 cm; red (10R 4/6) clay; strong coarse prismatic structure parting to strong coarse subangular and moderate fine and medium subangular blocky structure; friable; few very fine roots; common very fine and fine irregular pores; strongly acid; clear smooth boundary.

Bt1 -- 42 to 79 cm; reddish yellow (7.5YR 6/8) clay; red (10R 4/6) coatings on faces of peds; strong coarse prismatic structure parting to strong medium and coarse subangular blocky and strong medium and fine angular blocky; friable; many medium and very fine irregular pores; very strongly acid; clear smooth boundary.

Bt2 -- 79 to 110 cm; mottled red (10R 4/6) and reddish yellow (7.5YR 6/8) silty clay; strong coarse to very coarse prismatic structure parting to strong medium and coarse subangular and strong fine and medium angular blocky; friable; common quartz and weathered greenstone

Table B.14-Continued.

pebbles; common very fine, fine and medium pores; very strongly acid; clear smooth boundary.

2Bt3 -- 110 to 140 cm; mottled red (10R 4/8), strong brown (7.5YR 5/8), and white (10YR 8/2) clay; strong fine, medium and coarse subangular and angular blocky structure; friable; thick (1-2 mm) clay skins; very strongly acid; many quartz pebbles and blue-black iron-manganese concretions.

Table B.15-Profile description of pedon O II-18.

Soil Mapping Unit: Davidson clay (clayey, kaolinitic, thermic family of Rhodic Kandiudults), 7 to 15% slopes, severely eroded.

Location: Gordonsville, Va. quadrangle; Sedwick Farm; approximately 2900 m, NE 8 degrees from the intersection of Route 639 and Route 15; approximately 1750 m, NE 35 degrees from the junction of Route 652 and Route 616.

Vegetation: Corn.

Parent Material: Greenstone.

Landscape Position: Upland sideslope.

Elevation: 180 m.

Relief: 75 m.

Slope: 9%.

Sampled By: Mike Genthner - 7/29/87.

Ap -- 0 to 23 cm; dark red (2.5YR 3/6) silty clay; strong medium prismatic structure parting to moderate fine, medium and coarse subangular blocky structure; friable, sticky, slightly plastic; common very fine, fine and medium roots; common very fine and medium random irregular and tubular pores; strongly acid; abrupt smooth boundary.

Bt1 -- 23 to 60 cm; red (2.5YR 4/6) clay; moderate medium prismatic structure parting to moderate fine, medium, and coarse subangular blocky structure; friable, sticky, plastic; few very fine and fine roots; common very fine, fine and medium random tubular and irregular pores; common faint clay skins; strongly acid; clear smooth boundary.

Bt2 -- 60 to 96 cm; red (2.5YR 4/6) clay; moderate fine, medium and coarse subangular and angular blocky structure; friable, sticky, plastic; few very fine and fine roots; few very fine and fine random irregular tubular pores; many distinct clay films on ped faces; very strongly acid; clear smooth boundary .

Bt3 -- 96 to 150 cm; red (2.5YR 4/6) clay; common fine and medium distinct yellow (10YR 8/8) mottles; moderate coarse subangular blocky structure parting to moderate fine and

Table B.15-Continued.

medium angular and subangular blocky structure; few very fine roots; few very fine and fine random irregular and tubular pores; strongly acid; clear smooth boundary.

Bt4 -- 150 to 260 cm; red (2.5YR 4/6) clay; common fine and medium distinct yellow (10YR 8/8)mottles; weak fine, medium and coarse subangular blocky structure; very strongly acid.

Table B.16-Profile description of pedon O II-33.

Soil Mapping Unit: Davidson clay (clayey, kaolinitic, thermic family of Rhodic Kandiudults), 7 to 15% slopes, severely eroded.

Location: Gordonsville, Va. quadrangle; Sedwick Farm; approximately 2900 m, NE 8 degrees from the intersection of Route 639 and Route 15; approximately 1750 m, NE 35 degrees from the junction of Route 652 and Route 616.

Vegetation: Corn.

Parent Material: Greenstone.

Landscape Position: Upland sideslope.

Elevation: 180 m.

Relief: 75 m.

Slope: 9%.

Sampled By: Mike Genthner - 7/29/87.

Ap1 -- 0 to 10 cm; yellowish red (5YR 4/6) silty clay loam; weak coarse subangular blocky structure parting to moderate fine and medium subangular and moderate fine granular; friable; common fine and very fine vertical roots; common irregular oblique pores; moderately acid; abrupt smooth boundary.

Ap2 -- 10 to 28 cm; yellowish red (5YR 4/6) silty clay loam; weak coarse subangular blocky structure parting to weak fine and medium subangular blocky; friable; few fine and common very fine and medium roots; common fine and very fine irregular pores; moderately acid; abrupt smooth boundary;

Bt1 -- 28 to 62 cm; red (2.5YR 4/6) clay; moderate coarse and very coarse prismatic structure; friable; common very fine and few fine roots; common fine and very fine irregular pores; moderately acid; clear smooth boundary.

Bt2 -- 62 to 100 cm; red (2.5YR 4/8) clay; weak coarse and weak and moderate very coarse prismatic structure parting to moderate fine medium and coarse subangular blocky; friable; common very fine roots; common fine and very fine irregular pores; strongly acid; clear wavy boundary.

