Taxonomy, Genesis, and Parent Material Distribution of High-Elevation Forest Soils in the Southern Appalachians

by

Steven B. Feldman

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APPROVED:

Lucian W. Zelazny, Chairman	James C. Baker
David C. Martens	William J. Edmonds

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(ABSTRACT)

High-elevation spruce-fir forests in the southern Appalachians may potentially be in a state of decline as a result of either natural or anthropogenic causes. Soils were investigated in areas representative of 117 permanent intensive field plots established to evaluate changes in forest composition that may be influenced by the deposition of atmospheric pollutants. A total of 35 pedons were described, sampled, and characterized. Over 75% of the soils studied were classified in the field as either Typic or Pachic Haplumbrepts, but weakly developed spodic horizons were identified in 13 of the soils by chemical determinations in the laboratory. A high degree of morphological similarity exists between soils in these areas despite widespread differences in parent material and local geology. This similarity is the result of physical mixing of these soils by climatically-driven slope processes. A considerable amount of chemical variability exists in these soils which is not expressed in morphological characteristics. Multiple discriminant analysis established that physical and morphological properties used to separate and classify these soils in the field were not significantly different between study areas. Parent material differences, however, expressed in both soil chemical and mineralogical properties, were sufficiently different between study areas to result in the clear separation of soils into distinct groups. The importance of nutrient cycling in these spruce-fir forests is underscored by high levels of exchangeable bases in surface horizons relative to lower in the profile. This suggests that disturbances to the forest floor resulting from fire, overgrazing, logging, or erosion could have a major impact on ecosystem resilience during stress.

雁過長空影沈寒水雁無遺蹤意水無沈影心

Wild geese

Passing the length of the sky

Cast a shadow

Into the cold water.

The geese do not wish

To leave their reflection behind,

The water has no mind

To retain their image.

From the *Zenrinkushu*

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Gassho

Table of Contents

I. Introduction 1

II. Taxonomy and Description of Soils in the Southern Appalachian Spruce-Fir Ecosystem . . . 5

Review of Literature 5

Pedological Studies 5

Soil Survey Activities 9

Field Investigations and Sampling 11

Physiography and Geology of the Study Areas 12

Mt. Rogers 12

Great Smoky Mountains National Park 14

Black Mountains 15

Soil Genesis, Classification, and Description 17

Soil Genesis and Morphology 17

Soil Classification 20

Correlation with Permanent Plots 30

Conclusions 35

III. Distribution of Parent Materials and Soil-Landscape Relationships **36**

Introduction 36

Study Area 38

Geology 39

Climate 40

Materials and Methods 40

Field and Laboratory Methods 40

Statistical Analysis 43

Results and Discussion 46

Model Derivation and Validation 46

Interpretation 47

Conclusions 57

IV. Summary and Conclusions **61**

Literature Cited **64**

Appendix A. Protocol for Soil Description and Classification **68**

Appendix B. Soil Descriptions **73**

Appendix C. Location of the Soils Examined **124**

Vita **131**

List of Illustrations

Figure 1. Location of the study areas. 3

Figure 2. Pedon GSM 1; loamy-skeletal, mixed, frigid Typic Haplorthod formed in colluvium from Thunderhead Sandstone. 26

Figure 3. Pedon BM 1; loamy-skeletal, mixed, frigid Typic Haplumbrept formed in colluvium from mica schist. 27

Figure 4. Pedon MR 7; loamy-skeletal, mixed, frigid Typic Haplumbrept formed in colluvium from rhyolite. 28

Figure 5. Pedon MR 10; loamy-skeletal, mixed, frigid Pachic Haplumbrept formed on NE-facing upper sideslope from rhyolite colluvium. 29

Figure 6. Pedon GSM 14; coarse-loamy, mixed, frigid Typic Dystrochrept found on broad upland ridgetop over feldspathic quartzite. 31

Figure 7. Pedon GSM 14; loamy-skeletal, mixed, frigid Typic (Histic) Haplumbrept located on the south face of Whitetop Mtn. 32

Figure 8. Scatterplot of individual observations and group centroids (*) illustrating differences between study areas. 53

Figure 9. Relative contribution of the predictor variables in discriminating between study areas. 54

Figure 10. Scatterplot of differences between layers over all observations. 58

Figure 11. Relative contribution of the predictor variables used to discriminate between layers. 59

List of Tables

Table 1. Distribution of soils in the GSMNP by landscape position and slope aspect. 22

Table 2. Distribution of soils in the Black Mountains by landscape position and slope aspect. 23

Table 3. Distribution of soils in the Mt. Rogers area by landscape position and slope aspect. 24

Table 4. Classification of soils in the permanent plot areas. 34

Table 5. Classification of the soils used in the analysis. 42

Table 6. Definitions of symbols and units of measurement used in the analyses. 45

Table 7. Variables retained after ANOVA and probability levels associated with the hypothesis of no signigicant difference between study areas for Layers 1-3. 48

Table 8. Variables selected by the forward stepwise discriminant analysis for each layer, summary statistics, and significance levels for variable entry into the model. 49

Table 9. Parameters of the canonical discriminant functions and tests of significance for each analysis. 50

Table 10. Classification of pedons into groups using all pedons and a split-sample (SS) cross-validation procedure. 51

I. Introduction

Southern Appalachian spruce-fir [*Picea rubens* Sarg. - *Abies fraseri* (Pursh) Poir.] forests are biologically unique and geographically restricted remnants of a boreal forest community whose areal extent has fluctuated greatly since the Pleistocene Epoch (Delcourt and Delcourt, 1984; 1986). Today, spruce-fir forests in the South are isolated from related northern vegetation and are confined to elevations above about 1450 m on the higher mountain peaks of eastern Tennessee, western North Carolina, and southwestern Virginia. These areas dominate the headwaters of mountain streams and influence downstream water quality in addition to supporting a diverse population of rare plants and animals. Although the economic importance of the timber resource is a relatively minor concern, the aesthetic importance to recreational users cannot be overemphasized.

Despite the recognized biological importance and aesthetic value of the spruce-fir ecosystem, very little research has been done to document the types of soil resources which actually exist on the landscape. This phenomenon is likely the result of the severe climate, remoteness, difficult terrain, and marginal economic value of the land resource in these high mountain areas. No detailed studies of the nature and origin of the soil mantle have been made in these areas resulting in some controversy as to the whether these steeply sloping soils have developed in place from residuum or from transported colluvial materials (Daniels et al., 1984; Daniels et al., 1987). Soil series concepts throughout these areas are ill-defined making the correct classification of many

pedons below the Family level impossible. Moreover, the lack of benchmark knowledge makes it difficult to attempt interpretive predictions regarding the effects of soil/site variability on tree species composition and the ability of these soils to supply, retain, or immobilize nutrients. These factors are becoming increasingly important as public concern grows about potential spruce-fir ecosystem decline.

Soil properties were observed in the three study areas selected by the USDA-Forest Service Northeastern Experiment Station's Eastern Spruce-Fir Research Cooperative, a research organization within the congressionally-mandated National Acid Precipitation Assessment Project. These areas, the Mount Rogers National Recreation Area in Virginia, the Great Smoky Mountains National Park (GSMNP) in Tennessee and North Carolina, and the Black Mountains in North Carolina, contain the largest remaining contiguous stands of old growth spruce-fir vegetation in the southeastern United States (Fig. 1).

In order to evaluate changes in forest composition, structure, regeneration, and growth as they may be influenced by the deposition of atmospheric pollutants, scientists from the Spruce-Fir Research Cooperative established 22, 55, and 40 permanent intensive field plots in each respective study area. The 50 x 20 m plots were randomly selected within well-defined strata which were representative of gradients in atmospheric deposition that may influence the forest. The three levels of stratification included: i) exposure class (exposed to or protected from prevailing winds), ii) topography (ridgetops, sideslopes, and cove positions), and iii) elevation (1215-1515, 1515-1825, and > 1825 m). At each plot, baseline data was collected in order to assess forest productivity and to establish a reference for any observed decline. A complete survey of overstory, understory, and herbaceous vegetation was conducted with the following measurements taken: stem density and basal area of dominant and co-dominant trees, crown height and condition, leaf area index, site index, tree age and interpretation of dendrochronology. Finally, an assessment of overall tree vigor and previous site disturbance was made.

Evaluation of soil properties influencing forest productivity at each plot was required for the overall site characterization. However, because inaccessible terrain, remoteness, and limited time and manpower constraints precluded a detailed, on-site soil investigation at each plot, only a limited

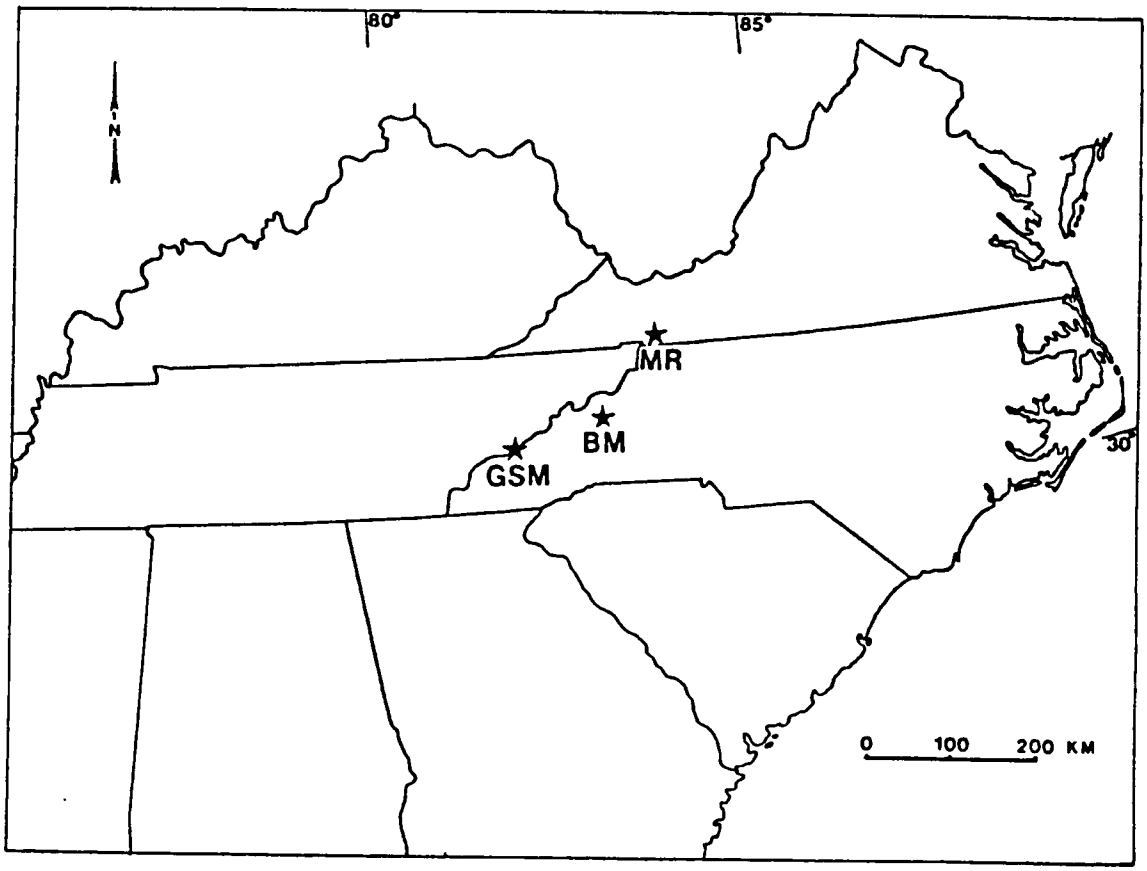

Figure 1. Location of the study areas.

number of observations were used to describe the distribution of soils over broad areas of the southern Appalachian mountains. This thesis reports on the results of both field investigations and the statistical analysis of spatial variability with regard to selected soil morphological, physical, chemical, and mineralogical properties at each study area. Toward that end, this research has been directed toward meeting the following specific objectives:

1. To describe and characterize soil morphological features and to classify the soils in the spruce-fir zones of each of the three study areas,

2. To explain the probable genesis of the soils.

3. To determine the general distribution and extent of major soil taxonomic units by relating basic soil properties to landscape position and geology, and

4. To investigate soil variability both within and between study sites.

II. Taxonomy and Description of Soils in the Southern Appalachian Spruce-Fir Ecosystem

Review of Literature

Pedological Studies

While an extensive body of ecological information exists for the spruce-fir region of the southern Appalachians, only a relatively small amount of soils research has been conducted in these areas (Daniels et al., 1984). Because of the non-agricultural use of the land, early soil surveys of the southern mountain region were largely conducted on a reconaissance basis. The soils were often classified in these surveys simply as 'stony roughlands or rough mountainous land' (Springer, 1984). Similar soils mapped in adjoining counties across state lines were commonly given different names (see e.g. Perkins and Gettys, 1947; Goldston et al., 1954; Beesley et al., 1955; Hubbard et al., 1956; Elder et al., 1959). Modern soil surveys using the criteria in *Soil Taxonomy* (Soil Survey Staff, 1975) have been completed in only a few areas. In fact, the existence of areas having frigid soil temper-

ature regimes (mean annual soil temperature at a depth 50 cm below the soil surface of <8°C) in the high mountains of North Carolina was only officially recognized as recently as 1982 (Daniels et al., 1984). The distribution and extent of these areas is still poorly documented, but on-going monthly measurements made in the Mt. Rogers area indicate that areas with frigid soil temperature regimes are generally restricted to elevations above 1400 m on north- and east-facing slopes and 1475 m on other aspects (D. Hatch, 1988, Va. Tech Soil Survey, Abingdon, VA 24210, personal communication).

In an early study, Coile (1938) reported on the occurrence of well-defined Podzols in the West Virginia highlands and less well-developed Podzols at higher elevations in the southwest North Carolina and east Tennessee mountains. He attributed the weak expression of spodic morphology to the higher base content of the metamorphic and igneous rocks of North Carolina and Tennessee as compared to the more siliceous rocks of West Virginia. He also reported a zone of Fe accumulation under Podzol soils which developed under red spruce, whereas a similar zone of Fe accumulation was not found in soils formed under pure fir stands. No mechanism for these observations was proposed.

McCracken et al. (1962) were among the first researchers to do detailed research on the soils of the GSMNP. They described the majority of soils above 1400 m in the Park as having "duff mull" horizons (a type of forest humus where both moderately and highly decomposed organic horizons are mixed somewhat with the underlying mineral soil, but where there exists a distinct boundary between the two). They also described relatively thick A1 horizons, and B horizons differentiated by color but not by the accumulation of illuvial silicates or Fe-oxides.

They compared the soils formed under spruce-fir, beech gap, grassy bald, and heath bald communities and placed the soils into two groups. Soils of the first group represented the most extensive soils in the area and were described as "lacking A2" (eluvial) "horizons with thin A1 and 'color' B horizons". Soils in this group were restricted to well drained sites under spruce-fir, beech gap, and grassy bald vegetation and were classified as Sols Bruns Acides [1] on the basis of low base

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[1] Based on the 1938 U.S. Soil Classification system; these soils are now classified as Dystrochrepts and Haplumbrepts using *Soil Taxonomy* (Soil Survey Staff, 1975).

status, high exchangeable Al and C/N levels, and the lack of eluvial or illuvial horizons. The authors found only slight differences in soil chemical properties between study sites, but they emphasized that neither grass vegetation nor spruce-fir vegetation has acted to produce extreme soil morphological differences. The absence of distinct eluvial horizons or spodic morphology in these soils was suggested to have been the result of a combination of the mixing of horizons by soil creep and the large amount of weatherable primary minerals in the soils, which, by providing a source of divalent cations, limits colloidal dispersion and translocation through the profile. Soils of the second group exhibited spodic morphology and were restricted to gently sloping convex mountaintops underlain by more "quartzose conglomeratic rock". The distribution of these soils was relatively inextensive.

In a study of the effect of forest type on soils formed over both the coarse-grained rocks of the Thunderhead sandstone and the medium-textured Anakeesta rocks in the GSMNP, Wolfe (1967) reported that the majority of soils under spruce-fir vegetation were Inceptisols which lacked distinct eluvial and illuvial horizons. Soils with incipient spodic morphology were less extensive and were restricted to the crests of higher domes or peaks. Soils with well-expressed spodic morphology were reported to be relatively rare because of the lateral movement of Fe-oxides from above and because of the effects of windthrow and soil creep, all of which tend to impede soil horizon differentiation. Soils selected under spruce-fir vegetation were compared with soils on adjacent beech (*Fagus grandifolia* Ehrh.) stands and were found to have similar textural and mineralogical compositions, but varying chemical characteristics. Wolfe (1967) therefore suggested that bedrock differences were not responsible for sudden changes in vegetation, but that vegetation was responsible for differences in soil chemistry. These differences were largely attributed to the lower exchange acidity and higher base status of the litter produced by beech as compared to the litter produced by spruce-fir. Cheluviation of Fe and Al was also reported to be much greater under spruce-fir than under beech vegetation.

Weaver (1972) recognized Inceptisols with immature profiles formed over mica gneiss and mica schist parent materials in the spruce-fir region of the Balsam Mountains of North Carolina. He noted the occurrence of block fields above elevations of 1524 m on steep slopes and in the

headwaters of streams and reported them to be of colluvial origin, formed by the mechanical weathering of massive bedrock on higher slopes and the subsequent removal of interstitial material by surface runoff. Soils in the study area were highly variable with respect to chemical properties such as exchangeable cation levels and pH. These differences were attributed to variations in litter distribution on the forest floor, soil creep, windthrow, and the effects of stemflow. However, net forest biomass was found to be related more to stand structure and species than to soil and site parameters.

Springer and Elder (1980), in a summary of the major soils of Tennessee, reported that the soils of the spruce-fir zone of the GSMNP included mainly Dystrochrepts, Haplumbrepts, and Spodosols formed from sandstone, graywacke, schist, slate, and colluvium. Soils were described as having loamy, permeable subsoils with variable stone contents, and ranging from 0.3 m in depth on the crests and upper mountain sideslopes to as much as 2 m deep in coves and lower sideslopes where downslope soil creep has accumulated. Lacking other suitable existing soil series for descriptive purposes, they placed the Tennessee section of the spruce-fir region into the Ditney-Jeffrey-Brookshire soil association. Members of this soil association, however, are Dystrochrepts which have thin or light-colored epipedons and which were established for areas having mesic rather than frigid soil temperature regimes. They also have coarse-loamy particle-size distributions and therefore fail to account for the extensive areas of skeletal soils (>35% coarse fragments by volume) which are dominant throughout these high-elevation areas.

More recently, Springer (1984) related general soil patterns in the spruce-fir zones of the GSMNP to parent material, slope aspect, elevation, and vegetation based on transect information and results of research in the available literature as background. He related decreasing mean annual soil temperature and moisture availability at both higher elevations and sheltered positions (protected from prevailing southerly winds and solar insolation) to the presence of dark-colored soils that are high in organic matter. Most soils above 1500 m under spruce-fir were described as Inceptisols with organic matter of the mor type (little mixing of the highly decomposed surface organic material with the underlying mineral horizon). Where parent material was coarse in these areas, Spodosols were predicted. He noted that tree-throw, soil creep, landslides, and changing

vegetation are continually shifting these patterns. He also noted that while these general relationships are reasonably valid, there is currently only a fragmentary knowledge of soils in the spruce-fir region and cited the need for more detailed surveys of these high elevation areas, particularly where research or intensive management is conducted.

The occurrence of soils in the southern Appalachians with well-defined spodic morhology was documented by McGuire (1983) who noted that many of the soils originally classified as Podzols in the southern mountains may not meet all the morphological, physical, and chemical criteria of the present concepts of Spodosols defined in *Soil Taxonomy* (Soil Survey Staff, 1975). Of the eleven pedons he studied, each exhibiting Bhs/Bs horizonation, only 2 met all the present criteria for Spodosols while the remaining 9 pedons were classified either as Dystrochrepts or Haplumbrepts. He proposed the formation of a spodic subgroup of Inceptisols for soils which show evidence of distinct Bhs/Bs horizonation but which otherwise cannot be classified as Spodosols. These soils merit distinction because they contain high levels of Fe- and Al-oxides which can result in NO_3^-, SO_4^{2-}, and PO_4^{3-} retention and/or fixation.

Soil Survey Activities

Soil survey activities in the southern mountains have increased in recent years resulting in an increase in the available knowledge about these high altitude soils, but to date few modern surveys have attempted to deal with soil correlation and classification problems that exist (Daniels et al., 1984; Daniels et al., 1987). As new information is collected, some soil series will be narrowed or eliminated, many older soil series will be reclassified, and new series will be established.

In the explanatory text accompanying the general soils map of North Carolina, Daniels et al. (1984) indicated that only two soil series are currently established for the high-elevation frigid areas of North Carolina. Both the Craggey (loamy, mixed, frigid Lithic Haplumbrepts) and the Burton (coarse-loamy, mixed, frigid Typic Haplumbrepts) series have thick, dark surface horizons and are shallow (<50 cm) and moderately deep (50-100 cm), respectively, over hard acid crystalline

(granitic, gneissic) bedrock. Large boulders and coarse fragments ranging up to 50% in the C horizons are common in these soils. The authors point out that it is likely that other soil series may be established to better define the soil resource in these diverse, high mountain ecosystems as future investigations are initiated.

Tennessee correlated Unicoi variant soils in the recently published soil survey of Unicoi Co. (McCowan, 1985) to include cobbly soils formed in shallow residuum over feldspathic quartzites in the frigid zones above 1345 m. The small area of these soils within the survey area (about 607 ha) was apparently insufficient to merit establishing a new soil series and therefore a variant of the mesic Unicoi series was correlated.

A soil survey of the Mt. Rogers National Recreation Area conducted in 1983 for the U.S. Forest Service (T. Bailey, 1985, USDA-Forest Service, Roanoke, Va. 24011, personal communication) recognized extensive areas of loamy-skeletal, mixed, frigid Typic Haplumbrepts formed in rhyolite colluvium above elevations of 1372 m. Although no suitable soil series existed for correlation in this survey area, a variant of the mesic Spivey series was tentatively placed into the mapping legend.

Another recent (unpublished) soil survey of the Clingman's Dome, Mt. Collins, and Mt. Mingus areas of the GSMNP (C. Eagar, 1986, Uplands Field Research Laboratory, Gatlinburg, TN. 37738, personal communication) documented the occurrence of extensive areas of both Typic and Pachic Haplumbrepts, Umbric Dystrochrepts, and lesser areas of Lithic Haplorthods for which no suitable soil series exists for further classification. All of the soils mapped above 1400 m were reported to have loamy-skeletal particle-size control sections and to exhibit morphological differences primarily resulting from the effects of slope aspect and position, and parent material differences.

Currently, three tentative soil series have been proposed in North Carolina in addition to the existing Burton and Craggey series to better define these high-elevation frigid soils. The Wayah series (coarse-loamy, mixed, frigid Typic Haplumbrepts) are deep, well-drained soils formed in residuum over acid crystalline rocks. The Tanassee series are similar soils (coarse-loamy, mixed, frigid Typic Haplumbrepts) derived from colluvium from similar acid crystalline materials. The

Oconoluftee series (coarse-loamy, mixed, frigid Typic Haplumbrepts) are deep, well-drained soils formed in residuum from phyllite, slate, and other metasediments with high susceptibility to slope failure. The soil scientists conducting the ongoing progressive soil survey in Yancey and Mitchell Counties, North Carolina, are currently investigating the suitability of these proposed new series for use in their survey area (R. Ransom, 1986, USDA-SCS, Burnsville, NC, 28714, personal communication).

The existence of only 2 active soil series to describe the diversity of parent material, regional geology, topographic, and vegetation differences in these high mountain areas reflects the need for more detailed soil survey investigations and adequate communication between cooperating agencies to ensure that soil series concepts are consistently applied in future mapping endeavors.

Field Investigations and Sampling

Because time, manpower, and funding constraints precluded an on-site investigation at each of the remote permanent intensive plots, reconnaissance soil survey techniques were implemented in order to describe the distribution of soils over the extensive study areas. A minimum number of soils were selected for description and characterization which were representative of the landforms, exposure classes, and elevations that these plots occupied. At least two soil observations were made in excavated pits within each level of topographic and exposure stratification variable that was used by the site characterization team to locate the permanent intensive plots. Soils were deemed representative and selected for further observation if they adequately characterized dominant geomorphic and vegetational features of the landform based on information generated from transects, auger descriptions, and observation of landscape surface features. Care was taken to avoid transitional areas in order to ensure uniformity of soils in the area. The relationship between internal soil properties and geomorphic features was recorded in the field. These relationships were then used to predict the occurrence of soils on similar landscape positions within each of the study

areas. Field checking on a random or established basis was used to confirm the reliability of the relationships which were developed. At each site, the soil was classified and described, and detailed field notes were taken on features such as slope geometry, landscape position and local geology, surface stoniness and vegetation characteristics. A detailed description of the field procedures used to describe and classify the soils in the study areas can be found in Appendix A. A comprehensive list of pedon descriptions recorded in the field can be found in Appendix B.

