SOILS AND SOIL CLAY MINERAL FORMATION IN THE VIRGINIA BLUE RIDGE AND PIEDMONT PROVINCES

by

William Merle Flock, III

Thesis submitted to the Graduate Faculty of the
Virginia Polytechnic Institute
in candidacy for the degree of
MASTER OF SCIENCE
in
GEOLOGY

March 1963

Blacksburg, Virginia

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ACKNOWLEDGEMENTS

The author wishes to express his appreciation to Dr. B. W. Nelson for his helpful criticisms and suggestions during the studies and for his assistance during the preparation of the manuscript. He is also indebted to Prof. H. C. Porter of the Agronomy Department for his assistance during the field sampling. Appreciation is also expressed to Dr. C. I. Rich of the Agronomy Department for his advice and suggestions on laboratory procedures.

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CHAPTER I

Introduction

About 60 years ago it was suggested that soils are the result of four factors; climate, vegetation, time, and parent material. A few years later a fifth factor was added, topography. Since that time pedologists have accepted these factors as the ones controlling soil formation.

One present concept of soil development is that the effectiveness of the other four factors varies with time and that climate and its associated vegetation can if given long enough, erase any differences due to parent material or relief. The result is that similar soils may exist side by side which have developed from quite different rock types. Grim (1953) makes a similar statement concerning the clay mineralogy of soils.

Purpose and Objectives

The Virginia Piedmont and Blue Ridge provinces have been subjected to prolonged chemical weathering. They have in fact probably undergone nearly continuous erosion since Cretaceous time. Many soils in these provinces are mature and according to the present concept of soil development should have similar soil features and clay minerals. A review of the literature on Piedmont soils indicated that the present concept may not hold for the soils of this area. That is climate and vegetation may not have erased the influence of the other soil forming

factors, particularly the effect of parent rock. This study was proposed to evaluate the time-climate concept of soil development in an area where soils have developed under prolonged chemical weathering from rocks of various compositions. The specific objectives of the investigation were (1) to study soils and soil clay minerals formed from rocks of varying composition. (2) to compare the amount and character of soil clay minerals formed under two different climates. (3) to evaluate the effect of changes in topography on soil clay minerals. It was also found during the investigation that new information could be obtained on the mode of formation of clay minerals, and on the weathering of the minerals.

CHAPTER II

FIELD METHODS

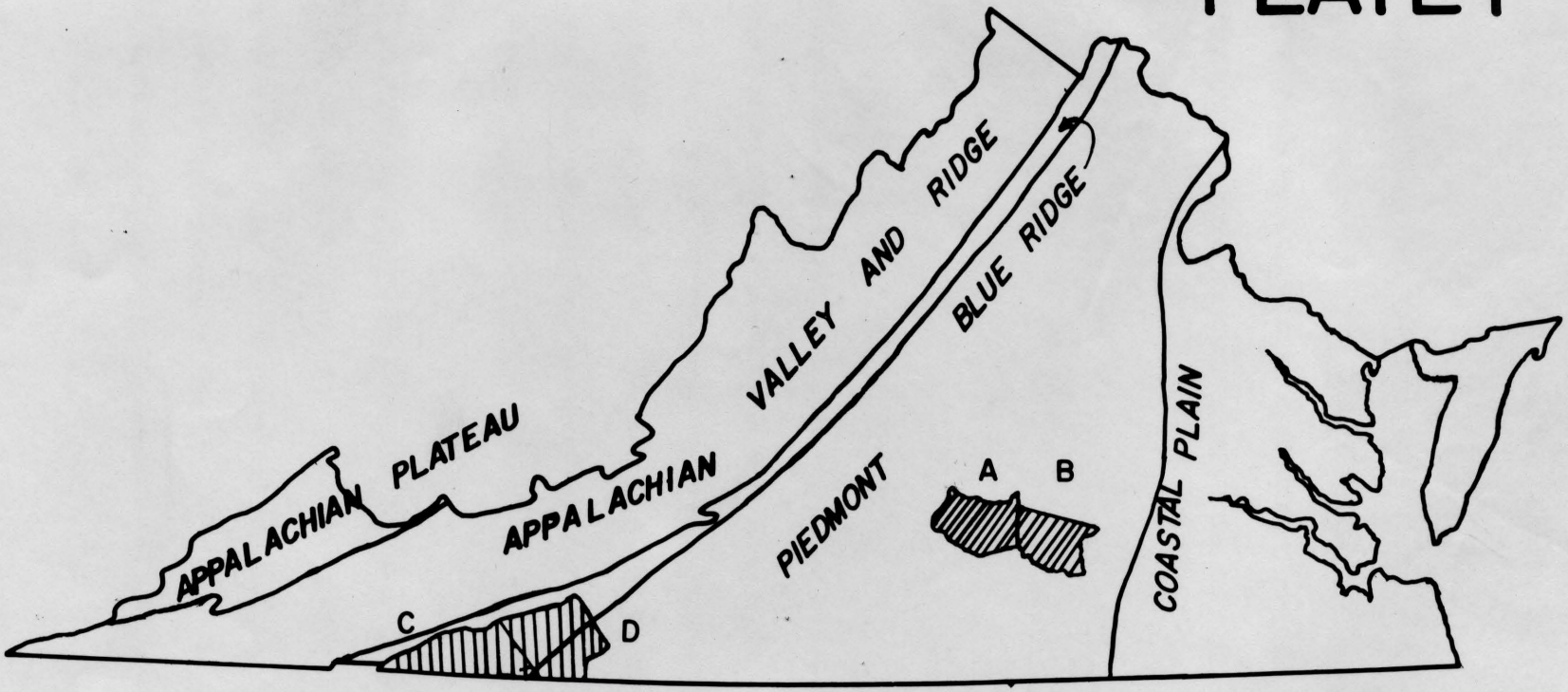
Introduction

The Virginia Blue Ridge and Piedmont are ideally suited for a study of this nature. The difference in elevation between the two permits an evaluation of the effect of climate. The rocks range in composition from mafic to silicic, which permits an evaluation of parent material. The physiography of the areas is rather similar, both are very old erosional features with deep residual soils.

Location of Areas

In the Piedmont the profiles were collected in Prince Edward and Nottoway Counties. These counties were chosen because: (1) Recently published soil survey bulletins which contained soil maps were available. The maps constructed on aerial photographs at a scale of 1 to 20,000 made it possible to accurately locate the different soil types. (2) The bulletins indicated that the soils developed from rocks of widely different compositions. (3) The bulletins also indicated that a variety of soils were present in the counties. In the Blue Ridge the profiles were collected in Carroll and Grayson Counties. These counties were chosen because of the occurrence of a great variety of rock types, and particularly because of the presence of highly mafic rocks. Soil maps do not exist for these counties but Professor H. C. Porter of the V. P. I. Agronomy

PLATE I



LOCATIONS OF COUNTIES

A. PRINCE EDWARD COUNTY
B. NOTTOWAY COUNTY
C. GRAYSON COUNTY
D. CARROLL COUNTY

Department aided in the location, identification, and sampling of the profiles.

Prince Edward and Nottoway Counties lie entirely within the Piedmont physiographic province in the south-central part of Virginia (Plate 1). Carroll and Grayson Counties lie within the Blue Ridge physiographic province in the south-western part of the state (Plate 1).

Field Samples

The field work was completed during the summer of 1961. In all, 29 soil profiles were collected in the Blue Ridge and Piedmont areas. In the 29 profiles there are 19 different soil types: 12 Piedmont soils from 5 catenas and 7 Blue Ridge soils from 5 catenas (Table 1). A physical description of each profile, a petrographic description of the parent rock, and a modal analysis of the rock are given in Appendices I and II. The soils are grouped in the appendix by catenas. The catenas are listed according to the composition of the parent rock beginning with the most mafic rock and going to silicic rocks.

The Piedmont soil profiles from Nottoway County (samples 1, 2, 3, 4, and 5) and the Blue Ridge profiles (samples 19 to 25) were collected jointly by the writer and Professor H. C. Porter. The profiles (samples 7 through 18, and 26, 28, 29, 30, and 31) were collected by the writer in Prince Edward County. These profile sites are shown in Plate III. The sites were chosen by the combined use of the Prince

TABLE I

Soil Profile, Parent Rock and Climatic Zone

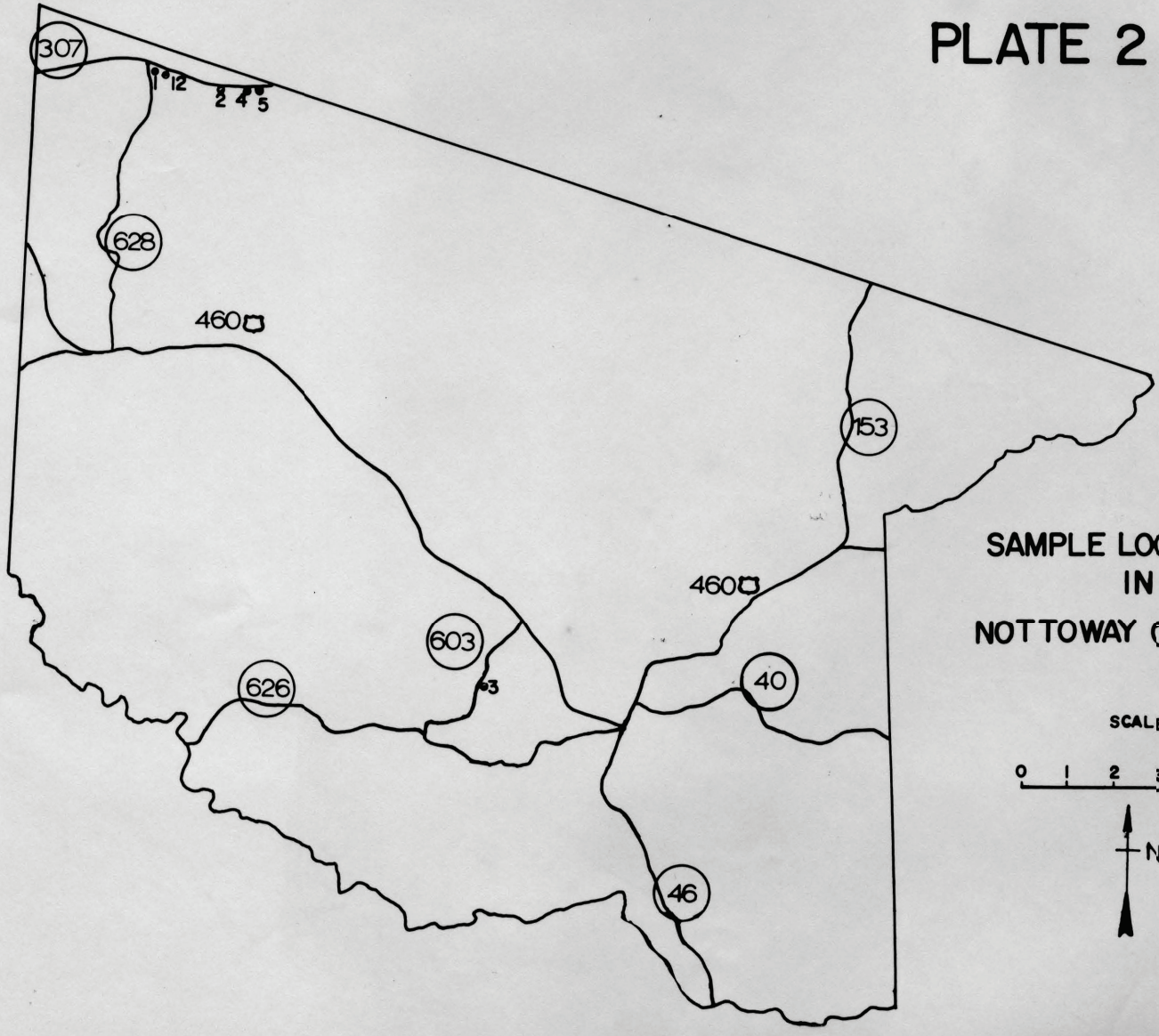
Sample No.	Soil Type	Parent Rock	Climate
1	Mecklenburg loam	hornblende-epidote schist	Piedmont
2	Bremo loam	hornblende-epidote schist	Piedmont
3	Madison sandy loam	biotite gneiss	Piedmont
4	Iredell sandy loam	diabase	Piedmont
5	Louisburg sandy loam	granite pegmatite	Piedmont
6	Zion fine sandy loam	hornblende-epidote schist	Piedmont
7	Madison clay loam	biotite gneiss ?	Piedmont
8	Louisa sandy loam	biotite gneiss	Piedmont
9	Cecil fine sandy loam	muscovite schist	Piedmont
10	Madison fine sandy loam	biotite gneiss	Piedmont
11	Iredell sandy loam	diabase	Piedmont
12	Iredell fine sandy loam	hornblende-epidote schist ?	Piedmont
13	Louisa fine sandy loam	muscovite-biotite gneiss ?	Piedmont
14	Bremo loam	garnet-amphibolite gneiss	Piedmont
15	Louisa sandy loam	muscovite-biotite schist	Piedmont
16	Lloyd clay loam	garnet-amphibolite gneiss ?	Piedmont
18	Worsham sandy loam	colluvial	Piedmont
19	Talladega silt loam	biotite-muscovite schist	Blue Ridge
20	Catoctin silt loam	greenstone	Blue Ridge
21	Rabun silty loam	talc-chlorite soapstone	Blue Ridge
22	Elbert silt loam	serpentized gabbro	Blue Ridge
23	Eubanks loam	biotite-epidote gneiss	Blue Ridge
24	Rabun silt loam	biotite-hornblende gneiss	Blue Ridge
25	Louisburg sandy loam	granite	Blue Ridge
26	Cecil fine sandy loam	muscovite schist ?	Piedmont
28	Lloyd clay loam	garnet-amphibolite gneiss	Piedmont
29	Iredell fine sandy loam	hornblende-epidote schist	Piedmont
30	Wilkes sandy loam	muscovite-biotite gneiss	Piedmont
31	Helena fine sandy loam	hornblende-biotite schist	Piedmont

? The Rock is too weathered to determine the exact composition.

Edward County soil survey map and a geologic map of the Baker Mountain area (Espenshade and Potter, 1960).

All profiles were sampled by genetic horizons A, B, C, and D. A continuous sample was taken across each horizon. Only spot samples were taken from the thick saprolitic rock material (D or C_4 horizons). Whenever possible the parent rock was collected directly beneath the profile or offset from the profile at an angle determined by the dip of the rock foliation. However in many cases it was impossible to reach fresh rock. When this occurred the rock was usually obtained from nearby outcrops. Even this method was not successful for samples 7, 12, 13, 16 and 26 and no fresh rock could be obtained. An estimate of the composition of these rocks was made by petrographic and x-ray analysis of the saprolitic material.

PLATE 2



SAMPLE LOCATIONS
IN
NOTTOWAY COUNTY

SCALE

0 1 2 3 4 5 MILES

N

PLATE 3

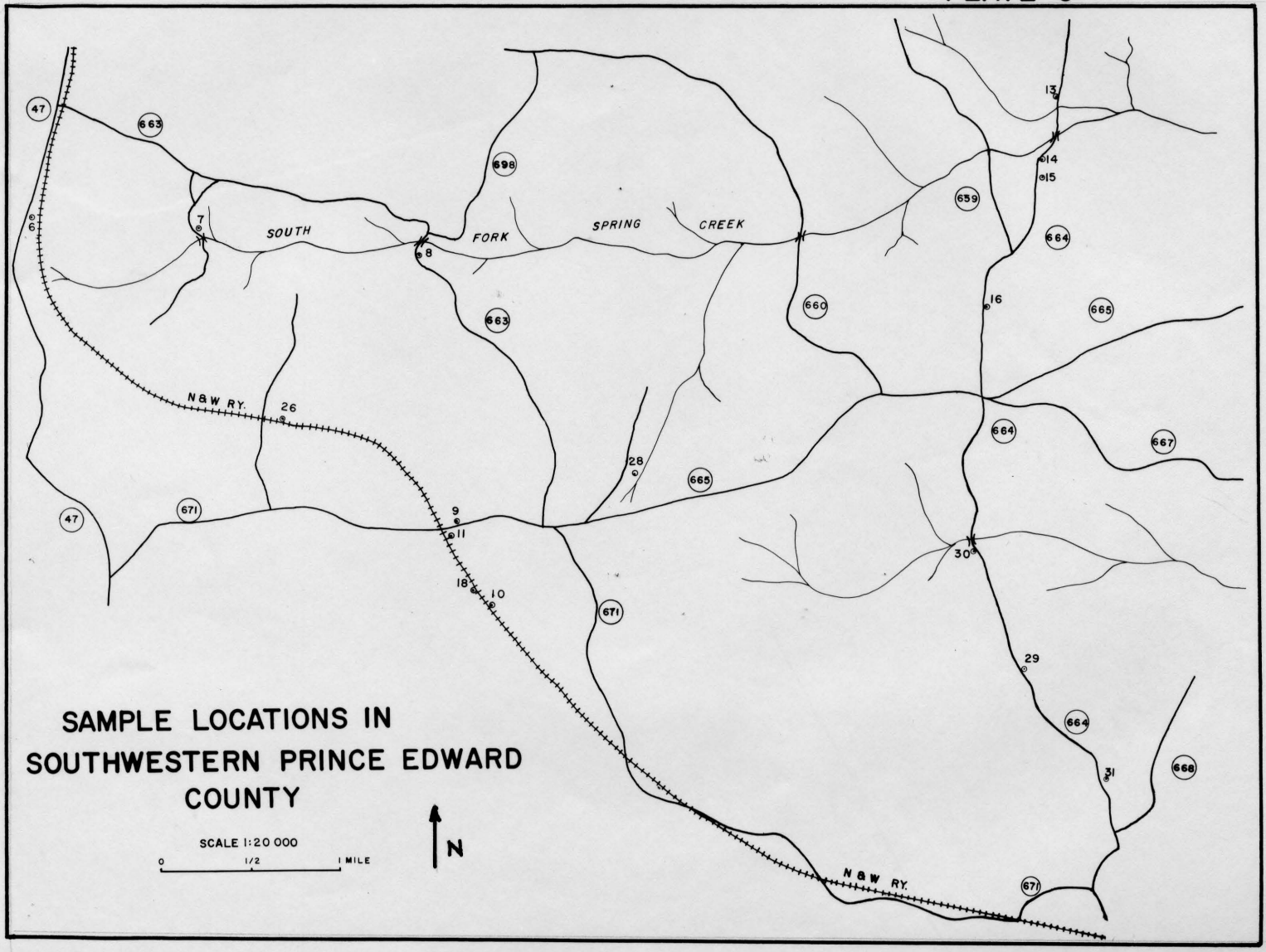
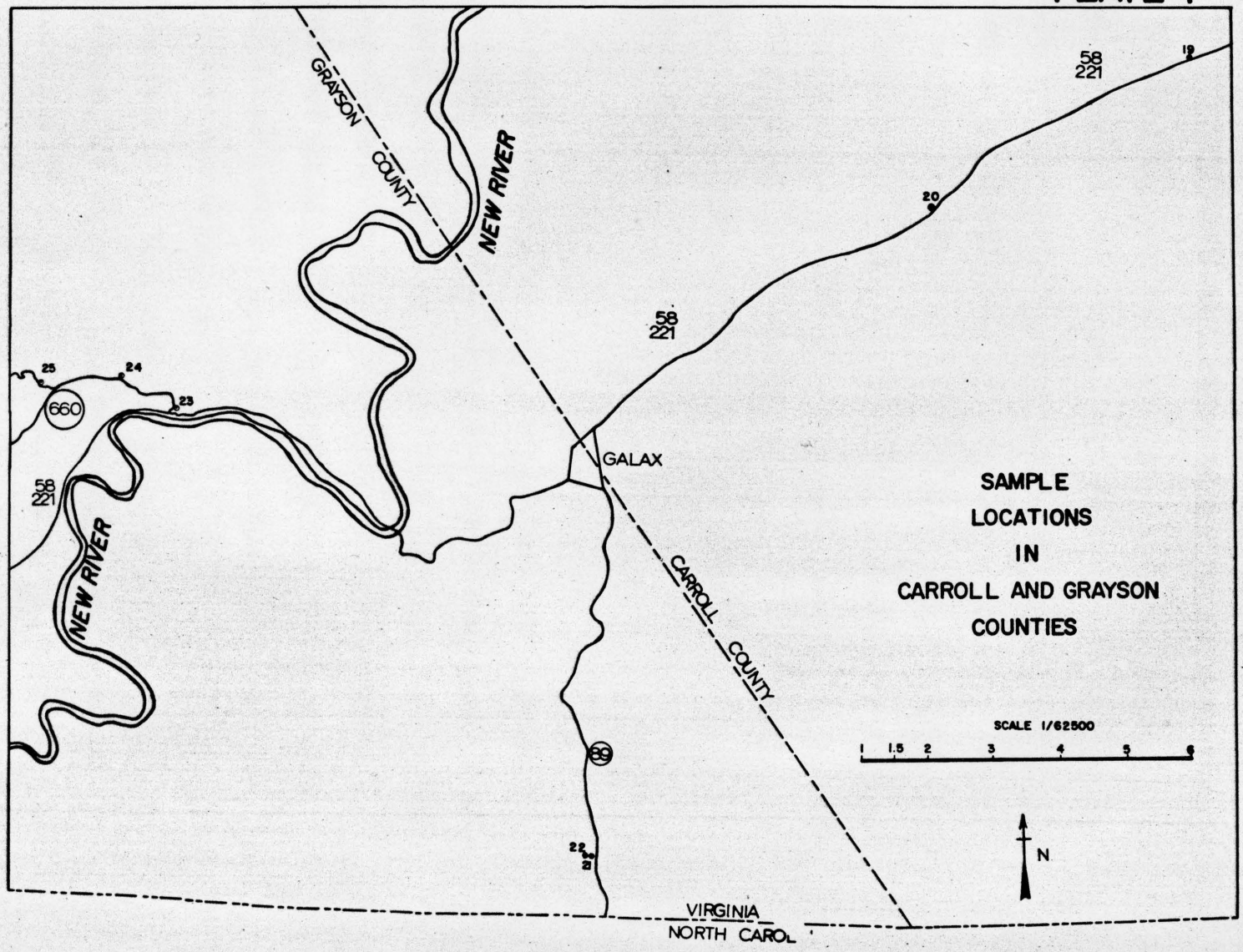