Table B.16-Continued.

Bt3 -- 100 to 110 cm; red (2.5YR 4/6) clay; moderate fine and medium subangular blocky and fine and medium angular blocky structure; friable; few very fine roots; few fine and common very fine irregular pores; strongly acid; clear wavy boundary.

2Bt4 -- 110 to 140 cm; reddish brown (2.5YR 4/4) clay; moderate fine and medium subangular and angular blocky structure; friable; few very fine roots; common very fine irregular pores; strongly acid; approximately 50% rock fragments; clear wavy boundary.

2Bt5 -- 140 to 220 cm; red (2.5YR 4/8) clay; weak fine, medium, and coarse subangular blocky structure; friable; very strongly acid; clear boundary.

2BC -- 220 to 250 cm; mottled red (2.5YR 4/6) and olive yellow (2.5Y 6/6) clay; weak fine and medium subangular blocky structure; very friable; very strongly acid; clear boundary.

2C -- 250 to 300 cm; yellowish red (5YR 5/6) sandy loam; weak fine, medium, and coarse subangular blocky structure; friable; very strongly acid.

Table B.17-Profile description of pedon O III-13.

Soil Mapping Unit: Davidson clay (clayey, kaolinitic, thermic family of Rhodic Kandiudults), 7 to 15% slopes, severely eroded .

Location: Orange, Va. quadrangle; Taylor farm; 800 m, NW 300 degrees from the junction of Route 612 and Route 20; 3650 m, NE 32 degrees from the junction of Route 638 and Route 647.

Vegetation: Pasture.

Parent Material: Greenstone.

Landscape Position: Upland sideslope.

Elevation: 160 m.

Relief: 55 m.

Slope: 10%.

Sampled By: Mike Genthner, 7/31/87.

Ap1 -- 0 to 9 cm; dark red (2.5YR 3/6) silty clay; moderate coarse prismatic structure parting to moderate fine and medium subangular blocky structure; friable, sticky, slightly plastic; common very fine and fine roots; common very fine and fine irregular and tubular pores; slightly acid; clear smooth boundary.

Ap2 -- 9 to 24 cm; dark red (2.5YR 3/6) silty clay loam; moderate coarse prismatic structure parting to moderate fine, medium and coarse subangular blocky structure; friable, sticky, slightly plastic; common very fine and fine roots; common very fine and fine irregular and tubular pores; 10% gravel; slightly acid; clear smooth boundary.

BA -- 24 to 61 cm; dark red (2.5YR 3/6) gravelly silty clay loam; weak fine, medium and coarse subangular blocky structure; friable, sticky, slightly plastic; few very fine and fine roots; common very fine tubular pores; neutral; 20% rock fragments; clear smooth boundary.

Bt1 -- 61 to 109 cm; red (2.5YR 4/6) gravelly silty clay loam; moderate fine, medium and coarse subangular structure and fine angular blocky structure; friable,

Table B.17-Continued.

sticky, plastic; few very fine and fine roots; common very fine and fine tubular and irregular pores; neutral; 30 % rock fragments; clear smooth boundary.

2Bt2 -- 109 to 126 cm; red (2.5YR 5/8) silty clay loam; many fine and medium distinct reddish yellow (5YR 6/8) and reddish brown (5YR 4/3) mottles; weak fine, medium and coarse subangular blocky structure; friable, sticky, plastic; few very fine roots; common very fine and fine tubular and irregular pores; neutral; less than 2% rock fragments; clear smooth boundary.

2Bt3 -- 126 to 151 cm; red (2.5YR 5/8) silty clay; many fine and medium distinct reddish yellow (7.5YR 7/8) mottles; weak fine, medium and coarse subangular blocky structure; friable, sticky, plastic; less than 2% rock fragments; neutral; clear smooth boundary.

2C -- 151 to 175 cm; brownish yellow (10YR 6/8) silt loam; many fine and medium distinct black (10YR 2/1) and light red (2.5YR 6/8) mottles; massive; friable, slightly sticky, slightly plastic; 2% rock fragments; neutral.

Table B.18-Profile description of pedon O III-48.

Soil Mapping Unit: Davidson clay (clayey, kaolinitic, thermic family of Rhodic Kandiudults), 7 to 15% slopes, severely eroded.

Location: Orange, Va. quadrangle; Taylor farm; 790 m, NW 300 degrees from the junction of Route 612 and Route 20; 3650 m, NE 32 degrees from the junction of Route 638 and Route 647.

Vegetation: Pasture.

Parent Material: Greenstone.

Landscape Position: Upland sideslope.

Elevation: 160 m.

Relief: 55 m.

Slope: 10%.

Sampled By: Mike Genthner, 7/31/87.

Ap -- 0 to 26 cm; dark red (2.5YR 3/6) silty clay; moderate coarse prismatic structure parting to moderate fine granular and fine, medium, and coarse subangular blocky; friable; common fine and very fine roots; many very fine, fine, and medium tubular and irregular pores; clear smooth boundary.

Bt -- 26 to 57 cm; red (2.5YR 4/8) silty clay; moderate very coarse prismatic structure parting to moderate fine, medium, and coarse subangualr blocky; friable; few fine and very fine roots; many very fine tubular and common fine and medium irregular pores; gradual wavy boundary.