Physiography and Geology of the Study Areas

Mt. Rogers

The northernmost study site, located in the Mt. Rogers National Recreation Area in southwestern Virginia, includes both Whitetop Mtn. (1682 m) and Mt. Rogers (1746 m), the tallest mountains in the state. These northeast-southwest trending mountains occupy an area between the unmetamorphosed Paleozoic rocks of the Appalachian Valley and Ridge Province to the north, and the Precambrian crystalline rocks of the Blue Ridge mountains to the south. The summits of Mt. Rogers and Whitetop Mountain are smooth, broad dome-like structures of low relief. Sideslopes below the summits are steep and broken. North-facing slopes in the area are steep and bouldery in contrast to the more gentle south-facing slopes. Elevation ranges from about 950 m at valley floors to more than 1700 m at the highest peaks. Surface water in the area is drained into the Gulf of Mexico by both the New/Ohio River systems and the Holston/Tennessee River systems.

The Mt. Rogers Formation, a thick mass of upper Precambrian stratified rocks, is a sequence about 3048 m thick of interbedded and intertonguing volcanic and sedimentary rocks. Rankin (1970) divided the Mt. Rogers Formation into three members: a middle volcanic member separating a lower volcanic and sedimentary sequence from an upper sedimentary sequence. The spruce-fir

zone of the Mt. Rogers area is influenced primarily by the middle and upper members. The volcanic rocks of the Mt. Rogers area range in composition from basalt (a fine-grained crystalline rock high in biotite, hornblende, pyroxene, and other ferromagnesian minerals) to rhyolite (a fine-grained crystalline rock high in silica and alkali feldspars). Thick masses of rhyolite make up about 50% of the formation and, in fact, this area is one of the two largest masses of felsic volcanic rocks in the eastern United States. Sedimentary rocks of the middle and upper members of the Mt. Rogers Formation include a complex association of interbedded and interfingering arkosic sandstone and conglomerate, rhythmically layered argillite, pebbly mudstone, and tillite (Rankin 1967, 1970). Because of nonconformities in the ages of the beds and the sizes of the grains/clasts (up to 1 m across), it has been suggested that these rocks may be of glacial origin with ice postulated to be a mechanism for the rafting of fragments into place (Harland and Rudwick, 1964; Blondeau, 1970; Haselton, 1973,1979). The theory of a general late Precambrian glaciation is a controversial issue which has both been applauded and criticized in the literature (Hack and Newell, 1974).

Most of the rocks of the Mt. Rogers Formation have been influenced by at least one episode of Paleozoic metamorphism to some degree although the metamorphic gradient increases toward the southeast. Many areas of the Mt. Rogers National Recreation Area contain small outcroppings of greenschist (albite-epidote-chlorite-tremolite assemblages). Small bodies of plutonic rocks such as gabbro and diabase (coarse-grained ferromagnesian crystalline rocks) intrude in the upper part of the Mt. Rogers Formation (Rankin 1967, 1970), but these rocks are not extensive and are probably not significant to soil formation or forest nutrition. The Mt. Rogers Formation rest nonconformably on the Cranberry Gneiss, which is one of the oldest rock units in the area and which forms the core of much of the southern Appalachian anticlinorium (Rankin 1964, 1970). These rocks, however, do not crop out in the spruce-fir zone of the Mt. Rogers area.

Great Smoky Mountains National Park

The crest of the GSMNP forms the northeast-southwest trending boundary between Tennessee and North Carolina for a distance of about 80 km. Elevation within the Park ranges from about 300 m to more than 2000 m. Surface water in the Smokies drains into the Tennessee River system before flowing into the Gulf of Mexico. Stream dissection is deep and intricate throughout the area.

The Precambrian sedimentary rocks of the Ocoee Series (Great Smoky Group) form the main mass of the GSMNP, extending its entire length. These rocks are predominantly clastic sedimentary rocks (composed principally of fragments derived from pre-existing rocks and transported mechanically to their places of deposition) including pebbly conglomerate, coarse- to fine-grained sandstones, and silty to argillaceous rocks (King et al., 1968). The Great Smoky Group can be divided into three intertonguing formations: the Elkmont Sandstone below, the Thunderhead Sandstone in the middle, and the Anakeesta Formation above.

The Elkmont Sandstone does not occur at the higher elevations of the GSMNP and will not be discussed. The Thunderhead sandstones are massive, thick-bedded rocks composed principally of quartz and potassic feldspars with lesser amounts of plagioclase feldspars, mica, granite, and quartzite. Sandstone beds commonly occur in layers ranging from about 1 to 10 m thick and are graded with the coarsest material at the base. Silty or argillaceous material separates repeating sandstone layers (King et al., 1968)

Rocks of the Anakeesta Formation form the steep ridges and pinnacles at the higher parts of the GSMNP. This formation is composed primarily of dark silty and argillaceous rocks altered to slate, phyllite, or schist (King et al., 1968). These rocks contain mica minerals in amounts intermediate between the relatively little metamorphosed Mt. Rogers Formation and the highly metamorphosed rocks of the Black Mountains. Coarse-grained rocks of the Anakeesta Formation are composed largely of quartz and microcline (a potassic feldspar) with minor amounts of sodic plagioclase, muscovite, biotite, and chlorite. Fine-grained rocks of this formation consist mostly

of muscovite, sodic and potassic feldspar, and quartz. Most of the rocks of the Anakeesta Formation also contain small amounts of Fe-sulfides and free C which give rise to a strongly oxidized appearance when weathered. The Anakeesta Formation intertongues extensively with the Thunderhead Sandstone making the separation of soils into areas with discrete parent materials difficult in many areas. The only igneous rock mapped in the GSMNP is metadiorite, a coarse-crystalline rock high in hornblende and plagioclase. Thin beds of this rock occur parallel to beds in the Thunderhead sandstone between Clingman's Dome and Newfound Gap. It's significance to soil formation in the spruce-fir region, however, is minimal.

Many of the higher peaks of the GSMNP can be characterized as dome-like structures with flattened summits of low relief. This feature is also characteristic of Mt. Rogers and Whitetop Mountain and is in stark contrast to the narrow pinnacles and sharp ridge crests that form the Black Mountains chain. This dome-like structure is related to the control of the underlying bedrock on landform development. The specific geometries of major topographic features in the mountains are closely related to lithology and geologic structure. The Thunderhead sandstone and the Mt. Rogers Formation, for example, both consist of relatively dense, massive rocks which do not commonly exhibit natural planes of weakness between and within mineral grains. They are relatively resistant materials which weather to smooth, broad landforms. Areas in the GSMNP that are underlain by the Anakeesta Formation are more steep and rugged, owing principally to the fact that these rocks are highly fractured with bedding planes often dipping strongly in the direction of the eroding slopes. Similarly, the Black Mountains are underlain by mica gneisses and schists which are dominantly composed of minerals exhibiting well developed high angle cleavage planes. These rocks therefore weather to steeply sloping areas with sharp ridge crests above highly incised valleys.

Black Mountains

The southern Appalachian mountain region may be described as an intensely dissected plateau bounded by two southwest to northeast trending mountain chains (Stuckey and Steel, 1953). To

the east, the Blue Ridge mountain chain, which includes both Mt. Rogers and Whitetop Mountain, rises about 600 m above the Piedmont Plateau below, forming the main divide between the Atlantic and Gulf of Mexico drainage systems south of Roanoke, Virginia. The western boundary of the southern Appalachian mountain region is made up of a series of ranges collectively known as the Unaka Mountains which include the GSMNP. The area between these mountain chains is divided by a number of cross ranges, most prominantly including the Black Mountains of North Carolina which rise to a maximum elevation of 2045 m at Mt. Mitchell. This range consists of a distinct single ridge extending 24 km northward from the Blue Ridge Mountains and containing 12 peaks which rise above 1829 m in elevation. The Black Mountains are characterized by rugged, steep slopes and sharp ridge crests extending in all directions above narrow, deeply incised valleys below. Surface water is drained by the Cane River to the northwest, the Ivy River to the west, the North fork of the Swannanoa River to the south, and the South Toe River to the east, all of which ultimately flow into the Tennessee River and the Gulf of Mexico.

Rocks at the higher elevations of the Black Mountains are chiefly interlayered quartz-rich mica gneisses and schists with small amounts of dark greenish-black amphibole gneisses and schists, all of Precambrian age (Stuckey and Steel, 1953; Brobst, 1962; Hadley, 1970). They are highly metamorphosed rocks derived mainly from feldspathic sandstones and shales. There are also a few small outcroppings of quartzite, but these rocks are not extensive and are not important to soil formation. The layers of mica gneiss and schist are generally bluish- or brownish-gray on fresh outcrops and tan to rusty brown on weathered surfaces. The chief minerals of the mica gneisses are oligoclase (a sodic plagioclase with some calcium), quartz, biotite, and muscovite with lesser amounts of garnet, epidote, staurolite, and kyanite (Brobst, 1962). Mica schists tend to be somewhat more coarse-grained than the mica gneisses, but are mineralogically similar with the exception that muscovite tends to dominate the mica fraction rather than biotite (Brobst, 1962). These rocks weather to soils which are very high in sand-sized mica flakes.

Soil Genesis, Classification, and Description

Soil Genesis and Morphology

Soils vary in their response to the interactions of climate, parent materials, organisms, relief, and time (Jenny, 1941). Above an elevation of about 1450 m, the effects of increasing elevation on climate modification and soil formation can be assumed to be minimal. Soil variability within each study area is therefore mostly a function of landscape position, slope aspect, and insolation levels which modify all other soil-forming factors. The effects of exposure to prevailing winds on gross soil morphology are insignificant. At the high elevations, there are few areas that can truly be considered as coves, or depositional areas along drainageways with double concave slopes. This is especially true in the Mt. Rogers area which lacks the extremely dissected topography characteristic of the Black Mountains and the GSMNP. The influence of slope aspect may be especially important in these areas.

Local differences in soil properties can also be attributed to microrelief and its affect on mean annual soil temperatures, chemical weathering rates, freeze-thaw cycles, and organic decay rates. Although the influence of different parent materials are largely masked by other soil-forming processes in the southern Appalachians, chemical and mineralogical properties of soils between study areas may differ significantly. These differences in soil properties may also result from different vegetation histories at any given site. Soils in the study areas are all relatively young, having undergone weathering in a relatively cool environment on unstable slopes, all of which has given rise to a relatively short soil-forming interval and weak soil development.

Soils of the spruce-fir region are very strongly acid to extremely acid with moderately high cation exchange capacities (CEC) and low base saturations. They are well-drained, dark surfaced soils with high amounts of surface and subsoil coarse fragments. They range from about 50 cm in depth on narrow ridges, convex knobs and upper shoulder slopes to >100 cm on lower mountain

sideslopes and cove positions. Effective soil depth is not easily observable because of high subsoil coarse fragment content. As a result, depth to hard bedrock measurements for these soils can be grossly underestimated.

Soil morphological features at each of the 3 major study areas are remarkably similar despite significant differences in parent material composition and geology (see Appendix B). This phenomenon can be attributed to the dominant influence of climate on pedogenesis and the fact that there is very little "residuum" at these high elevations. Localized areas of soils derived from residual materials are of limited extent and are restricted to ridgetops and benches where slopes are less than about 15%. Most of these areas, however, are capped with more recent deposits of colluvial material. The lack of any observed residuum underlying the soils of the Mt. Rogers area, especially on gently sloping, "stable" summit positions, provides evidence of the effects of both present day slope instability and past periglacial activity.

Present day frost churning and windthrow on sloping ground results in significant physical weathering of the local bedrock and ultimately transforms residuum into other mixed parent materials. At high elevations, particularly on low gradient domes, these churned parent materials are not transported very far and are not sorted appreciably. Farther downslope, coarse fragment content decreases as finer material flows downward on steeper gradients. Periglacial activity during both the Holocene and late Pleistocene (Clark, 1968; Richter, 1973; Clark and Ciolkosz, 1988). has also acted to produce widespread geomorphic instability thereby increasing the rate of slope movement and the transport of sediments, especially in areas of strongly dipping phyllite and slate.

Periglacial areas have been defined as areas "peripheral to Pleistocene ice sheets and glaciers" (French, 1976). However, while in the strict sense the southern Appalachians were not peripheral to the glacial margin in eastern North America, it may be assumed from pollen and geologic records that a climate sufficient to create periglacial conditions existed in the southern Appalachians during the Pleistocene and early Holocene (Clark, 1969; Richter, 1973; Goudie, 1983; Delcourt and Delcourt, 1984, 1986).

Gelifluction and frost creep are both periglacial processes resulting in the gradual downslope mass-movement of mixed rock rubble and soil. The term gelifluction is used to describe the slow

flowing of saturated soil material (congeliturbate) from higher to lower ground (Bryan, 1946). This phenomenon commonly occurs as frozen ground thaws downward from the surface during the warm season. Suitable conditions for gelifluction occur when the downward percolation of water is limited by frozen ground. Rainfall, snowmelt, and the melting of segregated ice lenses provide excess water which reduces internal friction and cohesion in the active layer thus creating conditions favorable for fluid movement (Embleton and King, 1975). In contrast to gelifluction, frost creep is regarded as a much slower process which results from the net downward displacement that occurs when the soil expands normal to the ground surface during a freeze-thaw cycle, and then settles in a more nearly verticle direction (Benedict, 1976). Both of these processes have occurred extensively within the last 15,000 years resulting in the congeliturbate-mantled slopes which exist today. Mass slope movements occur today only on a small scale and at much slower rates than in times of former cold climates. Active gelifluction may in fact be occurring at the present time, but only on a microscale of little significance to landform evolution or soil development.

As a result of these slope processes, the high-elevation soils of the southern Appalachians are all young. Many of the soils in the study areas exhibit evidence of time or lithologic discontinuities and other indicators of slope instability such as buried A horizons, rounded boulder trains in drainageways, and shattered angular coarse fragments which tend to become oriented more or less parallel to the slope on steeper gradients. Another feature of these soils which provides further evidence for multiple periods of colluvial deposition is the common occurrence of abrupt increases in coarse fragment content with depth in nearly all soils examined. The existence of parent material discontinuities at these high elevations is extensive, resulting in younger material covering older material and the mixing of weathered soil with fresh coarse fragments.

Chemical weathering processes also contribute greatly to soil formation in these high mountain areas. Primary and secondary minerals, which are abundant throughout all the study areas, currently are being destroyed and altered in these soils by hydrolysis, oxidation, dissolution, ion exchange, and other weathering mechanisms. Chemical weathering processes are active in these soils despite the relatively cool climate because of high rainfall and leaching conditions, the naturally acid environment, and the presence of great amounts of organic chelating agents in the surface horizons.

Podzolization appears to be an important pedogenic process occurring in nearly all of these high-elevation soils despite the lack of well-expressed spodic morphology in most instances. As soil minerals weather, solubilized Fe and Al is complexed by fulvic acid in the organic-rich surfaces and is transported downward in the profile where they can react with other soil minerals (commonly phyllosilicates) or precipitate in the form of oxides, hydroxides, or oxyhydroxides. Gibbsite, which is usually associated with surficial weathering in tropical soils, increases with depth in nearly all of the soils studied, presumably as a result of its precipitation lower in the profile (Feldman et al., in preparation). Iron and Al compounds in these soils can act as sinks for NO_3^-, SO_4^{2-}, and PO_4^{3-} thereby providing a buffer against the potentially detrimental effects strong acid anion loading from acid deposition (Richter et al., 1983). Under the high leaching and low pH conditions of these organic-rich soils, mica readily transforms to other, more reactive phyllosilicates which provide a large source of cation exchange capacity (CEC) and an important buffer against the depletion of basic cations and the release of toxic metals such as Al, Mn, and heavy metals associated with acid deposition (Richter et al., 1983).

Soil Classification

The vast majority of these high-elevation mountain soils were classified in the field as loamy-skeletal, mixed, frigid Haplumbrepts[2] (Table 1-3). These are the dark-surfaced soils that have undergone enough physical and/or chemical alteration to exhibit features representing pedogenic development, but which lack any significant accumulation of illuvial clay minerals or other indicators of geomorphic stability. Haplumbrepts have umbric epipedons and cambic subsurface horizons. Umbric epipedons are the humus-rich diagnostic surface horizons which are at least 25 cm thick but which contain low amounts of exchangeable bases (<50% of the CEC). Cambic diagnostic subsurface horizons in these soils exhibit moderate to strongly developed structure in most

[2] No established soil series exist for classification below the Family level.

pedons and significant chemical alteration, usually involving the hydrolysis of weatherable minerals and the chelation and redistribution of Fe and Al. As a result of weathering in a relatively cold climate, cambic horizon colors in these soils range from strong brown (7.5YR 5/6) to yellowish brown (10YR 5/6) and do not reflect the redder hues that are characteristic of soils developed on older, more highly weathered landforms.

Although most high-elevation soils of the southern Appalachians exhibit morphological evidence for diagnosis of umbric epipedons and cambic subsurface horizons, laboratory analysis has established that levels of organically-bound (Na-pyrophosphate-extractable) Fe and Al are sufficiently high in at least one subhorizon of many pedons to meet the requirements for a spodic horizon. Thus, although the majority of these soils show no distinct Bh/Bs horizonation and were classified in the field as Haplumbrepts, podzolization has had a major impact on soil properties resulting in many of these soils being being classified as Haplorthods (Table 1-3). Detailed physical, chemical, and mineralogical characterization is thus essential to the correct classification of these soils and to the establishment of new soil series.

The term "loamy-skeletal" is used at the Family level of *Soil Taxonomy* (Soil Survey Staff, 1975) to describe soils in which the fine earth fraction (<2 mm) contains <35% clay by weight, and in which rock fragments (>2 mm) make up >35% of the total volume between given depth limits. This particle-size control section for nearly all of these high-elevation soils includes the zone from a depth of 25 cm to a depth of 1 m. Similar soils with coarse-loamy (<18% clay by weight and <35% rock fragments by volume) or fine-loamy (18-34% clay by weight and <35% rock fragments by volume) particle-size distributions can be found throughout the mountains, but they are of relatively minor extent. These soils usually occur intermingled in a complex association with the more extensive skeletal soils. Most soils in the frigid zones of the southern Appalachians also have <40% of any one mineral other than quartz or feldspar in the fine sand to coarse sand fraction and are therefore classified as having "mixed" mineralogy.

The majority of the soils in the three study areas were classified in the field as Typic Haplumbrepts. These soils are the Haplumbrepts with umbric epipedons <50 cm thick overlying cambic diagnostic subsurface horizons. They are extensive throughout the mountains and are

Table 1. Distribution of soils sampled in the GSMNP by landscape position and slope aspect.

Soil Classification	Ridge		Sideslope		Cove		Total
	E†	W	E	W	E	W	
Typic Haplumbrepts, loamy-skeletal, mixed, frigid	1	-	1	-	1	-	3
Pachic Haplumbrepts, loamy-skeletal, mixed, frigid	-	-	-	-	1	-	1
Umbric Dystrochrepts, loamy-skeletal, mixed, frigid	-	-	-	1	-	2	3
Umbric Dystrochrepts, coarse-loamy, mixed, frigid ‡	1	1	-	-	-	-	2
Typic Haplorthods, loamy-skeletal, mixed, frigid §	-	-	1	1	-	-	2
Lithic Haplorthods, loamy-skeletal, mixed, frigid	-	1	-	-	-	-	1
Total	**2**	**2**	**2**	**2**	**2**	**2**	**12**

† E = 0-179°; W = 180-359° Azimuth
‡ Exhibited well-expressed spodic morphology in the field.
§ Classified as Typic Haplumbrepts in the field due to the lack of spodic morphology.

Table 2. Distribution of soils sampled in the Black Mountains by landscape position and slope aspect.

Soil Classification	Ridge		Sideslope		Cove		Total
	E†	W	E	W	E	W	
Typic Haplorthods, loamy-skeletal, mixed, frigid ‡	-	1	2	1	2	1	7
Typic Haplorthods, coarse-loamy, mixed, frigid §	2	-	-	-	-	-	2
Typic Haplumbrepts, loamy-skeletal, mixed, frigid	-	1	-	-	-	1	2
Lithic Haplumbrepts, coarse-loamy, mixed, frigid	-	-	-	1	-	-	1
Total	**2**	**2**	**2**	**2**	**2**	**2**	**12**

† E = 0-179°; W = 180-359° Azimuth
‡ Classified in the field as Typic or Pachic Haplumbrepts.
§ Classified in the field as Umbric Dystrochrepts.

Table 3. Distribution of soils sampled in the Mt. Rogers area by landscape position and slope aspect.

Soil Classification	Ridge		Sideslope		Cove		Total
	E†	W	E	W	E	W	
Typic Haplumbrepts, loamy-skeletal, mixed, frigid	1	1	2	-	-	1	5
Pachic Haplumbrepts, loamy-skeletal, mixed, frigid	1	1	-	2	-	-	4
Typic Haplumbrepts, fine-loamy, mixed, frigid	-	-	-	-	1	-	1
Typic Haplorthods, loamy-skeletal, mixed, frigid‡	-	-	-	-	1	-	1
Total	**2**	**2**	**2**	**2**	**2**	**1**	**11**

† E = 0-179°; W = 180-359° Azimuth
‡ Classified in the field as Pachic Haplumbrept.

found on all landscape positions, exposures, and geologic formations. They are most commonly found on steep upper sidelsopes as well as on lower sideslopes and coves. Surface boulders in these areas commonly range from 15-50%. Although these soils are deeper than 100 cm to bedrock, solum thickness or the depth to impermeable gravel layers is commonly about 75 cm. Slopes in these areas range from about 20 to greater than 60%. Soils which were classified as Typic Haplumbrepts are virtually indistinguishable, based on morphology alone, from many soils which meet the chemical criteria for Spodosols (Fig. 2-4).

Soils on north- to east-facing sideslopes, where insolation levels are relatively low, are cooler and moister resulting in organic matter accumulation deeper in the profile. Soils in these areas were classified as Pachic Haplumbrepts (Fig. 5). They have umbric epipedons that are thicker than Typic Haplumbrepts, ranging from 50 cm to greater than 1 m in some areas. Pachic Haplumbrepts often contain more coarse fragments than similar soils found on warmer landscape positions because of the effects of greater frost action on slope stability. Surface boulders in these areas range from 20 to >60%. These soils are deeper than 100 cm to bedrock with slopes ranging to as much as 90% in some areas. They are commonly found in areas which are too steep to have been subjected to past logging and as a result, the effects of erosion in these areas generally has been minimal.

Umbric Dystrochrepts are the Inceptisols that have dark surface horizons which are too thin to qualify as Haplumbrepts. These organic-rich surface horizons have either undergone significant decomposition or have eroded to <18 cm. Umbric Dystrochrepts are found on long sinuous ridges, spurs, and upper west-facing sideslopes in all three study areas. They are most abundant in the GSMNP and the Black Mountains where the terrain is highly dissected, but they also can be found in the Mt. Rogers area, especially in areas that are heavily grazed by livestock. These soils have been affected by geologic and/or man-induced erosion to the extent that their morphology, classification, and behavior has been altered. Past logging, forest fires, and forest disease may have been significant disturbances in these soils.

There are also a few areas of Lithic Haplumbrepts in the study areas. These soils are shallower than 50 cm to hard bedrock and are most commonly found on convex knobs and upper shoulder

Figure 2. Pedon GSM 1; loamy-skeletal, mixed, frigid Typic Haplorthod formed in colluvium from Thunderhead Sandstone.

Figure 3. Pedon BM 1; loamy-skeletal, mixed, frigid Typic Haplumbrept formed in colluvium from mica schist.

Figure 4. Pedon MR 7; loamy-skeletal, mixed, frigid Typic Haplumbrept formed in colluvium from rhyolite.

50% COTTON
ENGLISH BOND

Figure 5. Pedon MR 10; loamy-skeletal, mixed, frigid Pachic Haplumbrept formed on NE-facing upper sideslope from rhyolite colluvium.

slopes in the GSMNP and the Black Mountains. Lithic Haplumbrepts are generally found where the rate of erosion has exceeded the rate of soil formation or deposition.

A few localized areas of soils with well-expressed spodic morphology occur almost exclusively on broad, gently sloping summits over quartzitic bedrock in the GSMNP (Fig. 6). These soils are classified as Typic or Lithic Haplorthods and range in depth from 50-100 cm above hard bedrock to <50 cm to rock, respectively. These well-drained Spodosols commonly have thin, dark surfaces and bleached albic (eluvial) horizons overlying illuvial accumulations of Fe, Al, and/or humic material in the spodic horizon. In some areas, the process of cheluviation has degraded mineral surface horizons to such an extent that the albic horizon is now directly overlain by organic horizons in various states of decomposition (Fig. 6).

A few small areas of organic soils can be found in these high elevation areas, particulary in the GSMNP and the Black Mountains. These soils have hemic and sapric organic materials directly overlying bedrock and are classified as Lithic Borofolists. They commonly do not support forest vegetation. Small areas of mineral soils with histic epipedons can also be found throughout the mountains (Fig. 7). These soils may be particularly sensitive to the effects of fire, occurring as either wildfire or in a controlled burn, which may oxidize much of the total effective rooting volume. Inceptisols with histic epipedons are not currently recognized in U.S. soil classification system (Soil Survey Staff, 1975). However, the significant contribution of organic horizons to nutrient cycling, available water holding capacity, soil temperature modification, and CEC in these forest soils makes it important to consider including Histic subgroups of Haplumbrepts as an amendment to *Soil Taxonomy* (Soil Survey Staff, 1975).

Correlation with Permanent Plots

Thus far in this report, an attempt has been made to provide information concerning a) the geologic diversity of the high-elevation areas of the southern Appalachians, b) the nature and general distribution of soils in the study areas noting similarities and differences both between and

Figure 6. Pedon GSM 14; coarse-loamy, mixed, frigid Typic Dystrochrept found on broad upland ridgetop over feldspathic quartzite.