SOUTH FORK SPRING CREEK
N&W RY.
N&W RY.
47
663
698
659
664
660
665
667
671
668
SAMPLE LOCATIONS IN SOUTHWESTERN PRINCE EDWARD COUNTY
SCALE 1:20 000
0 1/2 1 MILE
N

PLATE 4


GRAYSON COUNTY
NEW RIVER
58
221
12
20
58
221
25
24
23
660
58
221
NEW RIVER
GALAX
CARROLL COUNTY
SAMPLE
LOCATIONS
IN
CARROLL AND GRAYSON
COUNTIES
SCALE 1/62500
1 1.5 2 3 4 5 6
N
89
22
21
VIRGINIA
NORTH CAROL

CHAPTER III

SOIL FORMING FACTORS

The Blue Ridge and Piedmont areas studied are rather similar except for the higher elevation of the Blue Ridge. This elevation produces a cooler climate which is apparently sufficient to produce a change in the character of the mature soils. According to the U.S.D.A. soil classification map, the zonal soils of the Blue Ridge are characteristic of the Gray-Brown Podzolic great soil group and the zonal soils of the Piedmont are characteristic of the Red-Yellow Podzolic great soil group. A detailed description of the five soil forming factors which have affected these soils is given in the following section.

Time

The Piedmont and Blue Ridge provinces have been geologically rather stable since the Triassic. They have in fact, probably been undergoing nearly continuous erosion since the Cretaceous. In both areas nearly level erosional surfaces have in recent geologic time been uplifted and subjected to renewed erosion. The soils in drainage divide areas are unaffected by this recent erosion and still contain mature features.

The soils of the Blue Ridge are undoubtly older than those of the Piedmont, but the time needed for a soil to reach maturity in the Piedmont has been exceeded, so that the difference in age is no

longer important. For this same reason time is not variable for mature soils in the same province. Soils developed on hillside slopes and near major streams are of course much younger and have less mature profiles. In these soils time is one of the principal variables.

Climate

The climate of the Piedmont area is a Humid Temperate climate with hot summers (Koppen, 1954). The average temperature of the warmest month is greater than 71.6° F. The following data were compiled from records of the United States Weather Bureau station at Farmville, Va. The average yearly temperature is 57.6° F. The average winter temperature is 38.7° F. and the summer average is 76.3° F. The average yearly precipitation is 40.88 inches and is evenly distributed.

The climate of the Blue Ridge area is classified as Humid Temperate with cool summers. The average temperature of the warmest month is under 71.6° F. The following data for the area were compiled from records of the United States Weather Bureau at Galax, Va. The average yearly temperature is 52° F. The average winter temperature is 33° F. and the summer average is 69° F. The average yearly precipation is 42 inches and is evenly distributed.

Vegetation

The vegetation of a region is directly related to its climate and since the Blue Ridge and Piedmont climates are not very different, the types of vegetations are also similar. Both areas consist of mixed farm and forest lands. About 65 percent of the land in the Piedmont

counties is forested. The counties lie in the oak-pine subdivision of the southern hardwood forest in the eastern forest region of the United States. The oak-pine forests consist of pines and southern hardwoods. These forests appear to contain a higher percentage of pines than the Blue Ridge forests. It is believed that practically all soils in the counties have been cultivated for some time; and therefore the effects of vegetation on the soil are considered constant throughout the counties. This is probably also true for the less dissected areas studied in the Blue Ridge. The picture on page 15 shows typical Piedmont vegetation.



Plate 5.

This picture shows the typical vegetation and topography of the Piedmont

Physiography and Relief

The Piedmont topography in Nottoway and Prince Edward Counties is mainly undulating to rolling. Recent uplift has rejuvenated the streams and enabled them to cut V-shaped valleys into the old erosional surface. Many of the streams have cut through the deep mantle of soil and saprolitic material and are now flowing on bedrock. The streams have a dendritic drainage pattern. The wide undulating interstream areas are nearly level but are occasionally broken by low hills such as Baker and Leigh Mountains in Prince Edward County. The range in elevation for this area is from 750 feet (Baker Mountain in southwestern Prince Edward County) to 200 feet (southeastern Nottoway County). In general the land slopes gently towards the southeast.

The Blue Ridge area of Carroll and Grayson Counties is a plateau which has been greatly dissected by the New River and its tributaries. The tributaries have dendritic drainage patterns. The river has formed entrenched meanders due to recent uplift. The interstream areas are rolling to slightly hilly and have elevations between 2500 and 3000 feet. Near the New River the Plateau surface is preserved only on the tops of narrow winding ridges.

Three of the seven Blue Ridge profiles (samples 23, 24 and 25) were collected near the New River along these ridges. The other four profiles (samples 19 - 22) were collected on the rolling plateau farther from the river. These relations can be seen in Plate IV.

Parent Material

The rocks of the Piedmont are a structurally complex series of metamorphic gneisses and schists which are cut by a number of quartz veins and a few pegmatites. All rocks are in turn intruded by cross cutting diabase dikes of Triassic age. The diabase dikes have a general north-south strike and range in width from one to several hundred feet. Diabase texture and grain size vary with the width of the dikes, but the composition is nearly constant in all dikes. The diabase is composed mainly of calcic plagioclase and augite with lesser amounts of olivine.

A-C-F and A-K-F diagram constructed by the writer for the metamorphic rocks indicate that they are in metamorphic equilibrium and have mineral assemblages characteristic of the amphibolite facies. The assemblages are: muscovite-quartz-biotite, muscovite-microcline-quartz-biotite-oligoclase, hornblende-epidote-quartz-andesine, biotite-oligoclase-quartz, hornblende-cummingtonite-garnet. The biotite-oligoclase-quartz gneiss. Western Prince Edward County (Plate 3, sample 10), is believed by Espenshade and Potter (1960) to be correlative with the Lynchburg formation. This is important, since the Talladega mountain soil (sample 19) is also developed from rocks mapped as Lynchburg by Stose and Stose (1957).

The Blue Ridge area contains intensely metamorphosed sedimentary and igneous rocks of Precambrian age. Stose and Stose (1957 mapped the area studied and believe that Precambrian sedimentary gneisses and diorites were metasomatically replaced by later granites. Thin

section studies made in this investigation indicate that epidotization and sericitization are common alterations found in many of the granitic rocks.

The specimens collected from Carroll and Grayson Counties range from meta-gabbro to granite. The mineral assemblages are: chlorite-talc-tremolite-olivine-magnetite, chlorite-talc-tremolite, hornblende-epidote-quartz-andesine, sericite-hornblende-biotite-quartz, quartz-microcline-epidote-albite (Grayson granodiorite), quartz-microcline-muscovite-biotite-albite (Lynchburg Formation), quartz-sericite-microcline-biotite-albite (Carsonville Granite).

Many of these assemblages are similar to those of the Piedmont source rocks. However, only two of them have metamorphic textures similar to the schists and genisses of the Piedmont. The other rocks have textures more typical of igneous rocks.

CHAPTER IV

CHARACTERISTICS OF THE SOIL CATENAS

Introduction

The next section is a discussion of the physical properties of the soil catenas included in this investigation. The catenas are discussed in terms of (1) minerelogical composition of the parent rock, (2) physical characteristics of each soil type, and (3) relationship between members of a catena in terms of drainage, profile maturity, and topography. These data are also summarized in Table 2. Before discussing these catenas a brief summary of soil classification will be given, which should help to clarify the organization of the catenas.

Soil Classification

The highest categories of the soil classification are the zonal, intrazonal, and azonal soils. Zonal soils have well developed profiles with distinct A, B, and C horizons. They are said to reflect only the influence of climate. Intrazonal soils have rather well developed soil profiles but reflect the dominate influence of some local factor such as relief, parent material, or age over the normal effect of climate and vegetation. Azonal soils have imperfectly developed profiles, either because the soils are young or because some condition of parent material or relief prevents the formation of well developed profile characteristics.

Each of the above categories are composed of great soil groups. Zonal great soil groups are named on the basis of differences in climate and vegetation. The zonal soils of the Piedmont, such as the Cecil, belong chiefly to the Red-Yellow Podzolic great soil group. The zonal soils of the Blue Ridge are also Red-Yellow Podzolic soils but some, such as the Eubanks intergrade into the Gray-Brown Podzolic great soil group. Soils from one other zonal great soil group were collected in the Piedmont and belong to the Reddish-Brown Lateritic great soil group. The Rabun soil belong to this great soil group.

Gray-Brown Podzolic soils are best developed under deciduous forests in humid temperate regions. Geographically they lie between the Podzolic soils on the north and the Red-Yellow Podzolic soils on the south. The dominate process in the formation of the Gray-Brown Podzolic soils is podzolization. During podzolization the surface layer is leached of its basic cations, aluminum and iron are concentrated in the B horizon, and silica remains in the A horizon. The surface layer of these soils is usually grayish-brown. The subsoil is heavier in texture than the A horizon.

Red-Yellow Podzolic soils are best developed in warm temperate humid forest regions. Podzolization is still the dominate process in the formation of these soils but the effect of laterization is also noticeable. They are characterized by light colored A horizons with friable loamy textures. The B horizons usually contain red, yellowish-red or yellow, firm clay, and overlie lighter colored, more friable, C horizons.

Reddish-Brown Lateritic soils are best developed in tropical climates under forest vegetation. Laterization is the dominate process in the formation of these soils. During laterization silica is removed and the content of aluminum and iron is increased. The soils are characterized by dark reddish-brown, granular surface layers and friable red clay subsoils.

Intrazonal and azonal great soil groups can occur in any climatic zone. Planosols and Low-Humic Gley are the intrazonal soils studied in this investigation. The Planosols are defined as soils that have one or more horizons abruptly separated from, and sharply contrasting with, an adjacent horizon because of cementation, compaction, or high content of clay. Planosols soils in this area have dense, compact, clayey B horizon's. The A horizon usually varies from gray to dark brown and is friable. The subsoil is composed of massive yellow-brown to olive-brown clay. The soils are usually shallow and the underlying rock quite fresh. Internal drainage is nearly always very poor.

Low-Humic Gley soils are a group of poorly drained soils with thin surface layers and a moderately high content of organic matter. The subsoil is commonly mottled gray and brown and has little soil texture. The soils occur chiefly under a natural cover of swamp forest and develop from a great variety of parent materials.

The azonal soils are represented in this study by the Lithosols great soil group. Soils of this group have no clearly expressed soil morphology. They occur on steep slopes or in other strongly eroded

areas. The profiles are very shallow and contain many partly weathered rock fragments.

Soil Catenas

Perhaps the most important soil division, as far as this investigation is concerned, is the soil catena. A catena is defined as a group of soils which have developed from the same parent material but under different relief and drainage. Thus all three zonal categories listed above occur in a catena. The relationship between categories can best be seen in Tables 2 and 3. In the tables azonal are listed in the left column under excessively drained soils. Zonal soils are listed in the center columns under well to moderately well drained soils. Intrazonal soils are listed in the right hand columns under poorly drained soils.

The next section is a discussion of the general characteristics of each catena studied in this investigation. In many cases not every member of a particular catena was sampled due to the difficulty of obtaining samples of fresh parent rock.

TABLE 2

Piedmont Soil Catenas

Parent Material	Drainage Sequence					
	Excessive	Well	Well to Mod. Well	Mod. Well	Somewhat Poorly Drained	Poorly Drained
MAFIC ROCKS						
Hornblende schist Diabase	Bremo 1-2	Davidson ?	Mecklenburg 3-5	Zion 4-6	Iredell 4-7	Elbert
INTERMEDIATE						
Hornblende-biotite schist			Fluvanna? Enon?	Vance?	Helena 6-8	
Garnet amphibolite gneiss	Bremo 1-2	Lloyd 10-15				
SILICIC ROCKS						
Biotite gneiss	Louisa 15 Wilkes 15	Grover?	Madison 15-40			
Muscovite schist Granite Granite pegmatite	Louisburg 12-15	Appling	Cecil 15-45	Durham?		

This table illustrates the relationship between parent material, drainage and depth of weathering for the various Piedmont soil catenas. Only the underlined soil members in each catena were studied. The other members were taken from a similar table constructed by Epperson and Porter (1960). The question marks indicate that the parent rock was not seen in the field and the soil may not belong to this catena. The numbers after each underlined member indicate the estimated depth in feet to fresh rock.

Piedmont Catenas Developed From Mafic Rocks

Bremo - Iredell-Mecklenburg Catena

The Bremo-Iredell-Mecklenburg catena develops on Triassic diabase dikes and lime-rich silicate rocks. The following soil types are included by Epperson and Porter (1960) in this catena: Bremo, Davidson, Mecklenburg, Zion, Iredell, and Elbert. All members were sampled except the Davidson and Elbert soils which do not occur in the area studied. The drainage relationships between members are shown in Table 2. A complete soil description of each of these soils is given in Appendix I-A.

The parent rock of this catena is a very highly basic rock. In the area studied it is either a diabase or a hornblende-epidote schist or gneiss. The schist (or gneiss) is a dark greenish-black, fine to medium grained schist composed chiefly of common hornblende, (about 50%) and calcic epidote (15 to 20%). Other less abundant minerals are quartz and plagioclase (An 35-40%). Biotite, sphene, and apatite occur as accessory minerals. Optical data indicate that the epidote contains only 10 percent iron. The other cations are calcium and aluminum, The percentage of epidote in the rock appears to vary indirectly with the content of calcic plagioclase. Rocks containing large amounts of plagioclase are usually low in epidote. Complete petrographic descriptions of these rocks are given in Appendix I-A, samples 1, 2, 6, 12, and 29.

The diabase is more uniform in composition than the hornblende schist, but varies greatly in grain size from very fine to coarse-grained, depending on the width of the dike. It is composed of about 55% laboradorite (An 50-70) with about 20 to 30% interstitial augite. Olivine is less abundant (2 to 10%) and is usually partly altered to antigorite, bowlingtonite and magnetite. For a complete petrographic description of these rocks see Appendix I-A (samples 4 and 11).

Even though the two source rocks of this catena have very different origins, textures and mineralogical compositions, the bulk chemical compositions are similar. Common hornblende, the chief constituent of the schistose rocks, contains more calcium and aluminum than many of the other amphibole minerals. Epidote, the other major constituent in the schist, is also a calcium-aluminum rich silicate, and of course plagioclase (An 30-40) is a calcium-aluminum rich silicate, The most abundant minerals in the diabase are also rich in calcium and aluminum. As will be pointed out later, this chemical composition is probably one of the prime controls in the formation of montmorillonite from these rocks.

A characteristic feature of this catena is the small amount of weathered rock beneath the profile. In most cases the soil rests directly on fresh bedrock, which is rarely at a depth of over 6 feet. The depth to bedrock in the other catenas, which were formed from more silicic parent rocks, may be as great as 35 or 40 feet. The difference undoubtly results from the presence of the dense clay pan in the

Iredell type soils, which protects the parent rock from leaching solutions. The variations in depth of weathering can be seen in the pictures on pages 29 and 32.