CB -- 57 to 94 cm; mottled red (2.5YR 4/6), light red (2.5YR 6/8), and brownish yellow (10YR 6/8) silty clay; weak fine, medium, and coarse subangular blocky structure; friable; few fine and very fine roots; few fine and medium irregular and tubular pores; gradual wavy boundary.

C -- 94 to 150 cm; mottled brownish yellow (10YR 6/8), red (2.5YR 4/8), and light red (2.5YR 6/8) silty clay loam; massive; very friable; few very fine roots; few very fine pores.

APPENDIX C: Physical and Chemical Characterization Data for Typical Experimental Site Soils.

Table C.1. Physical Characteristics of Typical Pedons.

Horizon	Depth	Coarse frag.	VCS	CS	MS	FS	VFS	Sand	Silt	Clay	Bulk Density
	cm	% by wt.									Mg m^{-3}
Pedon AN I-18											
Ap	0-14	8.9	3.0	5.2	10.4	20.6	10.8	50.1	26.1	23.8	1.70
ABp	0-27	3.8	3.3	4.6	8.3	18.5	11.3	46.1	24.4	29.5	1.76
Bt1	27-52	0.4	1.8	3.7	5.9	12.4	8.4	32.2	19.5	48.3	1.55
Bt2	52-75	0.1	0.8	1.7	3.3	7.6	7.2	20.7	30.6	48.7	1.49
BC1	75-89	0.2	0.9	4.7	9.7	16.7	10.1	42.1	21.1	36.8	1.56
2BC2	89-110	50.6	5.0	7.1	13.7	22.9	12.2	60.9	19.4	19.7	1.77
2BC3g	110-150	2.2	2.5	4.7	8.6	16.1	9.2	41.1	15.2	43.7	1.57
2BC4	150-192	0.4	1.5	4.1	7.4	14.8	11.6	39.4	17.3	43.3	
Pedon AN I-31											
Ap	0-20	5.9	2.7	5.4	12.6	20.1	10.2	51.0	26.7	22.3	1.76
Bt1	20-45	0.5	2.1	3.2	6.8	10.8	6.1	30.0	21.4	49.6	1.51
Bt2	45-85	0.2	1.1	3.6	6.8	10.9	7.6	29.9	20.7	49.3	1.44
C	85-150	0.3	3.4	7.1	8.9	17.2	16.4	53.0	27.2	19.8	1.45
Pedon AN II-41											
Ap	0-19	7.4	3.4	4.7	8.9	16.5	8.0	41.5	23.1	35.4	1.67
Bt	19-42	1.6	1.1	2.8	5.9	13.6	8.2	31.6	22.5	45.9	1.45
BC	42-52	0.2	0.7	2.7	7.0	19.6	11.2	41.2	20.0	38.8	1.44
C	52-150	2.3	2.8	4.3	10.3	28.3	14.0	59.7	16.5	23.8	1.45
Pedon AN III-21											
Ap	0-24	5.7	2.7	5.4	11.1	19.9	8.0	47.1	18.4	34.5	1.71
Bt	24-50	1.4	3.0	4.6	5.9	7.8	4.3	25.6	17.7	56.7	1.44
BC	50-74	3.8	3.9	5.2	5.3	7.4	7.1	28.9	13.4	57.7	1.41
C1	74-100	0.5	3.6	9.7	10.3	12.6	9.3	45.5	17.4	37.1	1.40
C2	100-150	0.5	6.1	12.0	11.6	13.6	9.8	53.1	17.8	29.1	1.44

Table C.1 (cont'd.). Physical Characteristics of Typical Pedons.

Horizon	Depth	Coarse frag.	VCS	CS	MS	FS	VFS	Sand	Silt	Clay	Bulk Density
	cm	% by wt.									Mg m^{-3}
					Pedon AS I-12						
Ap	0-21	3.3	1.5	3.7	6.7	23.8	11.4	47.1	27.2	25.7	1.53
Bt	21-60	1.1	1.9	3.2	3.9	13.9	8.3	31.2	30.9	37.9	1.58
CB	60-80	0.1	0.2	1.0	2.3	10.5	14.7	28.7	28.9	42.4	1.45
2C1	80-116	5.2	1.4	4.8	10.1	20.9	11.7	48.9	26.0	25.1	1.67
3C2	116-175	4.5	3.0	4.6	6.9	13.8	12.8	41.1	26.7	32.2	
3C3	175-195	20.6	10.2	9.2	8.5	17.3	19.4	64.6	22.2	13.2	
					Pedon AS II-38						
Ap	0-20	4.6	3.1	5.5	13.3	23.6	10.3	55.8	23.5	20.7	1.57
Bt	20-50	2.8	1.8	3.1	7.4	12.8	7.0	32.1	32.2	35.7	1.61
CB	50-72	0.5	1.5	3.8	9.0	17.2	9.5	41.0	28.1	30.9	1.63
2C1	72-124	1.2	3.4	6.9	15.0	24.3	9.7	59.3	9.5	31.2	
3C2	124-145	0.4	1.1	2.5	8.0	35.3	26.9	73.8	18.5	7.7	
3C3	145-175	0.4	3.5	5.6	9.8	28.7	24.7	72.3	20.7	7.0	
					Pedon AS III-15						
Ap	0-15	2.1	1.6	3.7	8.8	21.6	11.0	46.7	23.4	29.9	1.62
Bt1	15-45	0.3	0.5	1.0	1.7	10.0	7.8	21.0	29.8	49.2	1.42
Bt2	45-60	0.0	0.5	2.1	4.2	12.3	12.5	31.6	28.3	40.1	1.35
BC	60-89	0.0	1.0	2.4	6.5	17.6	14.2	41.7	28.4	29.9	1.21
C	89-150	0.1	5.2	8.2	12.2	29.4	16.6	71.6	19.0	9.4	1.28
					Pedon AS III-28						
Ap	0-20	2.0	2.7	5.1	12.3	24.0	13.1	57.2	23.7	19.1	1.69
Bt1	20-70	0.1	0.9	4.5	8.6	13.6	8.9	36.5	39.6	23.9	1.69
Bt2	70-100	0.2	1.6	4.1	7.6	11.8	9.2	34.3	33.4	32.3	1.66
Bt3	100-130	0.6	2.4	3.7	6.2	10.6	12.1	35.0	32.0	33.0	1.64
2Bt4	130-155	0.2	1.7	2.7	5.2	12.4	14.8	36.8	20.9	42.3	1.49
2C	155-208	7.6	3.2	4.5	6.5	15.0	17.4	46.6	23.7	29.7	