Figure 7. Pedon GSM 14; loamy-skeletal, mixed, frigid Typic (Histic) Haplumbrept located on the south face of Whitetop Mtn.

within the study areas, and c) the soil-forming processes that are currently active and which have been active in the past.

At this point, it is desirable to try to correlate some of the soil-landscape relationships which have been developed thus far with the areas of the permanent intensive plots. Table 4 lists soils in these plot areas, classified, based on field morphology, according to landscape elevation, slope aspect, and type of parent material. Unless otherwise specified, soils are classified to the Family level and as previously indicated, no suitable soil series currently exist for further classification. Most of the soils are assumed to be loamy-skeletal (centered on coarse-loamy in the fine earth fraction), with a few inclusions of less gravelly soils.

It should be clearly noted that levels of funding and therefore time and manpower constraints have precluded the possibility of conducting on-site soils investigations at each of the permanent plots. Classification of soils in many of these areas was based on knowledge of soil-landscape relationships developed during fieldwork, without the benefit of any remote sensing data. It was also beyond the scope of this research to prepare a soils map of the study areas, and in fact no soil boundaries have been delineated on any of the topographic maps found in Appendix C. Indeed, the level of detail required to provide a precise classification of the soils in any specific area is greater than most soil survey (mapping) programs provide and can only be obtained with an on-site investigation. Because the occurrence of spodic soils with Haplumbrept morphology cannot currently be accurately predicted on the landscape, both on-site investigations and sampling for laboratory characterization are needed at each permanent plot to accurately classify these soils and to assess their influence on anion retention, weathering rates, nutrient cycling, and forest productivity.

Table 4. Classification of soils in the permanent plot areas.†

Soil Classification	Plot Number
GSMNP	
Typic Haplumbrepts, loamy-skeletal, mixed, frigid‡	301,303,304,310,311,313,317,318,320,321,326,327,328,329 331,333,334,335,336,341,344,347,348,352,353,356,357
Umbric Dystrochrepts, loamy-skeletal,mixed, frigid	302,305,306,307,308,312,314,316,322,323,324,325,337, 340,342,346,349,351,354,355
Pachic Haplumbrepts, loamy-skeletal, mixed, frigid	315,319,330,332,338,339,350
Lithic Haplorthods, coarse-loamy, mixed, frigid	343
Black Mountains	
Typic Haplumbrepts, loamy-skeletal, mixed, frigid‡	2,6,7,8,15,16,17,18,21,22,24,26,31,32,33,34,35,36,37,39, 41,42,44,47,49,51,52,53,54,55,56
Pachic Haplumbrepts, loamy-skeletal, mixed, frigid	2,4,10,11,12,50
Umbric Dystrochrepts, loamy-skeletal,mixed, frigid	40,46,48
Mt. Rogers	
Typic Haplumbrepts, loamy-skeletal, mixed, frigid‡	4,5,6,7,12,13,14,15,18,19,21,22,23,24,26,28
Pachic Haplumbrepts, loamy-skeletal, mixed, frigid	1,2,8,11
Umbric Dystrochrepts, loamy-skeletal,mixed, frigid	20,27

† Classifications are tentative, pending on-site investigation and laboratory chemical determinations.
‡ Some soils classified as such may meet the chemical criteria for spodic horizons and may therefore be Haplorthods.

Conclusions

Soil morphological features throughout nearly all of the southern Appalachians are remarkably similar despite significant variation in topography, local geology, and parent material composition. This similarity is, in part, due to the dominant influence of both present-day and past climatic processes which have imparted a high degree of geomorphic instability throughout the area resulting in the youthful appearance of these soils. Despite obvious morphological similarities, important differences in soil chemical and mineralogical properties may exist as regional geology and other factors vary. Differences in the chemical properties of these soils may greatly affect the degree to which they are buffered against accelerated cation leaching, detrimental effects on plant nutrition and eventual losses of productivity. The identification and characterization of soil components, and determination of their distribution on the landscape is essential to being able to adequately assess the effects of acid weathering, nutrient cycling, and other biogeochemical processes in these forested ecosystems.

III. Distribution of Parent Materials and Soil-Landscape Relationships

Introduction

Subalpine spruce-fir forests of the southern Appalachians are biologically unique, geographically restricted remnants of a boreal forest community which was widespread throughout much of eastern North America during the end of Pleistocene glaciation (Delcourt and Delcourt, 1984, 1986). Today, spruce-fir forests in the southern Appalachians are isolated from related northern vegetation and are confined to elevations above 1450 m in the higher mountains of eastern Tennessee, western North Carolina, and southwestern Virginia.

The majority of soils throughout these high-elevation areas are classified, based on field morphology and observable physical properties, as loamy-skeletal, mixed, frigid Typic or Pachic Haplumbrepts. Soil morphological features are remarkably similar despite significant variation in local geology and parent material composition. This has resulted from the dominant influence of climate on pedogenesis and the fact that there is very little "residuum" at these high elevations. Present day frost churning and windthrow on sloping ground are active processes which transform

residuum into other mixed parent materials thus masking the geologic influence on gross soil morphology. Periglacial activity during both the Holocene and late Pleistocene (Goudie, 1983; Delcourt and Delcourt, 1984, 1986; Conners, 1986) has also acted to produce widespread geomorphic instability in these areas (Clark, 1968; Richter, 1973; Clark and Ciolkosz, 1988) increasing the rate of slope movement and transport of sediments, especially in areas of strongly dipping phyllite and slate. As a result of these slope processes, most high-elevation soils of the southern Appalachians exhibit time and/or lithologic discontinuities and other indicators of slope instability such as buried A horizons, boulder trains in drainageways, and shattered angular coarse fragments mixed throughout the solum and oriented parallel to the slope on steeper gradients. The youthful appearance of these soils is, in part, the result of weathering in a cold environment on unstable slopes which has given rise to a relatively short soil-forming interval and weak expression of morphological characteristics.

In an early study, Coile (1938) reported 'well-defined Podzols' formed on siliceous rocks of the West Virginia highlands, and 'less well-developed Podzols' formed over a wide range of igneous and metamorphic rocks throughout southwestern North Carolina and eastern Tennessee. He attributed the weak expression of spodic morphology in these areas to the high base content of parent rocks. McCracken et al. (1962) described the majority of soils at the high-elevations of the Great Smoky Mountains National Park as having 'thin A1 and color B horizons'. Similar results were reported by Wolfe (1967) who noted that effects of bedrock type and vegetation on soil chemical and morphological properties were minimal. Soils with well-expressed spodic morphology were reported to be relatively rare because of lateral movement of Fe-oxides from upslope and because of effects of windthrow and soil creep, which impeded soil horizon differentiation.

Because of the severe climate, remoteness, difficult terrain, and marginal economic value of land resources, few detailed studies of the nature and origin of these soils have been made and the relatively little amount of soil survey work that has previously been conducted in these areas has been done largely on a reconnaissance basis (Daniels et al., 1984; Springer, 1984; Daniels et al., 1987). As a result, soil series concepts in these areas are ill-defined, making correct classification of many pedons at the series level impossible. Although soil survey activities in the southern

mountains have increased in recent years, few modern surveys to date have adequately addressed existing soil correlation and classification problems. Moreover, lack of benchmark knowledge concerning physical, chemical, and mineralogical properties of these soils prevents interpretive predictions of the effects of soil variability on tree species composition, nutrient supplying capacity, or soil response to strong acid anion loading associated with atmospheric deposition (Richter et al., 1983). These factors are becoming increasingly important as public concern grows about potential spruce-fir ecosystem decline. Our objectives in this study were: i) to determine if multivariate statistical analysis can separate these soils on the basis of morphological, physical, chemical, and mineralogical properties, and ii) to evaluate the relative effectiveness of these properties in differentiating soils from each of three geologically distinct study areas.

Study Area

Soils were studied in each of the three most extensive areas of southern Appalachian spruce-fir forests: the Mt. Rogers National Recreation Area of Virginia (MR), the Great Smoky Mountains National Park (GSM) of Tennessee and North Carolina, and the Black Mountains (BM) of North Carolina (Fig. 1). Both BM and GSM are characterized by rugged, steep slopes and sharp ridge crests rising to over 2000 m in elevation and extending in all directions above narrow, deeply incised valleys. The summits of both Mt. Rogers (1746 m) and Whitetop Mtn. (1682 m) in Southwest Virginia are smooth, broad, dome-like structures of low relief above steep and broken sideslopes. The specific geometries of major topographic features in the mountains are closely related to lithologies and geologic structures of the underlying bedrock which is distinctly different at each site.

Geology

The Mt. Rogers study area is underlain by thick masses of upper Precambrian volcanic and sedimentary rocks ranging in composition from rhyolite with minor amounts of basalt to a complex association of interbedded and interfingering arkosic sandstone, rhythmically layered argillite, pebbly mudstone, and tillite (Rankin, 1967, 1970). Because rhyolite dominates in about 50% of the area, soils tend to be greatly influenced by the presence of fine-grained quartz and alkali feldspars. Most rocks of the Mt. Rogers area have been influenced by at least one episode of Paleozoic metamorphism, and as a result, small outcroppings of greenschist provide a source of ferromagnesian minerals (Rankin, 1967, 1970).

Rocks of GSM consist of a series of Precambrian clastic metasediments which intertongue extensively in the high-elevation spruce-fir zone. The Thunderhead sandstone is a series of massive, thick-bedded rocks composed largely of quartz and potassic feldspars with lesser amounts of plagioclase feldspars and mica. The Anakeesta Formation consists of dark, silty and argillaceous, highly fractured sediments metamorphosed to slate, phyllite, and schist. These rocks have fine textures and are composed largely of quartz, sodic and potassic feldspars, muscovite, biotite, chlorite, and small amounts of Fe-sulfides and free C (King et al., 1968).

The higher elevations of BM are underlain by high-grade, coarse-grained metamorphic rocks which are predominantly quartz-rich mica gneisses and schists interlayered with small amounts of amphibole-gneisses and schists, all of Precambrian age (Stuckey and Steel, 1953; Brobst, 1962; Hadley, 1970). These rocks contain large amounts of biotite, muscovite, plagioclase, quartz, and a wide range of accessory minerals including garnet, epidote, staurolite, and kyanite (Brobst, 1962).

Climate

The climate of the high-elevation areas of the southern Appalachians is characterized by a perhumid moisture regime, with cool summers and cold winters. Potential evapotranspiration in these areas rarely exceeds precipitation which is distributed uniformly throughout the year with a mean annual value of 208.5 cm in GSM (Shanks, 1954). Local intense thunderstorms cause much monthly variation in these averages. Snowfall is usually heaviest in March with accumulations exceeding 127 cm annually and persisting throughout much of the winter only on the more elevated northern slopes. Canopy drip from fog significantly increases moisture as most of the higher summits are enshrouded in clouds about 40% of the time (Smallshaw, 1953). Monthly mean temperatures at the GSM study area range from about -2°C in January to 17°C in July with a mean annual average value of 8°C (Shanks, 1954). The average frost-free period is 133 days at the summit of Mt. Mitchell, located in BM, with the earliest and latest dates of frost recorded as September 30 and June 6, respectively. Soils in all study areas have mean annual temperatures at a depth of 50 cm $\leq$8°C and therefore have frigid temperature regimes.

Materials and Methods

Field and Laboratory Methods

In order to adequately represent soil properties across the total landscape at each of the three study areas, sampling sites were separated into two groups based on landform (topographic position) and exposure to prevailing northwesterly and westerly winds. Duplicate soil pits were excavated and sampled at both exposed and protected sites on each of the three dominant landforms

occurring within the southern Appalachian Highlands: i) ridges and convex upper shoulder slopes, ii) mid-backslopes, and iii) lower backslope/cove positions. Sampling sites were deemed representative and selected for further study if they adequately characterized the dominant geomorphic and vegetational features of the landform based on information generated from transects, trail cut descriptions, and observation of landscape surface features. All sites had a mimimum of 50% spruce-fir vegetation in the overstory. At each sampling site, the soil was described and classified according to standard procedures (Soil Survey Staff, 1975, 1981) (Table 5). Because only one suitable site was found to represent protected coves at the Mt. Rogers study area, one observation was omitted from the analysis. Unequal sample size, however, does not affect the outcome of multiple discriminant analysis, the statistical technique employed (Klecka, 1980).

Samples of genetic soil horizons were air-dried, sieved to remove coarse fragments (>2 mm), and thoroughly mixed. Particle size distribution was determined by pipette analysis (Day, 1965) and the content of organic-C was estimated by dichromate titration (Allison, 1965). Soil pH was measured in the supernatant portion of a 1:1 soil-distilled water suspension after a 1 h equilibration period. Exchangeable Al was measured by extraction in 1 *M* KCl (Thomas, 1982). Cation exchange capacity (CEC) was calculated as the sum of neutral 1 *M* NH_4OAc-exchangeable bases plus total soil acidity as determined by a modified $BaCl_2$-TEA method (Mehlich, 1938). Effective cation exchange capacity (ECEC) was calculated as the sum of exchangeable bases plus KCl-extractable acidity. Organically-bound and reductant-soluble Fe and Al were determined by Na-pyprophosphate extraction (McKeague and Day, 1966) and by the dithionite-citrate-bicarbonate (DCB) method of Mehra and Jackson (1960), respectively.

Pretreatments for mineralogical analysis included removal of organic matter with 30% H_2O_2 in *N* NaOAc adjusted to pH 5 (Kunze, 1965). All samples were treated with DCB to remove Fe-oxide coatings (Mehra and Jackson, 1960). Sand was separated by wet sieving, dried, and ground for 5 min in a reciprocating ball mill. Silt and clay fractions were separated by centrifugation and decantation using dilute *N* Na_2CO_3 adjusted to pH 9.5 as a dispersant. Oriented mounts of the clay fraction were prepared by depositing approximately 250 mg of suspension on unglazed ceramic tiles mounted on a suction apparatus (Rich and Barnhisel, 1977). X-ray diffraction was used to deter-

Table 5. Classification of soils used in the analysis.

Classification	Location			Total
	GSM	BM	MR	
Typic or Pachic Haplumbrepts	4	2	10	16
Umbric Dystrochrepts	5	--	--	5
Lithic Haplumbrepts	--	1	--	1
Typic or Lithic Haplorthods†	3	9	1	13
Total	12	12	11	35

† These pedons meet the chemical criteria for a spodic horizon but were classified as Typic or Pachic Haplumbrepts in the field.

mine clay mineral suites present by analyzing Mg-saturated, glycerol-solvated samples with no heat treatment and after 4 h of heating at 110°C, and K-saturated samples with no heat treatment and after heating for 4 h at 110, 300, and 550°C, respectively. Semi-oriented smear mounts of the silt (0.002-0.05 mm) and ground sand (0.05-2.0 mm) fractions were prepared by depositing about 0.5 g onto a glass slide using distilled H_2O and a spatula. Samples were scanned with CuKα radiation at a rate of 0.075° 2θ $4s^{-1}$ using a Diano XRD 8300 AD x-ray diffractometer equipped with a graphite crystal monochrometer, L11/73 computer, and a printing device. Mineral quantities were entered into the statistical analysis as the integrated intensities of their respective XRD peaks with the exception of kaolinite and gibbsite, which were recorded as percent by weight. Subsamples of the K-saturated clay fractions were also analyzed with differential scanning calorimetry (DSC) using a DuPont 1090 Thermal Analyzer. Samples were heated from 50 to 625°C in an N_2 atmosphere at a rate of 20°C min^{-1}. Kaolinite and gibbsite were quantified by mass-equivalent calibration of endothermic peak areas using poorly crystalline Georgia kaolinite and Reynolds synthetic gibbsite (RH-31F) as standards.

Statistical Analysis

Soil and site properties that effectively separated the observations into areas of geologic origin were determined by multiple discriminant analysis. The principle objectives of this procedure were: i) to assign objects or observations into mutually exclusive groups based on a set of independent variables, ii) to determine whether group centroids are statistically different, and iii) to determine contributions of variables to discrimination of groups. The approach involves finding the best linear combination of variables that will discriminate between *a priori* groups by maximizing between-group variance relative to within-group variance (Dillon and Goldstein, 1984). The linear combination for a discriminant function:

$$Z = \mu_1 X_1 + \mu_2 X_2 + \ldots + \mu_m X_m , \qquad [1]$$

where μ_x = discriminant coefficients and X_x = independent variables, transforms the original m measurements on an individual observation into a single discriminant score, Z. Group centroids represent the average discriminant score for all the individuals in a group. The hypothesis of no significant difference between group centroids was tested by Wilks' λ statistic and the degree of relatedness between groups and calculated functions was assessed by canonical correlation coefficients (Klecka, 1980). The effectiveness of the discriminant functions in classifying observations into mutually exclusive groups was determined by using a split-sample crossvalidation technique which reduces upward bias introduced by classifying the same individuals used in computing the functions (Klecka, 1980; Dillon and Goldstein, 1984). In the split-sample method, original observations from each group are randomly divided into two subsamples: an analysis sample to derive the discriminant function, and a hold-out sample used to classify individuals.

Variables initially selected for the analysis included physical, chemical, mineralogical and morphological soil properties (Table 6). In order to compare sampling units, data generated from genetic soil horizons of each pedon were coded into three layers based on the following criteria: Layer 1 consisted of data obtained from the mineral horizon nearest to the surface; Layer 2 was composed of the weighted average of data obtained from horizons comprising the uppermost diagnostic subsurface horizon (Soil Survey Staff, 1975); and Layer 3 consisted of data generated from the deepest horizon sampled, which was usually restricted to a dense gravelly horizon at a depth of 60 to 120 cm.

Multiple discriminant analysis was performed on each respective layer to examine differences between study areas. Separate analyses were also performed using exposure class and landform, respectively, as grouping variables. Finally, we examined the nature of differences between layers over all observations.

The analysis included a preliminary data screening to reduce the number of variables under consideration and to assess the statistical distribution of the selected variables. Computation of a Shapiro-Wilk W statistic (Afifi and Clark, 1984) and interpretation of histograms and normal

Table 6. Definitions of symbols and units of measurement used in the analyses.

Symbol	Definition and unit of measurement
SAND	0.05 to 2.0 mm fraction (g kg^{-1} soil)
SILT	0.002 to 0.05 mm fraction (g kg^{-1} soil)
CLAY	< 0.002 mm fraction (g kg^{-1} soil)
SOLUM	Solum thickness (cm)
EPI	Epipedon thickness (cm)
OA	Oa horizon thickness (cm)
HU	Hue of the matrix
VA	Value of the matrix
CH	Chroma of the matrix
pH	pH (-log $[H^+]$)
H^+	$BaCl_2$-TEA, pH 8.2, exchangeable acidity ($cmol_c$ kg^{-1} soil)
FE	Dithionite-citrate-bicarbonate (DCB) extractable Fe (% as free Fe)
SPODIC	Meets chemical criteria for spodic horizon†
OC	Acid dichromate-digestible organic C (g kg^{-1} soil)
SBAS	$\sum$ NH_4OAc, pH 7, extractable Ca^{2+}, Mg^{2+}, and K^+ ($cmol_c$ kg^{-1} soil)
CEC	Cation exchange capacity determined by $\sum$ SBAS + H^+ ($cmol_c$ kg^{-1} soil)
ECEC	Cation exchange capacity determined by $\sum$ SBAS + KCL extractable Al^{3+} ($cmol_c$ kg^{-1} soil)
BSS	Base saturation of the CEC (%)
BSE	Base saturation of the ECEC (%)
ALSAT	KCl extractable Al^{3+} (% of CEC)
KSAT	NH_4OAc, pH 7, extractable K^+ (% of CEC)
MGSAT	NH_4OAc, pH 7, extractable Mg^{2+} (% of CEC)
CASAT	NH_4OAc, pH 7, extractable Ca^{2+} (% of CEC)
CQTZ	Clay fraction quartz (intensity 4.24 Å XRD peak)
CGIBB	Clay fraction gibbsite (% determined by DSC)
CKAOL	Clay fraction kaolinite (% determined by DSC)
CMICA	Clay fraction mica (intensity 10.0 Å XRD peak)
C21	Clay fraction expansible 2:1 phyllosilicates ($\sum$ intensity 12-14 Å XRD peaks)
SIQTZ	Silt fraction quartz (intensity 4.24 Å XRD peak)
SIMICA	Silt fraction mica (intensity 10.0 Å XRD peak)
SIKAOL	Silt fraction kaolinite (% determined by DSC)
SIGIBB	Silt fraction gibbsite (% determined by DSC)
SIPLAG	Silt fraction plagioclase (intensity 3.18 Å XRD peak)
SIKSPAR	Silt fraction K-feldspar (intensity 3.24 Å XRD peak)
SI21	Silt fraction expansible 2:1 phyllosilicates ($\sum$ intensity 12-14 Å XRD peaks)
SIINT	Silt fraction interstratified phyllosilicates ($\sum$ intensity > 14 Å XRD peaks)
SQTZ	Sand fraction quartz (intensity 4.24 Å XRD peak)
SMICA	Sand fraction mica (intensity 10.0 Å XRD peak)
SPLAG	Sand fraction plagioclase (intensity 3.18 Å XRD peak)
SKSPAR	Sand fraction K-feldspar (intensity 3.24 Å XRD peak)
S21	Sand expansible phyllosilicates ($\sum$ intensity 12-14 Å XRD peaks)

† The ratio of pyrophosphate (Py)-extractable Fe + Al to percentage of clay ≥ 0.2 and the ratio of Py-Fe + Py-Al to DCB-Fe + DCB-Al ≥ 0.5.

probability plots were used to determine that a logarithmic transformation of the data was preferred over no transformation to achieve marginal normality and variance equality for each of the observed variables. All variables were transformed using the log transformation with the exception of pH since it already represented the log of a concentration and was approximately normally distributed.

Analysis of variance (ANOVA) was used to identify soil and site properties that did not differ significantly ($\alpha = 0.05$) between at least two of groups. Variables which had similar distributions were considered to contribute very little to the overall discrimination between groups and were therefore eliminated as differentiae.

A stepwise selection procedure was used to determine the best subset of remaining variables for derivation of discriminant functions. Successive stepwise additions or deletions of variables from the system were based on their effect on the discrimination achieved by variables already entered, taking $\alpha = 0.15$ as the fixed significance level associated with the partial F statistic for entry (Costanza and Afifi, 1979).

Statistical analyses were performed using programs of the Statistical Analysis System (SAS Institute, 1985) and the Biomedical Statistical System (Dixon, 1983).

Results and Discussion

Model Derivation and Validation

The independent variables retained by the ANOVA procedure for each analysis included soil properties that differed significantly ($p \leq 0.05$) between study areas (Table 7). Of these variables, a smaller subset was retained by the forward stepwise selection procedure which further eliminated variables not useful in discriminating between groups. The remaining variables primarily included mineralogical and chemical soil properties which, together with summary statistics, are presented

in Table 8. Because significant differences between soil physical and morphological properties were not observed, these variables were eliminated in the early stages of initial data screening.

The canonical functions calculated in each of the analyses were statistically significant, as measured by transformation of Wilks' λ to a multivariate F-statistic for testing group differences (Table 9). Canonical correlation coefficients ranged from $r^* = 0.85\text{-}0.99$ in each analysis (Table 9) indicating that the calculated functions are indeed valid predictors of the observed group differences.

The model was further validated by comparing classification accuracy relative to chance. The proportional chance criteria, or the percentage of individuals that would be correctly classified by chance, weighted for unequal sample size, is:

$$C_{pro} = p_1^2 + p_2^2 + p_3^2 \qquad [2]$$

where C_{pro} = proportional chance criterion and p_x = proportion of individuals in group x. For analysis of Layers 1-3, the proportional chance criterion of each analysis is:

$$C_{pro} = (0.34)^2 + (0.34)^2 + (0.31)^2 = 0.35. \qquad [3]$$

Results of the classification procedure presented in matrix form (Table 10) indicate that the 97-100% accuracy achieved by the model is substantially higher than the 35% accuracy attributable to chance alone.

Interpretation

Results for the analysis of Layers 1-3 show clear separation of groups, thus illustrating distinct differences between soils of each study area (Fig. 8). The first discriminant function, which accounts for 76-89% of the total discriminating power in each analysis (Table 9), is the primary source of difference between soils formed from volcanic parent materials (MR) versus soils formed

Table 7. Variables retained after ANOVA and probability levels associated with the hypothesis of no significant difference between study areas for Layers 1-3.

Property†	Layer 1	Layer 2	Layer 3
	P > F		
SAND	0.0001	0.0001	0.0002
SILT	0.0001	0.0001	0.0001
CLAY	0.4498	0.0008	0.0484
SOLUM	0.0859	0.0859	0.0859
EPI	0.4776	0.4776	0.4776
OA	0.0025	0.0025	0.0025
HU	0.9999	0.3092	0.0005
VA	0.4052	0.2174	0.4643
CII	0.1770	0.2670	0.0326
pH	0.2128	0.9545	0.5738
H^+	0.0120	0.0010	0.0027
FE	0.1129	0.5452	0.3351
SPODIC	0.0005	0.0005	0.0005
OC	0.0060	0.0007	0.0151
SBAS	0.0232	0.0003	0.1326
CEC	0.0134	0.0011	0.0028
ECEC	0.3373	0.4181	0.7356
BSS	0.0001	0.0003	0.0001
BSE	0.3062	0.3898	0.0509
ALSAT	0.0029	0.0003	0.0027
KSAT	0.0962	0.1043	0.2048
MGSAT	0.0092	0.0126	0.1496
CASAT	0.0001	0.0001	0.0001
CQTZ	0.0184	0.0844	0.0623
CGIBB	0.0161	0.0326	0.0020
CKAOL	0.1062	0.0013	0.0006
CMICA	0.0030	0.0440	0.0685
C21	0.0652	0.0033	0.0001
SIQTZ	0.2253	0.1625	0.0085
SIMICA	0.0001	0.0001	0.0001
SIKAOL	0.0010	0.0161	0.0026
SIGIBB	0.4695	0.3461	0.2357
SIPLAG	0.0001	0.0001	0.0001
SIKSPAR	0.0001	0.0001	0.0001
SI21	0.0001	0.0001	0.0001
SIINT	0.0024	0.0130	0.1491
SQTZ	0.0001	0.0001	0.0001
SMICA	0.0001	0.0001	0.0001
SPLAG	0.0001	0.0001	0.0001
SKSPAR	0.0001	0.0001	0.0001
S21	0.0001	0.0097	0.0094

† See Table 1 for definitions of symbols used to designate soil properties.