The Bremo soil (sample 2) is an azonal soil which belongs to the Lithosols great soil group. It occurs on undulating to hilly terrane and has strong internal drainage. The degree of profile development and contrast between horizons is weak. In this study only one profile of Bremo soil derived from the parent rock of this catena was collected. The profile (sample 2) occurs on a hillside slope near samples 1 and 12 (Mecklenburg and Iredell soils). Other Bremo soil profiles are included in this study, but they have developed from parent material of the Lloyd catena. The physical appearance of both types of Bremo soil is similar but the clay minerals are not. The Bremo soil of this catena contains a dark brown, friable surface layer. The B horizon is not developed. The C horizon is yellowish-brown, silty clay and contains many fragments of partly weathered hornblende schist. The depth to bedrock is usually less than 2 feet.

The Mecklenburg soil (sample 1) is a zonal red-yellow podzolic soil intergrading to a Planosol soil on one side and Gray Brown soil on the other side. There is little difference between this soil and the Planosols members of the catena. The soil occurs on undulating to rolling terrane and has fair to poor internal drainage. The profile is mapped in a soil complex of Iredell-Mecklenburg soils. The surface layer contains grayish-brown, very friable, loam. The B horizon contains yellow brown clay with an angular blocky structure. The C horizon contains a mixture of

weathered greenish-black hornblende schist and yellow-brown clay. This profile is shown in the upper picture on page 29. The depth to bedrock is usually 4 to 6 feet.

The Zion soil (sample 6) is an intrazonal soil and a member of the Planosols great soil group. It also occurs on undulating to rolling terrain and has slow internal drainage. The degree of profile development is strong and like all Planosols the contrast between horizons is sharp. The profile occurs in close association with the Iredell soils. The Zion soils are similar to the Iredell soils except for a concretionary pan in the lower A and upper B horizons. They contain more clay than Mecklenburg soils. A picture of this profile is illustrated on page 29. The depth to bedrock is usually 3 to 7 feet.

The Iredell soil (samples 4, 11, 12, and 29) like the Zion belongs to the Planosols great soil group. The soil occurs on undulating to rolling terrain and has slow internal drainage. The Iredell differs from the Zion by the lack of a concretionary pan and from the Mecklenburg by the presence of a distinct clay pan. The A horizon contains light yellowish-brown, very plastic, sticky, massive clay (clay pan). The depth to bedrock is usually 4 to 8 feet.

Catenas Developed From Intermediate Rocks

Two new catenas are proposed in this section. Previously the soils of the two catenas were considered as one catena which had developed from mixed acidic and basic rocks. According to Epperson and Porter's 1960 Key for Southern Piedmont Soils, the catena contained

Plate 6a
Mecklenburg soil, sample 1, Nottoway County. The A, B, C, and D horizons are clearly visible in the photograph.

Plate 6b
Zion soil, sample 6, Prince Edward County.





the following soils; Bremo, Wilkes, Lloyd, Fluvanna, Enon, Vance, Helena, and Worsham. Not all of these soils could be sampled due to the difficulty of obtaining fresh rock samples. However, the ones that were sampled indicate that this group can be separated into two catenas and that several soils can be placed in other catenas. The Bremo and Lloyd soils are proposed as members of a new catena developed from garnet amphibolite gneiss. The Helena soil is proposed as the poorly drained member of a catena developed from hornblende-biotite gneiss and is placed in the Madison catena. The relationship of the Worsham soil to these has not been completely determined but it probably does not belong to any of the above catenas. The only profile of Worsham soil sampled developed from alluvial material. The Enon, Fluvanna and Vance soils are the remaining members of Epperson and Porter's Group (1960). The latter two were not sampled due to the lack of fresh parent material, and the Enon soil does not occur in the area studied. The Vance is a moderately light colored, moderately well drained soil which is commonly associated with Iredell and Helena soils. The Fluvanna is associated with the Helena and Lloyd soils. The significance, if any, of field associations is not known since the area is one of reoccurring rock types due to very complex folding.

Helena Catena

The Helena is the only soil that will be described in this catena. The other probable members are the Vance and Fluvanna soils. The Helena (sample 31) is similar to the Iredell and Zion soils of the

Iredell catena. Like these soils it is a rather poorly drained Planosols soil, and contains sticky, plastic clay in the subsoil. The amount of plastic clay is not nearly as high as in the Iredell soil. This lower content of sticky clay is probably directly related to the more acidic nature of the Helena parent rock.

The soil has a well developed but poorly drained profile. The A horizon consists of grayish-white, highly leached, friable sandy loam. The B horizon is thick and contains yellowish-brown, slightly sticky, firm plastic clay. Weathered brownish-green hornblende-biotite gneiss occurs at three feet. These features can be seen in the picture of this profile on page 32.

The parent rock is a hornblende-biotite schist composed of quartz, plagioclase (An33), biotite, and hornblende. Epidote and magnetite are present in accessory amounts. The rock appears to be intermediate in composition between the hornblende-epidote schist of Iredell catena and the biotite gneiss of the Madison catena. Optical data indicate that hornblende, plagioclase and epidote, like those of the Iredell parent rock, are calcium-aluminum rich. The rock differs from Iredell rocks since quartz and plagioclase are the major constituents and hornblende and epidote the varietal minerals. Biotite, which seldom occurred in Iredell source rocks, is an important varietal mineral in this parent material.



Plate 7. HELENA SOIL (sample 31)

Lloyd-Bremo Catena

The Lloyd soil belongs to the Red-Yellow Podzolic great soil group, but according to the Prince Edward County soil bulletin it grades toward Reddish-Brown Lateritic soils. In southwestern Prince Edward County the Lloyd and Bremo soils are developed from a rather uncommon rock type. The parent rock is a massive coarse-grained garnet amphibolite gneiss which contains hornblende (20 to 35%), cummingtonite (10 to 20%), quartz (20 to 30%), and plagioclase (15 to 30%)(An_{28}). Magnetite, epidote, and garnet are also present. Cummingtonite is a rare iron-magnesium amphibole. Optical data indicate that in these rocks it contains 40 modal percent ferrous iron. Cummingtonite is colorless and in these specimens usually occurs intergrown with dark green hornblende. Magnetite is closely associated with both amphiboles. Both the garnet and epidote are the iron rich members of their respective groups. The high iron content of this rock is reflected in the dark red color of the resulting soils. For a complete petrographic description of this rock see Appendix I-B, samples 14 and 28.

The Bremo soil (sample 14) forms from this rock in hilly terrain and near major streams. The soil is shallow and the degree of profile development and contrast between horizons is weak. The surface layer is dark reddish-brown, friable, clay loam. The subsoil is dark brown and contains many rock fragments. The depth to bedrock is less than three feet.

The Lloyd soil (samples 16 and 28) is a well drained Red-Yellow Podzolic soil. It develops on the garnet amphibolite gneiss in areas of undulating to rolling terrain. The Lloyd has one of the deepest soil profiles in the Piedmont. The degree of profile development is strong. The A horizon contains reddish-brown friable loam. The B horizon is very thick and contains dark red firm clay.

Catenas Developed From Silicic Rocks

The two remaining Piedmont catenas are discussed in this section. Detailed soil and petrographic descriptions are given in Appendix I-C. The parent rocks of the two catenas are gradational between one another. The end members are biotite gneiss of the Madison catena, and muscovite schist of the Cecil catena.

Madison-Louisa Catena

Epperson and Porter (1960) list the following soils as members of this catena: Louisa, Madison, Grover, Colfax, and Worsham. The members included in this study are the Louisa and Madison soils. Grover and Colfax soils did not occur in the area studied. The Worsham soils occurs but does not develop from residual rock. Data collected in this study indicate that the Wilkes soil belongs to this catena. Epperson and Porter include it in the Vance-Fluvanna-Lloyd-Helena catena, as the shallow, strongly drained member. The parent rock of the Wilkes soil lies nearly midway between the two end members listed above, but the clay minerals are more closely related to those of the Madison soils and it is therefore included in this catena.

The parent rock of the Madison catena is fine to medium-grained biotite gneiss composed chiefly of quartz 45 percent and 30 to 35 percent plagioclase (An 30). Biotite ranges from 10 to 18 percent. Muscovite and epidote are usually present but make up less than 2 percent of the rock. Garnet, zircon, calcite and magnetite are common accessory minerals. Espenshade and Potter (1960) in a paper on the geology of Baker Mountain kyanite deposit included a chemical analysis of this rock which is given in Appendix I-C of this report. The major oxides are: SiO_2 65%, Al_2O_3 15%, FeO and Fe_2O_3 6%, and CaO 4%.

Madison soils (samples 3, 7, and 10) are the deep well drained, Red-Yellow Podzolic members of this catena. They have light yellow-brown to yellowish-gray A horizons and yellowish-brown to red, highly micaceous subsoils. The red color and mica content increase toward the C horizon. Soils developed in nearly level upland areas contain deep profiles and highly mottled subsoils. Two Madison soils are shown in the pictures on page 36. The lower picture illustrates the great depth to which biotite gneiss weathers in level upland areas (60 ft.). The upper picture shows the structure and character of the parent rock and soil profile of sample 3. In general fresh rock in this catena occurs at a depth of 15 to 35 feet.

The Louisa soil (sample 13) is a member of the Lithosols great soil group. It has a shallow immature profile and occurs on steep slopes and near major streams. The profile contains a light yellowish-



Plate 8a
Madison soil, sample 3, Nottoway County



Plate 8b
Madison soil, sample 10, Prince Edward County

brown, slightly micaceous A horizon and yellow-brown, micaceous C horizon. The B horizon is not developed.

The Wilkes soil (sample 30) is also a Lithosols but unlike the Louisa soil it has a deeper and more mature profile. Its parent rock also differs from those of the Madison and Louisa soils, since it contains about equal amounts of biotite and muscovite. The profile contains a light yellowish-brown, slightly micaceous surface layer, and yellowish-red to slightly micaceous clayey B horizon. The depth to rock material is less than three feet but the depth to fresh rock is about 15 feet.

Louisburg-Cecil-Appling Catena

This catena develops from granite, pegmatite and muscovite schist. Epperson and Porter list the following soil members (from excessively to poorly drained soils) Louisburg, Cecil, Appling, Durham, Colfax and Worsham. In this study the Louisburg and Cecil soils were sampled.

The muscovite schist consists chiefly of quartz (40%) and muscovite (45%). Other minerals present are: albite, biotite, and microcline. The pegmatite parent material also consists chiefly of quartz, albite and muscovite. The muscovite flakes in the schist range from two to five mm. and are always coarser than the biotite flakes.

The Cecil soil (samples 9 and 26) is a deep, well drained, Red-Yellow Podzolic soil. The soil occurs on gentle to rolling slopes. The A horizon consists of brownish-yellow to yellowish-red, friable, sandy loam. The B horizon contains red to reddish-brown, firm clay.

The C horizon is usually red and slightly micaceous. The depth to fresh rock varies from 20 to 40 feet.

The Louisburg soil (samples 5, 8, and 15) is a member of the Lithosols great soil group. It occurs on undulating to hilly terrain and has strong internal drainage. The degree of profile development and contrast between horizons is weak. The A horizon contains grayish-brown to yellowish-brown, friable, sandy soil material. The B horizon is not developed. The C horizon contains yellowish-brown, coarse sandy soil material. The depth to rock material is less than three feet, but the depth to fresh rock is about 15 feet.

Soils Developed From Alluvium

Worsham Soil

The Worsham soil (sample 18) collected in this study does not belong to any catena since it is developed from weathered alluvial material. The Worsham is a poorly drained soil and like the Iredell contains a dense clay pan in the B horizon. The clay however, is not plastic or sticky like that in the Iredell soils. The A horizon contains friable sandy loam and is light yellowish-gray in color. The B horizon consists of very firm, compact mottled gray clay (clay pan). The B horizon rests on residual saprolitic rock material. The rock was too highly weathered to accurately determine its composition but it appears to be a coarse-grained, light green micaceous gneiss. The clay fraction of the residual rock is the most montmorillonitic material studied in this investigation. The clay minerals are discussed in detail in a later section.

BLUE RIDGE CATENAS

The Blue Ridge soils were sampled and analyzed in the same manner as the Piedmont soils. Only one soil profile for each rock type was collected, since there was not sufficient time to extend the investigation to cover a complete soil catena. Soil descriptions, based on field descriptions by H. C. Porter, and petrographic descriptions of the parent rock are given in Appendix II. The descriptions are arranged in catenas in order of decreasing basicity of the parent rock.

Catenas Developed From Mafic Rocks

The catena developed on basic rocks in the southern Blue Ridge has, according to Epperson and Porter (1960), Key to Northern Piedmont Soils*, the following members; (from strongly to poorly drained soils) Catoctin, Davidson, Rabun, Fauquier, Clifton, Myersville, Rohersville, and Elbert. Not all of these soils were sampled in this study, but the three that were sampled, Catoctin, Rabun, and Elbert, developed from different rock types. The rocks can be divided into two general groups on the basis of chemical compositions: a calcium rich meta-gabbro and three ferromagnesium-rich rocks, a greenstone schist, a hornblende-biotite gneiss, and a soapstone. All rocks of the latter group weather to dark red well drained Catoctin and Rabun

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* Soils developed in the northern Piedmont are given the same names as those in the southern Blue Ridge. - H. C. Porter (Personal Communication)

TABLE 3

Blue Ridge Soil Catenas

Parent Material	Drainage Sequence					
	Excessive	Well Drained	Well to Mod. Well	Mod. Well	Somewhat Poorly Drained	Poorly Drained
MAFIC ROCKS						
Meta-Gabbro	Bremo?					Elbert 5-7
Hornblende-biotite gneiss Talc-chloritic soapstone Greenstone (hornblende schist)	Catoctin 2-3		Clifton? Myersville?	Rabun 4-12		
INTERMEDIATE						
Epidote-biotite gneiss	Brandywine?		Eubanks 8-10 Montalto? Chester?			
SILICIC ROCKS						
Muscovite-biotite schist	Talladega 20-35					
Granite	Louisburg 2-4		Cecil	Appling		

This table illustrates the relationship between parent material, drainage and depth of weathering for the various Blue Ridge soil catenas. Only the underlined soil members in each catena were studied. The other members were taken from a similar table constructed by Epperson and Porter (1960). The question marks indicate that the parent rock was not seen in the field. The numbers after each underlined member indicate the estimated depth in feet to fresh rock.

soils and are, therefore, included in the same catena. The meta-gabbro weathers to a yellow-gray very poorly drained Elbert soil which is included in a separate catena. The soils of the two catenas are closely related and grade into one another by a change in composition. Such a change occurs between the Elbert soil (sample 22) and the Rabun soil (sample 21). The soils were formed on a zoned meta-gabbro body south of Galax (see Plate IV). The Elbert soil formed near the core of the body on the tremolite-talc-chlorite zone. The Rabun soil formed on an outer talc-chlorite zone. The Elbert is a very poorly drained, gray soil and the Rabun a well drained, red to dark red oxidized soil. The two adjacent soils are a striking example of the effect of parent rock composition on soil morphology.

Elbert Catena

The Elbert soil is a very poorly drained Low Humic Gley soil with a very distinct clay pan. This soil contains more plastic clay and has poorer internal drainage than the Iredell and Zion Planosols of the Piedmont. The soil occurs over a meta-gabbro on a nearly level plain south of Galax. The rock is composed of equal amounts of tremolite (40%) and chlorite-talc (40%). Other minerals are olivine (5), serpentine (5%), and magnetite (10%). Chlorite and talc occur as radial, bent fibrous aggregates which are cut by very long (30 to 40 mm) euhedral tremolite crystals. The profile has an organic-rich, grayish-black to black, friable surface layer. The B horizon (clay pan) is thick and contains light gray to olive brown, very firm, and very

plastic clay, Fresh bedrock was not reached but probably occurs at a depth of 6 to 8 feet.

Rabun-Catoctin Catena

The Rabun-Catoctin catena develops from ferromagnesium-rich rocks. Two Rabun soils and one Catoctin soil developed from these three rock types. The parent rocks for the Rabun soils have the following compositions. The Rabun soil (sample 21) formed from a talc-chloritic soapstone composed of 90 percent chlorite and talc and 10 percent tremolite. The talc and chlorite occur as radial bent fibrous aggregates and are cut by long bladed euhedral tremolite crystals. The tremolite crystals are generally altered to reddish-brown clay material. The Rabun soil (sample 24) formed on a coarse-grained, wellfoliated, hornblende-biotite gneiss. The main constituent is sericitized plagioclase (An ?). Hornblende, biotite, and quartz occur as varietal minerals and apatite, chlorite, and magnetite as accessory minerals.

Rabun soils are well drained and occur on undulating to steeply sloping terrain. In general the surface horizon is dark reddish-brown to brown, friable, silt loam. The B horizon contains dark red, slightly sticky, slightly plastic clay. The effect of different parent rocks is shown in the two profiles by an increase in depth to fresh rock from 3 feet in the soapstone profile to 12 feet in gneissic profile and by the very micaceous character of the soapstone profile.

The Catoctin soil (sample 20) is the strongly drained member of this catena and was formed from greenstone schist. The schist is composed of dark green, very fine-grained needles of hornblende (65%), quartz, epidote, and plagioclase, probably of andesine composition. Magnetite and biotite are present in very minor amounts. In plain light the epidote is yellow indicating that it is rich in iron. This rock commonly referred to as Virginia greenstone occurs in both the Blue Ridge and Piedmont. It is similar in appearance to the hornblende-epidote schist of the Iredell catena, but its bulk chemical composition is different. The greenstone contains more iron and silica and less alumina. This is because neither epidote or plagioclase are very abundant. Furthermore, the epidote is not the Ca-Al variety. This point is discussed in greater detail in the section on montmorillonite formation.

The Catoctin soil occupies the same position in this catena as the Bremo, Louisa, and Louisburg soils do in their Piedmont catenas. It is a shallow soil and occurs on undulating to hilly terrain. The profile contains a dark brown, silty loam, surface horizon, and a very weakly developed brown, friable B horizon. The C horizon is brown to reddish-brown and contains about 50 percent weathered rock fragments. The depth to fresh rock is about 2 1/2 feet.

Catenas Developed From Intermediate Rocks

Eubanks Catena

Epperson and Porter list the following members as forming from sheared and unsheared granodiorites: (from strongly to poorly drained soils) Brandywine, Montalto, Eubanks, Chester, Belvoir, and Worsham. The only member sampled in this catena was the Eubanks (sample 23). This soil develops from a pink and green, coarse-grained, augen gneiss composed chiefly of quartz and large pink microcline phenocrysts enclosed by dark green epidote veins. The microcline phenocrysts make up about 40 percent of the rock, quartz about 30 percent, epidote 15 percent, and albite 10 percent. Biotite and magnetite are also present. Granodiorites are acidic rocks, but the presence of epidote veins in this rock gives it a more basic composition which is clearly reflected in the dark brown color of the profile and in the clay mineralogy of the soil. None of the rocks studied in the Piedmont had this composition or texture. The composition of this rock lies between the Lloyd-Bremo and Madison-Louisa Piedmont catenas.