Table C.1 (cont'd.). Physical Characteristics of Typical Pedons.

Horizon	Depth	Coarse frag.	VCS	CS	MS	FS	VFS	Sand	Silt	Clay	Bulk Density
	cm	% by wt.									Mg m^{-3}
					Pedon L I-23						
Ap	0-12	1.4	8.2	17.6	17.7	22.0	9.1	74.6	18.2	7.2	1.60
C	12-33	0.8	9.4	22.6	20.9	22.7	7.4	83.0	12.9	4.1	1.76
A\C	33-74	0.1	5.9	18.9	20.7	22.7	9.4	77.6	15.7	6.7	1.76
Ab	74-86		2.1	5.9	5.1	8.0	9.2	30.3	60.5	9.2	1.34
Ab'	86-103	0.9	5.7	20.6	21.8	19.8	6.8	74.7	17.9	7.4	1.75
Eb	103-130	0.6	5.1	19.9	18.3	25.5	7.8	76.6	17.5	5.9	1.70
Btb	130-180	0.6	5.9	20.6	18.1	18.8	6.4	69.8	11.5	18.7	1.75
					Pedon L I-33						
Ap	0-24		9.0	21.4	23.9	25.6	8.5	88.4	8.5	3.1	1.70
A1	24-40	1.1	9.3	23.1	21.7	24.5	8.8	87.4	8.9	3.7	1.74
A2	40-55	0.8	7.9	21.5	20.8	26.3	10.2	86.7	10.6	2.7	1.65
A3	55-71	1.4	4.7	21.3	23.3	19.9	6.2	75.4	20.9	3.7	1.68
E	71-88	0.9	5.7	18.3	21.2	21.3	8.0	74.5	19.9	5.6	
EB	88-114	4.0	7.3	19.1	18.7	19.1	7.6	71.8	19.8	8.4	
Bt	114-150	3.6	6.3	14.0	15.5	17.8	6.3	59.9	10.5	29.6	
C	150-200	1.4	7.3	17.1	17.6	17.6	6.4	66.0	9.8	24.2	
					Pedon L II-45						
Ap	0-22	0.4	9.0	21.4	24.2	25.9	7.7	88.2	8.4	3.4	1.75
E	22-40	0.8	4.2	18.4	25.2	30.2	9.3	87.3	12.6	0.1	1.85
EB	40-58	0.5	3.1	15.2	22.1	25.9	9.8	76.1	17.0	6.9	1.77
Bt1	58-86	1.3	5.4	16.3	17.3	20.0	7.5	66.5	21.4	12.1	1.75
Bt2	86-125	3.7	10.2	18.2	16.6	21.9	7.6	74.5	11.4	14.1	1.94
Bt3g	125-185	21.2	11.6	16.1	15.6	15.5	5.4	64.2	15.0	20.8	1.85
2Cg	185-200	6.6	18.3	11.5	8.2	10.2	6.9	55.1	12.7	32.2	
					Pedon L III-28						
Ap	0-27	0.8	4.1	12.5	20.2	31.6	11.2	79.6	13.3	7.1	1.79
BA\Bw	27-50	1.0	3.5	12.9	16.5	23.1	9.6	65.6	19.1	15.3	1.87
Bt	50-84	0.8	7.8	13.8	11.7	14.1	5.5	52.9	9.1	38.0	1.71
BC	84-116	0.9	7.0	13.9	14.7	16.6	5.9	58.1	8.1	33.8	1.78
C	116-180	0.9	6.2	15.5	18.8	20.8	7.4	68.7	10.2	21.1	1.79

Table C.1 (cont'd.). Physical Characteristics of Typical Pedons.