Table 8. Variables selected by the forward stepwise discriminant analysis for each Layer, summary statistics, and significance levels for variable entry into the model.

Property†	P > F‡	GSM Mean	GSM SD§	BM Mean	BM SD	MR Mean	MR SD
			Layer 1				
SIMICA	0.0001	183.7	105.4	96.8	64.8	4.4	10.2
SQTZ	0.0001	115.5	20.3	50.8	12.4	92.3	20.1
BSS	0.0001	1.8	0.5	0.8	0.3	1.3	0.5
SIPLAG	0.0054	53.8	30.8	42.8	29.6	5.6	10.1
SPLAG	0.0173	27.4	24.5	79.7	24.3	1.0	0.0
SI21	0.0386	19.5	36.7	102.9	74.8	1.0	0.0
			Layer 2				
SIMICA	0.0007	150.8	75.5	103.7	49.7	6.1	10.3
SQTZ	0.0001	103.6	22.9	48.8	14.7	84.4	8.3
BSS	0.0001	1.8	0.6	0.7	0.6	0.7	0.4
SPLAG	0.0001	24.5	21.5	71.3	21.3	1.0	0.0
SI21	0.0246	54.2	36.4	166.8	65.1	3.2	5.0
MGSAT	0.0407	0.2	0.1	0.1	0.1	0.1	0.1
CASAT	0.0405	0.8	0.2	0.3	0.3	0.2	0.2
ALSAT	0.0225	11.2	10.2	21.5	6.6	11.2	5.3
CGIBB	0.0432	12.0	10.7	8.2	8.7	3.3	5.0
SKSPAR	0.0114	1.6	2.0	1.0	0.0	20.8	14.0
			Layer 3				
SQTZ	0.0001	99.9	25.6	49.7	13.0	84.3	16.3
SPLAG	0.0001	23.8	2.6	78.8	17.1	1.0	0.0
ALSAT	0.0122	24.8	25.3	10.3	10.1	11.3	5.5
SKSPAR	0.0001	1.8	2.6	1.0	0.0	21.1	13.2
SIQTZ	0.0009	41.7	33.4	45.9	22.4	91.7	45.4

† See Table 1 for definitions of symbols used to designate soil properties.
‡ Probability levels associated with no significant contribution to the discrimination between study areas at $\alpha = 0.05$.
§ Standard deviation.

Table 9. Parameters of the canonical discriminant functions and tests of significance for each analysis.

Canonical discriminant function	Relative Percentage†	Canonical Correlation	Wilks' λ	Significance level
		Layer 1		
I	75.6	0.9750	0.00068	0.0001
II	24.4	0.9234	--‡	--
		Layer 2		
I	87.3	0.9862	0.00281	0.0001
II	12.7	0.9181	--	--
		Layer 3		
I	88.6	0.9740	0.01229	0.0001
II	11.4	0.8453	--	--

† Percentage of total variability accounted for by the function.
‡ SAS does not recalculate Wilks' λ and significance level on the residual variance after the first function is extracted.

Table 10. Classification of pedons into groups using all pedons and a split-sample (SS) crossvalidation procedure.

Original group	No. of pedons	Predicted Group: GSM All	GSM SS	BM All	BM SS	MR All	MR SS	% All	% SS
				Layer 1					
GSM	12	12	12	0	0	0	0		
BM	12	0	0	12	12	0	0		
MR	11	0	0	0	0	11	11	100	100
				Layer 2					
GSM	12	12	12	0	0	0	0		
BM	12	0	1	12	11	0	0		
MR	11	0	0	0	0	11	11	100	97.1
				Layer 3					
GSM	12	11	12	1	0	0	0		
BM	12	0	1	12	11	0	0		
MR	11	0	0	0	0	11	11	97.1	97.1

from more metamorphic parent materials (BM and GSM). The second discriminant function, expressing the remaining 11-24% of the total variance, vertically distinguishes between soils formed from acid crystalline rocks (MR and BM) and soils derived from metasediments (GSM).

In order to examine *how* these groups differ, the variables retained in the final model were projected onto the space defined by the two discriminant functions for each analysis (Fig. 9). In doing so, each attribute vector points toward the group having the highest mean level for that variable and away from groups having the lowest mean level. The length of each vector is therefore an indicator of the relative importance of each variable in discriminating between groups.

Visual inspection of the plots for function 1 (Fig. 9) indicates that this dimension corresponds most closely to SPLAG, SI21, SKSPAR, SIMICA, and SIPLAG. Thus, the primary differences distinguishing soils of BM and GSM from those of MR are that the former are higher in silt-size phyllosilicates and both sand- and silt-size plagioclase feldspars. Soils of MR are more siliceous and are characterized by high levels of quartz and K-feldpars lower in the profile, indicative of the dominant influence of rhyolite in that area.

In Layer 1, both BSS and SQTZ were found to be the primary sources of difference between soils of GSM and those of both BM and MR which are similar with respect to these two variables. Sand-size quartz, which increases toward GSM, reflects the high initial content of quartz in the Thunderhead sandstone and the coarse-grained members of the Anakeesta Formation. Base saturation is highest in GSM and is an important discriminator in both Layer 1 and Layer 2 where organic matter decomposition and base cycling provide the bulk of plant-available nutrients in these spruce-fir ecosystems. The large amount of SIPLAG, which provides a source of Na and Ca, and SIMICA, which provides K, also contribute to the observed base saturation trends in GSM soils.

Plagioclase is a dominant feldspar in the metamorphic rocks of BM and GSM and is of relatively minor importance in MR where K-feldspars dominate. Plagioclase occurs predominantly in the sand fraction of BM soils in contrast to its abundance in the silt fraction of GSM soils because the coarse-grained gneisses and schists of BM have high initial amounts of this mineral. Coarse-grained rocks of GSM such as the Thunderhead Sandstone are dominated by quartz and K-feldspars with plagioclase important only in areas influenced by the fine-grained members of the

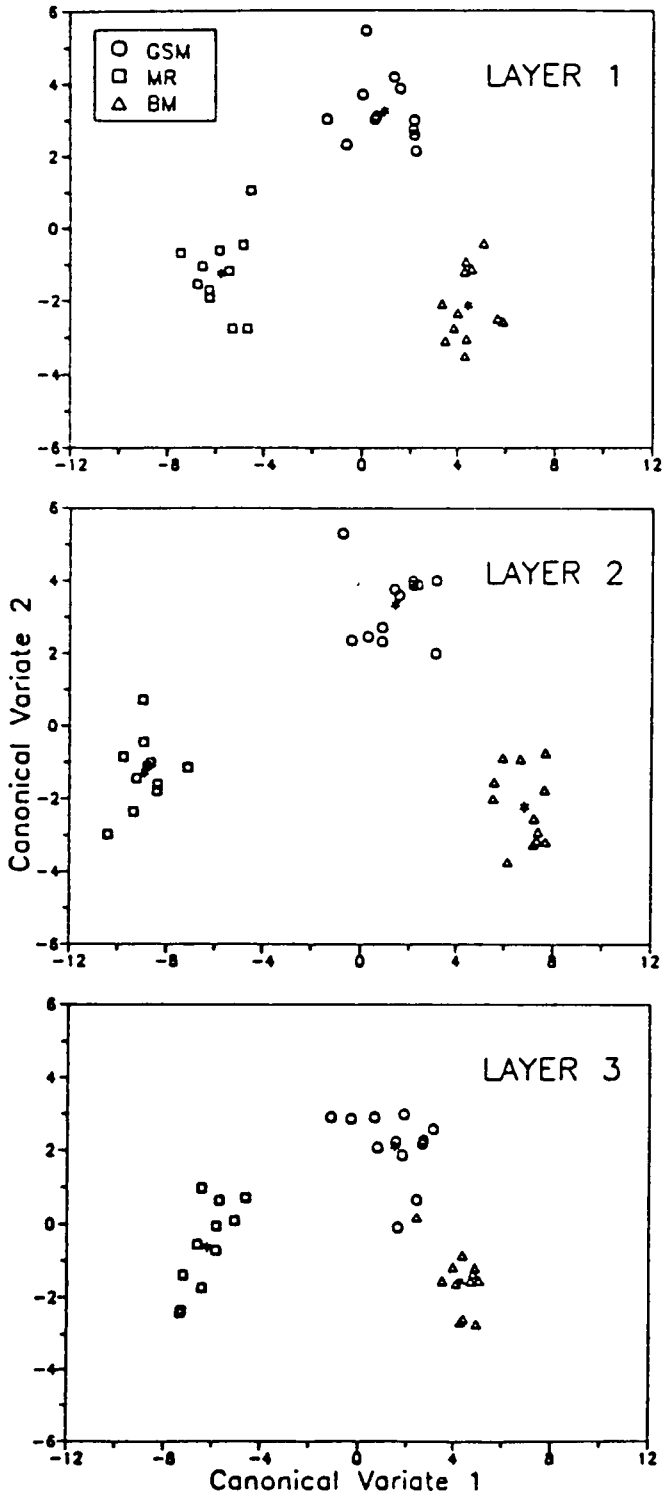

Figure 8. Scatterplot of individual observations and group centroids (*) illustrating differences between study areas.

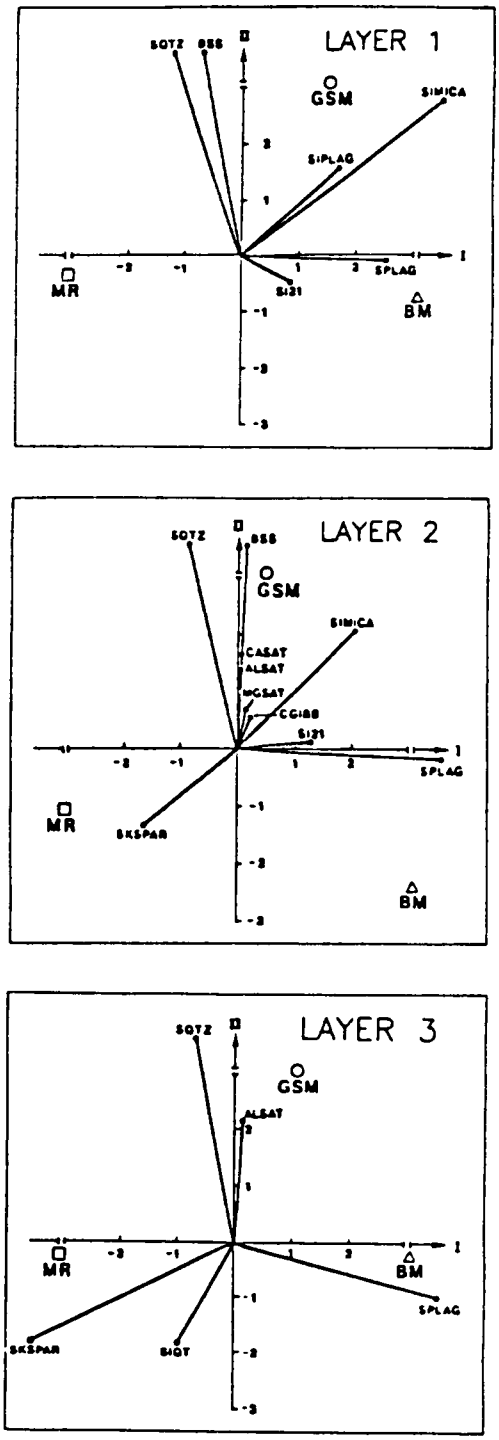

Figure 9. Relative contribution of the predictor variables in discriminating between study areas.

Anakeesta Formation (King et al. 1968). The high content of expansible 2:1 phyllosilicates (SI21), representing the secondary weathering products of micas, are important discriminators in both Layers 1 and 2, accounting for observed differences between GSM and BM versus MR soils. The relative abundance of SI21 in BM soils, despite higher initial mica content of parent material in that area, may suggest a more intense chemical weathering environment than in GSM soils where mica persists. However, the high content of SI21 in BM soils also may reflect the high content of biotite initially present in the parent material relative to the more resistant muscovite (White et al., 1988). The relative increase in all observed silt-size minerals toward the surface in BM and GSM soils not only reflects inheritance from parent material, but also suggests increased physical weathering associated with abrasion during the colluvial transport of surface materials.

The lack of SKSPAR and the presence of both SIPLAG and SPLAG as important discriminators in Layer 1 should not be interpreted as evidence of instability of the former mineral relative to the latter in these soils, despite the fact that some researchers (Todd, 1968; James et al., 1981) have questioned classical weathering schemes which rate K-feldspars as more stable than plagioclase feldspars in near surface environments (Goldich, 1938; Loughnan, 1969). Although relative decreases occur toward the surface for both minerals, more detailed analyses would be needed to determine specific weathering trends and mineral stabilities at each location.

Significant Layer 1 differences between landforms were limited to clay content and horizon thickness which increased along the order of cove > mid-backslope > ridge. These trends reflect the influence of slope processes involved in the transport of sediment, with colluvium becoming deeper, finer, and more well-sorted as it flows downslope onto steeper gradients and depositional landforms.

The analysis of samples from Layer 2, which represents the uppermost diagnostic subsurface horizon of each pedon, resulted in trends which were similar to those observed in Layer 1 indicating homogeneity of the colluvial parent material and a similar pedogenic environment. Layers 1 and 2 comprise the solum of most profiles and therefore represent the zone of biological activity which, in contrast to Layer 3, is significantly influenced by organic matter and nutrient cycling. In addition to BSS, Ca- and Mg-saturation of the exchange complex (CASAT and MGSAT) were important

discriminators in Layer 2, resulting from the weathering of plagioclase and chlorite and nutrient biocycling in these soils.

Both ALSAT and CGIBB are important discriminators lower in the profile of all pedons, but these trends were best expressed in GSM soils. Gibbsite was most abundant in the clay fraction of all soils, commonly increasing with depth in contrast to trends which would be expected under conditions of intense desilication. Gibbsite formation in these soils is related to weathering of primary aluminosilicate minerals in surface horizons, cheluviation and downward percolation of Al, and subsequent reprecipitation as $Al(OH)_3$ lower in the profile (Feldman et al., in preparation). Specific mechanisms of gibbsite precipitation in these soils are uncertain at the present time because pH levels throughout the profile are usually < 4.5 and are typically low enough for Al to remain soluble even in an unchelated form. However, it is possible that as critical Al:organic chelate levels are exceeded at some depth in the profile, Al may be rapidly released to solution in amounts that represent oversaturation with respect to gibbsite, resulting in the precipitation of this mineral even at low pH values.

Layer 2 variables which distinguish between landforms include pH, clay fraction mica, and silt-size kaolinite which show the following trends: cove > mid-backslope > ridge emphasizing the importance of slope processes in the transport of base cations and fine-earth materials.

Layer 3 was defined as the lowest horizon sampled because deep observations were limited by high subsoil coarse fragment content which ranged from about 50-85% by volume and which effectively restricted root penetration and significant amounts of biological activity to depths of less than about 110 cm. As a result, Layer 3 differences between study areas are attributable primarily to soil mineralogy with BSS and other chemical characteristics of minor importance. Sand-size quartz, plagioclase, and K-feldspar (SQTZ, SPLAG, and SKSPAR) show equal or greater importance as discriminators in Layer 3 than they do in either Layer 1 or 2 due to the high coarse fragment content. Given the colluvial nature of the parent material, the absence of silt-size minerals as an important discriminator in Layer 3 suggests that abrasion and physical weathering of materials in this layer is minimal. Coarse fragments in this layer are often oriented parallel to the slope thus creating a dense, impermeable zone which effectively restricts downward movement of drainage

waters. Under saturated conditions such as after winter snowmelt, laterally flowing subsurface waters may limit colluvial processes in these soils to the more "active" surface layers. The high content of silt-size quartz in Layer 3 of MR soils, rather than being an exception, is the result of the fine-grained nature of the rhyolite in that area. Aluminum saturation of the exchange complex is increasingly important in Layer 3, indicating a lack of rooting activity and base cycling at this depth, and suggesting that soil acidity and chemical weathering gradients change only minimally with depth in these soils. Layer 3 differences between landform were limited to clay-size mica which was greatest on depositional landscape positions.

Differences between exposure classes were not significant for all variables with the exception of CECE which was greater on exposed rather than protected sites, possibly resulting from higher levels of windthrow and soil mixing on these cooler sites.

From an analysis of multivariate differences between layers over all observations, we conclude that Layers 2 and 3 are nearly alike and that they differ from Layer 1 mainly in terms of the first discriminant function which accounts for 98% of the total dispersion in the data (Fig. 10). Layer 1 differs from Layers 2 and 3 mainly by having a larger amount of extractable bases (SBAS), lower pH levels, and by having lower matrix color values (VA) (Fig. 11). These differences indicate the importance of organic matter on soil physical and chemical properties and help distinguish between umbric epipedons and cambic diagnostic subsurface horizons. Differences between layers are also attributable to free Fe, which is associated with mineral weathering in near surface horizons, and CGIBB, which increases with depth.

Conclusions

The use of multiple discriminant analysis to differentiate between these morphologically similar soils has resulted in the clear separation of soils into distinct groups. Physical and morphological properties used to separate and classify these soils in the field did not differ significantly for any of

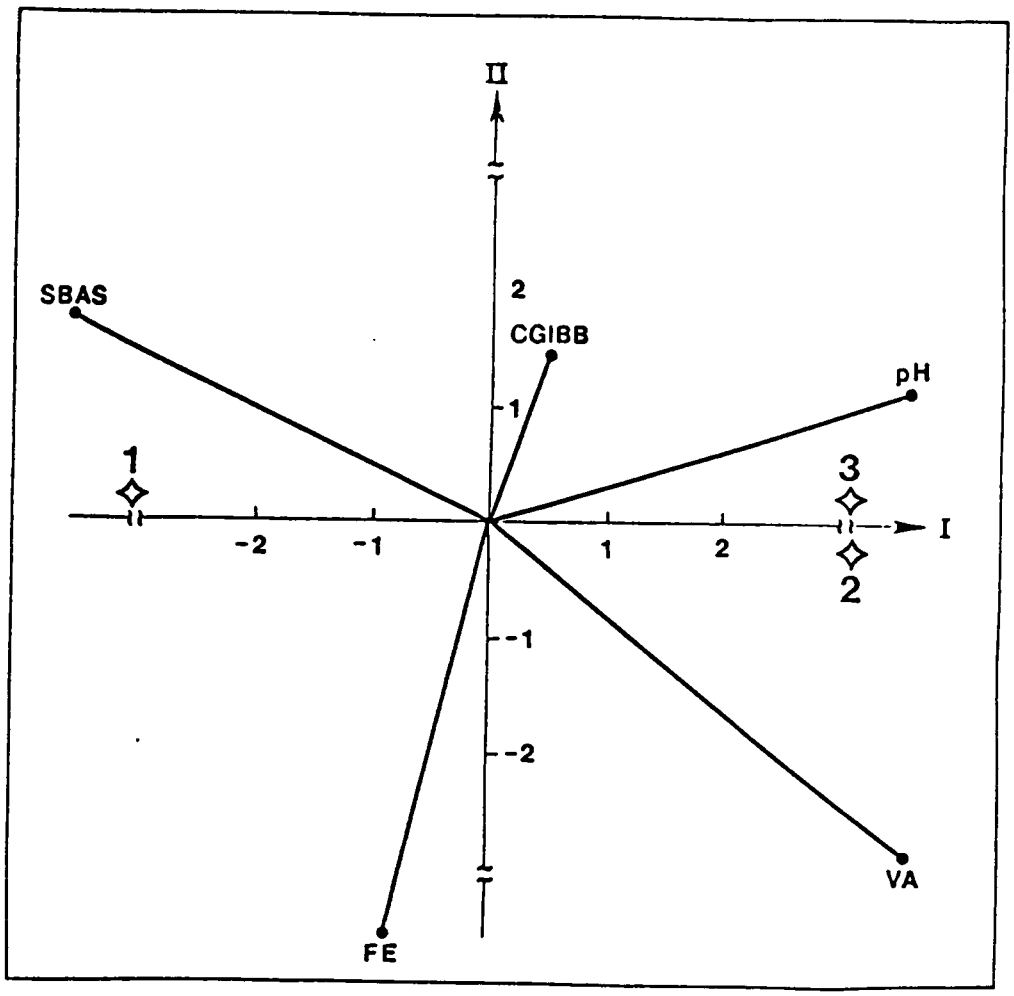

Figure 10. Scatterplot of differences between layers over all observations.

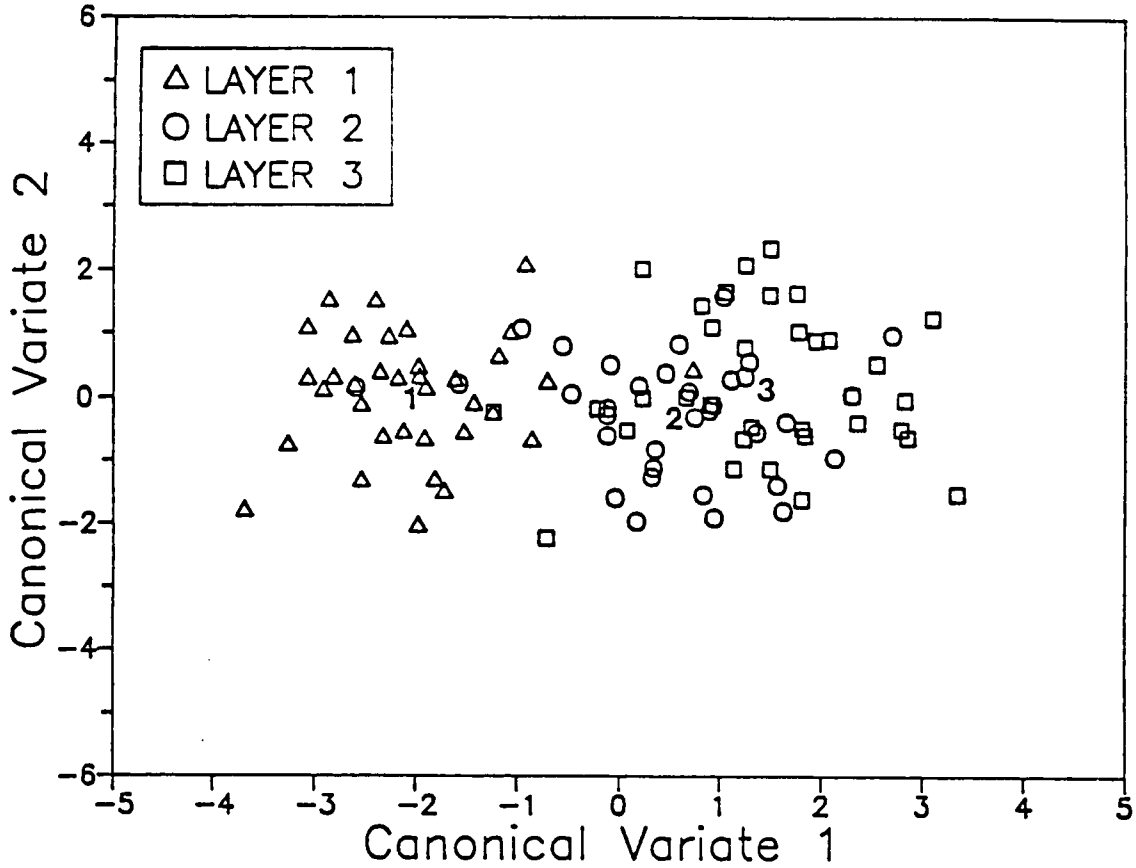

Figure 11. Relative contribution of the predictor variables used to discriminate between layers.

the soils studied. Because climate, vegetation, and time of soil formation are similar at each study site, major differences in soil properties were influenced primarily by parent material and topography. Parent material differences between study areas were reflected in soil mineralogical and chemical properties which provided the clearest separation between groups of soils. Soils formed from siliceous volcanic parent materials (MR) were high in K-feldspar and quartz in both the sand and silt fractions. Soils derived from metamorphic rocks (GSM and BM) had plagioclase as the dominant feldspar, were less quartzitic, and had high contents of mica and 2:1 phyllosilicates. Differences in soil properties between landforms, such as soil depth, clay content, and pH, increased along the order: cove > mid-backslope > ridge, indicating the importance of slope processes involved in the surface and subsurface transport of materials.