The Eubanks is a deep, well drained, zonal soil. The surface layer is brown, very friable loam. The B horizon contains red, slightly firm, clay loam. The C horizon is yellow red and contains partly weathered potassium feldspar crystals and green epidote veins.

Catenas Developed From Silicic Rocks

Soils from two catenas which developed from silicic parent rocks were studied in this investigation. The source rocks are micaceous quartz schist and sericitized biotite granite.

Chandler-Talladega-Halewood Catena

Soils of this catena are formed from muscovite-biotite schist. The soil members are: (from strongly to poorly drained) Chandler, Fannin, Halewood, Talladega, and Glenville (H. C. Porter, personal communication). The Talladega soil (sample 19) is the only member sampled from this catena. It is developed from a mica schist which Stose and Stose (1957) mapped as the Lynchburg formation. The rock is composed of quartz (59%), muscovite (18%), biotite (13%), microcline (8%), and albite (2%).

The soil is a shallow well-drained zonal soil and occurs on rolling topography. The A horizon is brown, highly micaceous, silt loam. The B horizon is yellow red to strong brown, highly micaceous, silt loam. The C horizon contains reddish-brown friable rock material. The depth to rock material is about 5 feet, but the depth to fresh rock is about 35 feet.

Louisburg-Cecil-Appling Catena

The Louisburg soil (sample 25) was sampled in one locality, and is the only member sampled from the mountain Cecil catena. The parent material is sericitized granite. The formation of sericite strongly effected the clay mineralogy of the soil, but the physical appearance

of the soil is still typical of the Louisburg series. The granite is a light gray medium-grained rock composed of quartz (50%), microcline (25%), some of which is coarsely perthitic, plagioclase (An 28) (12%), and sericite (8%). Most of the plagioclase is fresh but some grains are altered to coarse-grained sericite (1/32 mm), which occurs in aggregate masses. Sericite also occurs in cross cutting veins which have altered the biotite flakes to irregular masses of light yellow, weakly pleochroic material. Stose and Stose mapped this rock as the Carsonville Granite.

CHAPTER IV

EXPERIMENTAL METHODS

Laboratory Procedures

Soils

The soil samples were air dried and then broken into aggregates small enough to pass through the sample spitter. A slurry of the approximate 50 gram splits was made in distilled water. Dispersal of the suspension was accomplished by gentle mechanical stirring for at least ten minutes with a Fisher laboratory mixer at moderate speed, so that the soil material suffered very little mechanical abrasion. If flocculation occurred, a few drops of calgon solution were added to the slurry. A suspension containing particles less than two microns was siphoned off at 10 cm after the slurry had settled for 8 hours and 10 minutes. Two ml of this slurry were allowed to dry on a glass slide to form an oriented aggregate specimen for x-ray analysis. Two slides were made for each sample. One was saturated with ethylene glycol and the other slide was subjected to heat treatments at: 200°C, 300°C, and 525°C for an hour each. A few samples were heated at 600°C for an hour and other samples were heated at 300°C and 500°C for 24 hours. The glycolated slides were prepared, according to the procedure described by Brunton (1955), by heating them at 75°C in an ethylene glycol atmosphere for one hour. Afterwards they were kept warm and allowed to remain in the atmosphere for 24 hours.

X-ray diffraction patterns of the samples were obtained with a General Electric XRD-5 diffractometer. Ni-filter Cu K radiation and a 1 degree beam silt were used. The X-ray reflections were recorded on a linear scale.

Parent Rock

The thin sections of parent rock were prepared by use of standard methods. In a few cases the parent material had to be impregnated with lakeside 70 before thin sections could be cut. The mineralogical composition of the parent rock was determined chiefly by use of a polarizing microscope. The volume percent of each mineralogical constituent was determined in each section by systematically point counting along a fixed traverse. At least three traverses were made, two at right angles and one diagonally across the slide at 45° to the other two. A minimum of 750 counts were taken per slide.

Special Treatments

The following treatments were given to a small number of samples. The samples were chosen to represent the various types of clay minerals studied.

Cation Saturation

The samples were saturated with Mg or K by washing five times with either N Mg Cl_2 solution or N KCL solution. Saturation was accomplished by shaking the salt solution and sample, and then centrifuging the resulting suspension. Excess salt was removed by one

wash of water followed by 100% acetone washes until the supernatant liquid no longer flocculated.

Removal of Interlayer Hydroxides

The following treatment was suggested by Dr. C. I. Rich (personal communication) to remove fixed interlayer aluminum hydroxide. A tenth of a gram of < 2u clay was shaken in 20 cc of N NH_4Cl_1, 0.2N NH_4F, and 0.1N H Cl for 15 minutes. The samples were then washed and K saturated following the procedure described above.

The following treatment was used to remove interlayer iron hydroxide from montmorillonitic clays. A tenth of a gram of < 2u clay material was shaken for various lengths of time up to 4 hours in N acetic acid. The samples were then washed and Mg saturated following the procedure described above under cation saturation.

Mechanical Agitation

To determine the effect of mechanical agitation on soil clay minerals a number of samples were subjected to various degrees of shaking and mixing. (1) Samples were shaken by hand in a cylinder for a short length of time. A < 4u or < 2u fraction was separated from this suspension and oriented slides made for x-ray analysis. (2) The same amount of sample was shaken in a mechanical shaker for 15 minutes and oriented slides were made from the resulting suspension. (3) The same amount of material was mixed in a Waring blendor at half speed for 12 to 15 minutes and oriented slides were made from the resulting sus-

pension. All samples were mixed in a Fisher laboratory mixer for 12 to 15 minutes, the amount of agitation caused by this method lies approximately between procedures (2) and (3) described above.

Identification of Clay Mineral Species

Clay mineral identifications were based upon x-ray diffraction patterns of < 2u oriented aggregates and their response to glycolation and various heat treatments. The criteria for clay mineral identification are listed below.

Kaolinite

Kaolinite is present in all horizons of all profiles. It is one of the first clay minerals to form and is one of the most stable in A horizon. Kaolinite is identified by diffraction peaks at 7.2 A and 3.58 A in untreated specimens. These peaks are unaffected by glycolation and heat treatment up to 400° C. Above 400° C. the kaolin peaks lose intensity, and above 500° C. kaolinite is thermally unstable and the 7.2 A and 3.58 A peaks disappear. Kaolinite response to heat treatment may be seen by examination of the 7.2 A peaks in Figure 2.

Atypical Vermiculite

The second most abundant clay mineral is vermiculite. It is present in all soil profiles but not in all horizons. Vermiculite and kaolinite are the only clay minerals found in the A horizon. It is characterized by an x-ray diffraction peak at about 14.5 A. The peak is unaffected by ethylene glycol treatment but gradually decreases its d spacing under thermal treatment. The rate of collapse depends on the position of the sample in the soil profile and somewhat on its ion saturation. However, in general the average rate of decrease is as follows:

Oriented aggregate, untreated - 14.5 A

Oriented aggregate, 200°C. - 14.1 A

Oriented aggregate, 300°C. - 13.5 A

Oriented aggregate, 525°C. - 11.3 A

The peak value at 525°C. is taken as the average value since the peak is broad and diffuse. Usually temperatures greater than 600°C. are necessary to cause complete collapse to 10 A. This response to heat treatments is shown in Figures 9 and 11 and in the treated specimens of the garnet amphibolite in Figure 2. All vermiculite studied exhibited gradual collapse on heat treatment. Since normal vermiculite collapses fully to 10 A at 200°C. this clay mineral will be referred to as atypical vermiculite.

The atypical vermiculite is similar to the vermiculite described by Rich and Obenshain (1955) from Nason and Tatum soils, developed on Wissahickon schist in the Piedmont. They identified the mineral as dioctahedral vermiculite which was prevented from collapse to 10 A on K saturation by fixation of basic aluminum ions in the interlayer position. They also found that the exact temperature necessary to cause collapse varied with the saturating ions. Mg saturated specimens in this study were found to be slightly more stable (See figure 11). The relationship between thermal stability and depth in the profile is shown in Figure 3.

Atypical Montmorillonite

Montmorillonite is the characteristic clay mineral found in subsoil horizons developed from highly basic rock. Montmorillonite is characterized by (1) a first order peak at 14.5 A which shifts to about 17 A or higher when the specimen is glycolated. (2) lack of suborder reflections, (3) collapse to about 10 A after heating to 525° C.

The response of montmorillonite to heat treatments is not the same as standard Wyoming bentonite montmorillonite which collapses to 10 A at 120°C. Soil montmorillonite is thermally more stable. Its stability is a function of depth in the profile, ion saturation and parent material. Response of soil montmorillonite to treatment at 200° C is the same for all samples regardless of parent rock or ion saturation. The intensity of the first order reflection is decreased, but no shift towards lower d spacing occurs. Response to treatment at 300° C varies depending on the type of ion saturation and composition of the parent rock. The usual response of unsaturated specimens at 300° C is a further loss of intensity of the 14 A peak but no shift in d spacing. However in a few specimens the peak completely disappeared after 300° heat and in a few other specimens the peak collapsed to 10 A. Magnesium saturation increased the thermal stability and relative intensity of all 14 A peaks. Heating at 525° C collapsed both unsaturated and saturated clays to 10 A. Furthermore the peak which disappeared in some specimens at 300° C reappeared at 10 A after 525° C heat. The effects of K saturation are similar for all

samples. The 14 A peak is completely destroyed, but no 10 A peak is formed.

Illite

Illite is uncommon in all soils sampled, and where present, it occurs only as a low diffuse peak at about 10 A. Illite usually occurs in the lower C horizon but in some profiles it appears in the A horizon, probably due to collapse of some vermiculite by K saturation from organic matter. Illite is identified by a 10 A peak which persists after heat treatment at 525° C. When heated at 600° C, the peak intensity is enhanced. Illite peaks are shown in Figure 4, C_2 horizon, and Figure 10 samples 23 and 24.

Chlorite

Chlorite clay minerals are found in profiles developed only from chloritic rich parent rocks. In these profiles it occurs in all horizons. Chlorite is characterized by: (1) first order basal reflections at approximately 14.5 A and strong suborder reflections at approxmately 7.2 A (sec. order), 4.7 A (third order) and 3.5 A (fourth order). (2) by its lack of response to heat treatment up to and including 500° C. (3) enhancement of the 14 A peak at 600° C. This response to heat treatment is shown in Figure 8.

Random Mixed Layer Clay Minerals

Random mixed-layer clay minerals occur as peaks, broad humps or continuous bands extending between first order clay mineral

reflections. Such features occur in these soil clays only between the 7 A and 14 A peaks. Random mixed-layer clay minerals form when the basic units of two clay minerals are combined in irregular repetition. The position and intensity of the resulting peak depends on the abundance of each unit. Equal abundance of the units creates a new reflection half way between the two end members. The peak intensity of this new mineral is the lowest at equal abundance of the units and increases with a decrease of either member. Random mixed-layer minerals are identified by the occurrence of a nonintegral series of basal reflections.

Three types of random mixed-layer clay material were observed in this study. These are: (1) Randomly interstratified kaolin and illite layers; characterized by an uneven or sloping band of material between the 7 A kaolin peak and the 10 A illite peak. This material is usually found in soils developed from muscovite-bearing schist. Such material is shown in the C horizons of Figures 3 and 4 and in Figure 11. (2) Randomly interstratified illite and vermiculite clay material; characterized by an uneven sloping band between the first order 10 A illite peak and the first order 14 A vermiculite peak. Such material is usually found in the upper horizon of soils developed from biotite gneiss. Figure 2, sample 16, A_3 horizon illustrates material as do the A_p horizons in Figures 6 and 11. (3) Sharp reflections between 11.5 A and 12.4 A produced by mixed 10 A illite and 14 A vermiculite units. This mineral is formed in soils developed

from biotite gneiss. Its d spacing increases toward the A horizon. Such a mineral is shown in Figures 3 and 4.

CHAPTER VI

RESULTS

Clay Mineralogy of Piedmont Soils

The following section deals with the clay mineralogy of the soils. The soils are again discussed by catenas which are listed in order of increasing acidity of the parent rock. The clay mineralogy is discussed on the basis of genetic soil horizons A, B, and C. The A horizon is often referred to as the surface layer and includes the A_p, A_2 and A_3 horizons. The C horizon or parent soil material includes the C_1, C_2, C_3 and C_4 horizons. In each genetic horizon the kinds of clay minerals, their characteristics, and their response to treatments are discussed. The relative intensities of the first order reflections of all clay minerals are given in tabular form in Appendix I and II.

Clay Mineralogy of Soils Developed From Mafic Rocks

Iredell-Mecklenburg-Bremo Catena

The soils of this catena have formed from weathered products of Triassic diabase and hornblende-epidote schist. The subsoils contain heavy yellow-brown clay, which is extremely hard when dry and extremely plastic and sticky when wet. The clay is characterized by a large amount of kaolin and montmorillonite.

The clay mineralogy of the three deep, poorly drained soils of this catena-Zion, Iredell and Mecklenburg- is nearly the same and

will be discussed together in the next section. Greater differences occur between soils developed from diabase or hornblende schist, than between the three soil types. However, the differences are small and will be discussed with the clay mineral characteristics.

The clay mineralogy of the shallow, strongly drained Bremo soil does differ from the other members of the catena. The Bremo soil contains nearly all vermiculite, even in the subsoil. Montmorillonite replaces vermiculite in the C_4 horizon. The C_4 horizon is the lowest horizon in the profile and consists of slightly hard, friable weathered rock material. Other differences between the Bremo and the deeper members of this catena are given in the following discussion.

The surface layers of the profiles are composed of kaolin, vermiculite, and quartz. Occasionally a small amount of montmorillonite is present. (Fig. 1, A_3 horizon). Interstratified mixed-layer clay material characteristically occurs as a low band between 7A and 14 A peaks. The first order vermiculite reflections are more intense than the kaolin reflections. Kaolin peaks range in intensity from 150 to 400 counts. The vermiculite peaks range between 200 and 450 counts. The vermiculite peak is sharper and not as broad as the kaolin peak. Quartz is a common constituent of all surface layers. The quartz reflection occurs at 3.33 A with an average intensity of 90 counts.

Response of kaolinite to the various treatments is that of normal kaolinite. The response of vermiculite is characteristic of atypical vermiculite: collapse to 14.03 A at 200° C, 13.60 A at 300° C. and

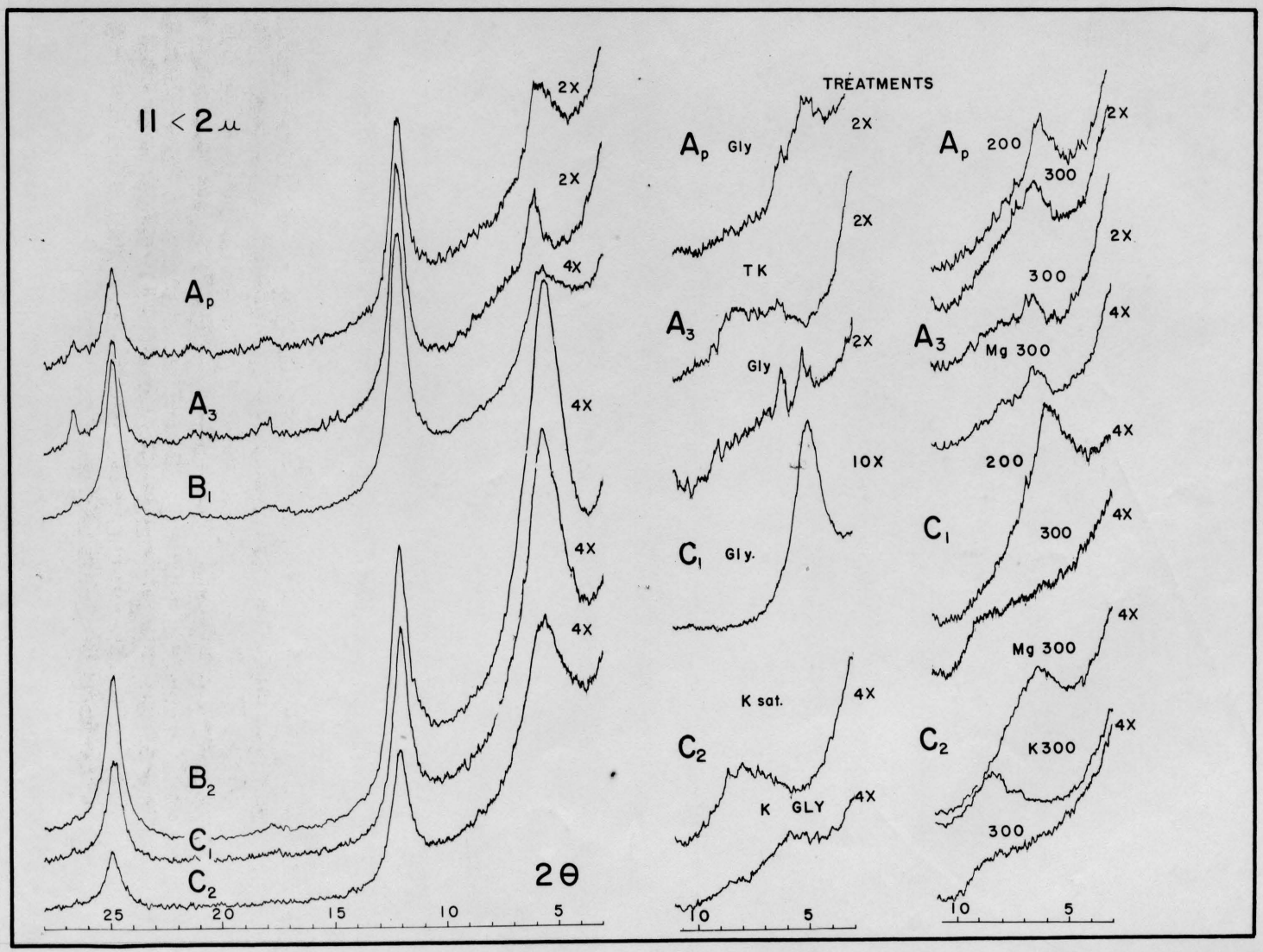
11.0 A at 525° C. The vermiculite in the surface layer of the Bremo soil showed a similar gradual collapse.

Ion saturation had little effect on the 14 A vermiculite peak. Potassium saturation fails to cause collapse to 10 A. It merely reduces the peak intensity and produces more interstratified I/V material. Leaching with NH_4F solutions and K saturation fails to completely collapse the mineral to 10 A (See Fig. 1, A_3 horizon). Magnesium saturation increased the peak intensity and made the 14 A peak slightly more stable to heat treatments.