Horizon	Depth	Coarse frag.	VCS	CS	MS	FS	VFS	Sand	Silt	Clay	Bulk Density
	cm	% by wt.									Mg m^{-3}
Pedon O I-22											
Ap	0-20	2.3	1.4	2.8	3.3	4.6	3.6	15.7	46.3	38.0	1.69
BA	20-38	4.0	1.6	2.7	3.8	4.7	4.5	17.3	40.0	42.7	1.62
Bt1	38-57	10.0	2.5	3.4	2.4	6.3	4.7	19.3	29.5	51.2	1.59
2Bt2	57-90	10.3	1.9	2.7	3.4	5.0	4.6	17.6	24.6	57.8	1.56
2Bt3	90-123	2.9	2.4	3.6	4.5	6.4	6.4	23.3	29.1	47.6	1.65
3Bt4	123-150	12.1	2.6	3.0	2.9	3.9	4.0	16.4	22.8	60.8	
3BC	150-170	6.1	2.3	3.2	3.2	4.4	4.3	17.4	29.2	53.4	
3C	170-200	0.5	0.7	1.1	1.4	1.5	2.2	6.9	33.5	59.6	
Pedon O I-48											
Ap	0-16	3.2	1.4	1.3	1.4	1.9	1.6	7.6	27.2	65.2	1.59
BA	16-42	0.7	0.5	0.7	0.9	1.1	1.6	4.8	31.1	64.1	1.48
Bt1	42-79	2.2	1.1	1.1	1.1	1.3	1.8	6.4	28.7	64.9	1.50
Bt2	79-110	2.0	1.6	1.1	1.0	1.4	1.7	6.8	45.2	48.0	1.50
2Bt3	110-140	8.1	2.4	2.8	1.9	3.4	3.3	13.8	28.3	57.9	1.58
Pedon O II-18											
Ap	0-23	1.7	1.8	1.2	1.2	1.8	1.8	7.8	43.9	48.3	1.59
Bt1	23-60	0.2	0.4	0.3	0.5	1.2	1.6	4.0	27.3	68.7	1.49
Bt2	60-96	0.2	0.5	0.5	0.5	0.9	1.4	3.8	29.9	66.3	1.52
Bt3	96-150	2.6	0.6	0.5	0.7	1.1	1.9	4.8	29.6	65.6	1.53
Bt4	150-260	0.4	0.7	0.5	0.9	1.3	1.5	4.9	30.5	64.6	
Pedon O II-33											
Ap1	0-10	3.5	4.5	1.5	1.3	1.7	1.7	10.7	57.6	31.7	
Ap2	10-28	10.1									1.61
Bt1	28-62	0.5	0.8	0.7	0.6	1.3	1.5	4.9	38.9	56.2	1.50
Bt2	62-100	0.1	0.2	0.4	0.6	1.1	1.4	3.7	31.0	65.3	1.55
Bt3	100-110	0.3	1.1	0.8	0.7	1.0	1.8	5.4	31.1	63.5	1.53
2Bt4	110-140	48.6	1.3	1.1	0.9	1.6	2.6	7.5	30.5	62.0	1.50
2Bt5	140-220	0.1	0.6	0.5	0.8	2.6	7.2	11.7	33.8	54.5	
2BC	220-250	4.1	1.4	2.0	2.1	3.4	6.9	15.8	32.7	51.5	
2C	250-300	0.0	0.0	0.2	0.3	0.6	2.1	3.2	52.1	44.7	

Table C.1. (cont'd.). Physical Characteristics of Typical Pedons.

Horizon	Depth	Coarse frag.	VCS	CS	MS	FS	VFS	Sand	Silt	Clay	Bulk Density
	cm	% by wt.									Mg m^{-3}
						Pedon O III-13					
Ap1	0-9	1.0	2.5	1.2	1.6	2.8	2.5	10.6	45.7	43.7	1.38
Ap2	9-24	10.3	1.2	1.0	1.8	3.1	3.0	10.1	50.1	39.8	1.53
BA	24-61	22.2	1.2	1.3	1.3	2.7	3.4	9.9	55.8	34.3	1.59
Bt1	61-109	29.2	2.2	1.7	1.2	2.9	3.3	11.3	49.8	38.5	1.57
2Bt2	109-126	1.6	1.8	1.3	0.9	1.5	3.8	9.3	51.3	39.4	1.50
2Bt3	126-151	1.2	1.6	1.2	0.9	1.0	2.5	7.2	48.0	44.8	
2C	151-175	2.1	1.4	1.4	1.2	1.5	5.3	10.8	71.3	17.9	
						Pedon O III-48					
Ap	0-26	8.7	1.7	1.3	1.5	2.4	2.6	9.5	41.4	49.1	1.56
Bt	26-57	0.8	0.5	0.5	1.0	2.6	3.2	7.8	42.0	50.2	1.49
CB	57-94	0.0	0.5	0.8	1.0	4.3	6.8	13.4	46.5	40.1	1.37
C	94-150	0.1	0.3	0.7	0.7	2.1	6.7	10.5	62.2	27.3	1.17

Table C.2. Chemical Characteristics of Typical Pedons.