Although genetic interpretation of mineral weathering is highly uncertain in colluvial soils, several observed trends can provide insight into major pedogenic processes occurring in the spruce-fir zone of the southern Appalachians. The increasing content of silt-size minerals toward the surface of these soils suggests that mechanical abrasion of coarse fragments and soil minerals is an important physical weathering process in these soils. The increase in both exchangeable Al and clay-fraction gibbsite with depth suggests that podzolization is also an active pedogenic process occurring in these soils. Thirteen of the 35 total pedons sampled meet the chemical criteria for Spodosols (Table 5), but only two of the soils studied exhibited any evidence of spodic morphology. These two soils, however, were unique in that they formed exclusively in quartzitic parent materials on stable landforms with slopes $\leq$ 15%. The lack of spodic morphology in the vast majority of these soils can be attributed to the high content of Fe-bearing weatherable minerals and to the geomorphic instability caused by frost churning, windthrow, and soil creep on these steeply sloping terrains, all of which retard horizon development. Base cycling is an important component of forest nutrition in these spruce-fir ecosystems which is indicated by increasing trends in BSS, CASAT, and MGSAT toward the surface. Disturbances to the forest floor caused by fire, overgrazing, logging, or erosion may have a major impact on ecosystem resilience during stress.

IV. Summary and Conclusions

High-elevation spruce-fir forests, occupying an area of over 14,000 ha in the southern Appalachians, may potentially be in a state of decline as a result of either natural or anthropogenic causes. Soils observed in areas representative of 117 permanent intensive research plots established to evaluate changes in forest growth exhibited a high degree of morphological similarity across contrasting landforms, elevations, and parent materials. Morphological similarity in these soils is largely attributable to the influence of both present and past climatic effects in promoting sufficient geomorphic instability throughout the area to retard horizonation and maintain these soils in a youthful condition. Soils in the study areas are presently weathering in a cool, perhumid climate which has resulted in conditions of organic matter production and accumulation, and high acidity. Although these soils have a large amount of weatherable minerals existing in coarse fragments mixed throughout the profile, levels of exchangeable cations are extremely low owing to intense leaching conditions and the abundance of soluble organic acids in surface horizons.

Podzolization appears to be a dominant pedogenic process occurring almost without exception in these soils. Weathering of primary and secondary soil minerals and mobilization of Fe and Al are greatly facilitated under these conditions, giving rise to smectite and interstratified phyllosilicates in surface horizons, and increasing levels of gibbsite with depth as cheluviated Al precipitates lower in the profile. Soils lacking evidence of even minimal E horizon expression commonly meet the

chemical criteria for spodic horizon determination. Consequently, there exists a considerable degree of chemical variability in these soils which is not manifest in morphological characteristics making it difficult to accurately predict the occurrence of soil types on the landscape without on-site investigations and laboratory analysis.

Because relatively little detailed soil survey work has been conducted in these high mountain areas, soil series concepts are ill-defined, and several problems exist with soil classification. By far, the vast majority of these high-elevation soils were classified in the field as loamy-skeletal, mixed, frigid Typic or Pachic Haplumbrepts. However, 12 of the 35 pedons sampled in this study were reclassified as Typic Haplorthods based on chemical criteria. Differences in soil chemical properties influencing soil classification at the Order level, including levels of both Na-pyrophosphate- and DCB-extractable Fe and Al, have a major bearing on anion retention, mineral weathering rates, cation leaching, and ultimately the buffering capacity of these soils with regard to any potential effects of atmospheric deposition.

Following is a summary of proposed changes that should accomodate some of the unique problems in classifying soils of the high elevations of the southern Appalachians:

1. Establishment of Spodic subgroups of Dystrochrepts and/or Haplumbrepts to include those soils with chemical properties of a Spodosol, but with Inceptisol morphology.

2. Recognition of soils with histic epipedons overlying mineral umbric or ochric epipedons. These organic-rich horizons contribute significantly to nutrient accumulation and recycling, soil temperature modification, and CEC and should be distinguished at the subgroup level.

3. Expansion of the concept of Ochrepts to include soils in areas with frigid soil temperature regimes. Soils in the frigid zones of the southern Appalachians which do not meet the thickness requirements for umbric epipedons currently must be classified as Umbrepts by default.

Multivariate statistical analysis was used to separate these soils on the basis of morphological, physical, chemical, and mineralogical properties, and to determine the effectiveness of these prop-

erties in differentiating soils from each of the three study areas. Physical and morphological properties used to separate and classify these soils in the field were not significantly different between study areas. Parent material differences, however, expressed in both soil chemical and mineralogical properties, were sufficiently different between study areas to result in the clear separation of soils into distinct groups. Soils formed from siliceous volcanic parent materials (MR) were dominated by K-feldspar and quartz in both the sand and silt fractions. Soils derived from more metamorphic rocks (GSM and BM) were less quartzitic, had plagioclase as the dominant feldspar, and had high contents of expansible 2:1 phyllosilicates. Exchangeable Al and gibbsite in the clay fraction of all soils increased with depth, suggesting that podzolization is indeed an important pedogenic process occurring in these young soils. The importance of nutrient cycling in these spruce-fir forests is indicated by high levels of exchangeable bases in surface horizons relative to deeper in the profile. This suggests that disturbances to the forest floor such as fire, overgrazing, logging, or erosion could have a major impact on ecosystem resilience during stress.

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Appendix A. Protocol for Soil Description and Classification

Purpose

To establish procedural guidelines for the field description and classification of soils in the study areas in order to:

1. Determine the general distribution and extent of major soil taxonomic units
2. Maintain field procedures consistant with established National Cooperative Soil Survey (NCSS) standards
3. Identify deviations from established soil series and identify major taxa for which there are no appropriate series available for use
4. Correlate soil genesis and morphology with observable landscape features thereby providing interpretive information for the study areas and a basis for broader extrapolation
5. Minimize disturbance to the present study sites and the ecosystem in general

Pre-Field Activity

1. Assemble existing information about area geology and established soil series. Resources include:
   a. U.S. Geological Survey and comparable State agencies
   b. Local Soil Conservation Districts; U.S.D.A.- Soil Conservation Service and Forest Service
   c. Modern published soil surveys - these provide much useful information but care should be exercised to ensure that series concepts conform to current standards
   d. Older soil surveys - useful to broadly characterize the area and develop physiographic-geologic relationships

2. Interpretation of topographic maps and aerial photography
    a. Study terrain and identify characteristic landforms
    b. Plan optimum routes of traverse

Procedure

Soil pits must be kept as small as possible while allowing for the examination of soil horizons in both horizontal and vertical dimensions. A pit exposing a vertical face up to approximately 1 meter across and to an appropriate depth is convenient for studying most soils in detail. Classification of soils according to NCSS procedures depends on soil properties to a depth of 2 meters or less. However, high levels of subsoil coarse fragments make it impractical to dig deep enough to reveal all of the soil-geologic-vegetation relationships in many of the study areas. In these cases, an attempt should be made to expose diagnostic surface and subsurface horizons as well as any unweathered parent material where appropriate. Criteria for determining the appropriate soil depth for observation include:

1. Depth of dominance of soil structure over relict rock structure
2. Depth of penetration of common roots and other biological activity that transports organic matter and contributes to the destruction of inherited structure
3. Evidence of clay illuviation, and
4. Evidence of types of weathering associated with modern surface conditions

A further consideration involves defining the nature of the parent material and detecting contrasting strata or time discontinuities. Deeper observations can sometimes be important in these soils and may be obtained on lower slopes where contrasting strata may be close to the surface or even crop out.

The sides of freshly exposed pits are cleaned of loose material disturbed by digging and exposed vertical faces are then examined. Initially, gross morphological features are observed which are dominant or extend over several horizons. These features, including overthickened epipedons, the presence of cemented or dense layers, or great variation in soil depth, may indicate some important pedogenic process and may be helpful in classifying the soil. After gross soil morphology is considered, genetic horizon boundaries are located and marked with pegs or large nails. Horizon dif-

ferentiation is dominantly based on contrasts in soil structure, soil texture, and soil color or degree of mottling. Further delineations can also be made on the basis of soil consistence and contrasting parent materials.

It is important to distinguish between genetic soil horizons and the diagnostic horizons used in the United States soil classification scheme. Genetic soil horizons have properties produced by soil-forming processes which differ from those of the overlying and underlying horizons. They reflect qualitative judgements about morphological changes that are believed to have occurred. Diagnostic horizons, on the other hand, express quantitatively defined features which are used to differentiate between taxa. An umbric epipedon, for example, can include part or all of both A and B genetic horizons, especially in soils on northern slope aspects at the higher elevations of the southern Appalachians. Careful documentation of soil morphological features will provide the diagnostic criteria to accurately classify the soil. Detailed soil descriptions include the documentation of every meaningful characteristic that can be determined in the field including, in part, the following:

1. Horizon thickness and topography
2. Soil texture noting inclusions of dissimilar material
3. Structural organization within horizons including observations on surface features of peds
4. Soil color noting any evidence of restrictive drainage conditions
5. Soil consistence determined at field moisture conditions
6. Rooting abundance and depth
7. Degree and organization of pores and voids
8. Depth to impermeable layers

A detailed description of the terminology, class limits and standards used to compile complete soil descriptions is beyond the scope of this document, but field procedures should be followed as outlined in the Soil Survey Manual (Soil Survey Staff. 1981. Agric. Handb. No. 430. U.S. Government Printing Office, Washington, DC., chapter 4).

In many of the soils at the higher elevations of the southern Appalachians, it is difficult to distinguish between highly decomposed organic horizons and mineral soil because both materials most often are the same color and generally organic horizons include some mineral matter as a re-

sult of frost churning and tree throw. Organic horizons have low bulk density and are often "greasy" to the touch. They generally lack any significant degree of structural organization, but may exhibit a weak degree of fine granular structure, the result of binding effects of colloidal organic matter and pressures exerted by plant roots. Underlying A1 horizons in these areas commonly exhibit moderate coarse or very coarse granular (or crumb) structure which is identifiable in the field, particularly in undisturbed soils. Textural and structural separations made in the field can be reliable especially when checked periodically with loss on ignition and mineralogy data.

Linear, areal, volume, and frequency measurements are made as the soil is studied. Depth and thickness of horizons and root penetration, and dimensions of soil structural units are linear measurements which are easily made in the field. Volume estimates of rock fragments, and frequency counts of soil pores and plant roots are also recorded. These measurements are facilitated by traverses on an established grid to determine the composition or density of the unknown. On-site observations should also include the following:

1. Slope aspect and gradient
2. Surface configuration including slope shape both parallel to, and perpendicular to landform contours
3. Surface stoniness
4. Vegetation characteristics
5. Physiography
6. Parent material
7. Relief
8. Degree of erosion
9. Soil drainage conditions
10. Date of observation

Additionally, the location of each observation must be accurately recorded either by measuring along designated compass bearings to a permanent benchmark, or by permanent record on standard 7 1/2 minute topographic quadrangles.

Each soil should be assigned a field classification to the family level at the time of pit description pending the results of any laboratory analysis that may be required for final placement into

Soil Taxonomy. Classification at the series level should be provided when appropriate series are available for use. However, few detailed soil investigations have been conducted in the remote high mountain areas of the southern Appalachians and correlation of most of these soils with established series is difficult or even impossible.

Bulk samples are taken of each major horizon or subhorizon for mineralogical, chemical, or other required analysis. Volume estimates of the amount of each material are recorded. In sampling stony or gravelly soils, volume estimates are made of material larger than 8 cm. This material is discarded and the remainder is sieved through a 2 cm screen. This fraction is weighed in the field. Bulk samples for laboratory analysis consist of the fraction smaller than 2 cm and representative samples of the coarser material. Samples are collected from the bottom of the pedon towards the top to avoid contamination from material above.

Appendix B. Soil Descriptions

PEDON: GSM 1

Location: Great Smoky Mtn. National Park; SW face of Mt. Buckley; 3215 m at S 80° E from Double Spring Gap shelter

Elevation: 1913 m

Aspect: 195° SW

Slope: 33%

Geomorphic: Upper sideslope; convex contour, linear downslope

Parent Material: Colluvium from Thunderhead sandstone

Vegetation:

Canopy: Fraser fir (about 50% canopy cover; about 20% standing dead)

Understory: Witch hobble, some second growth fir

Ground Cover: Ferns, oxalis, mosses, sedges

Classification: Typic Haplorthod, loamy-skeletal, mixed, frigid

Description

Oa --- 0 to 3 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A1 --- 3 to 21 cm., Very dark brown (10 YR 2/2) gravelly loam; moderate very coarse granular structure; very friable; many fine and very fine roots; about 15% channers of sandstone and phyllite; gradual smooth boundary.

A2 --- 21 to 31 cm., Very dark grayish brown (10 YR 3/2) gravelly loam; common medium distinct brown (10 YR 4/3) mottles; moderate coarse parting to medium subangular blocky structure; very friable; common fine and very fine roots; about 15% coarse fragments; clear wavy boundary.

Bw1 -- 31 to 44 cm., Mottled brown (10 YR 4/3), very dark grayish brown (10 YR 3/2), and strong brown (7.5 YR 4/6) gravelly loam; weak medium subangular blocky structure; friable; few fine roots; about 15% coarse fragments; clear smooth boundary.

Bw2 -- 44 to 72 cm., Strong brown (7.5 YR 4/6) very gravelly loam; weak fine subangular blocky structure; friable; about 50% fragments; clear smooth boundary.

C --- 72 to 92+ cm., Dark yellowish brown (10 YR 4/4) extremely gravelly loam; massive; firm; greater than 60% sandstone and phyllite fragments up to 10 cm across.

Notes:

1. Classified as Typic Haplumbrept in the field.
2. Described from spaded pit.
3. Stopped by gravel at 92 cm.
4. Apparent time discontinuity in colluvium at 44 cm.

PEDON: GSM 2

Location: Great Smoky Mtns. National Park; near Clingman' Dome; 725 m at S 28° E from Clingman's Dome tower

Elevation: 1885 m

Aspect: 236° SW

Slope: 18%

Geomorphic: Upper shoulder slope; double convex

Parent Material: Residuum/colluvium derived from feldspathic quartzites

Vegetation:

Canopy: Fraser fir, few yellow birch (about 75% canopy closure)

Ground Cover: Ferns, mosses, many fallen dead fir

Classification: Lithic Haplorthod, coarse-loamy, mixed, frigid

Description

Oi --- 3 to 0 cm., Fibric material.

Oa --- 0 to 8 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A --- 8 to 18 cm., Very dark grayish brown (10 YR 2/2) mucky loam; weak medium granular structure; very friable; many fine and very fine roots; abrupt wavy boundary.

E --- 18 to 28 cm., Very dark gray (10 YR 4/1) loam; weak fine subangular blocky structure; very friable; common fine and very fine foots; clear wavy boundary.

Bw -- 28 to 50 cm., Dark yellowish brown (10 YR 4/4) loam; weak medium subangular blocky structure; friable; few fine roots.

R --- 50+ cm., Quartzitic bedrock

Notes:

1. Described from spaded pit.
2. Material appears to be churned in place and not transported very far.

PEDON: GSM 3

Location: Great Smoky Mtns. National Park; 183 m at N 25° E from Clingman's Dome tower

Elevation: 1965 m

Aspect: 28° NE

Slope: 25%

Geomorphic: Footslope along ridge; area is slight bench position above slight drop-off

Parent Material: Colluvium from Thunderhead formation (mixed with some phyllite)

Vegetation:

Canopy: Fraser fir (about 50% cover)

Ground Cover: Ferns, mosses, oxalis

Classification: Umbric Dystrochrept, loamy-skeletal, mixed, frigid

Description

Oi -- 3 to 0 cm., Leaf litter, cones, needles.

Oa -- 0 to 3 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A -- 3 to 18 cm., Dark brown (10 YR 3/2) mucky loam; very friable.

Bw -- 18 to 56+ cm., Dark yellowish brown (10 YR 4/4) loam; friable.

Notes:

1. Auger description.
2. Stopped by gravel at 56 cm.
3. About 20% boulders in area.

PEDON: GSM 4

Location: Great Smoky Mtns. National Park; 335 m at N 46° E from Clingman's Dome tower

Elevation: 1938 m

Aspect: 320° NW

Slope: 20%

Geomorphic: Footslope between ridges

Parent Material: Colluvium from Thunderhead sandstone

Vegetation:

Canopy: Fraser fir-red spruce, yellow birch

Understory: Not significant

Ground Cover: Ferns, sedges, mountain aster, vaccinium

Classification: Umbric Dystrochrept, loamy-skeletal, mixed, frigid

Description

Oi -- 3 to 0 cm., Leaf litter, cones, needles.

Oa -- 0 to 3 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A -- 3 to 13 cm., Very dark grayish brown (10 YR 3/2) loam.

Bw -- 13 to 46+ cm., Dark yellowish brown (10 YR 4/4) loam.

Notes:

1. Auger description.
2. Stopped by gravel at 46 cm.
3. About 15% surface boulders in area.

PEDON: GSM 5

Location: Great Smoky Mtns. National Park; 1231 m at S 58° E from Collins Shelter

Elevation: 1570 m

Aspect: 58° NE

Slope: 45%

Geomorphic: Mid to lower backslope position; convex contour, linear downslope

Parent Material: Colluvium from Thunderhead sandstone mixed with phyllite and schist

Vegetation:

Canopy: Fraser fir, red spruce, yellow birch,

Understory: Sugar maple, witch hobble, rhododendron

Ground Cover: Ferns, oxalis, mosses

Classification: Typic Haplumbrept, loamy-skeletal, mixed, frigid

Description

Oi -- 3 to 0 cm., Leaf litter, cones, needles.

Oa -- 0 to 8 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A1 --- 8 to 15 cm., Black (10 YR 2/1) gravelly loam; moderate medium granular structure; very friable; many fine feeder roots; about 15% channers; clear smooth boundary.

A2 --- 15 to 30 cm., Very dark grayish brown (10 YR 3/2) gravelly loam; moderate medium granular structure; very friable; many fine roots; about 15% channers; clear smooth boundary.

Bw --- 30 to 43 cm., Dark yellowish brown (10 YR 4/4) gravelly very fine sandy loam; moderate medium subangular blocky structure; friable; common fine and very fine roots; about 25% phyllite and sandstone channers; clear smooth boundary.

Ab --- 43 to 64 cm., Dark brown (10 YR 3/4) loam; moderate medium subangular blocky structure; friable; few fine and very fine roots; about 10% coarse fragments; clear wavy boundary.

2Bw -- 64 to 109 cm., Yellowish brown (10 YR 5/6) very gravelly loam; moderate medium subangular blocky structure; friable; about 40% phyllite and sandstone channers; clear smooth boundary.

2C --- 109 to 120+ cm., Yellowish brown (10 YR 5/6) very gravelly sandy loam; massive; firm; about 40% phyllite and sandstone channers and flags.

Notes:

1. Described from spaded pit.
2. Stopped by gravel at 64 cm.
3. Time discontinuity at 43 cm.
4. A transect along B-B′ (13 m interval) indicated an average depth to impermeable gravel of 110 cm.

PEDON: GSM 6

Location: Great Smoky Mtns. National Park; 1890 m at S 55° E from Collins Shelter

Elevation: 1664 m

Aspect: 20° NE

Slope: 15%

Geomorphic: Double convex spur ridge

Parent Material: Colluvium from sandstone, phyllite, slate and schist overlying residuum from similar materials

Vegetation:

Canopy: Large spruce, fraser fir (about 50% canopy cover)

Understory: Striped maple, mountain ash, yellow birch, second growth fir, witch hobble

Ground Cover: Ferns, oxalis, mosses, vaccinium

Classification: Typic Haplumbrept, loamy-skeletal, mixed, frigid

Description

Oi -- 10 to 0 cm., Leaf litter, cones, needles.

Oa -- 0 to 5 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A --- 5 to 25 cm., Very dark gray (10 YR 3/1) gravelly loam; weak fine granular structure; very friable; many fine and very fine roots; about 20% phyllite channers; clear smooth boundary.

Bw -- 25 to 51 cm., Yellowish brown (10 YR 5/6) very gravelly loam; weak fine subangular blocky structure; friable; about 40% phyllite and slate channers; clear smooth boundary.

2C -- 51 to 69 cm., Mottled dark yellowish brown (10 YR 4/4), yellowish brown (10 YR 5/6), and pale brown (10 YR 6/3) sandy loam; massive; friable; about 10% weathered phyllite and slate fragments.

2Cr - 69+ cm., Rippable sandstone saprolite.

Notes:

1. Described from spaded pit.
3. Lithologic discontinuity at 51 cm.

PEDON: GSM 7

Location: Great Smoky Mtns. National Park; Noland Creek headwaters area; 1621 m at N 84° E from Clingman's Dome tower

Elevation: 1719 m

Aspect: 65° NE

Slope: 45%

Geomorphic: Double concave sideslope (cove) position

Parent Material: Colluvium from phyllite, sandstone and schist

Vegetation:

Canopy: Large spruce, fraser fir, yellow birch

Understory: Rhododendron, sugar maple, witch hobble, second growth spruce-fir

Ground Cover: Ferns, oxalis, mosses, brambles

Classification: Pachic Haplumbrept, loamy-skeletal, mixed, frigid

Description

Oi --- 8 to 0 cm., Leaf litter, cones, needles.

Oa --- 0 to 3 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A --- 3 to 20 cm., Black (10 YR 2/1) gravelly loam; moderate very coarse granular parting to fine subangular blocky structure; very friable; many fine and very fine roots; about 15% channers of phyllite; clear smooth boundary.

Bw1 -- 20 to 46 cm., Very dark grayish brown (10 YR 3/2) gravelly loam; moderate coarse subangular blocky structure; friable; few fine roots; about 20% phyllite channers; clear smooth boundary.

Bw2 -- 46 to 132 cm., Dark brown (10 YR 3/3) very gravelly loam; weak medium subangular blocky structure; friable; about 50% phyllite channers and flags.

Notes:

1. Described from spaded pit.
2. Stopped by gravel at 132 cm.

PEDON: GSM 8

Location: Great Smoky Mtns. National Park; Clingman's Creek area; 1463 m at S 80° E from Clingman's Dome tower

Elevation: 1560 m

Aspect: 190° SW

Slope: 50%

Geomorphic: Double concave sideslope position

Parent Material: Colluvium from Thunderhead sandstone, phyllite and schist

Vegetation:

Canopy: Spruce-fir (about 25% cover), yellow birch

Understory: Rhododendron

Classification: Umbric Dystrochrept, loamy-skeletal, mixed, frigid

Description

Oi --- 10 to 0 cm., Leaf litter, cones, needles.

Oa --- 0 to 3 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A --- 3 to 10 cm., Very dark brown (10 YR 2/2) loam; moderate fine granular structure; very friable; many fine and very fine roots; about 10% channers of phyllite and schist; abrupt wavy boundary.

Bw -- 10 to 51 cm., Dark yellowish brown (10 YR 4/6) gravelly loam; moderate medium subangular blocky structure; firm; few fine and very fine roots; about 20% phyllite and schist channers and flags; clear smooth boundary.

C --- 51 to 66 cm., Dark yellowish brown (10 YR 4/6) very gravelly loam; weak fine subangular blocky structure; firm; about 40-50% phyllite and schist channers and flags.

Notes:

1. Described from spaded pit.
2. Stopped by gravel at 66 cm.
3. Area has about 15-30% surface boulders.
4. Depth to Bw horizon in area ranges from 18-30 cm.

PEDON: GSM 9

Location: Great Smoky Mtns. National Park; Clingman's Dome area; 353 m at S 48° E from Clingman's Dome tower

Elevation: 1963 m

Aspect: 115° SE

Slope: 15%

Geomorphic: Double convex ridge near Clingman's Dome crest

Parent Material: Colluvium from Thunderhead sandstone mixed with phyllite and schist

Vegetation:

Canopy: Fraser fir

Ground Cover: Ferns, oxalis, mosses, many blowdowns

Classification: Umbric Dystrochrept, loamy-skeletal, mixed, frigid

Description

Oi -- 5 to 0 cm., Leaf litter, cones, needles.

Oa -- 0 to 5 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A --- 5 to 15 cm., Black (10 YR 2/1) loam; moderate coarse granular structure; very friable; many fine and very fine roots; about 10% sansdtone and phyllite fragments; abrupt wavy boundary.

Bw -- 15 to 51 cm., Brown (10 YR 4/3) gravelly loam; weak medium subangular blocky structure; firm; about 20% coarse fragments; clear smooth boundary.

C --- 51+ cm., Stopped by extremely gravelly layer.

Notes:

1. Described from spaded pit.
2. Stopped by gravel at 51 cm.
3. Area has about 25% surface boulders up to 2 m across and 1 m high.
4. A transect along A---A′ (13 m interval) indicated an average depth to impermeable gravel of 30 cm.
5. Area is moderately eroded.

PEDON: GSM 10

Location: Great Smoky Mtns. National Park; 253 m at S 30° E from Clingman's Dome tower

Elevation: 1993 m

Aspect: 195° SW

Slope: 20%

Geomorphic: Upper shoulder slope below Clingman's Dome crest; convex contour, linear downslope

Parent Material: Colluvium from Thunderhead sandstone with some phyllite and schist

Vegetation:

Canopy: Fraser fir, some red spruce, yellow birch

Understory: Not signigicant

Ground Cover: Ferns, oxalis, mosses, blowdowns

Classification: Umbric Dystrochrept, loamy-skeletal, mixed, frigid

Description

Oi -- 8 to 0 cm., Fibric material: Leaf litter, cones, needles.

Oa -- 0 to 7 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A --- 7 to 14 cm., Black (10 YR 2/1) gravelly loam; moderate fine granular structure; very friable; many fine feeder roots; about 10% channers; clear smooth boundary.

Bw -- 14 to 36 cm., Brown (10 YR 4/3) gravelly loam; moderate fine subangular blocky structure; friable; few fine roots; about 20% channers.