The B horizon contains mainly kaolinite and montmorillonite. Kaolinite is usually more abundant than montmorillonite. The first order kaolin peak ranges in intensity from 425 to 1000 counts. Montmorillonite peaks range from 250 to 1700 counts. The most intense montmorillonite peaks occur in an Iredell soil (sample 11) developed in a level upland area from Triassic diabase. This profile is illustrated in Figure 1.

X-ray diffraction patterns of these subsoil samples are typically "clean" patterns: no interstratified material and low background intensity. The kaolin and montmorillonite peaks are broad and often skewed to the low angle side. This suggests that the kaolin is halloysitic and that montmorillonite contains extra layers of water (Fig. 3, hornblende schist). Halloysite was reported as the characteristic kaolin mineral of Iredell soils in North Carolina soils by Cady (1953). The response of montmorillonite to treatments is the

Figure 1 - This figure illustrates x-ray patterns of an Iredell profile. The horizons are designated by the letters A, B, etc. The counting rate is indicated by 2x, 4x etc., where x is 500 counts per second. The various treatments are indicated by the following letters: Gly-glycol saturated; K, potassium saturated; Mg- magnesium saturated; TK- washed with NH_4F solutions and potassium saturated; 200, 300, etc. heating treatments in Centigrade.


II < 2μ
2X
2X
4X
A_p
A_3
B_1
4X
4X
4X
B_2
C_1
C_2
2θ
25
20
15
10
5
TREATMENTS
A_p Gly
2X
2X
TK
A_3
2X
Gly
10X
C_1 Gly.
K sat.
4X
C_2
K GLY
4X
10
5
A_p 200
2X
300
2X
300
A_3
4X
Mg 300
4X
200
C_1
300
4X
Mg 300
4X
C_2
K300
4X
300
10
5

the same as that of atypical montmorillonite described in the previous chapter.

Clay minerals in the C horizon are the same as those in the B horizon. However, the relative amounts of each mineral and their response to treatments are different. The C horizon contains nearly equal amounts of kaolin and montmorillonite. Kaolinite peaks range in intensity from 250 to 600 counts. Montmorillonite peaks vary from 275 to 600 counts. X-ray diffraction patterns of the saprolitic material (C_4 horizon) contain low intensity kaolin and montmorillonite peaks which project above a background of interstratified kaolin-illite and illite- 14 A material.

The response of atypical montmorillonite to heat treatments at 200° C. is the same as it was in the B horizons, simply a loss of peak intensity but no shift in d spacing. Its behavior at 300° C. depends on the kind of ion saturation and the composition of the parent rock. The montmorillonite peak in soils developed from hornblende schist remains at 14.5 A or completely disappears after 300° C. heat. Montmorillonite in soils developed from diabase usually collapses to 10 A after 300° C. heat. Magnesium saturation affects the thermal stability of montmorillonite from both rock types. Peaks which disappeared in unsaturated specimens remain at 14.5 A after Mg saturation. Peaks which collapsed to 10 A at 300° C. remain at 14.5 A after Mg saturation. (See Figure 1). Unsaturated, Mg saturated, and K saturated specimens all collapse to a diffuse peak around 10 A after 525° C.

heat. Potassium saturation is more effective than it was in the B horizon. Collapse to nearly 10 A occurs on K saturation. Glycolation of K saturated specimens returns the peak to 14 A but does not expand it to 17 A (Fig. 1, C_2). Treatment of specimens with $\underline{N}$ NHF_4 solution is also more effective in this horizon. A rather intense peak occurs at about 10 A after washing with this solution and K saturation.

The saprolitic materials of the soils of this catena has an interesting clay mineralogy. Mixing of this friable rock material in a blendor aids in studying the clay minerals. The changes produced in x-ray patterns by various degrees of mixing during sample preparation are shown in Figure 5, sample 1. Blending results in the formation of clay material which gives clean x-ray patterns with intense first order kaolin and montmorillonite peaks. A hornblende peak at 8.5 A occurs in some specimens. Hornblende schist saprolite usually contains much more montmorillonite than kaolinite. This probably is a reflection of the low feldspar content of these schists. Diabase saprolite contains nearly equal amounts of kaolinite and montmorillonite.

The response to heat treatments of montmorillonite derived from diabase and hornblende saprolite is nearly the same. Montmorillonite is less resistant to heat treatment than it was higher in the profile, but still it does not collapse as rapidly as Wyoming bentonite. Heating at 200° C. produces an asymmetrical band beginning at 14 A

and trailing off to 10 A. Treatment at 300° C. produces an asymmetrical hump centered around 11 A. Heating at 400° C. for 24 hours produces a sharp peak at 10.16 A.

An attempt was made to produce greater collapse in these specimens by leaching them with N acetic acid before heat treatments. Unfortunately the leached samples were saturated with Mg which probably increased the thermal stability so that the results were about the same as the unsaturated samples. A few of the samples were also treated with NH_4F solution and then K saturated. The treatment destroyed the 14 A peak but did not quite produce a peak at 10 A.

Summary

The changes in clay mineralogy which occur with increase in depth in the profiles of this catena are as follows. Kaolinite increases in intensity to the bottom of the B horizon where it reaches a maximum, and then sharply decreases in the underlying C_1 horizon. The peak again slowly increases with increasing depth and reaches a secondary maximum in the lower C horizon (C_3). Vermiculite is the most abundant clay mineral in the A horizon, but decreases rapidly below the surface horizon. In the upper B horizon it is replaced by montmorillonite. The montmorillonite peak intensity increases downward to the lower B or upper C horizon and there may exceed kaolinite in intensity. The saprolitic material (C_4 horizon), when mixed in the Waring blendor, may have kaolin and montmorillonite peaks more intense than in those in the B horizon. Quartz and interstratified

clay material are abundant in the surface layer but are absent in the subsoil.

In short the clay mineralogy of these profiles suggests that clay minerals form early, directly from the primary silicates and that montmorillonite weathers to vermiculite. The kaolinite maximum in the lower B horizon suggests translocation of kaolin material. The lack of weathering in the subsoil is probably due to the self sealing nature of the montmorillonitic clay which maintains a neutral or basic environment.

Clay Mineralogy of Soils Developed From Intermediate Rocks

Helena Catena

The Helena soil is developed from weathered products of hornblende-biotite schist. The material is intermediate in composition between the biotite gneiss of the Madison catena and the hornblende schist of the Iredell catena. Like the Iredell catena, the subsoil is characterized by heavy, yellow brown, plastic, sticky clay containing kaolin and montmorillonite. However, the montmorillonite content is much lower. Its maximum intensity is only 175 counts. The peak intensities for the first order clay mineral reflections are given in tabular form in Appendix I-B.

The surface layer contains about equal amounts of kaolin and vermiculite. Interstratified clay material between the two peaks is well developed (100 counts). Vermiculite response to treatment is

that of atypical vermiculite. Heating at 200° C. reduces the 14 A peak to the background level of K/V material but leaves a high shoulder at 14.5 A. Treatment at 300° C. collapses the peak to 13.4 but treatment at 525° C. fails to completely collapse the clay to 10 A. Potassium saturation reduces the vermiculite peak intensity by one half. its former height. The loss in intensity is accompanied by an increase in intensity of interstratified K/V material. Treatment with NH_4F solutions and then K saturation completely destroys the peak but does not form a 10 A peak.

The B horizon is highly kaolinitic (800 to 1200 counts) and contains both vermiculite and montmorillonite. The vermiculite peak (575 counts) is nearly four times more intense than it was in the A horizon. Heating at 200° C. shifts the 14.5 A peak to 13.60 A, and 300° C. heat shifts the peak to 13.19 A. Magnesium saturation increases the peak intensity and thermal stability, for the peak remains at 13.60 A after 300° C. Both Mg saturated and unsaturated specimens collapse to 11.0 A at 525° C. heat.

Montmorillonite (125 to 175 counts) replaces vermiculite in the lower part of the profile. Heating at 200° C. causes the peak to completely disappear. Treatment at 300° C. restores the peak fully collapsed at 10 A. Blending of the C_4 material produces material which gives a clean x-ray pattern. Before blendor treatment only a low kaolin peak and interstratified 10 A and 14 A material were present. (See Fig. 5 sample 31). After mixing intense first order kaolin

and montmorillonite peaks appear. The montmorillonite peak is more intense than it was in the upper soil horizons.

Summary

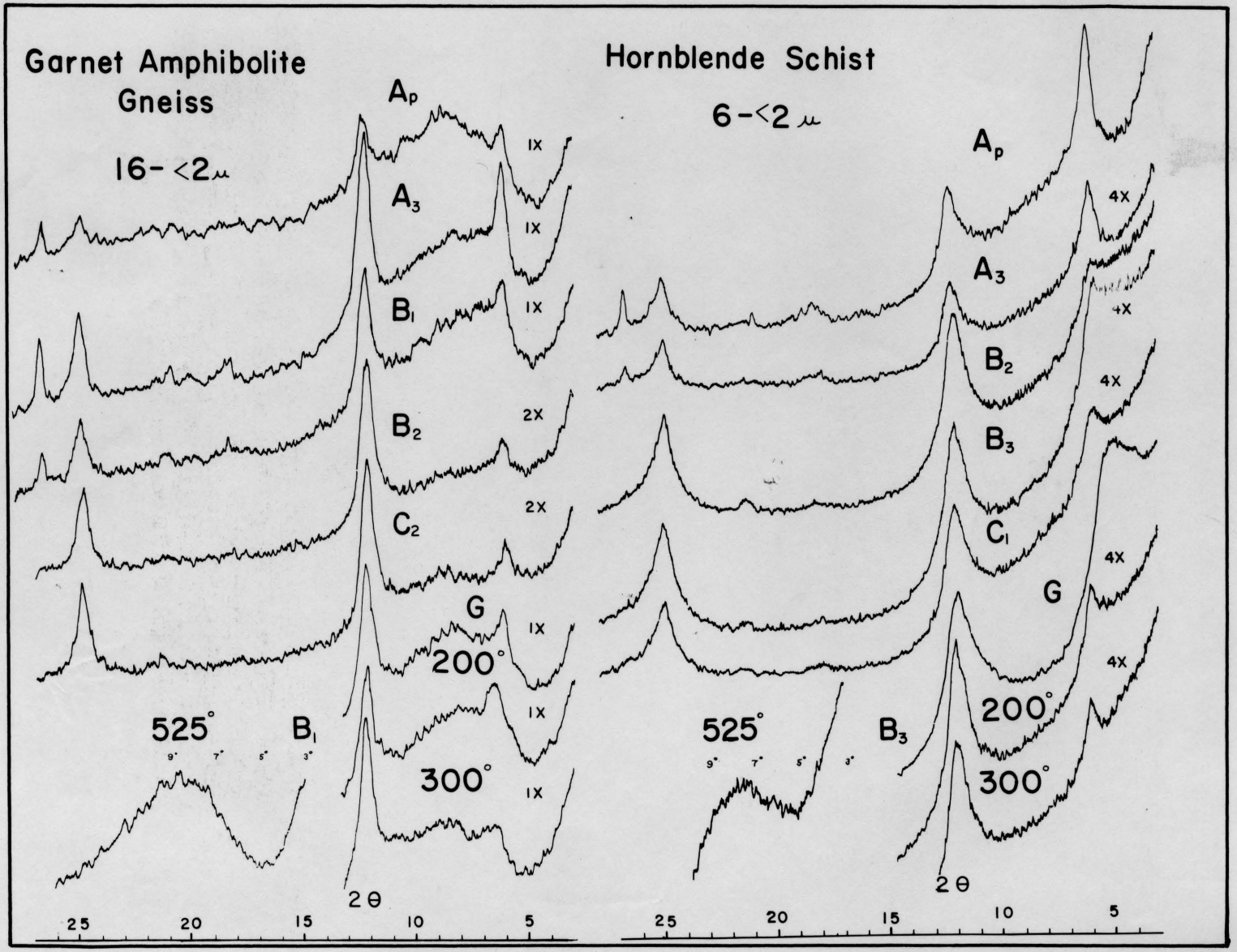
Increased peak intensities in the B horizon are probably a reflection of eluviation of the A horizon. The decrease in interstratified clay material in the B horizon is probably a reflection of decreased weathering in the subsoil. Transformation of montmorillonite to vermiculite in the upper B horizon is common and probably caused by the lower pH and higher rate of leaching. Magnesium saturation, as it did in the Iredell soils, increased the thermal stability of montmorillonite. Blendor treatment of the C_4 material produced first order reflections more intense than those of the overlying B horizon.

Lloyd-Bremo Catena

Lloyd and Bremo soils of this catena are developed from weathered massive, coarse-grained garnet amphibolite gneiss. The soils contain reddish-brown surface layers and dark red firm subsoils. They are characterized by kaolin and vermiculite clay minerals. Interstratified clay material between the 7 A and 14 A peaks occurs in every horizon. The kaolinite peak in the A horizon has an average intensity of 200 counts. The vermiculite peak has an intensity of 100 counts. Response of the 14 A reflection to heat and K treatments is that of atypical vermiculite.

Kaolin and vermiculite peaks are more intense in the subsoil than they were in the A horizon, but no definite trend towards increase or

Figure 2 - This figure illustrates x-ray patterns of soils from two different catenas. The patterns on the left are from kaolin-vermiculitic Lloyd soil. The ones on the right are from a kaolin-montmorillonitic Zion soil. The response of these soils to heat and chemical treatments are shown by the short patterns at the bottom of each profile.


Garnet Amphibolite Gneiss
16-<2μ
Ap
A3
B1
B2
C2
G
1X
1X
1X
2X
2X
1X
200°
1X
300°
1X
525°
B1
9°
7°
5°
3°
2θ
25
20
15
10
5
Hornblende Schist
6-<2μ
Ap
A3
B2
B3
C1
G
4X
4X
4X
4X
4X
200°
300°
525°
B3
9°
7°
5°
3°
2θ
25
20
15
10
5

decrease in intensity could be found in any of the profiles. Occasionally a low illite peak occurs in the lower horizons. Vermiculite is slightly less stable to heat treatment in the C horizons. Heating at 300° C. collapse the lattice, but no 10 A peak was formed.

Blendor treatment has little effect on the saprolitic material, except to increase the intensity of the first order reflections. The kaolin and vermiculite peaks in the weathered rock have nearly equal intensities. Mixed-layer material is abundant and extends from the kaolin to vermiculite peaks. The x-ray patterns of a Lloyd soil are illustrated in Figure 2.

Summary

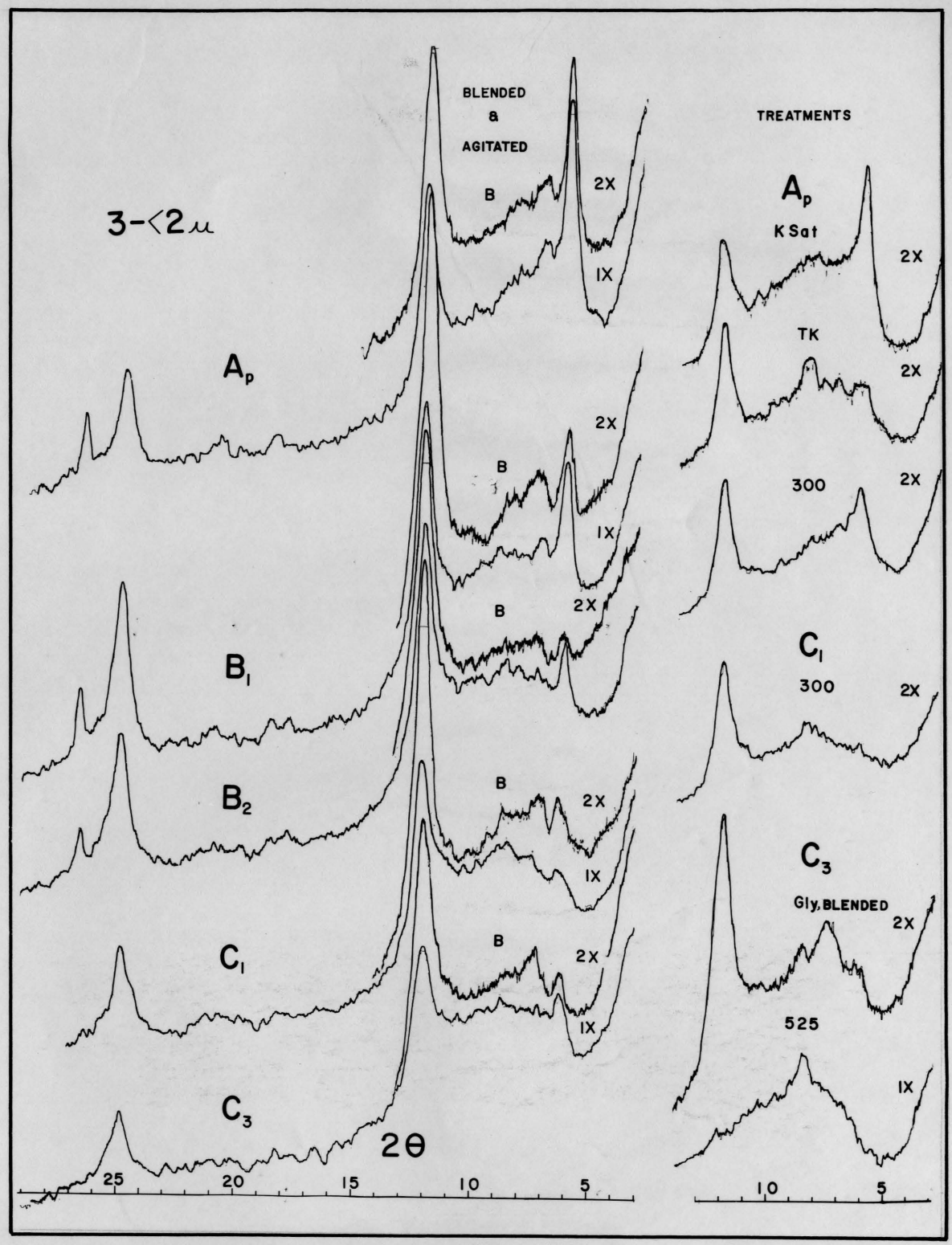
The dark red color and high clay content of these soils reflect the high iron content and basic composition of the parent rock. The occurrence of vermiculite in partly weathered rock material suggests that it, like montmorillonite, forms directly from the mafic minerals. The formation of a non-expanding 14 A lattice rather than an expandable one will be discussed later in the section on clay mineral formation.

Clay Mineralogy of Soils Developed From Silicic Rocks

Madison-Louisa-Wilkes

The soils of this catena are developed from weathered biotite gneiss. The gneiss is composed of plagioclase (AN 28), quartz and biotite, with minor amounts of microcline, garnet and muscovite.