Horizon	Depth	pH	Organic matter	Fe	P	Ca	Mg	K	H	Al	CEC	ECEC	Base satn.
	cm		--- g kg^{-1}---		ppm	------------------			cmol kg^{-1}			-----------------	%
Pedon AN I-18													
Ap	0-14	6.54	10.9	21.0	28	4.69	2.30	0.34	4.78	0.05	12.11	7.38	61
ABp	14-27	6.76		26.2	8	2.52	1.57	0.12	3.98	0.05	8.19	4.26	51
Bt1	27-52	5.58	3.6	46.1	3	2.66	2.05	0.09	6.37	0.25	11.17	5.05	43
Bt2	52-75	5.62	2.5	47.0	3	1.91	2.18	0.09	6.57	0.25	10.75	4.43	39
BC1	75-89	5.44	0.4	32.2	2	0.72	1.25	0.09	5.77	0.95	7.83	3.01	26
2BC2	89-110	5.36	0.4	10.7	2	0.10	0.48	0.07	3.78	1.05	4.43	2.60	15
2BC3g	110-150	4.91	0.4	28.1	2	0.08	1.50	0.20	7.96	1.95	9.74	3.73	18
2BC4	150-192	5.40	0.4	42.3	2	0.06	1.61	0.23	8.76	1.65	10.66	3.55	18
Pedon AN I-31													
Ap	0-20	6.23		17.2	11	2.77	1.14	0.27	4.38	0.05	8.56	4.23	49
Bt1	20-45	5.85		37.4	4	2.72	1.80	0.16	6.77	0.10	11.45	4.78	41
Bt2	45-85	5.33		43.8	2	1.64	2.50	0.13	8.96	0.65	13.23	4.92	32
C	85-150	5.10		25.4	2	0.14	1.20	0.28	7.56	2.45	9.18	4.07	18
Pedon AN II-41													
Ap	0-19	6.38		35.7	13	3.86	1.85	0.41	6.17	0.25	12.29	6.37	50
Bt	19-42	5.72		48.9	2	2.96	1.94	0.22	6.77	0.10	11.89	5.22	43
BC	42-52	5.67		46.3	2	2.58	1.87	0.18	7.16	0.25	11.79	4.88	39
C	52-150	5.28		33.3	2	1.34	1.84	0.16	5.17	0.65	8.51	3.99	39
Pedon AN III-21													
Ap	0-24	5.60		22.9	12	2.54	0.82	0.18	5.57	0.20	9.11	3.74	39
Bt	24-50	5.56		53.8	2	3.07	1.64	0.07	7.96	0.35	12.74	5.13	38
BC	50-74	4.92		54.8	1	0.63	0.91	0.43	10.55	2.55	12.52	4.52	16
C1	74-100	5.00		52.5	2	0.21	0.47	0.18	10.35	3.45	11.21	4.31	8
C2	100-150	5.27		48.2	1	0.15	0.30	0.16	8.16	2.65	8.77	3.26	7

Table C.2 (cont'd.). Chemical Characteristics of Typical Pedons.

Horizon	Depth	pH	Organic matter	Fe	P	Ca	Mg	K	H	Al	CEC	ECEC	Base satn.
	cm		$g\ kg^{-1}$		ppm	$cmol\ kg^{-1}$							%
Pedon AS I-12													
Ap	0-21	5.85	17.0	20.9	17	3.35	0.89	0.43	4.98	0.10	9.65	4.77	48
Bt	21-60	6.52	4.5	36.7	T	2.91	1.82	0.14	6.37	0.10	11.24	4.97	43
CB	60-80	6.38	2.8	45.4	T	1.96	2.80	0.14	7.76	0.20	12.66	5.10	39
2C1	80-116	5.97	2.2	27.0	T	0.60	1.90	0.10	5.57	0.10	8.17	2.70	32
3C2	116-175	5.37	1.7	54.6	T	0.13	2.00	0.24	9.35	0.15	11.72	2.52	20
3C3	175-195	5.30	0.8	74.6	2	0.06	1.63	0.19	10.55	0.10	12.43	1.98	15
Pedon AS II-38													
Ap	0-20	5.74		18.8	11	2.39	0.73	0.22	7.76	0.10	11.10	3.44	30
Bt	20-50	6.34		32.2	1	2.96	2.36	0.13	7.96	0.25	13.41	5.70	41
CB	50-72	6.30		33.4	T	1.82	2.70	0.12	6.97	0.10	11.61	4.74	40
2C1	72-124	5.70		29.5	T	0.45	2.50	0.15	6.77	0.15	9.87	3.25	31
3C2	124-145	5.35		44.7	1	0.17	2.50	0.35	8.16	1.35	11.18	4.37	27
3C3	145-175	5.31		18.6	2	0.10	1.84	0.31	5.97	1.65	8.22	3.90	27
Pedon AS III-15													
Ap	0-15	6.02			21	4.25	1.28	0.23	7.56	0.05	13.32	5.81	43
Bt1	15-45	6.16			3	3.58	2.50	0.25	10.55	0.30	16.88	6.63	38
Bt2	45-60	5.98		53.6	1	2.16	2.70	0.21	7.36	0.15	12.43	5.22	41
BC	60-89	5.52		41.8	2	0.76	2.10	0.35	5.97	0.55	9.18	3.76	35
C	89-150	5.32		31.4	2	0.37	0.72	0.51	5.97	0.85	7.57	2.45	21
Pedon AS III-28													
Ap	0-20	6.05		18.2	12	2.50	0.82	0.27	6.77	0.25	10.36	3.84	35
Bt1	20-70	6.16		20.1	2	2.12	1.04	0.12	6.37	0.35	9.65	3.63	34
Bt2	70-100	5.82		25.7	1	1.66	2.30	0.13	7.56	0.45	11.65	4.54	35
Bt3	100-130	5.52		29.7	1	1.14	2.46	0.17	7.36	0.55	11.13	4.32	34
2Bt4	130-155	5.38		41.0	2	0.65	2.50	0.23	10.35	0.95	13.73	4.33	25
2C	155-208	5.26		42.2	2	0.10	1.67	0.25	7.36	1.95	9.38	3.97	22

Table C.2 (cont'd.). Chemical Characteristics of Typical Pedons.