C -- 36+ cm., Stopped by extremely (greater than 60%) gravelly layer.

Notes:

1. Described from spaded pit.
2. Stopped by gravel at 36 cm.

PEDON: GSM 11

Location: Great Smoky Mtns. National Park; Noland Divide area; 2304 m at N 86° E from Clingman's Dome tower

Elevation: 1649 m

Aspect: 26° NE

Slope: 27%

Geomorphic: Upper sideslope; linear contour, slightly concave downslope

Parent Material: Colluvium from Thunderhead sandstone, phyllite, and some slate

Vegetation:

Canopy: Red spruce, fraser fir, yellow birch

Understory: Sugar maple, striped maple, yellow birch, witch hobble

Ground Cover: Ferns, oxalis, mosses

Classification: Typic Haplorthod, loamy-skeletal, mixed, frigid

Description

Oi -- 8 to 0 cm., Leaf litter, cones, needles.

Oa -- 0 to 5 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A1 -- 5 to 20 cm., Black (10 YR 2/1) gravelly loam; moderate very coarse parting to medium granular structure; very friable; many fine and very fine roots; about 15% channers of phyllite, sandstone, and slate; abrupt smooth boundary.

A2 -- 20 to 43 cm., Very dark grayish brown (10 YR 3/2) gravelly loam; moderate medium granular structure; friable; many fine and very fine roots; about 25% coarse fragments; clear wavy boundary.

Bw -- 43 to 74 cm., Dark yellowish brown (10 YR 4/6) very gravelly loam or very gravelly fine sandy loam; weak medium subangular blocky structure; firm; few fine roots; about 35% coarse fragments; clear wavy boundary.

C --- 74 to 147 cm., Yellowish brown (10 YR 5/6) extremely gravelly loam; massive; firm; greater than 60% small (up to 8 cm.) coarse fragments.

Notes:

1. Classified as Typic Haplumbrept in the field.
2. Described from spaded pit.
3. Stopped by gravel at 147 cm.
4. About 15-20% surface boulders in the area.

PEDON: GSM 12

Location: Great Smoky Mtns. National Park; Noland Divide area; 1951 m at N 84° E from Clingman's Dome tower

Elevation: 1730 m

Aspect: 178° SE

Slope: 60%

Geomorphic: Spur ridgetop; linear contour, linear downslope

Parent Material: Colluvium from sandstone, phyllite, and schist

Vegetation:

Canopy: Red spruce, fraser fir, mountain ash

Understory: Sugar maple, yellow birch

Ground Cover: Ferns, oxalis, mosses, brambles

Classification: Umbric Dystrochrept, coarse-loamy, mixed, frigid

Description

Oi -- 3 to 0 cm., Leaf litter, cones, needles.

Oa -- 0 to 5 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A --- 5 to 15 cm., Very dark brown (10 YR 2/2) loam; weak medium granular structure; very friable; many fine and very fine roots; about 10% channers; clear smooth boundary.

Bw1 -- 15 to 46 cm., Dark yellowish brown (10 YR 4/4) gravelly loam; moderate medium granular parting to weak fine subangular blocky structure; friable; few fine roots; about 20% channers; clear smooth boundary.

Ab --- 46 to 61 cm., Dark brown (10YR 4/3) loam; moderate medium subangular blocky structure; firm; about 10% sandstone channers; abrupt wavy boundary.

2Bw2 - 61 to 76 cm., Strong brown (7.5 YR 4/6) gravelly loam; weak medium subangular blocky structure; firm; about 20% channers; clear wavy boundary.

2C --- 76 to 91 cm., Brown (10 YR 5/3) very gravelly loam; massive; firm; about 35% channers and flags.

Notes:

1. Described from spaded pit.
2. Stopped by gravel at 91 cm.
3. Bedrock outcrops in nearby trailcut is strongly dipping in direction of slope.
4. This site is severely eroded; most soils in the area have their surfaces intact and are classified as Typic Haplumbrepts.

PEDON: GSM 13

Location: Great Smoky Mtns. National Park; 439 m at N 25° E from Meigs Post benchmark at Mt. Collins

Elevation: 1813 m

Aspect: 56° NE

Slope: 6%

Geomorphic: Broad upland saddle (near footslope position at base of ridge)

Parent Material: Colluvium from Thunderhead sandstone and phyllite

Vegetation:

Canopy: Spruce dominant, fraser fir

Understory: Not significant

Ground Cover: Ferns, oxalis, mosses

Classification: Umbric Dystrochrept, loamy-skeletal, mixed, frigid

Description

Oi --- 5 to 0 cm., Leaf litter, cones, needles.

Oa --- 0 to 3 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A --- 3 to 5 cm., Very dark grayish brown (10 YR 3/2) loam; weak medium granular structure; very friable; many fine feeder roots; about 10% sandstone channers; clear smooth boundary.

Bw1 -- 5 to 13 cm., Brown (10 YR 4/4) loam; weak medium subangular blocky structure; friable; few fine roots; about 20% channers.

Bw2 -- 13 to 50+ cm., Brown (10 YR 4/4) gravelly loam; weak medium subangular blocky structure; firm; about 30% channers and flags.

Notes:

1. Described from spaded pit.
2. Stopped by gravel at 50 cm.
3. About 10% surface boulders in area.

PEDON: GSM 14

Location: Great Smoky Mtns. National Park; Mt. Collins area; 756 m at N 4° E from Meigs Post benchmark at Mt. Collins

Elevation: 1792 m

Aspect: 325° NW

Slope: 12%

Geomorphic: Broad upland ridgetop; convex contour, linear downslope

Parent Material: Residuum from feldspathic quartzite; may be some slight overwash from upslope

Vegetation:

Canopy: Spruce dominant; some fir, yellow birch

Understory: Second growth spruce and fir

Ground Cover: Ferns, oxalis, mosses

Classification: Typic Dystrochrept, coarse-loamy, mixed, frigid

Description

Oi --- 5 to 0 cm., Leaf litter, cones, needles.

Oa --- 0 to 3 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

E ---- 3 to 15 cm., Gray (10 YR 5/1) fine sandy loam; many medium prominant dark grayish brown (10 YR 4/2) and very dark gray (10 YR 3/1) mottles; weak fine granular structure; very friable; many fine feeder roots; abrupt wavy boundary.

Bs --- 15 to 30 cm., Strong brown (7.5 YR 4/6) loam or fine sandy loam; common medium distinct dark yellowish brown (10 YR 4/4) and yellowish brown (10 YR 5/6) mottles; weak medium subangular block structure; friable; few fine roots; clear wavy boundary.

Bw -- 30 to 48 cm., Dark yellowish brown (10 YR 4/4) loam with common medium distinct yellowish brown (10 YR 5/6) mottles; weak medium subangular blocky structure; friable; clear smooth boundary.

C --- 48 to 74 cm., Yellowish brown (10 YR 5/4) loam; massive; firm.

R --- 74+ cm., Feldspathic quartzite bedrock from the Thunderhead formation

Notes:

1. Classified as Typic Haplorthod in the field.
2. Described from spaded pit.
3. Surface A horizon has been removed by erosion; Extensive tonguing of Oa mixed with dark mineral material into E horizon.

PEDON: GSM 15

Location: Great Smoky Mtns. National Park; Newfound Gap/Indian Gap area; 1475 m at N 88° W from Newfound Gap benchmark

Elevation: 1682 m

Aspect: 192° SW

Slope: 18%

Geomorphic: Double convex spur ridge

Parent Material: Colluvium from Anakeesta Formation- mixed phyllite, sandstone, slate and schist

Vegetation:

Canopy: Dominantly spruce and fir with beech gap vegetation farther downslope closure)

Ground Cover: Ferns, oxalis, mosses

Classification: Umbric Dystrochrept, loamy-skeletal, mixed, frigid

Description

Oi --- 5 to 0 cm., Leaf litter, cones, needles.

Oa --- 0 to 1 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A1 --- 1 to 4 cm., Very dark brown (10 YR 2/2) loam; moderate coarse granular structure; very friable; many fine and very fine roots; about 10% phyllite channers; clear smooth boundary.

A2 --- 4 to 15 cm., Very dark brown (10 YR 3/2) loam; moderate coarse granular structure; very friable; many fine and very fine roots; about 10% phyllite channers; clear wavy boundary.

Bw1 -- 15 to 53 cm., Dark yellowish brown (10 YR 4/4) gravelly loam; weak medium subangular blocky structure; friable; about 15% phyllite channers; clear smooth boundary.

Bw2 -- 53 to 74 cm., Dark yellowish brown (10 YR 4/4) gravelly loam with common medium distinct dark brown (10 YR 3/3) mottles; friable; about 20% phyllite and sandstone channers; clear wavy boundary.

C --- 74 to 122+ cm., Mottled dark yellowish brown (10 YR 4/4), dark brown (10 YR 3/3), and gray (10 YR 5/1) extremely gravelly loam; massive; firm; about 60% phyllite and sandstone channers and flags.

Notes:

1. Described from spaded pit.
2. Stopped by gravel at 122 cm.
3. Apparent time discontinuity at 74 cm.

PEDON: GSM 16

Location: Great Smoky Mtns. National Park; Newfound Gap/Indian Gap area; 671 m at N 74° W from Newfound Gap benchmark

Elevation: 1548 m

Aspect: 37° NE

Slope: 62%

Geomorphic: Upper sideslope; convex contour, linear downslope

Parent Material: Colluvium from Anakeesta formation- mixed phyllite, sandstone, slate, and schist

Vegetation:

Canopy: Spruce and fir (about 50% cover),

Understory: Striped maple, sugar maple, witch hobble

Ground Cover: Ferns, oxalis, mosses, brambles

Classification: Typic Haplumbrept, loamy-skeletal, mixed, frigid

Description

Oi --- 10 to 0 cm., Leaf litter, cones, needles.

Oa --- 0 to 5 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A ---- 5 to 23 cm., Very dark brown (10 YR 2/2) loam; moderate very coarse parting to fine granular structure; very friable; many fine feeder roots; about 10% channers and flags of phyllite and sandstone;abrupt smooth boundary.

Bw1 -- 23 to 56 cm., Dark yellowish brown (10 YR 4/4) gravelly loam; moderate medium subangular blocky structure; friable; few fine roots; about 20% phyllite and sandstone channers and flags; clear smooth boundary.

Bw2 -- 56 to 91+ cm., Dark yellowish brown (10 YR 4/4) very gravelly loam; weak fine subangular blocky structure; firm; about 40% phyllite and sandstone channers and flags.

Notes:

1. Described from spaded pit.
2. Stopped by gravel at 91 cm.
3. About 10-15% surface boulders in area.

PEDON: GSM 17

Location: Great Smoky Mtns. National Park; Indian Gap area; 2377 m at N 89° W from Newfound Gap benchmark

Elevation: 1539 m

Aspect: 215° SW

Slope: 40%

Geomorphic: Double concave lower sideslope

Parent Material: Colluvium from Anakeesta Formation- mixed phyllite, slate, sandstone, schist

Vegetation:

Canopy: Spruce-fir, yellow birch, few beech

Ground Cover: Ferns, oxalis, mosses, brambles

Classification: Umbric Dystrochrept, loamy-skeletal, mixed, frigid

Description

Oi --- 5 to 0 cm., Leaf litter, cones, needles.

Oa --- 0 to 3 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A --- 3 to 13 cm., Very dark grayish brown (10 YR 3/2) loam; moderate fine granular structure; very friable; many fine feeder roots; about 10% phyllite channers; clear smooth boundary.

Bw1 --13 to 56 cm., Dark yellowish brown (10 YR 4/4) gravelly loam; moderate fine subangular blocky structure; friable; few fine roots; about 20% phyllite and sandstone channers.

Bw2 -- 56 to 76+ cm., Dark yellowish brown (10 YR 4/4) very gravelly loam; weak fine subangular block structure; firm; about 40% phyllite and sandstone channers and flags.

Notes:

1. Described from spaded pit.
2. Stopped by gravel at 76 cm.

PEDON: BM 1

Location: Black Mtns.; Mt. Gibbes summit; 3048 m at S 38° W from Mt. Mitchell lookout tower

Elevation: 1951 m

Aspect: 348° NW

Slope: 5%

Geomorphic: Ridgetop summit; convex contour, linear downslope

Parent Material: Colluvium from mica schist overlying residuum from similar material

Vegetation:

Canopy: Fraser fir, with some red spruce

Understory: Second growth spruce-fir, mountain ash, yellow birch

Ground Cover: Ferns, sedges, aster

Classification: Typic Haplumbrept, loamy-skeletal, mixed, frigid

Description

Oi --- 5 to 0 cm., Leaf litter, cones, needles.

Oa --- 0 to 10 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A --- 10 to 30 cm., Dark brown (10 YR 3/3) mucky loam; moderate very coarse parting to medium granular structure; very friable; many fine and very fine roots; about 10% schist fragments; clear smooth boundary.

Bw -- 30 to 64 cm., Dark yellowish brown (10 YR 4/4) gravelly loam; moderate medium subangular blocky structure; friable; few fine roots; about 20% schist fragments up to 10 cm across; abrupt wavy boundary.

2C -- 64 to 84 cm., Brown (7.5 YR 4/6) gravelly loam; massive; friable; about 20% oriented weathered schist fragments up to 5 cm across; abrupt smooth boundary.

2Cr - 84+ cm., Rippable schist saprolite.

Notes:

1. Described from spaded pit.
2. Stopped by paralithic contact at 84 cm.
3. Coarse fragments in the upper 64 cm are disoriented.

PEDON: BM 2

Location: Black Mtns. Camp Alica area; 108 m at S 15° W from Mt. Mitchell tower

Elevation: 1749 m

Aspect: 104° SE

Slope: 40%

Geomorphic: Mid-sideslope; slightly concave slope; linear contour

Parent Material: Colluvium from mica schist

Vegetation:

Canopy: Spruce-fir, yellow birch

Understory: Sugar maple, striped maple, rhododendron

Ground Cover: Ferns, sedges, mosses

Classification: Typic Haplorthod, loamy-skeletal, mixed, frigid

Description

Oi --- 8 to 0 cm., Leaf litter, cones, needles.

Oa --- 0 to 5 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A --- 5 to 38 cm., Very dark grayish brown (10 YR 3/2) gravelly loam; moderate very coarse parting to fine granular structure; very friable; many fine feeder roots; about 10% mica schist channers; clear smooth boundary.

Bw1 -- 38 to 64 cm., Dark yellowish brown (10 YR 4/4) gravelly loam; moderate medium subangular blocky structure; friable; about 40% mica schist channers and flags; clear smooth boundary.

Bw2 -- 64 to 91 cm., Dark yellowish brown (10 YR 4/4) very gravelly loam or fine sandy loam; common medium distinct yellowish brown (10 YR 5/4) mottles; weak medium subangular blocky structure; friable; about 50% mica schist channers and flags; clear smooth boundary.

Bw3 -- 91 to 122+ cm., Yellowish brown (10 YR 5/6) very gravelly loam or fine sandy loam; few fine distinct dark yellowish brown (10 YR 4/4) mottles; weak medium subangular blocky structure; friable; about 50% mica schist fragments.

Notes:

1. Classified as Typic Haplumbrept in the field.
2. Described from spaded pit.
3. Stopped by gravel at 122 cm.
4. Apparent time discontinuity at 91 cm.

PEDON: BM 3

Location: Black Mtns.; Near Steppes Gap; 1981 m at S 40° W from Mt. Mitchell tower

Elevation: 1719 m

Aspect: 330° W

Slope: 50%

Geomorphic: Double concave sideslope

Parent Material: Colluvium from mica schist/gneiss

Vegetation:

Canopy: Red spruce, fraser fir, yellow birch

Understory: Sugar maple, rhododendron

Ground Cover: Ferns, oxalis, mosses

Classification: Typic Haplorthod, loamy-skeletal, mixed, frigid

Description

Oi --- 8 to 0 cm., Leaf litter, cones, needles.

Oa --- 0 to 3 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A1 --- 3 to 25 cm., Black (10 YR 2/1) gravelly loam; moderate very coarse parting to medium granular structure; very friable; many fine feeder roots; about 20% mica schist channers; gradual smooth boundary.

A2 -- 25 to 41 cm., Very dark grayish brown (10 YR 3/2) very gravelly loam or fine sandy loam; moderate medium granular structure; very friable; few fine and very fine roots; about 35% mica schist channers; clear smooth boundary.

Bw -- 41 to 91+ cm., Dark yellowish brown (10 YR 4/4) very gravelly loam or fine sandy loam; moderate medium subangular blocky structure; friable; about 35% schist fragments.

Notes:

1. Classified as Typic Haplumbrept in the field.
2. Described from spaded pit.
3. Stopped by gravel at 91 cm.
4. About 20% surfae boulders in area.

PEDON: BM 4

Location: Black Mtns.; Commissary Ridge; 408 m at N 18° E from Mt. Mitchell tower

Elevation: 1978 m

Aspect: 100° SE

Slope: 12%

Geomorphic: Ridgetop

Parent Material: Colluvium from mica schist

Vegetation:

Canopy: Old growth fraser fir

Understory: Not significant

Ground Cover: Ferns, oxalis, mosses, brambles

Classification: Typic Haplorthod, coarse-loamy, mixed, frigid

Description

Oi --- 3 to 0 cm., Leaf litter, cones, needles.

Oa --- 0 to 5 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A ---- 5 to 18 cm., Very dark grayish brown (10 YR 3/2) gravelly loam; weak medium granular structure; very friable; many fine and medium roots; about 15% channers of mica schist; clear smooth boundary.

Bw1 -- 18 to 38 cm., Dark yellowish brown (10 YR 4/4) gravelly loam or fine sandy loam; moderate medium subangular blocky structure; friable; about 15% schist channers; gradual smooth boundary.

Bw2 -- 38 to 64+ cm., Dark yellowish brown (10 YR 4/4) gravelly loam or fine sandy loam; weak medium subangular blocky structure; friable; about 25% mica schist channers and flags.

Notes:

1. Classified as Umbric Dystrochrept in the field.
2. Described from spaded pit.
3. Stopped by gravel at 64 cm.
4. Coarse fragments in Bw2 horizon have some degree of orientation; but no evidence of saprolite within 64 cm.

PEDON: BM 5

Location: Black Mtns.; North of Steppes Gap; 1372 m at S 30° W from Mt. Mitchell tower (152 m at N 8° E from park restaurant)

Elevation: 1914 m

Aspect: 210° SW

Slope: 10%

Geomorphic: Ridgetop; linear slope, convex contour

Parent Material: Colluvium from mica schist over residuum from similar material

Vegetation:

Canopy: Old growth fraser fir with some spruce

Understory: Not significant

Ground Cover: Ferns, oxalis, mosses

Classification: Typic Haplumbrept, coarse-loamy, mixed, frigid

Description

Oi --- 2 to 0 cm., Leaf litter, cones, needles.

Oa --- 0 to 8 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A1 --- 8 to 18 cm., Very dark grayish brown (10 YR 3/2) gravelly loam; very coarse parting to medium granular structure; very friable; many fine and very fine roots; about 15% channers of mica schist; clear wavy boundary.

A2 -- 18 to 25 cm., Very dark brown (10 YR 2/2) gravelly loam; weak medium subangular blocky structure; very friable; common fine and very fine roots; about 15% schist channers; abrupt wavy boundary.

Bw -- 25 to 64 cm., Dark yellowish brown (10 YR 4/6) gravelly loam; weak medium subangular blocky structure; friable; few fine roots; about 15% schist channers; abrupt wavy boundary.

2C -- 64 to 89 cm., Dark yellowish brown (10 YR 4/4) sandy loam; massive; friable.

Notes:

1. Described from spaded pit.
2. Stopped by paralithic contact at 89 cm.
3. Coarse fragments in upper 64 cm show no preferred orientation.

PEDON: BM 6

Location: Black Mts.; South face of Commissary Ridge; 988 m at S 15° E from Mt. Mitchell tower

Elevation: 1871 m

Aspect: 215° SW

Slope: 43%

Geomorphic: Mid-sideslope; linear to slightly convex slope and contour

Parent Material: Colluvium from mica schist/gneiss

Vegetation:

Canopy: Spruce-fir, some yellow birch

Understory: Yellow birch, mountain ash

Ground Cover: Ferns, oxalis, mosses, brambles

Classification: Typic Haplumbrept, loamy-skeletal, mixed, frigid

Description

Oi --- 2 to 0 cm., Leaf litter, cones, needles.

Oa --- 0 to 5 cm., Black (10 YR 2/1) sapric material; many fine feeder roots; clear wavy boundary.

A ---- 5 to 20 cm., Very dark grayish brown (10 YR 3/2) very gravelly loam; moderate very coarse parting to medium granular structure; very friable; many fine and very fine roots; about 15% schist fragments; clear wavy boundary.

Bw1 -- 20 to 38 cm., Very dark grayish brown (10 YR 3/2)very gravelly loam; strong medium subangular blocky structure; friable; few fine roots; about 35% schist channers and flags; clear smooth boundary.

Bw2 -- 38 to 48 cm., Dark brown (10 YR 3/3) very gravelly loam with few fine distinct brown (7.5 YR 4/6) mottles; moderate medium subangular blocky structure; about 35% schist fragments; clear smooth boundary.

BC -- 48 to 65+ cm., Brown (7.5 YR 4/6) very gravelly loam; massive in place parting to weak medium subangular blocky structure; firm; about 45% schist channers and flags.

Notes:

1. Described from spaded pit.
2. Stopped by gravel at 65 cm.
3. About 10% surface boulders up to 2 m across and 1 m high in area.
4. Numerous small rills and gullies (area was previously logged and burned).

PEDON: BM 7

Location: Black Mtns.; 1335 m at N 73°E from Clingman's Peak radio tower

Elevation: 1689 m

Aspect: 80° NE

Slope: 4%

Geomorphic: Spur ridgetop; convex contour, linear downslope

Parent Material: Colluvium from from mica schist overlying residuum from mica schist

Vegetation:

Canopy: Fraser fir-red spruce, yellow birch

Understory: Rhododendron

Ground Cover: Ferns, mosses, sedges

Classification: Umbric Dystrochrept, coarse-loamy, mixed, frigid

Description

Oa --- 0 to 8 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A ---- 8 to 15 cm., Black (10 YR 2/1) loam.

Bw --- 15 to 40 cm., Dark yellowish brown (10 YR 4/4-4/6) loam or clay loam.

2BC -- 40 to 61 cm., Dark yellowish brown (10 YR 4/4- 4/6) loam or clay loam.

2Cr -- 61+ cm., Saprolite from mica schist that crushes to fine sandy loam.

Notes:

1. Auger observation.
2. No evidence of clay films in Bw horizon.
3. Less than 10% surface boulders in area.

PEDON: BM 8

Location: Black Mtns.; 2188 m at N 55°E from Clingman's Peak radio tower

Elevation: 1594 m

Aspect: 145° SE

Slope: 15%

Geomorphic: Spur ridgetop; double convex

Parent Material: Colluvium from mica schist overlying residuum from similar material

Vegetation:

Canopy: Spruce-fir (about 25% of overstory), yellow birch, mountain ash

Understory: Rhododendron, fire cherry

Ground Cover: Ferns, sedges, mountain aster, vaccinium

Classification: Typic Haplumbrept, coarse-loamy, mixed, frigid

Description

Oa --- 0 to 8 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A1 --- 8 to 18 cm., Black (10 YR 2/1) mucky loam.

A2 --- 18 to 30 cm., Very dark grayish brown (10 YR 3/2) loam.

2Bw1 -- 30 to 41 cm., Dark yellowish brown (10 YR 4/4) loam to clay loam.

2Bw2 -- 41 to 61 cm., Dark yellowish brown (10 YR 4/6) loam.

2Cr --- 61+ cm., Saprolite from mica schist

Notes:

1. Auger description.

PEDON: BM 9

Location: Black Mtns.; Near Deep Gap; From intersection of Black Mtn. Crest Trail and Colbert Creek Trail, 200 m down Colbert Creek Trail, then drop off trail at 532° E for 30 m.

Elevation: 1524 m

Aspect: 175° SE

Slope: 55%

Geomorphic: Steep colluvial backslope; convex contour, linear downslope

Parent Material: Colluvium from mica schist with some quartzite

Vegetation:

Canopy: Fraser fir-red spruce, yellow birch

Understory: Rhododendron and second growth fir

Ground Cover: Ferns, oxalis, mosses

Classification: Typic Haplorthod, loamy-skeletal, mixed, frigid

Description

Oi --- 8 to 0 cm., Fibric material.

Oa --- 0 to 15 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A1 --- 15 to 23 cm., Black (10 YR 2/1) gravelly loam; weak coarse granular parting to medium subangular blocky structure; very friable; common fine and very fine roots; about 15% mica schist fragments up to 5 cm across; clear wavy boundary.

A2 --- 23 to 36 cm., very dark grayish brown (10 YR 3/2) gravelly loam; moderate medium subangular blocky structure; friable; common fine roots; about 20% mica schist fragments.

Bw1 -- 36 to 48 cm., Strong brown (7.5 YR 5/6) gravelly loam or clay loam with many medium distinct dark yellowish brown (10 YR 4/4) mottles; moderate medium subangular blocky structure; friable; few fine roots; about 20% coarse fragments; clear wavy boundary.

Bw2 -- 36 to 58+ cm., Strong brown (7.5 YR 5/8) very gravelly loam; few medium distinct dark yellowish brown (7.5 YR 4/4) mottles; weak fine subangular blocky structure; friable; about 35% coarse fragments.