Figure 3 - This figure illustrates x-ray patterns of horizons from a Madison soil profile. The effect of blending is shown by short superimposed diagrams which are marked with the letter B. The short patterns on the right illustrate the effect of heat and chemical treatments. The letters designating the treatments are the same as those used previously.


3-<2μ
BLENDED & AGITATED
TREATMENTS
A_p
B
2X
1X
A_p
K Sat
2X
TK
2X
300
2X
B_1
B
2X
C_1
300
2X
B_2
B
2X
1X
C_3
Gly, BLENDED
2X
C_1
B
2X
1X
525
1X
C_3
2θ
25
20
15
10
5
10
5

The soils are Red-Yellow Podzolic soils characterized by highly vermiculitic A horizons. The vermiculite peak gradually decreases in intensity with increasing depth and kaolin becomes the dominate clay mineral in the subsoil. The decrease in intensity of the vermiculite peak can be correlated with the amount of mica observed in the profile. In the lower horizons weathered mica flakes are very abundant and the vermiculite peak is low or missing. In the A and upper B horizons, biotite flakes are absent and the vermiculite peak is very intense.

The kaolin content also varies with depth. It increases in intensity with depth and generally reaches a maximum in the C_2 horizon. A secondary maximum occurs in the B_1 horizon of some profiles (See Tables 3, and 10 in Appendix I-C).

The profiles contain abundant mixed-layer clay material. The amount and distribution of this material changes with depth (Fig. 4). In the upper horizon a band of mixed-layer clays extends from 7 to 10 A (60 counts) and a more intense band from 10 to 14 A (120 counts). In the C horizon the opposite occurs and the 7 to 10 A band is more intense.

The response of vermiculite to heat treatment is that of atypical vermiculite and is nearly the same for all horizons. The 14.6 A peak lost intensity and collapsed to 14.0 A after 200° heat. The 300° heat caused a further loss of intensity and collapse to 13.6 A. In the B horizon the amount of collapse increased to 13.8 A after 200° C. and to 13.4 A after 300° C. The small amount of vermiculite in the C horizon usually collapses to 10 A after 300° C heat (See Fig. 3 treatments).

Potassium saturation collapses about a third of the 14 A peak, increases the amount of interstratified I/V material, but produces no 10 A peak. Treatment with NH_4F solution and then K saturation causes greater collapse and forms a low diffuse 10 A peak (Fig. 3, A_p horizon). Magnesium saturation sharpens and increases the intensity of the 14 A peak, but does not increase its thermal stability.

Soil material from two Madison profiles was mixed in the Waring blendor. The new intensities of the first order peak are listed in tabular form in Appendix I-C, Tables 3 and 10, columns 2B and 4B. The difference in x-ray patterns between blended and unblended samples is shown in Figure 3. The principal effects of the blending are: (1) to change the distribution of the interstratified clay material, (2) to nearly double the intensity of the first order peaks, and (3) to resolve a random mixed layer reflection from the background at about 12 A. In unblended specimens the interstratified material occurs as a sloping continuous band. When the specimen is blended, the distribution of material is changed. A new peak appears between the first order illite and vermiculite peaks. The peak represents a random mixture of interstratified mica and vermiculite layers, whose exact position and intensity depends on the number of layers of each component. This is shown by the gradual shift of the peak from 11.94 A to 12.48 A going up from the C_4 horizon and in the low peak intensity in the middle horizons. This peak is not affected by glycol treatment or heat treatment at 200° C.

Blendor treatment also produces an illite peak in the surface layer and lower C horizon. The blended < 4u fraction of A horizon of sample 10 contains an illite peak of 170 counts intensity (Figure 5, sample 10). This peak is much less intense in the < 2u fraction of the same sample. Illite does not occur in the blended specimens of sample 3 of the Madison soil. (Fig. 3). This is probably due to the separation of only a < 2u fraction.

One other soil profile (sample 7) was collected from an area mapped as, Madison clay loam, eroded hilly phase (Prince Edward Soil Survey, 1958). The parent rock and clay mineralogy of this soil differs from the typical Madison soils. The parent rock was highly weathered but appears to be a coarsed grained biotite-microcline-quartz gneiss. Microcline is probably the most abundant mineral. This is unusual, since microcline is present in only minor amounts in the other Piedmont rock samples. The clay minerals of this profile are characterized by the usual kaolin and vermiculite peaks. Low but sharp illite peaks are also present in the C horizon. In the C_2 horizon the illite peak is partly expanded after glycol treatment.

A common feature in x-ray diffraction patterns of the Madison specimens, and in general of all micaceous specimens, is the occurrence of a reflection with a 4.84 A spacing. This reflection can be seen in the upper horizons in figures 3 and 6. The peak is often associated with thermally resistant atypical vermiculite and could be the third order reflection of Al rich vermiculite. Gibbsite also

has an intense reflection at 4.84 A. The origin of this reflection will be discussed later in the section on clay mineral formation.

Louisa Soil

The shallow soils differ slightly in their clay mineralogy from the Madison soils. The main differences are: (1) the vermiculite content is low, (2) illite is common and occurs throughout the profile, and (3) kaolinite exhibits little change in intensity in the profile. These differences are undoubtly due to the fact that weathering has not had sufficient time to form vermiculite or eluviation of kaolinite.

Two Louisa profiles (samples 8 and 13) were collected in Prince Edward County. Profile 8 is not mapped as a Louisa soil, but as a Louisburg soil. The parent material and clay mineralogy of the profile is similar to those of a Louisa soil. Therefore it is designated in this investigation as a Louisa soil. The parent rock is composed chiefly of plagioclase, quartz, and biotite with minor amounts of epidote, garnet and muscovite.

Kaolin and vermiculite are the principal clay minerals formed from this rock. The kaolin peak is about twice as intense as the vermiculite peak. A 10 A reflection occurs in the lower C horizon which is as intense as the vermiculite peak (100 counts). The unusual feature about this clay is that it expands to a broad band centered at 11.6 A after glycol treatment. Blending of the saprolitic material produces an intense non-expandable illite peak. The origin of this expandable illite is discussed in the section on clay mineral formation.

The soil mapped as Louisa (sample 13) is an extremely shallow soil developed from weathered biotite-muscovite gneiss composed chiefly of quartz, feldspar, and biotite. Muscovite is common and chlorite occurs in minor amounts. Vermiculite is present only as the high shoulder side of the interstratified material. A low intensity illite peak occurs in all horizons. This peak is increased after glycol treatment. The increase in intensity accompanies a decrease in the randomly interstratified kaolin-illite layers. Blendor treatment had little effect on the C_4 material of this profile other than to increase the intensity of the kaolin peak.

Wilkes Soil

The Wilkes soil sampled in Prince Edward County is a transitional soil between the Madison and Cecil catenas. The parent material, biotite-muscovite gneiss, has a composition intermediate between the rocks of the two catenas and the clay mineralogy possesses characteristic features of both catenas.

The A horizon contains about twice as much kaolin as vermiculite, and, as in the Madison soils, vermiculite decreases in the subsoil and kaolinite increases. In the lower horizons vermiculite occurs as a high shoulder at the end of a band of interstratified kaolin-vermiculite. Low intensity illite peaks project above the background in all horizons, but are more intense in surface and lower horizons.

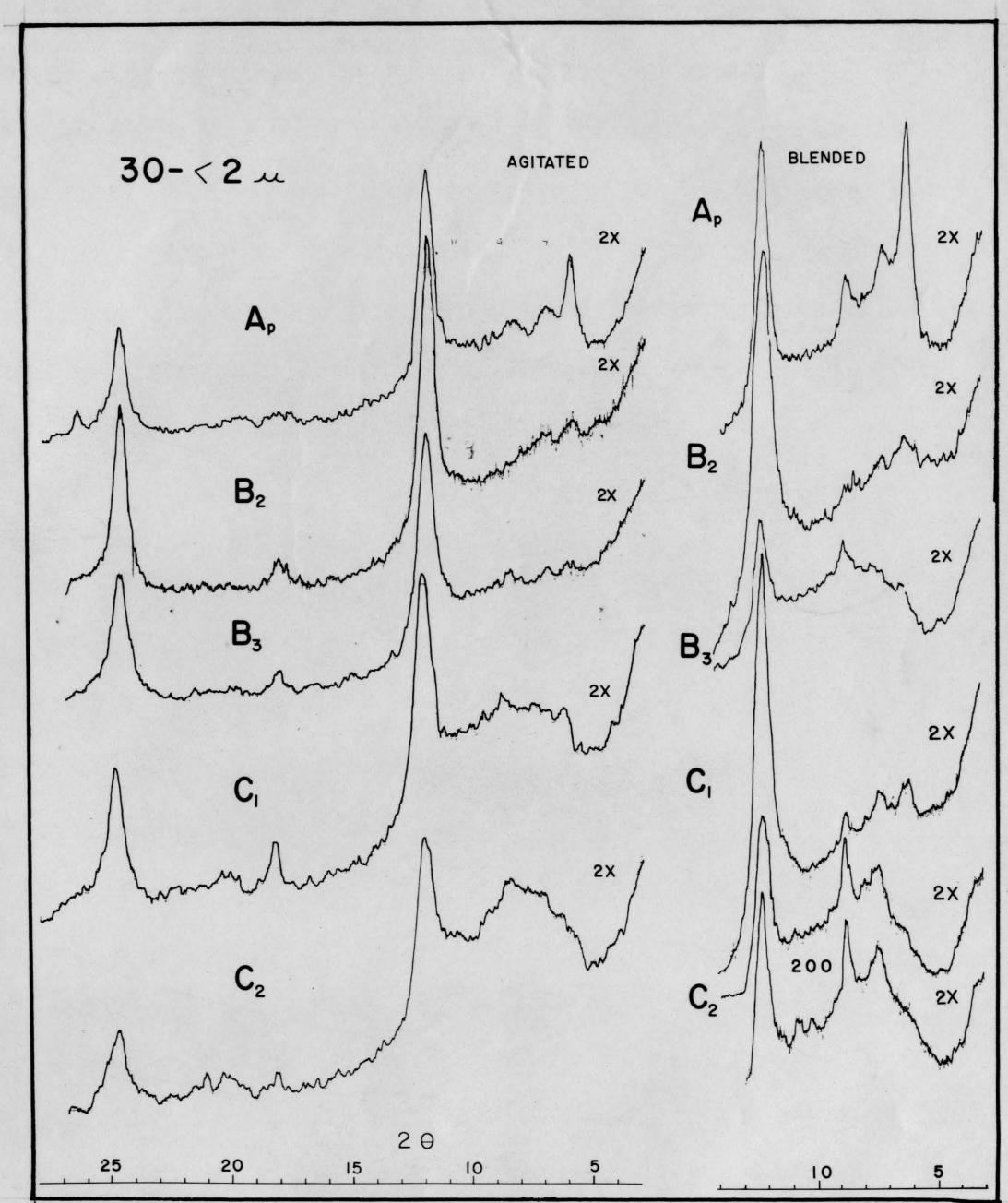


Figure 4 - This figure illustrates x-ray diffraction patterns of a Wilkes profile. The patterns on the right illustrate the effect of blending on the profile. The letter designations are the same as those previously used.

The most intense reflections occur in the B_2 horizon (1350 counts), but in specimens treated in the Waring blendor two maxima occur, one in the B_2 horizon and the other in the C_1 horizon. Blendor treatment also affects the intensity of the illite peak in all horizons. The illite peak in the A horizon increased from 30 counts in the unblended sample to 130 counts in the blended sample. The illite content in the blended samples decreased in the middle horizons, but increased in the lower layers. As in the Madison soils, blendor treatment separated a random mixed-layer illite-vermiculite peak which gradually shifted to higher d spacing going up the profile. The peak is most intense in the A horizon. In the C_2 horizon this peak and the illite peak are present, but no vermiculite peak occurs (Fig. 4).

The Wilkes clay mineralogy is more typical of the Cecil soils in unblended specimens. However, blending produces specimens which give x-ray patterns typical of Madison soils. The difference is apparently due to incomplete weathering in the youthful Wilkes soil. Blending appears to have the same effect further weathering would have. It separates the clay from decomposed rock fragments. The presence of a strong illite peak in this profile and its absence in typical Madison profiles is again a characteristic of soils developed from muscovite bearing rocks.

Summary

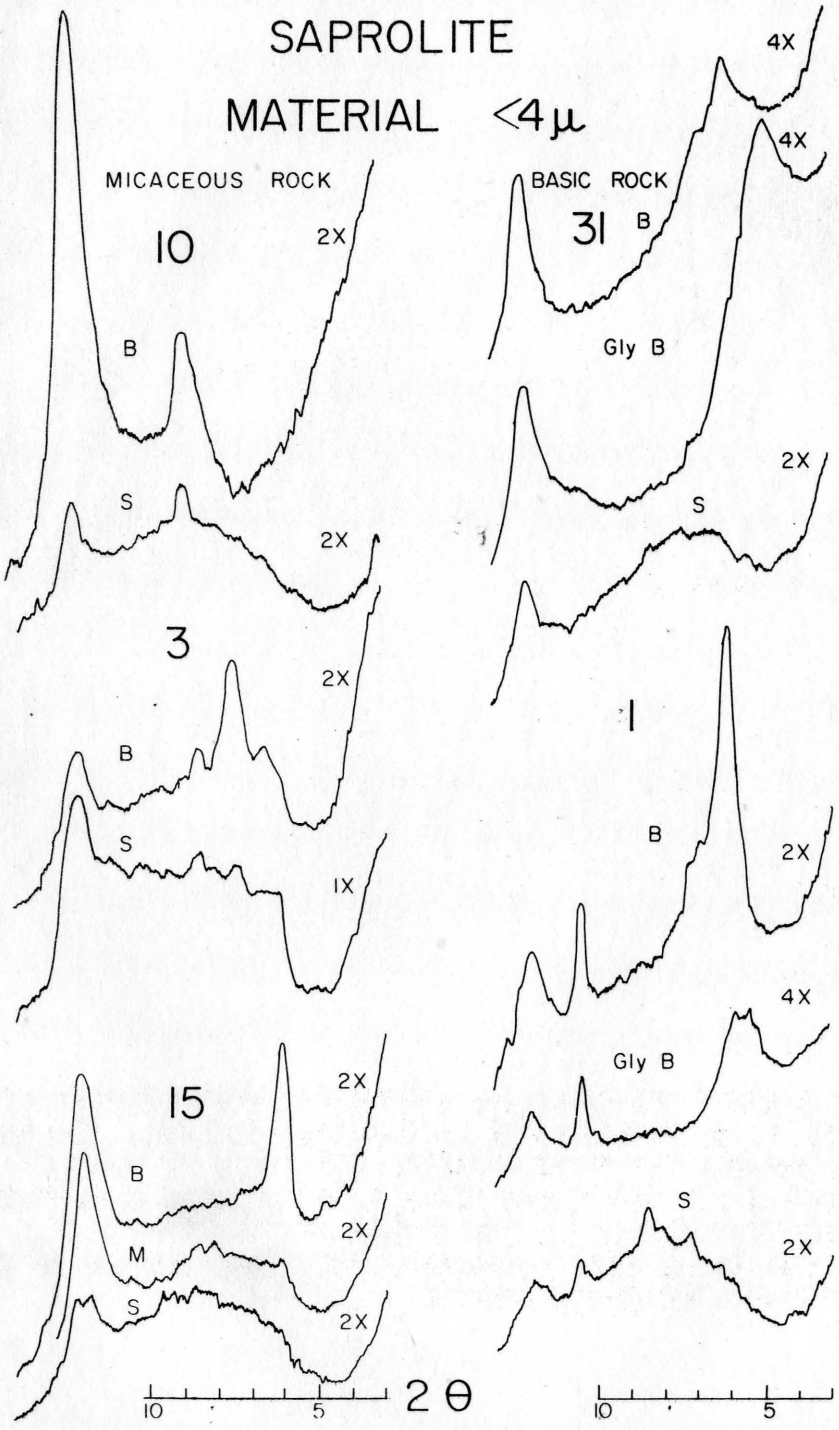
The characteristic clay minerals in soils of the Madison catena are kaolin and vermiculite. Increase in intensity of the vermiculite

peak with decrease in depth in the soil profile is related to the weathering rate of biotite. The presence of a random mixed-layer clay mineral at about 12 A, which gradually increases in d spacing with decreasing depth in the profile, indicates that biotite gradually weathers to vermiculite. The low content of vermiculite in the immature Louisa soils indicates that biotite has not had sufficient time to weather. The expendable illite reflection in the friable rock material of the shallow immature soils may be related to the first stage of biotite alteration. The significance of a weak 4.84 A reflection in a few profiles is not clearly understood but is probably related to transformation of Al in the soil system.

Cecil-Louisburg-Appling Catena

The soils of this catena have developed from weathered products of muscovite schist and pegmatite. Muscovite and quartz make up almost 90 percent of the rock. The remainder is composed of biotite, albite, and microcline. The soils are typical Red-Yellow Podzolic soils and are characterized by very intense kaolin peaks, which are generally 5 to 6 times more intense than the kaolin peaks of the Madison soil. Vermiculite is also present but the peak has low intensity. Unlike the Madison profiles, vermiculite occurs in the lower horizons and maintains nearly the same intensity throughout the profile (Fig. 6). Kaolin reaches its maximum intensity in the B horizon. It decreases above and below this horizon and has nearly the same intensity in the uppermost and lowermost horizons.

Figure 5 - This figure illustrates the effect of various degrees of agitation on saprolitic material from the Piedmont. The degree of agitation is indicated by the letters B, M, and S; B-treatment in the Waring blendor, M-mixing in a mechanical shaker, S-hand shaker. Gly indicates saturation with ethylene glycol after agitation. The large numbers on each pattern are the sample numbers.