Horizon	Depth	pH	Organic matter	Fe	P	Ca	Mg	K	H	Al	CEC	ECEC	Base satn.
	cm		--- g kg^{-1}---		ppm	------------------ cmol kg^{-1}						-----------------	%
						Pedon L I-23							
Ap	0-12	5.38	9.1	1.9	44	0.58	0.22	0.07	4.58	0.25	5.45	1.12	16
C	12-33	5.76	5.3	1.2	43	0.26	0.08	0.03	4.98	0.25	5.35	0.62	7
A\C	33-74	5.51	7.5	1.6	10	0.10	0.04	0.02	3.98	0.45	4.14	0.61	4
Ab	74-86	5.15	2.6	3.8	15	0.08	0.03	0.04	9.55	1.05	9.70	1.20	2
Ab'	86-103	5.28	13.6	1.3	6	0.05	0.01	0.02	4.58	0.75	4.66	0.83	2
Eb	103-130	5.27	3.7	1.3	4	0.06	0.03	0.02	3.78	0.55	3.89	0.66	3
Btb	130-180	5.30	1.7	5.9	T	0.41	0.26	0.11	5.77	1.75	6.55	2.53	12
						Pedon L I-33							
Ap	0-24	5.66		1.3		0.32	0.11	0.04	3.98	0.20	4.45	0.67	11
A1	24-40	5.86		1.8		0.22	0.10	0.02	2.39	0.15	2.73	0.49	12
A2	40-55	5.90		1.1	20	0.16	0.08	0.02	4.18	0.15	4.44	0.41	6
A3	55-71	5.41		1.6	7	0.05	0.03	0.02	2.79	0.35	2.89	0.45	3
E	71-88	5.45		1.5	3	0.05	0.03	0.02	2.19	0.35	2.29	0.45	4
EB	88-114	5.25		3.0	1	0.06	0.04	0.05	3.98	0.75	4.13	0.90	4
Bt	114-150	5.06		13.1	T	1.12	0.47	0.20	6.97	3.05	8.76	4.84	20
C	150-200	4.92		12.4	T	0.14	0.10	0.06	8.96	2.55	9.26	2.85	3
						Pedon L II-45							
Ap	0-22	5.46	10.2	1.0	33	0.48	0.15	0.04	1.99	0.10	2.66	0.77	25
E	22-40	5.84	5.0	1.2	36	0.28	0.10	0.02	2.19	0.10	2.59	0.50	15
EB	40-58	6.02	3.4	1.7	12	0.30	0.16	0.03	3.38	0.10	3.87	0.59	13
Bt1	58-86	5.34	2.3	6.0	2.9	0.28	0.21	0.09	6.17	1.05	6.75	1.63	9
Bt2	86-125	5.40	1.1	5.8	T	0.46	0.18	0.09	4.98	1.65	5.71	2.38	13
Bt3g	125-185	5.00	1.0	10.0	T	0.56	0.16	0.11	8.76	2.45	9.59	3.28	9
2Cg	185-200	5.14	0.9	18.5	T	0.74	0.52	0.24	11.54	3.55	13.04	5.05	12
						Pedon L III-38							
Ap	0-27	5.70		2.1	17	0.54	0.20	0.14	2.59	0.15	3.47	1.03	25
BA\Bw	27-50	4.91		7.0	4	0.45	0.34	0.08	1.99	1.15	2.86	2.02	30
Bt	50-84	5.00		20.7	T	1.16	0.53	0.14	7.76	2.65	9.59	4.48	19
BC	84-116	4.64		18.2	T	0.17	0.22	0.10	7.56	3.25	8.05	3.74	6
C	116-180	4.82		8.3	T	0.21	0.10	0.05	4.98	2.25	5.34	2.61	7

Table C.2 (cont'd.). Chemical Characteristics of Typical Pedons.