Notes:

1. Classified as Typic Haplumbrept in the field.
2. Described from spaded pit.
3. No apparent clay films on ped faces.
4. Stopped by coarse fragments at 58 cm.

PEDON: BM 10

Location: Black Mtns., Near Potato Hill; 963 m at N 14° E from Cattail Peak benchmark; 25 m SW of Black Mtn. Crest Trail

Elevation: 1838 m

Aspect: 285° NW

Slope: 13%

Geomorphic: Upland summit along main ridge crest of Black Mtns.; convex contour, linear downslope

Parent Material: Colluvium from mica schist and quartzite

Vegetation:

Canopy: Fraser fir, mountain ash, yellow birch, fire cherry

Ground Cover: Brambles, ferns, mosses

Classification: Typic Haplorthod, loamy-skeletal, mixed, frigid

Description

Oi --- 8 to 0 cm., Fibric material.

Oa --- 0 to 10 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A --- 10 to 18 cm., Black (10 YR 2/1) mucky loam; moderate very coarse granular parting to medium subangular blocky structure; very friable; many fine feeder roots; about 10-15% mica schist fragments; clear wavy boundary.

E --- 18 to 25 cm., Brown (10 YR 5/3) fine sandy loam with common medium distinct yellowish brown (10 YR 5/4) mottles; weak medium subangular blocky structure; friable; common fine roots; about 10-15% schist fragments up to 3 cm across; common fine root channels filled with dark material from above; clear wavy boundary.

Bw1 -- 25 to 51 cm., Dark yellowish brown (10 YR 4/4) gravelly loam to fine sandy loam with common medium faint yellowish brown (10 YR 5/4)mottles; weak medium subangular blocky structure; friable; about 15% schist fragments; clear smooth boundary.

Bw2 -- 51 to 59+ cm., Dark yellowish brown (10 YR 4/4) extremely gravelly loam; massive; firm; about 50-60% gravels.

Notes:

1. Classified as Umbric Dystrochrept in the field.
2. Described from spaded pit.
3. Stopped by gravel at 59 cm.

PEDON: BM 11

Location: Black Mtns.; Potato Hill; 558 m at N 36° E from Cattail Peak benchmark; Pit is 20 m NW of Black Mtn. Crest Trail

Elevation: 1902 m

Aspect: 330° NW

Slope: 18%

Geomorphic: Upper shoulder slope below main ridge crest; convex contour, linear downslope

Parent Material: Residuum from mica schist with a slight colluvial cap

Vegetation:

Canopy: Fraser fir, mountain ash, fire cherry

Understory: Thick stand of second growth fir and rhododendron

Ground Cover: Brambles, ferns, mosses

Classification: Lithic Haplumbrept, coarse-loamy, mixed, frigid

Description

Oi -- 23 to 15 cm., Fibric material: Leaf litter, cones, needles.

Oe -- 15 to 0 cm., Partially decomposed hemic material

Oa -- 0 to 18 cm., Black (N 2/) sapric material; many fine feeder roots.

A -- 18 to 49 cm., Black (N 2/) mucky loam; weak very coarse granular parting to medium subangular blocky structure; very friable; many fine feeder roots.

R -- 49+ cm., Mica schist bedrock.

Notes:

1. Described from spaded pit.
2. Area is just below convex heath knob; this area is somewhat transitional between the less extensive Lithic Haplumbrepts above, and the deeper Typic and Pachic Haplumbrepts downslope.
3. Due to the high coarse fragment content of the surrounding soils, it was not possible to determine whether bedrock was reached, or whether a large "floater" was encountered.
4. This pedon comes close to the Craggey series.
5. This pedon has a histic epipedon and might more properly be classified as a Histic Haplumbrept, although no such class exists.

PEDON: BM 12

Location: Black Mtns.; Commissary Ridge; 1384 m at S 35° E from Mt. Mitchell lookout tower

Elevation: 1780 m

Aspect: 175° SE

Slope: 38%

Geomorphic: Upper sidelope; convex contour, linear downslope

Parent Material: Colluvium from mica schist

Vegetation:

Canopy: Fraser fir, red spruce, yellow birch

Ground Cover: Ferns, oxalis, mosses

Classification: Typic Haplumbrept, coarse-loamy, mixed, frigid

Description

Oi --- 8 to 0 cm., Leaf litter, cones, needles.

Oa --- 0 to 10 cm., Black (10 YR 2/1) sapric material

A -- 10 to 23 cm., Very dark brown (10 YR 2/2) loam

Bw -- 23 to 56+ cm., Brown (10 YR 4/3) heavy loam; about 10-15% gravels

Notes:

1. Auger description.
2. Stopped by gravel at 56 cm.
3. Numerous rills and gullies in area.

PEDON: BM 13

Location: Black Mtns.; Commissary Ridge; 122 m at N 40° W from intersection of Black Mtn. Campground Trail and Maple Camp Bald Trail

Elevation: 1792 m

Aspect: 115° SE

Slope: 25%

Geomorphic: Steep double concave colluvial backslope

Parent Material: Colluvium from mica schist

Vegetation:

Canopy: Fraser fir with some red spruce

Understory: Mostly rhododendron

Ground Cover: Ferns, sedges, mosses, aster

Classification: Typic Haplorthod, loamy-skeletal, mixed, frigid

Description

Oi --- 5 to 0 cm., Fibric material derived from sedges, mosses, ferns and needles

Oa --- 0 to 8 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A --- 8 to 33 cm., Very dark grayish brown (10 YR 2/2) loam; moderate very coarse parting to medium granular structure; very friable; many fine feeder roots; clear irregular boundary.

Bw1 -- 33 to 51 cm., Brown (7.5 YR 4/6) gravelly loam to fine sandy loam; moderate medium subangular blocky structure; friable; about 20% schist fragments up to 3 cm across; gradual wavy boundary.

Bw2 -- 51 to 76+ cm., Brown (7.5 YR 4/4) gravelly loam to fine sandy loam; moderate medium subangular blocky structure; friable; about 30% gravels up to 3 cm. across.

Notes:

1. Classified as Typic Haplumbrept in the field.
2. Described from spaded pit.
3. Stopped by gravel at 76 cm.
4. About 10-15% surface boulders in area up to 1 m high and 3 m across.

PEDON: BM 14

Location: Black Mtns.; Commissary Ridge; From intersection of Black Mtn. Campground Trail and Maple Camp Bald Trail; 258 m along Maple Camp Bald Trail (northeast), then 52 m at N 60° W

Elevation: 1792 m

Aspect: 165° SE

Slope: 38%

Geomorphic: Colluvial backslope (midslope position); convex contour, linear downslope

Parent Material: Colluvium from mica schist overlying residuum from similar material

Vegetation:

Canopy: Fraser fir, some red spruce and yellow birch

Understory: Rhododendron and mountain ash

Ground Cover: Ferns, mosses, sedges

Classification: Typic Haplorthod, loamy-skeletal, mixed, frigid

Description

Oi --- 5 to 0 cm., Leaf litter, cones, needles.

Oa --- 0 to 13 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A --- 13 to 36 cm., Very dark brown (10 YR 2/2) loam; weak coarse parting to medium granular structure; very friable; many fine feeder roots; about 10% small mica schist fragments; clear smooth boundary.

Bw -- 36 to 58 cm., Very dark grayish brown (10 YR 3/2) gravelly loam; moderate medium subangular blocky structure; friable; about 30% mica schist fragments; abrupt smooth boundary.

2Cr -- 58 to 76+ cm., Mottled strong brown (7.5 YR 5/6 - 5/8), brown (10 YR 4/3) and grayish brown (10 YR 5/2) saprolite that crushes to sandy loam.

Notes:

1. Classified as Pachic Haplumbrept in the field.
2. Described from spaded pit.
3. About 10-15% surface boulders in the area.

PEDON: BM 15

Location: Black Mtns.; Celo Knob area; 33m at S 70° E from intersection of Woody Ridge Trail and Celo Knob Trail

Elevation: 1852 m

Aspect: 130° SE

Slope: 12%

Geomorphic: Broad saddle (footslope) between two ridges (Horse Rock and Gibbs Mtn.)

Parent Material: Colluvium from mica schist over residuum from similar material

Vegetation:

Canopy: No signigicant overstory or understory (few small fire cherry)

Ground Cover: Sedges, ferns, goldenrod, creeping herbs

Classification: Typic Haplorthod, coarse-loamy, mixed, frigid

Description

Oi --- 8 to 0 cm., Leaf litter, cones, needles.

Oa --- 0 to 2 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A --- 2 to 5 cm., Black (10 YR 2/1) mucky loam; weak very coarse parting to fine granular structure; very friable; many fine and very fine roots; clear smooth boundary.

Bw1 -- 5 to 23 cm., Very dark grayish brown (10 YR 3/2) loam; moderate very coarse granular parting to medium subangular blocky structure; friable; few very fine roots; gradual wavy boundary.

Bw2 -- 23 to 36 cm., Dark brown (10 YR 3/3) loam; moderate medium subangular blocky structure; friable; clear smooth boundary.

2C --- 36 to 51 cm., Strong brown (7.5 YR 5/6) sandy loam weathered from mica schist.

R --- 51+ cm., Hard mica schist.

Notes:

1. Classified as Typic Haplumbrept in the field.
2. Described from spaded pit.
3. Depth to rock transect in this landscape unit (8 m interval) indicates mean depth to hard bedrock of 65 cm.

PEDON: BM 16

Location: Black Mtns., Celo Knob area; 488 m at N 46° W from the summit benchmark at Celo Knob

Elevation: 1753 m

Aspect: West facing

Slope: 35%

Geomorphic: Upper sideslope; convex contour, linear downslope

Parent Material: Colluvium from mica schist

Vegetation:

Canopy: Fraser fir, red spruce, yellow birch, mountain ash

Understory: Second growth fir

Ground Cover: Ferns, oxalis, mosses

Classification: Typic Haplorthod, loamy-skeletal, mixed, frigid

Description

Oi --- 5 to 0 cm., Fibric material.

Oa --- 0 to 10 cm., Black (10 YR 2/1) sapric material

A --- 10 to 18 cm., Very dark grayish brown (10 YR 3/2) loam; moderate coarse granular structure; very friable; many fine and very fine feeder roots; clear wavy boundary.

Bw1 -- 18 to 74 cm., Strong brown (7.5 YR 5/6) gravelly sandy loam; weak medium subangular blocky structure; friable; about 30-35% schist fragments up to 5 cm across; gradual smooth boundary.

Bw2 -- 74 to 100+ cm., Strong brown (7.5 YR 4/6) very gravelly sandy loam; weak fine subangular blocky structure; about 35-50% schist fragments.

Notes:

1. Classified as Umbric Dystrochrept in the field.
2. Described from spaded pit.
3. Stopped by gravels at 100 cm.

PEDON: BM 17

Location: Black Mtns.; Celo Knob area; 1097 m at N 52° W from Celo Knob summit

Elevation: 1524 m

Aspect: 346° NW

Slope: 35%

Geomorphic: Steep lower backslope position; convex contour, concave downslope

Parent Material: Colluvium from mica schist

Vegetation:

Canopy: Fraser fir, red spruce

Understory: Second growth fir and spruce

Ground Cover: Ferns, oxalis, mosses

Classification: Typic (or Pachic) Haplumbrept, loamy-skeletal, mixed, frigid

Description

Oi --- 5 to 0 cm., Fibric material

A --- 0 to 18 cm., Very dark grayish brown (10 YR 3/2) loam; moderate very coarse granular structure; very friable; many fine and medium roots.

Bw1 -- 18 to 48 cm., Dark brown (10 YR 3/3) loam to clay loam; moderate coarse granular parting to medium subangular blocky structure; friable; few fine roots; about 10-15% small mica schist fragments; clear wavy boundary.

Bw2 -- 48 to 77 cm., Dark yellowish brown (10 YR 4/4) very gravelly loam to fine sandy loam; weak medium subangular blocky structure; friable; about 35% mica schist fragments up to 10 cm across; clear wavy boundary.

C --- 77 to 100+ cm., Dark yellowish brown (10 YR 4/4) extremely gravelly loam to fine sandy loam; massive; greater than 60% coarse fragments.

Notes:

1. Mixing of surface to a depth of 50 cm allow Pachic subgroup.
2. Described from spaded pit.
3. Apparent time discontinuity in colluvium beginning at 48 cm.
4. No bedrock within 182 cm.

PEDON: MR 1

Location: Whitetop Mtn.; 177 m at N 41°W from radio tower at summit

Elevation: 1639 m

Aspect: North (at pit)

Slope: 27%

Geomorphic: Upper shoulder slope; slight bench position below ridgetop colluvial backslope

Parent Material: Colluvium from rhyolite with some arkosic sandstone

Vegetation:

Canopy: Red spruce, yellow birch, mountain ash (about 60-70% canopy closure)

Ground Cover: Ferns, oxalis, mosses, brambles

Classification: Pachic Haplumbrept, loamy-skeletal, mixed, frigid

Description

Oi --- 10 to 0 cm., Leaf litter, cones, needles

Oa --- 0 to 20 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A1 -- 20 to 53 cm., Black (10 YR 2/1) very gravelly loam; moderate fine granular structure; very friable; many fine feeder roots; about 40% rhyolite gravels; clear smooth boundary.

A2 -- 53 to 64+ cm., Dark brown (10 YR 2/3) very gravelly loam; moderate fine granular structure; friable; few fine roots; about 50% rhyolite gravels.

Notes:

1. Described from spaded pit.
2. Stopped by gravel at 64 cm.

PEDON: MR 2

Location: Whitetop Mtn.; 140 m at S 46°E from radio tower at summit

Elevation: 1673 m

Aspect: South (at auger hole)

Slope: 15%

Geomorphic: Upland ridgetop near shoulder; double convex

Parent Material: Colluvium from rhyolite with some arkosic sandstone

Vegetation:

Canopy: Red spruce (about 90% cover); no significant understory

Ground Cover: Ferns, oxalis, mosses

Classification: Umbric Dystrochrept, coarse-loamy (or loamy-skeletal), mixed, frigid

Description

Oi --- 5 to 3 cm., Leaf litter, cones, needles.

Oe --- 3 to 0 cm., Hemic material.

Oa --- 0 to 10 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A --- 10 to 30 cm., Black (10 YR 2/1) mucky loam; moderate very coarse granular structure; very friable; many fine feeder roots.

Bw -- 30 to 57+ cm., Dark yellowish brown (10 YR 4/4) loam or clay loam; friable; few fine roots.

Notes:

1. Auger description.
2. About 10-20% rhyolite fragments in Bw horizon increasing with depth.
3. About 2-5% surface boulders; hummocky surface.

PEDON: MR 3

Location: Whitetop Mtn.; 335 m at S 32°E from radio tower at summit

Elevation: 1634 m

Aspect: 140° SE facing

Slope: 28%

Geomorphic: Upper sideslope just below slight bench; convex contour, linear water flow direction

Parent Material: Colluvium from rhyolite and arkosic sandstone with some greenstone

Vegetation:

Canopy: Red spruce (about 90% cover); no understory

Ground Cover: Ferns, oxalis, mosses

Classification: Typic Haplumbrept, coarse-loamy (or loamy-skeletal), mixed, frigid

Description

Oe --- 8 to 0 cm., Slightly decomposed moss and fern litter.

Oa --- 0 to 15 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A1 -- 15 to 30 cm., Black (10 YR 2/1) mucky loam; moderate coarse granular structure; very friable; many fine feeder roots; clear smooth boundary.

A2 -- 30 to 41 cm., Very dark grayish brown (10 YR 3/2) loam; moderate medium granular structure; friable; many fine roots; clear wavy boundary.

Bw -- 41 to 66 cm., Dark yellowish brown (10 YR 4/4) gravelly loam; weak medium subangular blocky structure; friable; few fine and very fine roots; about 25% rhyolite gravels up to 7 cm across; clear smooth boundary.

BC -- 66 to 97+ cm., Dark yellowish brown (10 YR 4/4) very gravelly loam; weak fine and medium subangular blocky structure; friable; about 50% rhyolite gravels and cobbles.

Notes:

1. Described from spaded pit.
2. Stopped by coarse fragments at 97 cm.
3. About 2-5% surface boulders in area (up to 2 m across and 0.5 m high)

PEDON: MR 4

Location: Mt. Rogers; 116 m at N 40° E from the benchmark at the summit of Mt. Rogers

Elevation: 1728 m

Aspect: 20° NE

Slope: 7%

Geomorphic: Gently sloping ridgetop; double convex

Parent Material: Colluvium from rhyolite, arkose and greenstone

Vegetation:

Canopy: Fraser fir-red spruce-yellow birch (about 50% canopy closure; many large standing dead and dying fir)

Ground Cover: Ferns, oxalis, mosses, brambles, many fallen dead fir

Classification: Pachic Haplumbrept, loamy-skeletal, mixed, frigid

Description

Oe --- 5 to 0 cm., Hemic material: root mat and dead moss

Oa --- 0 to 10 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A1 -- 10 to 23 cm., Very dark brown (10 YR 2/2) gravelly loam; weak coarse to very coarse granular structure parting to weak medium subangular blocky structure; very friable; many fine feeder roots; about 25% rhyolite gravels; clear smooth boundary.

A2 -- 23 to 28 cm., Very dark grayish brown (10 YR 3/2) gravelly loam; weak coarse and medium subangular blocky structure; friable; common fine roots; about 25% rhyolite gravels; gradual smooth boundary.

A3 -- 28 to 56 cm., Very dark grayish brown (10 YR 3/2) very gravelly loam; weak medium subangular blocky structure; friable; about 40% coarse fragments; clear smooth boundary.

BC -- 56 to 69+ cm., Dark brown (10 YR 3/3) extremely gravelly loam; weak medium subangular blocky structure; friable; greater than 60% coarse fragments.

Notes:

1. Described from spaded pit.
2. Stopped by gravel at 69 cm.
3. Coarse fragments, ranging from 10 to 30 cm across, are dominantly rhyolite with some arkose and greenstone; there is no preferred orientation.
4. There appears to be a time discontinuity in the colluvium at the contact with the BC horizon.

PEDON: MR 5

Location: Mt. Rogers; 165 m at N 58° E from summit benchmark

Elevation: 1736 m

Aspect: 80° NE

Slope: 7%

Geomorphic: Gently sloping broad ridgetop; double convex

Parent Material: Colluvium from rhyolite, arkose, and greenstone

Vegetation:

Canopy: Fraser fir-red spruce, yellow birch, mountain ash

Understory:

Ground Cover: Ferns, oxalis, mosses, brambles, fallen fir trees

Classification: Typic (or Pachic) Haplumbrept, coarse-loamy, (or loamy-skeletal), mixed, frigid

Description

Oi -- 13 to 0 cm., Fibric material: fresh litter.

Oa -- 0 to 8 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A1 -- 8 to 18 cm., Very dark brown (10 YR 2/2) mucky loam; moderate coarse parting to fine granular structure; very friable; many fine roots; clear smooth boundary.

A2 -- 18 to 38+ cm., Very dark brown (10 YR 3/2) gravelly loam; moderate medium parting to fine granular structure; friable; common fine roots.

Notes:

1. Described from spaded pit.
2. Stopped by gravel in lower A horizon.
3. Pedon may classify as loamy-skeletal pending coarse fragment content in the 25 to 100 cm control section.

PEDON: MR 6

Location: Mt. Rogers; 671 m at S 33° E from Mt. Rogers summit benchmark

Elevation: 1519 m

Aspect: 115° SE

Slope: 34%

Geomorphic: Mid-sideslope below summit; convex contour, linear downslope

Parent Material: Colluvium from rhyolite with some arkose and greenstone

Vegetation:

Canopy: Fraser fir, red spruce, yellow birch

Understory: Sugar maple and second growth spruce-fir

Ground Cover: Ferns, oxalis, mosses

Classification: Typic Haplumbrept, loamy-skeletal, mixed, frigid

Description

Oi --- 3 to 0 cm., Fibric material: Leaf litter, cones, needles.

A1 --- 0 to 18 cm., Very dark grayish brown (10 YR 3/2) loam; weak coarse granular structure parting to fine subangular blocky structure; very friable; many fine and very fine feeder roots; about 10% rhyolite gravels; gradual smooth boundary.

A2 -- 18 to 43 cm., Very dark grayish brown (10 YR 3/2) gravelly loam; moderate coarse parting to fine subangular blocky structure; friable; common fine and very fine roots; about 25% rhyolite gravels; clear smooth boundary.

Bw -- 43 to 76 cm., Dark yellowish brown (10 YR 4/4) very gravelly loam; weak medium subangular blocky structure; friable; about 35% rhyolite fragments; clear wavy boundary.

C --- 76 to 80+ cm., Dark yellowish brown (10 YR 4/4) extremely gravelly loam; massive; about 50-75% coarse fragments.

Notes:

1. Described from spaded pit.
2. Stopped by gravel at 80 cm.
3. Area has common rills and small gullies; no Oa horizon present.
4. A1 horizon has root channels filled with highly decomposed sapric material.

PEDON: MR 7

Location: Mt. Rogers; Cabin Creek area; 2987 m at S 48° E from Mt. Rogers summit benchmark

Elevation: 1548 m

Aspect: 115° SE

Slope: 25%

Geomorphic: Upper sideslope; convex contour, slightly concave downslope

Parent Material: Colluvium from rhyolite with some arkosic sandstone and greenstone

Vegetation:

Canopy: Fraser fir, red spruce, yellow birch

Understory: Hawthorne, rhododendron

Ground Cover: Vaccinium, grasses, sedges, ferns (area is grazed by cattle)

Classification: Typic Haplumbrept, loamy-skeletal, mixed, frigid

Description

Oi --- 3 to 0 cm., Leaf litter, cones, needles.

A --- 0 to 13 cm., Very dark grayish brown (10 YR 3/2) loam ; moderate fine subangular blocky structure; very friable; common fine and very fine roots; gradual smooth boundary

BA -- 13 to 28 cm., Dark brown to brown (10 YR 3/3 to 4/3) gravelly loam; strong fine subangular blocky structure; friable; few fine roots; about 15% rhyolite gravels.

Bw1 -- 28 to 51 cm., Dark yellowish brown (10 YR 4/4) gravelly loam; moderate fine and medium subangular blocky structure; friable; about 25% rhyolite fragments; clear smooth boundary.

Bw2 -- 51 to 97+ cm., Dark yellowish brown (10 YR 4/4) very gravelly loam with many fine distinct yellowish brown (10 YR 5/8) mottles; weak fine and medium subangular blocky structure; about 40-50% coarse fragments.

Notes:

1. Described from spaded pit.
2. Stopped by gravels at 97 cm.

PEDON: MR 8

Location: Mt. Rogers; Cabin Ridge area; 2042 m at S 47° E from Mt. Rogers summit benchmark

Elevation: 1588 m

Aspect: 120° SE

Slope: 7%

Geomorphic: Gently sloping upland ridgetop

Parent Material: Colluvium from rhyolite with some arkosic sandstone and greenstone

Vegetation:

Canopy: Fraser fir, red spruce, yellow birch (about 75% canopy closure)

Understory: Second growth spruce-fir

Ground Cover: Ferns, oxalis, mosses

Classification: Typic Haplumbrept, loamy-skeletal, mixed, frigid

Description

Oi --- 5 to 0 cm., Leaf litter, cones, needles.

A1 -- 0 to 23 cm., Very dark brown (10 YR 2/2) loam; moderate coarse and medium granular structure; very friable; many fine feeder roots; clear smooth boundary.

A2 -- 23 to 46 cm., Very dark brown (10 YR 2/2) gravelly loam; moderate coarse and medium granular structure; friable; few fine roots; about 20% rhyolite gravels; clear smooth boundary.

C --- 46 to 55+ cm., Brown (10 YR 4/3) extremely gravelly loam; mostly massive in place; about 50-75% coarse fragments.

Notes:

1. Described from spaded pit.
2. Stopped by gravel at 55 cm.
3. Area has about 5-10% surface boulders up to 1 m high and 6 m across.
4. Average depth to impenetrable gravelly layer in this area (as determined by a 155 m transect (8 m sampling interval) at S13° W from the pit is 36 cm.

PEDON: MR 9

Location: Whitetop Mtn.; 311 m at N 68° W from radio tower at summit

Elevation: 1605 m

Aspect: 323° NE

Slope: 40%

Geomorphic: Steep upper colluvial sideslope; convex contour, linear downslope

Parent Material: Colluvium from rhyolite with some arkosic sandstone, greenstone and tillite

Vegetation:

Canopy: Red spruce, yellow birch, mountain ash (about 60-70% canopy closure)

Understory: Yellow birch and sugar maple

Ground Cover: Ferns, oxalis, mosses, brambles

Classification: Pachic Haplumbrept, loamy-skeletal, mixed, frigid

Description

Oi --- 6 to 0 cm., Fibric material: Leaf litter, cones, needles.

Oa --- 0 to 10 cm., Black (10 YR 2/1) sapric material; many fine and very fine feeder roots.

A1 -- 10 to 43 cm., Very dark brown (10 YR 2/2) gravelly loam; moderate very coarse parting to fine granular structure; very friable; many fine and very fine roots; about 25% coarse fragments up to 10 cm across; gradual wavy boundary.

A2 -- 43 to 64 cm., Very dark grayish brown (10 YR 3/2) very gravelly loam; weak fine subangular blocky structure friable; few fine roots; about 40% gravels and cobbles; clear smooth boundary.

Bw -- 64 to 91+ cm., Olive brown (2.5 Y 4/4) very gravelly loam; moderate fine and medium subangular blocky structure; friable; about 40% gravels and cobbles which increase with depth in the profile.