SAPROLITE
MATERIAL <4μ
MICACEOUS ROCK
10
B
2X
S
2X
3
2X
B
S
1X
15
2X
B
M
2X
S
2X
BASIC ROCK
31
B
4X
Gly B
4X
S
2X
1
B
2X
Gly B
4X
S
2X
10
5
2θ
10
5

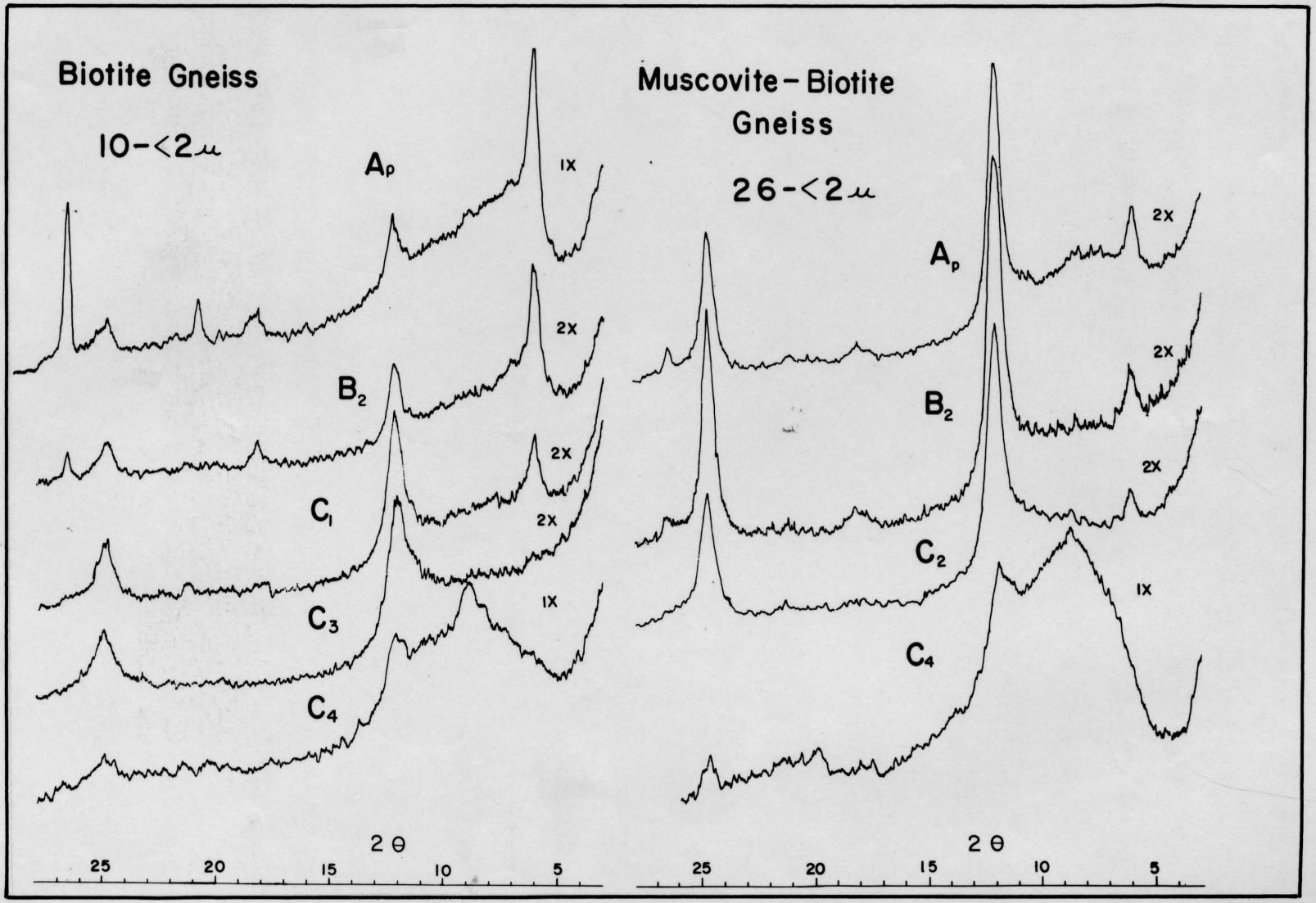
(Tables 9, and 26, Appendix I-C). The kaolin peaks in the lower horizon is asymmetrical towards the low angle side. Heat treatment at 300° C. collapsed most of this material. Glycol treatment of these lower horizons produced a broad band around 10 A.

Blendor treatment of sample 26 produced rather striking increases in the illite content of the profile. The greatest amount of illite occurs in the < 4u fraction of the A horizon (140 counts). (See table 26, Appendix I-C). The illite content decreases in the B_2, B_3, and C horizons and increases again in the lower C horizons, but only to 50 counts. The blendor treatment also increases the amount of random mixed-layer material between 10 A and 14 A.

A reflection from a 4.84 A d spacing is common in the B_1 and B_2 horizons of all Cecil soils. The low intensity of the first order vermiculite peak in the same horizons suggests that this peak is a gibbsite reflection rather than a third order vermiculite reflection.

A Louisburg soil (sample 5) developed from a pegmatite contains an unusual clay mineral assemblage. The most abundant clay minerals are kaolin and vermiculite which are the typical weathering products of granite, but in the C_2 horizon the intensity of the kaolin peak increases to 800 counts and the 14 A peak to 540 counts. About half of the 14 A peak shifts to 17 A on glycol treatment indicating the present of montmorillonite. In the C_3 horizon the kaolin intensity returns to that of the upper horizons (280 counts), and only a trace of montmorillonite remains. The occurrence of montmorillonite in the C_2 horizon appears to be associated with a cross-cutting quartz vein.

Figure 6 - This figure illustrates x-ray patterns of two Red-Yellow Podzolic soils developed from rocks with different mica contents. A kaolin-vermiculite, Madison profile is shown on the left and a kaolinitic Cecil profile is shown on the right.


Biotite Gneiss
10-<2μ
Ap
1X
2X
B2
2X
C1
2X
C3
1X
C4
2θ
25
20
15
10
5
Muscovite-Biotite Gneiss
26-<2μ
Ap
2X
B2
2X
C2
1X
C4
2θ
25
20
15
10
5

The vein contains coarse (2 inches) irregular quartz grains enclosed and filled with waxy, gray clay. X-ray analysis of this clay reveals that it is composed of kaolin (1140 counts) and montmorillonite (300 counts). The intimate association of the clay and the quartz grains indicates that it has formed in place as the result of weathering of coarse silicate material. The nature of the cross cutting stringer and its composition strongly indicates that the original material was feldspathic in composition.

Summary

The striking feature of the mature soils of this catena is the intense kaolin peak and the small content of vermiculite. The early occurrence of an intense kaolin peak suggests that it forms directly from the primary silicate minerals. Unlike the Madison soils, blendor treatment formed illite peaks in all soil horizons. The higher content of illite in the < 4u fraction suggests that it is formed chiefly by reduction in grain size of muscovite particles. The difference in clay mineralogy between this catena and the preceding Madison catena is illustrated in Figure 6. From this figure it can be seen that even the two mature Red-Yellow Podzolic soils developed from rather similar parent rock differ in clay mineral content.

Clay Mineralogy of Soils Developed From Alluvium

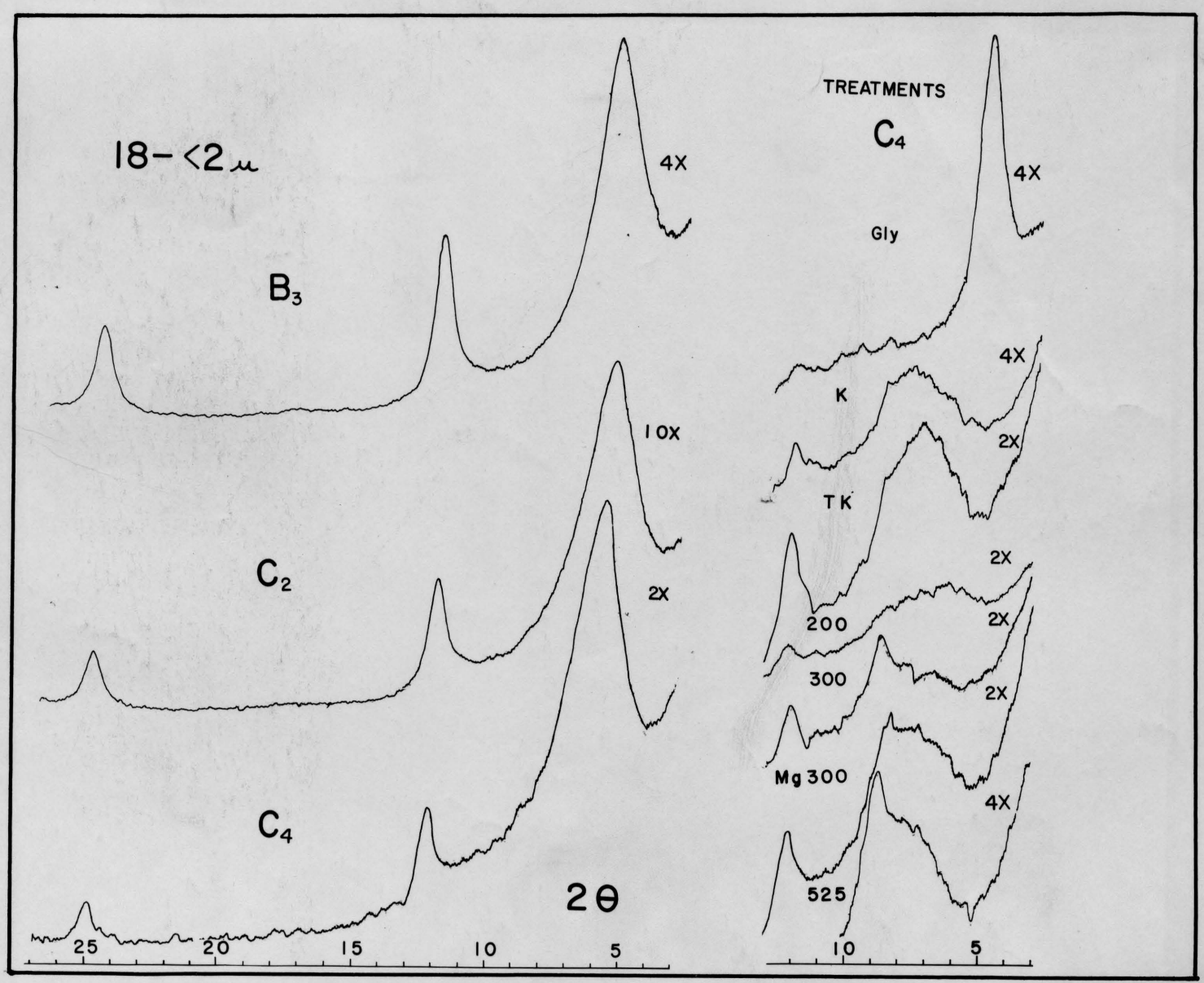
Worsham Soil

The Worsham soil develops from the weathered products of alluvial material. Kaolinite, vermiculite, quartz and interstratified clay material occur in the weathered alluvial material. The latter two are very abundant in the surface layer. The kaolin content increases down to the bottom of the alluvium, going from 175 counts in the A_p to 1300 counts in the B_2. The vermiculite content also steadly increases down to the residual saprolite but at a much lower rate, going from 150 to only 350 counts in the B_2 horizon. This difference is due to either much greater illuvation of the kaolinite or to the greater weathering rate of kaolinite to amorphous material.

The most interesting feature of this profile is the clay mineralogy of the residual material, identified as the C horizon in the soil descriptions. The material contains an exceptionally large amount of good crystalline montmorillonite. The relative intensity of the montmorillonite is 2400 counts. Kaolinite is also very abundant (1500 counts) but decreases sharply with increasing depth. Both peaks are broad but symmetrical. The x-ray patterns are characterized by the complete absence of any other reflections or interstratified material (Fig. 7).

Unlike the montmorillonitic clay material in the Iredell soils, which is extremely heavy, sticky, and plastic, the montmorillonite bearing material is this profile is light, friable, and only moderately

Figure 7 - This figure illustrates x-ray diffraction patterns of residual soil material beneath an alluvial Worsham profile. The diagrams on the right indicate the response of this material to chemical and heat treatments. The treatments are indicated by the following letters: 200, 300, etc. heating temperatures in centigrade; Gly-glycol saturated K potassium saturation; Mg magnesium saturation; TK- washed with NH_4F solutions and potassium saturation. 2x, and 4x counting rate in seconds where x equals 500 counts.


18-<2μ
B3
C2
C4
4X
10X
2X
2θ
25
20
15
10
5
TREATMENTS
C4
4X
Gly
4X
K
2X
TK
2X
200
2X
300
2X
Mg 300
4X
525
10
5

sticky when wet. Moreover, when this material is subjected to various heat treatments, it reacts more like a typical Wyoming bentonite clay. Heat treatment at 200° C. completely destroys the 15 A peak and collapses some layers to 10 A. Treatment at 300° C. produces a broad peak at 10 A; and heating at 525° C. produces a sharp peak at 10 A with an asymmetrical tail to the low angle side (See Fig. 7).

Montmorillonite response to ion saturation is greater than it was in any other soil. Mg saturation again affects the thermal stability of the clay at 300° C. It increases the amount of partly collapsed material between 10.0 A and 14.5 A and restricts the collapse to 10.6 A rather than 10.1 A as in the unsaturated material. Potassium saturation collapses the clay to a broad diffuse peak centered at 12 A, but glycolation completely expands it again to 17 A. Treatment with NH_4F solution and K saturation collapse the peak to a broad intense peak centered at 11.94 A (Fig. 7).

Mixing of the lowest exposed rock material in the Waring blendor produces clay material which gives a very clean x-ray pattern. Before mixing the x-ray pattern contained a band of interstratified material centered around 10 A and a very low diffuse kaolin peak. After treatment a very intense montmorillonite peak and a small but sharp kaolin peak are separated from the background material.

CHAPTER VII

RESULTS

Clay Mineralogy of Blue Ridge Soils

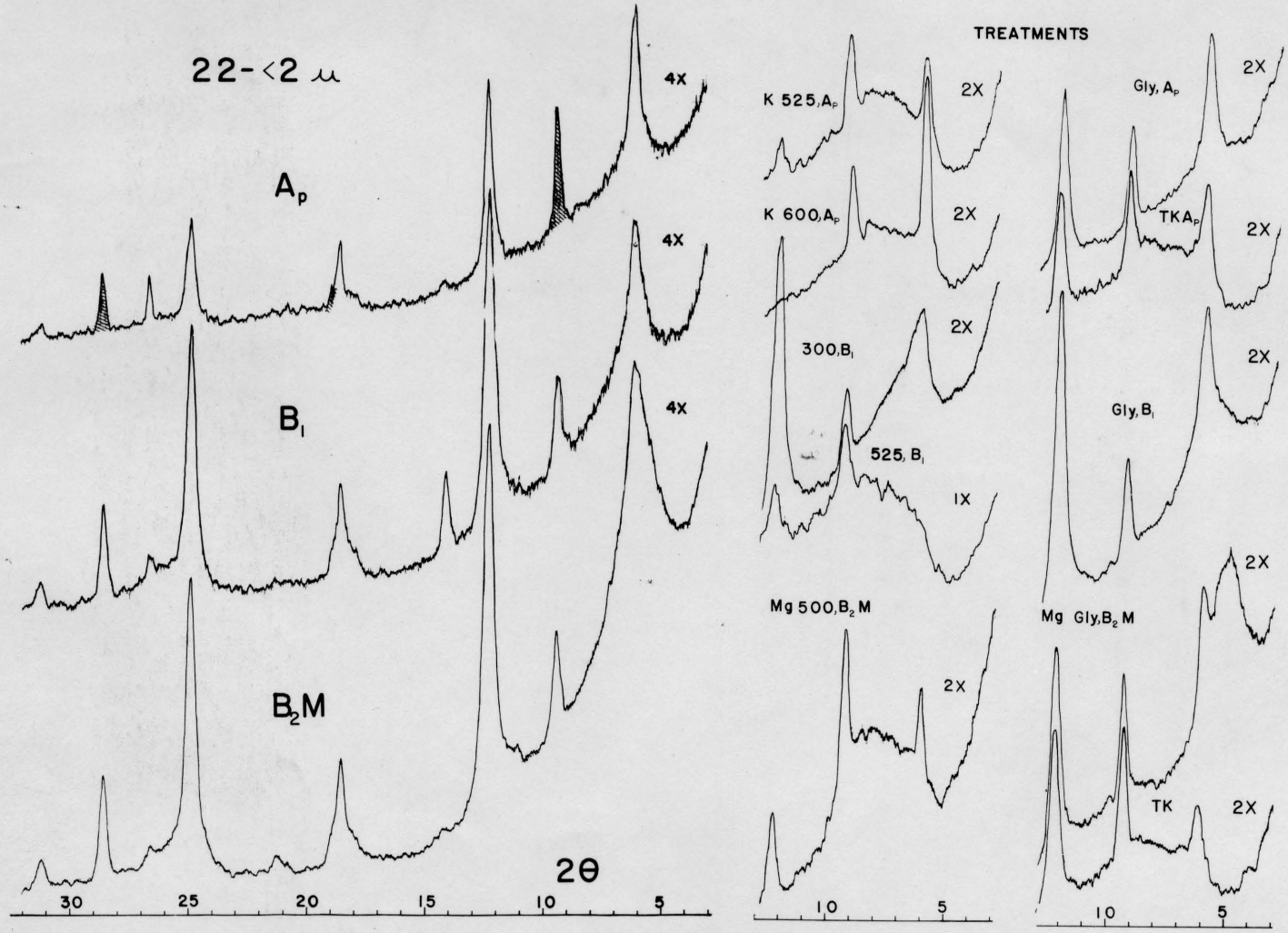
The clay mineralogy of the Blue Ridge soils is discussed in this section. The soils are considered in the same manner as the Piedmont soils. The intensities of all first order reflections are listed in tabular form in Appendix II. Gray-Brown Podzolic soils are the characteristic soils of this area. In general rocks which have compositions similar to Piedmont rocks also contain similar clay minerals, but the peak intensities, peak symmetries, and amount of mixed-layer material are different.

Clay Mineralogy of Soils Developed From Mafic Rocks

Elbert Soil

The Elbert soil (sample 22) is formed from the most basic rock sampled in the Blue Ridge. The parent rock is meta-gabbro composed chiefly of tremolite, talc, and chlorite with lesser amounts of magnetite and olivine. The profile is the most poorly drained sample collected in either the Blue Ridge or Piedmont. The profile contains a highly organic rich A horizon and an extremely dense sticky plastic subsoil. The surface horizon is characterized by a chlorite-talc assemblage and the subsoil by a chlorite-talc-montmorillonite assemblage. All peaks in the subsoil are sharp and intense except the montmorillonite peak. The 14 A peak in the subsoil is broad and

Figure 8 - This figure illustrates x-ray diffraction diagrams of the Elbert soil. The response of the clays to various chemicals and heat treatments is shown on the right. The cross hatched peaks in the A_p horizon and the corresponding peaks in the other patterns are talc reflections. The letters designating the various heat treatments are the same as the previous figures.