Horizon	Depth	pH	Organic matter	Fe	P	Ca	Mg	K	H	Al	CEC	ECEC	Base satn.
	cm		--- g kg^{-1}---		ppm	------------------ cmol kg^{-1} -----------------							%
						Pedon O I-22							
Ap	0-20	6.14	8.6	67.4	41	3.81	0.91	0.43	9.15	0.10	14.30	5.25	36
BA	20-38	6.54	2.0	65.6	7	4.38	0.77	0.09	7.16	0.05	12.40	5.29	42
Bt1	38-57	6.68	0.9	72.2	5	5.52	0.80	0.08	6.57	0.05	12.97	6.45	49
2Bt2	57-90	5.70	0.8	91.6	5	4.67	1.27	0.07	9.15	0.05	15.16	6.06	40
2Bt3	90-123	4.60	0.1	54.3	5	0.38	0.95	0.07	11.74	3.95	13.14	5.35	11
3Bt4	123-150	4.42	0.9	84.0	2	0.37	1.02	0.10	15.72	6.75	17.21	8.24	9
3BC	150-170	4.40	0.4	80.2	2	0.42	1.15	0.11	19.30	10.25	20.98	11.93	8
3C	170-200	4.40	0.6	161.9	4	0.14	1.14	0.15	23.88	11.15	25.31	12.58	6
						Pedon O I-48							
Ap	0-16	5.70		101.6	9	5.49	1.53	0.51	9.75	0.05	17.28	7.58	44
BA	16-42	5.30		128.3	2	2.44	1.93	0.11	9.75	0.25	14.23	4.73	31
Bt1	42-79	5.00		81.9	2	0.25	1.33	0.18	13.73	1.55	15.49	3.31	11
Bt2	79-110	4.95		121.0	2	0.07	1.04	0.20	14.33	2.65	15.64	3.96	8
2Bt3	110-140	4.90		104.8	2	0.10	0.94	0.15	15.52	5.75	16.71	6.94	7
						Pedon O II-18							
Ap	0-23	5.54		92.9	17	4.36	1.91	0.58	11.54	0.10	18.39	6.95	37
Bt1	23-60	5.48		107.9	2	2.98	2.11	0.14	12.14	0.85	17.37	6.08	30
Bt2	60-96	5.04		102.0	2	0.59	1.24	0.24	12.74	2.85	14.81	4.92	14
Bt3	96-150	5.10		101.7	2	0.21	0.85	0.26	13.93	3.65	15.25	4.97	9
Bt4	150-260	4.92		107.0	2	0.23	0.74	0.21	14.93	3.65	16.11	4.83	7
						Pedon O II-33							
Ap1	0-10	5.98		77.1	46	5.74	2.19	0.19	10.35	0.10	18.47	8.22	44
Ap2	10-28	5.80		77.4	7	3.48	0.49	0.07	9.75	0.20	13.79	4.24	29
Bt1	28-62	5.81		89.7	4	4.26	1.25	0.07	9.15	0.20	14.73	5.78	38
Bt2	62-100	5.32		97.4	2	2.20	1.73	0.10	12.94	2.15	16.97	6.18	24
Bt3	100-110	5.30		100.9	2	1.01	1.29	0.15	14.53	2.80	16.98	5.25	14
2Bt4	110-140	5.20		98.9	2	0.79	1.09	0.19	12.54	2.85	14.61	4.92	14
2Bt5	140-220	4.93		93.5	2	0.58	0.89	0.23	13.73	2.65	15.43	4.35	11
2BC	220-250	5.01		92.9	4	0.25	0.48	0.17	12.54	3.05	13.44	3.95	7
2C	250-300	4.85		104.8	3	0.21	0.47	0.12	13.53	3.95	14.33	4.75	6

Table C.2 (cont'd.). Chemical Characteristics of Typical Pedons.

Horizon	Depth	pH	Organic matter	Fe	P	Ca	Mg	K	H	Al	CEC	ECEC	Base satn.
	cm		g kg^{-1}		ppm	cmol kg^{-1}							%
						Pedon O III-13							
Ap1	0-9	6.15	41.4	97.0	19	7.60	2.80	1.00	13.13	0.10	24.53	11.50	46
Ap2	9-24	6.40	18.2	97.6	6	6.41	2.12	0.36	10.95	0.10	19.84	8.99	45
BA	24-61	6.58	4.2	92.6	4	3.85	1.48	0.27	11.54	0.05	17.14	5.65	33
Bt1	61-109	6.63	2.2	88.0	2	4.99	1.50	0.18	9.75	0.05	16.42	6.72	41
2Bt2	109-126	6.65	1.0	104.3	2	5.35	2.30	0.09	9.95	0.05	17.69	7.79	44
2Bt3	126-151	6.60	1.1	111.3	2	4.89	2.40	0.10	8.36	0.05	15.75	7.44	47
2C	151-175	6.52	0.8	119.1	5	3.34	2.30	0.07	8.96	0.05	14.67	5.76	39
						Pedon O III-48							
Ap	0-26	6.42		93.1	13	6.86	1.89	0.15	9.35	0.05	18.25	8.95	49
Bt	26-57	6.68		100.5	2	4.74	1.91	0.08	9.95	0.05	16.68	6.78	40
CB	57-94	5.92		104.8	2	2.75	2.50	0.08	10.55	0.05	15.88	5.38	34
C	94-150	6.00		110.2	3	1.50	1.82	0.14	10.95	0.75	14.41	4.21	24

Vita

Michael Hoffman Genthner was born on September 22, 1955, in Paris, France. He graduated from Charles A. Lindbergh Sr. High in Hopkins, Minnesota in June of 1973. After abortive careers as a nurseryman, a student, an appliance salesman, a student, a construction worker, a student, and a residential teacher at a school for ED/LD children, he enrolled in the Agronomy Department at Virginia Polytechnic Institute and State University in September of 1981. While working toward an undergraduate degree, Mike worked in the Extension Soil Testing Lab and the Turfgrass Research Center, and he assisted with mine land reclamation and mountain soils studies. Upon graduation in 1985, he began a Masters study of Piedmont soils, under W. Lee Daniels. Mike has worked for VPI Soil Survey since November of 1988. He is a member of the American Society of Agronomy and the Soil Science Society of America.