Notes:

1. Described from spaded pit.
2. Stopped by gravel at 91 cm.
3. About 10% surface stones and boulders.

PEDON: MR 10

Location: Whitetop Mtn.; 247 m at N 89° E from Whitetop Mtn. tower

Elevation: 1661 m

Aspect: 152° NE

Slope: 12%

Geomorphic: Double convex ridgetop

Parent Material: Colluvium from rhyolite, arkose, greenstone and some tillite

Vegetation:

Canopy: Red spruce

Understory: Not significant

Ground Cover: Ferns, oxalis, mosses

Classification: Typic (or Pachic) Haplumbrept, loamy-skeletal, mixed, frigid

Description

Oi --- 7 to 0 cm., Leaf litter, cones, needles.

Oa --- 0 to 7 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A1 --- 7 to 23 cm., Very dark brown (10 YR 2/2) gravelly loam; moderate coarse parting to medium granular structure; very friable; many fine feeder roots; about 25% rhyolite gravels; gradual smooth boundary.

A2 -- 23 to 40+ cm., Very dark brown (10 YR 2/2) very gravelly loam; weak medium subangular blocky structure; friable; common fine and very fine roots; about 35-50% rhyolite gravels and cobbles.

Notes:

1. Described from spaded pit.
2. Stopped by gravel at 40 cm.
3. Pedon may classify as Pachic if <3.5 chroma colors continue below 50 cm.

PEDON: MR 11

Location: Whitetop Mtn.; 1021 m at N 88° E from tower at summit

Elevation: 1469 m

Aspect: 150° SE

Slope: 25%

Geomorphic: Lower sideslope position; concave contour, linear downslope

Parent Material: Colluvium from rhyolite, arkose, and greenstone

Vegetation:

Canopy: Red spruce, yellow birch, beech, maple

Understory: Maples, yellow birch, buckeye

Ground Cover: Ferns, oxalis, mosses, brambles

Classification: Typic Haplumbrept, fine-loamy, mixed, frigid

Description

Oi --- 3 to 0 cm., Leaf litter, cones, needles.

Oa --- 0 to 3 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A --- 3 to 23 cm., Very dark grayish brown (10 YR 3/2) loam; moderate very coarse parting to medium granular structure; very friable; many fine feeder roots; about 10% rhyolite gravels; clear wavy boundary.

Bw1 -- 23 to 61 cm., Dark brown (10 YR 4/4) gravelly loam or clay loam; moderate medium subangular blocky structure; friable; few fine roots; about 20% rhyolite gravels; gradual smooth boundary.

Bw2 -- 61 to 91+ cm., Yellowish brown (10 YR 5/4) very gravelly loam; few medium distinct dark brown (10 YR 4/4) mottles; weak fine subangular blocky structure; about 35% rhyolite gravels.

Notes:

1. Described from spaded pit.
2. Stopped by gravel at 91 cm.

PEDON: MR 12

Location: Mt. Rogers; 1524 m at S 80° E from benchmark at summit

Elevation: 1603 m

Aspect: 332° NW

Slope: 27%

Geomorphic: Upper sideslope; convex contour, linear downslope

Parent Material: Colluvium from rhyolite, arkose, and some greenstone

Vegetation:

Canopy: Fraser fir, red spruce, yellow birch

Understory: Second growth spruce and fir, yellow birch

Ground Cover: Ferns, oxalis, mosses, sedges

Classification: Pachic Haplumbrept, loamy-skeletal, mixed, frigid

Description

Oi --- 3 to 0 cm., Leaf litter, cones, needles.

Oa --- 0 to 5 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A1 --- 5 to 18 cm., Very dark grayish brown (10 YR 2/2) gravelly loam; moderate coarse granular structure; very friable; many fine feeder roots; about 20% rhyolite gravels; gradual smooth boundary.

A2 -- 18 to 56 cm., Very dark grayish brown (10 YR 3/2) very gravelly loam; moderate fine granular structure; friable; common fine and very fine roots; about 40% rhyolite gravels; clear smooth boundary.

BC -- 56 to 76+ cm., Yellowish brown (10 YR 5/4) extremely gravelly loam; massive in place parting to weak fine subangular blocky structure; firm; about 60-75% rhyolite gravels and cobbles.

Notes:

1. Described from spaded pit.
2. Stopped by gravel at 76 cm.
3. About 10-15% surface boulders in area up to 1 m across and 1 m high.

Pedon: MR 13

Location: Mt. Rogers; Wilburn Ridge area; 2499 m at N 78° E from benchmark at summit of Mt. Rogers

Elevation: 1575 m

Aspect: 332° NW

Slope: 12%

Geomorphic: Ridgetop; convex contour, linear slope colluvial backslope

Parent Material: Colluvium from rhyolite with some arkosic sandstone

Vegetation:

Canopy: Fraser fir, red spruce, yellow birch, mtn. ash

Understory: Second growth spruce and fir, yellow birch, maples

Ground Cover: Ferns, oxalis, mosses, brambles, sedges

Classification: Typic Haplumbrept, loamy-skeletal, mixed, frigid

Description

Oi --- 3 to 0 cm., Leaf litter, cones, needles.

Oa --- 0 to 3 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A --- 3 to 23 cm., Very dark brown (10 YR 2/2) gravelly loam; moderate medium granular structure; very friable; many fine feeder roots; about 20% rhyolite gravels; clear wavy boundary.

Bw -- 23 to 36 cm., Brown (10 YR 4/3) gravelly loam; moderate medium subangular blocky structure friable; few fine roots; about 30% rhyolite gravels; clear wavy boundary.

C --- 36 to 56+ cm., Yellowish brown (10 YR 5/4) extremely gravelly loam; massive; firm; greater than 50% rhyolite gravels and cobbles.

Notes:

1. Described from spaded pit.
2. Stopped by gravel at 56 cm.
3. About 10% surface boulders in area up to 1 m high.

PEDON: MR 14

Location: Mt. Rogers; 1945 m at N 60° E from summit benchmark

Elevation: 1314 m

Aspect: 340° NW

Slope: 26%

Geomorphic: Lower sideslope; convex contour, linear slope

Parent Material: Colluvium from rhyolite with some arkosic sandstone

Vegetation:

Canopy: Fraser fir, red spruce, yellow birch, some beech

Understory: Maples, beech

Ground Cover: Ferns, oxalis, mosses, brambles

Classification: Typic Haplumbrept, loamy-skeletal, mixed, frigid

Description

Oi --- 5 to 0 cm., Leaf litter, cones, needles.

Oa --- 0 to 5 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A1 --- 5 to 10 cm., Very dark grayish brown (10 YR 3/2) gravelly loam; moderate medium granular structure; very friable; many fine feeder roots; about 15% rhyolite gravels; clear smooth boundary.

A2 --- 10 to 23 cm., Mottled very dark grayish brown (10 YR 3/2), grayish brown (10 YR 5/2), and light yellowish brown (10 YR 6/4) gravelly loam; moderate medium granular structure; very friable; many fine and very fine roots; about 25% rhyolite gravels; clear wavy boundary.

Bw -- 23 to 61 cm., Dark yellowish brown (10 YR 4/4) gravelly loam to clay loam; weak medium subangular blocky structure; few fine roots; about 15% rhyolite gravels; clear smooth boundary.

C --- 61 to 76+ cm., Dark yellowish brown (10 YR 4/4) extremely gravelly loam; massive; greater than 60% gravels.

Notes:

1. Described from spaded pit.
2. Stopped by gravel at 76 cm.

PEDON: MR 15

Location: Mt. Rogers; 177 m at N 75° W of summit benchmark

Elevation: 1722 m

Aspect: 330° NW

Slope: 15%

Geomorphic: Double convex ridge

Parent Material: Colluvium from rhyolite with some arkose and greenstone

Vegetation:

Canopy: Fraser fir, red spruce, yellow birch

Understory: Second growth spruce and fir

Ground Cover: Ferns, oxalis, mosses, brambles

Classification: Pachic Haplumbrept, loamy-skeletal, mixed, frigid

Description

Oi -- 5 to 0 cm., Leaf litter, cones, needles.

Oa -- 0 to 10 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A --- 10 to 28 cm., Very dark brown (10 YR 2/2) loam; moderate coarse granular structure; very friable; many fine feeder roots; clear wavy boundary.

Bw1 -- 28 to 50 cm., Very dark grayish brown (10 YR 3/2) gravelly loam; moderate medium subangular blocky structure; friable; few fine roots; about 20% rhyolite gravels; clear smooth boundary.

Bw2 -- 50 to 66+ cm., Dark brown (10 YR 3/3) gravelly loam; moderate medium subangular blocky structure; about 30% rhyolite gravels.

Notes:

1. Described from spaded pit.
2. Stopped by gravel at 66 cm.

PEDON: MR 16

Location: Mt. Rogers; 920 m at S 32° E of summit benchmark

Elevation: 1539 m

Aspect: 130° SE

Slope: 28%

Geomorphic: Lower sideslope; convex contour, linear downslope

Parent Material: Colluvium from rhyolite with some arkose and greenstone

Vegetation:

Canopy: Fraser fir, red spruce, yellow birch

Understory: Second growth spruce and fir

Ground Cover: Ferns, oxalis, mosses, brambles

Classification: Typic Haplorthod, loamy-skeletal, mixed, frigid

Description

Oi -- 5 to 0 cm., Leaf litter, cones, needles.

Oa -- 0 to 5 cm., Black (10 YR 2/1) sapric material; many fine feeder roots.

A --- 5 to 20 cm., Very dark brown (10 YR 2/2) loam; moderate coarse granular structure; very friable; many fine feeder roots; about 10% rhyolite gravels; clear smooth boundary.

Bw1 -- 20 to 41 cm., Very dark grayish brown (10 YR 3/2) gravelly loam; weak medium subangular blocky structure; friable; common fine and very fine roots; about 20% rhyolite gravels; clear smooth boundary.

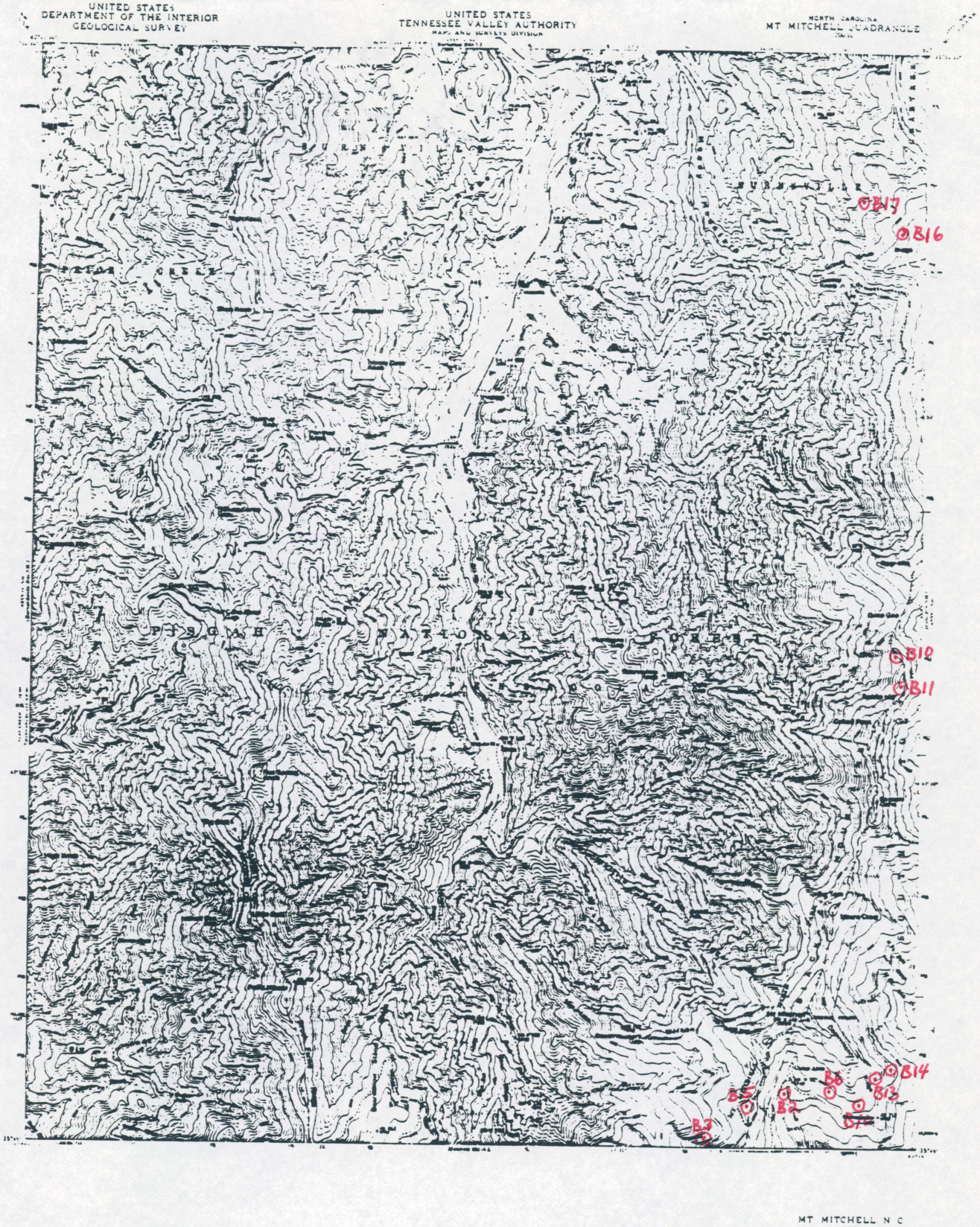
Bw2 -- 41 to 66+ cm., Dark brown (10 YR 3/3) gravelly loam; weak fine subangular blocky structure; few fine roots; about 30% rhyolite gravels.

Notes:

1. Classified as Pachic Haplumbrept in the field.
2. Described from spaded pit.
3. Stopped by gravel at 66 cm.

Appendix C. Location of the Soils Examined

Note: Although sampling sites are accurately depicted on the following topographic maps, the small size of reproduction may limit their use in the field. The interested reader is advised to obtain full-size maps and to transfer the sample locations accordingly.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UNITED STATES
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MAPS AND SURVEYS DIVISION
NORTH CAROLINA
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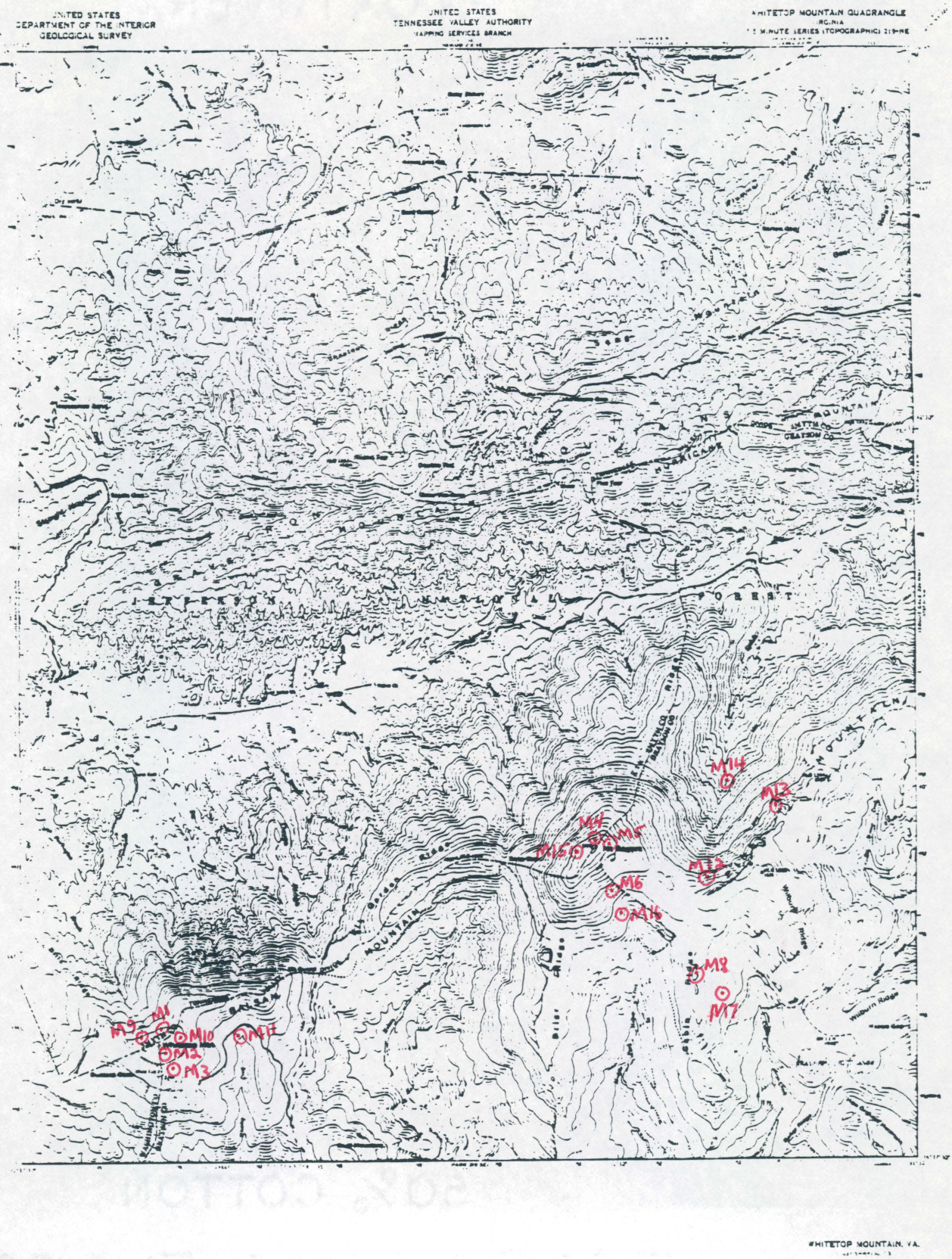
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WHITETOP MOUNTAIN, VA.

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GEOLOGICAL SURVEY
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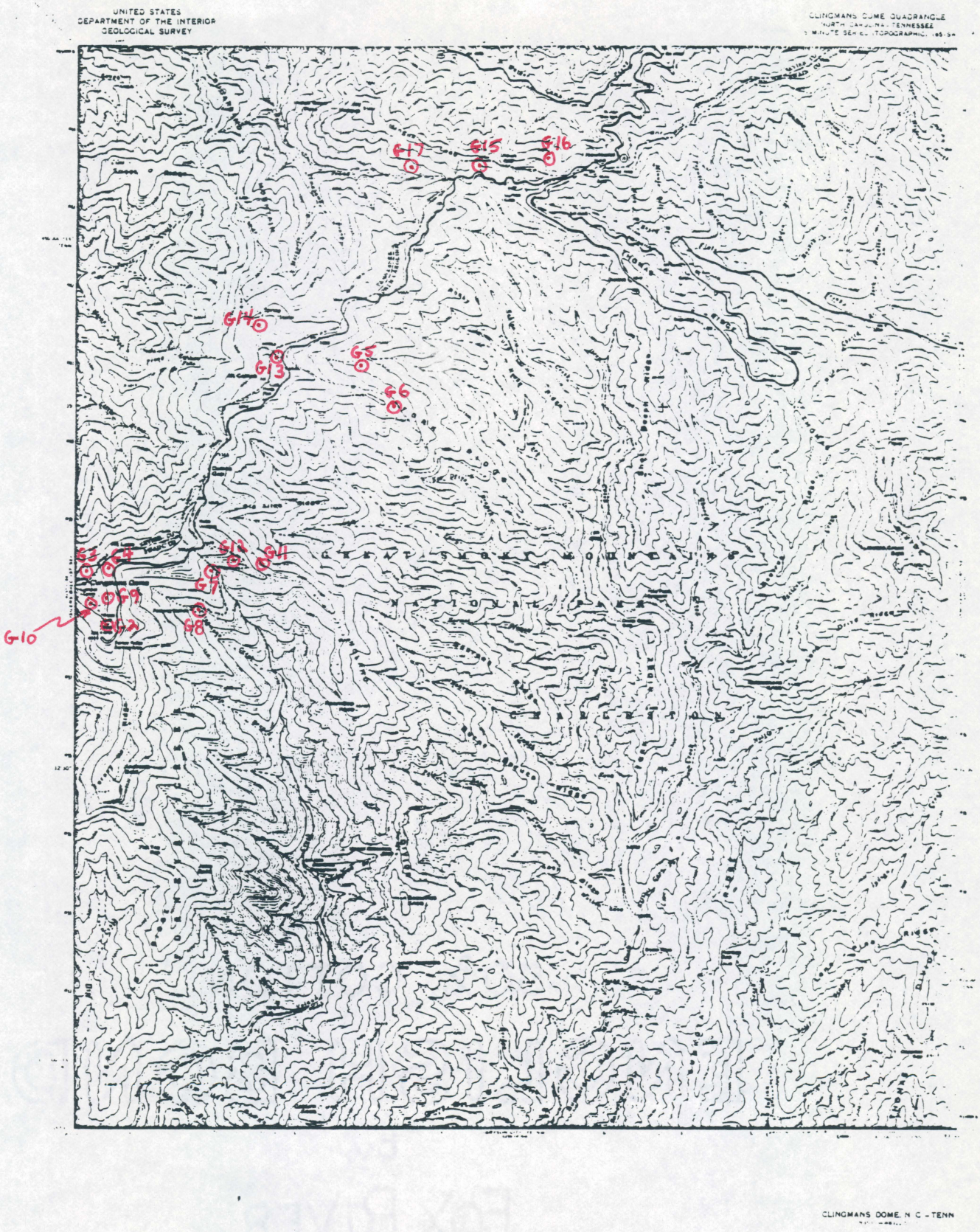
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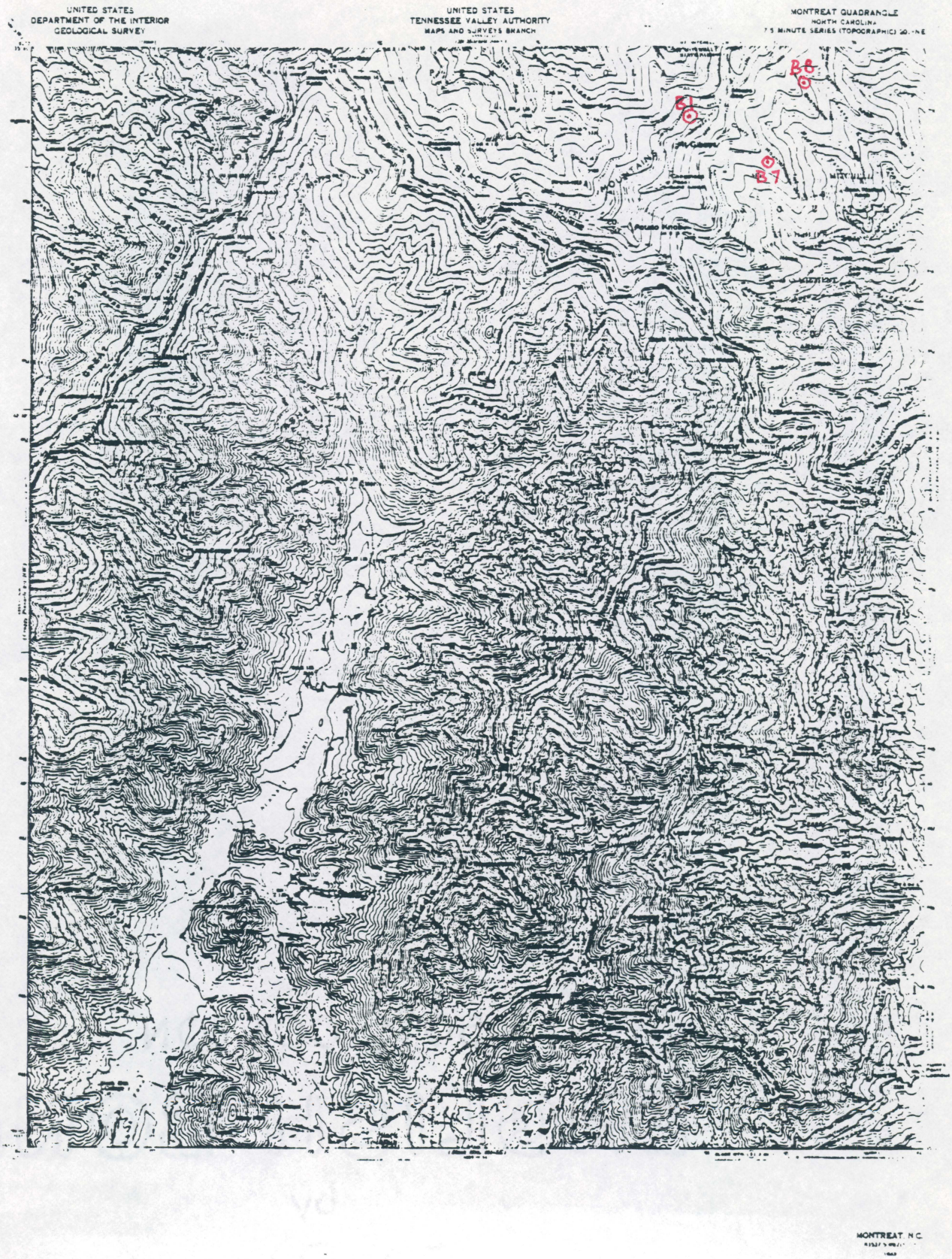
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