22-<2 μ
A_p
B_1
B_2M
4X
4X
4X
2θ
30
25
20
15
10
5
TREATMENTS
K 525, A_p
2X
K 600, A_p
2X
300, B_1
2X
525, B_1
1X
Mg 500, B_2M
2X
10
5
Gly, A_p
2X
TK A_p
2X
Gly, B_1
2X
Mg Gly, B_2M
2X
TK
2X
10
5

asymmetrical due to the presence of expandable montmorillonite layers. Talc occurs in all horizons and is identified by strong first and third order peaks at 9.5 A and 3.13 A and by a low peak at 4.7 A. These reflections are illustrated by the cross hatched peaks in the A_p horizon of Figure 8. Talc is not affected by any treatments. It is present in all horizons, but its intensity is the greatest in the A horizon. This is probably due to the removal of less resistant chloritic clays and the concentration of more resistant talc particles.

The 14 A° chlorite peak in the A horizon is not affected by any treatment. Heat treatment at 525° C. decreases the intensity of the 14 A° peak but does not shift the peak. Heat treatment of a K saturated specimen at 600° C increased the intensity of the 14 A° reflection, but the 7 A° peak was destroyed. Washing the clay with NH_4F solution and K saturation destroyed some of the 14 A peak but did not collapse the peak (See Fig. 8).

The occurrence of an intense quartz peak in the A horizon is surprizing since no quartz occurs in the parent rock. The quartz is either transported or it is formed from the weathering of primary silicates. The latter is probably the correct explanation since the entire area around the profile is composed of an altered olivine rich mafic rocks.

In the subsoil the only difference in clay mineralogy is the presence of an expandable 14 A° clay in the BM horizon, and the occurrence of a sharp peak at 6.26 A in the oxidized B horizon. The latter peak is missing in both the surface layer and lower BM horizon

and is destroyed by heat treatment at 400° C. Lepidocrocite has a similar d spacing but decomposes at 300° C. However this is probably lepidocrocite which is slightly more stable.

Rabun-Catoctin Catena

The soils of this catena have developed from ferromagnesium rich rocks and have dark red to brownish-red colors. The soils sampled developed from three different rock types. The Catoction forms from a greenstone schist. The Rabun soils formed from hornblende-biotite gneiss and chloritic soapstone composed almost entirely of chlorite and talc.

The clay mineralogy of the Rabun soil developed from the chloritic soapstone is the same as the Elbert soil except it lacks the montmorillonite and lepidocrocite peaks. Another important difference is the presence of abundant iron as shown by the very high background of all x-ray patterns. Coleman (1949) found that the Rabun soil in the Blue Ridge area in North Carolina is characterized by a high percentage of gibbsite and hematite.

Treatment of chloritic clay in this profile produced some changes which did not occur in the Elbert soil. Heat treatment at 525° C. reduced the 14 A peak to background level but did not alter the 7 A peak. The 7 A peak is removed after treatment at 600° C. The 7 A material is probably serpentine. Potassium saturation reduces the intensity of the 7 A and 14 A peaks but causes no shift in their position. The 14 A material is identified as chlorite even though the peak was destroyed

at 525° C. The presence of well developed suborder reflections indicate that it is not soil vermiculite.

The Rabun soil (sample 24), developed from hornblende-biotite gneiss, probably contains clay minerals more typical of this soil. The A and B horizons are characterized by kaolin and vermiculite clays. The vermiculite content decreases with depth and does not project above the illite-vermiculite interstratified material in the C horizon. Low diffuse illite peaks occur in the B and C horizons. The peak is sharpened and intensified after glycol treatment.

In the A horizon of this profile the vermiculite and kaolin peaks have nearly equal intensities. Interstratified material occurs as an even band between the 7 A and 14 A reflections. Glycol treatment increases the amount of interstratified illite-vermiculite material. Heat treatment at 200° C. sharply reduces the intensity of the vermiculite peak and shifts it to 13.4 A. Further treatment at 300° C. collapses the peak to 13.2 A, but complete collapse to 10 A does not occur on treatment at 525° C. The B horizon has the same mineralogy but contains less vermiculite. The rate of collapse of the 14 A peak is the same as above. The C horizon contains less kaolinite and the vermiculite peak occurs only as a high shoulder at the end of the interstratified illite-vermiculite material. Glycol treatment forms a broad peak at about 10 A. After heat treatment at 300° C. a 10 A peak is formed in untreated samples.

Blendor treatment of the weathered rock material and overlying soil material had an adverse effect on the quality of the resulting

x-ray patterns. The kaolinite and illite peaks decreased in intensity instead of increasing in intensity as they normally due after blendor treatments. X-ray patterns after various degrees of mixing are shown in Figure 10, sample 24. The letters above the patterns indicate the type of mixing.

The Catoctin soil (sample 20) has a shallow reddish-brown profile, It is developed from greenstone schist composed chiefly of hornblende and lesser amounts of quartz, epidote and plagioclase (An 30). The soil is characterized by the presence of an intense vermiculite peak throughout the profile. Kaolinite is also common but has only one third the intensity of the vermiculite peak. The profile is also characterized by a small amount of interstratified material. The patterns contain only a low bank of randomly interstratified kaolin-vermiculite layers in the A horizon. The vermiculite is also unusual in that the peaks are very sharp and narrow for a soil clay mineral (Fig. 9).

The response of vermiculite to thermal treatment is typical of soil vermiculite. The vermiculite in the A horizon is slightly more stable than it is in the subsoil. In the A horizon the peak collapsed to 13.4 A after treatment at 300° C. and in the C horizon the peak s shifts to 13 A after the same treatment (See Fig. 9). The collapse and decrease in intensity of the peak are accompanied by an increase in the amount of interstratified illite-vermiculite material. Heat treatment at 500° C. produces a broad band centered around 11 A. Potassium saturation of the clay material in the A horizon reduces the

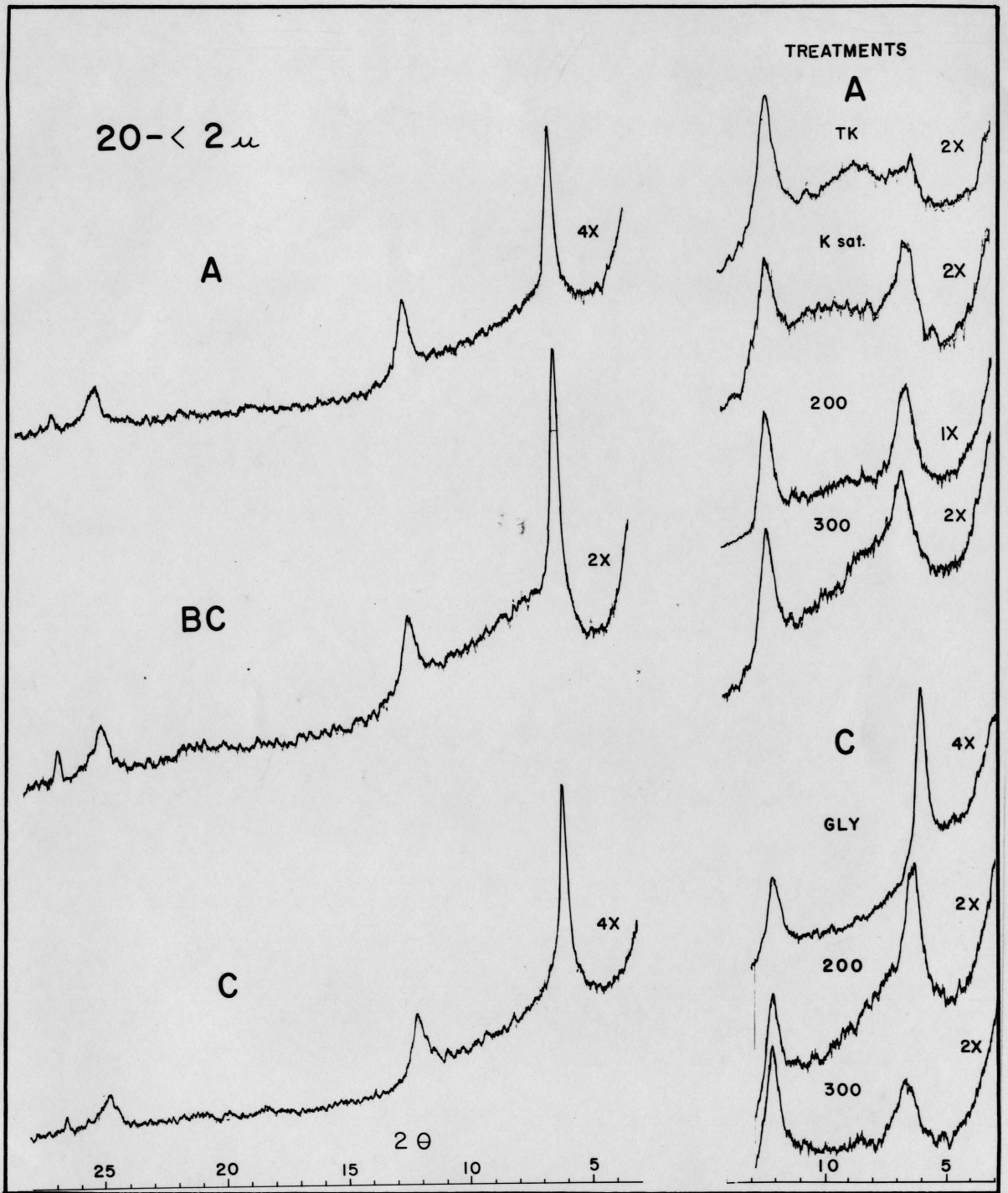


Figure 9 - This figure illustrates x-ray diffraction patterns of a Catoctin profile. The patterns on the right illustrate the response of clay in the A and C horizons to heat and chemical treatments. The letters designating the treatments are the same as those used previously.

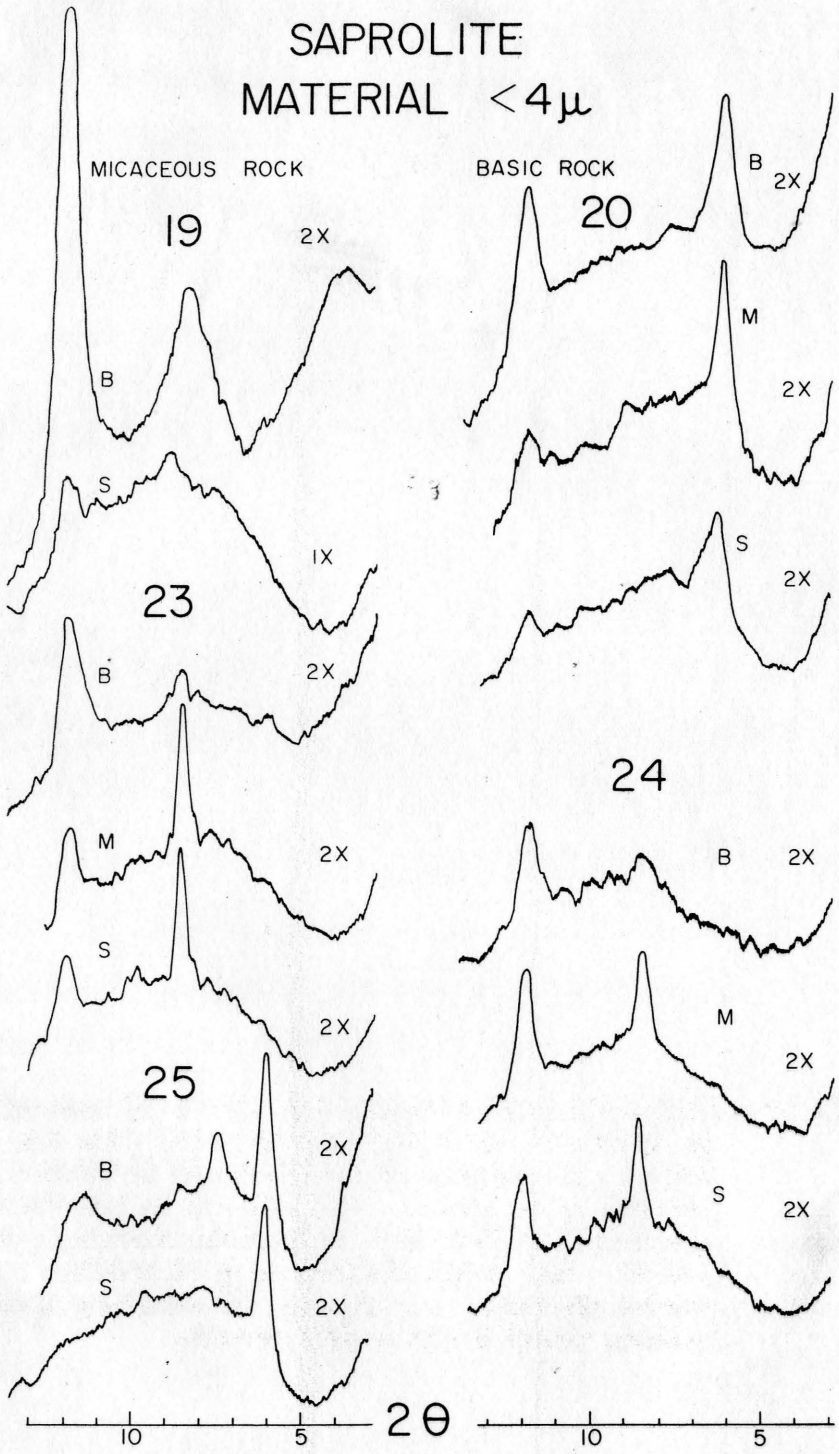
VIRGINIA POLYTECHNIC INSTITUTE
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intensity of the vermiculite peak from 800 counts to 200 counts and increase the intensity of the interstratified kaolin-vermiculite from 40 to 200 counts. Magnesium saturation increased slightly the thermal stability of the vermiculite. Leaching of the C horizon material with N. NH_4F solution and K saturation reduced the intensity of the vermiculite peak to the background level and produced a low band around 10 A. The treatments and x-ray patterns of the profile are illustrated in Figure 9. Treatment of the weathered rock in the blendor increased the intensity of the kaolin and vermiculite peaks (Fig. 10, sample 20).

Summary

The high iron content of the parent rocks is reflected by the dark reddish-brown color of the soil. The low kaolinite content of the Catoctin soil is probably due to the small amount of feldspar in the rock. The presence of interstratified K/V material only in the surface layer of this soil suggests that this material is formed by the break down of vermiculite in this highly leached horizon. Occurrence of rather sharp narrow vermiculite peaks and lack of interstratified material in lower horizons indicate that vermiculite is not being weathered in these horizons. Increases in thermal stability of vermiculite in the surface layer is probably a result of greater fixation of inter-layer aluminum (Rich 1960). Increase in intensity of the kaolin and vermiculite peaks after blendor treatment of the weathered rock material indicates that the clay minerals are formed early, probably directly from the primary crystals. The great differences

Figure 10 - This figure illustrates the effect of various degrees of agitation on saprolitic material from the Blue Ridge. The degree of agitation is indicated by the letters B, M, and S. B-treatment in the Waring blendor, M-mixing in a mechanical shaker, S-hand shaker. The large numbers on each pattern are the sample numbers. 1x, 2x etc. is counting rate in seconds where x equals 500 counts.


SAPROLITE
MATERIAL <4μ
MICACEOUS ROCK
BASIC ROCK
19
20
23
24
25
B
S
M
2X
1X
10
5
2θ

in clay mineralogy between the two Rabun soils is a reflection of the large differences in the source rocks. The distribution of the vermiculite in the Rabun soil (sample 24) is similar to that of the Piedmont Madison soils. The low diffuse 10 A peak in the B and C horizon which sharpened and intensified after glycol treatment, may be due to halloysite probably formed from the coarse-grained plagioclase. A 10 A peak is also formed in untreated specimens after 300° C. heat treatment. This may be true mica material formed from weathered biotite.

Clay Mineralogy of Soils Developed From Intermediate Rocks

Eubanks Catena

The Eubanks soil (sample 23) has a deep profile with a brown surface layer and a yellowish-red subsoil. It is developed from weathered granodiorite composed mainly of microcline, vein epidote, quartz, albite, and biotite. The A horizon contains more vermiculite than kaolin, but the B horizon contains more kaolinite. The vermiculite content decreases with increasing depth and finally disappears in the C horizon. The kaolin content also drops sharply in the C horizon and a small illite peak occurs in this horizon.

This is one of the few profiles in which vermiculite above a very distinct decrease in thermal stability with increasing depth. In the A and B horizons the response to treatment is the same. The peak shifts to 14.03 A after 200° C. heat and to 13.85 A after 300° C. heat. In the B_2 horizon the peak shifts to 13.85 A at 200°C. heat

and to 13.60 A at 300° C. heat. In the B_3 and C horizons the peak is destroyed completely and a diffuse peak is formed at 10A.

Glycol treatment does not shift the 14 A peak but does produce new peaks in the mixed-layer material. In the A and B_1 horizons a new low intensity peak forms at 12.27 A. The illite peak intensity is also increased in the lower horizons after glycol saturation. Blendor treatment of the saprolitic material destroyed the first order reflection. The x-ray patterns of the specimens after various degrees of mixing are shown in Figure 10, sample 23.

Summary

The decrease in thermal stability of the vermiculite peak with increasing depth is probably a reflection of decreased weathering in the lower horizons. The subsoil of this profile is quite thick (45 in.) and therefore the vermiculite is largely protected from surface leaching. The formation of new 10 A and 12 A peaks after glycol saturation are discussed in the section on clay mineral formation. Destruction of the clay mineral reflections by blendor treatment is probably the result of dilution of the clay by rock fragments.

Clay Mineralogy of Soils Developed From Silicic Rocks

Talladega-Chandler-Halewood Catena

The Talladega soil (sample 19) is a shallow, highly micaceous soil. It has a brown surface layer and a yellow red subsoil. The parent material is weathered biotite-muscovite schist composed mainly of quartz,

plagioclase and mica. Muscovite (18%) is more abundant than biotite (13%) and is coarser grained. The rock is similar to the micaceous rocks of the Piedmont. The clay mineralogy is about the same as the Wilkes soil.

The A horizon contains about twice as much kaolin as vermiculite and has a rather intense band of interstratified illite-vermiculite clay material. The vermiculite of the A horizon is only moderately stable under thermal treatment. At 200° C. the 14 A peak is reduced to the level of the interstratified I/V material. In the subsoil kaolin and vermiculite are the chief clay minerals. Interstratified I/V material is abundant in the B horizon. Blendor treatment of the friable parent material produces a very intense kaolin peak and a prominent but broad illite peak. Before treatment the kaolin and vermiculite peaks were low and diffuse. The effects produced by various degrees of mixing are illustrated in Figure 10, sample 19.

Summary

This soil exhibits about the same degree of soil development as the Piedmont Wilkes soil. The physical appearance of both soils is similar. They have shallow profiles and thin B horizons. The moderate intensity of the vermiculite peak is probably a reflection of incomplete weathering of the biotite. The large amount of interstratified illite-vermiculite material suggests that biotite is weathering to vermiculite. The formation of a very intense kaolinite peak after

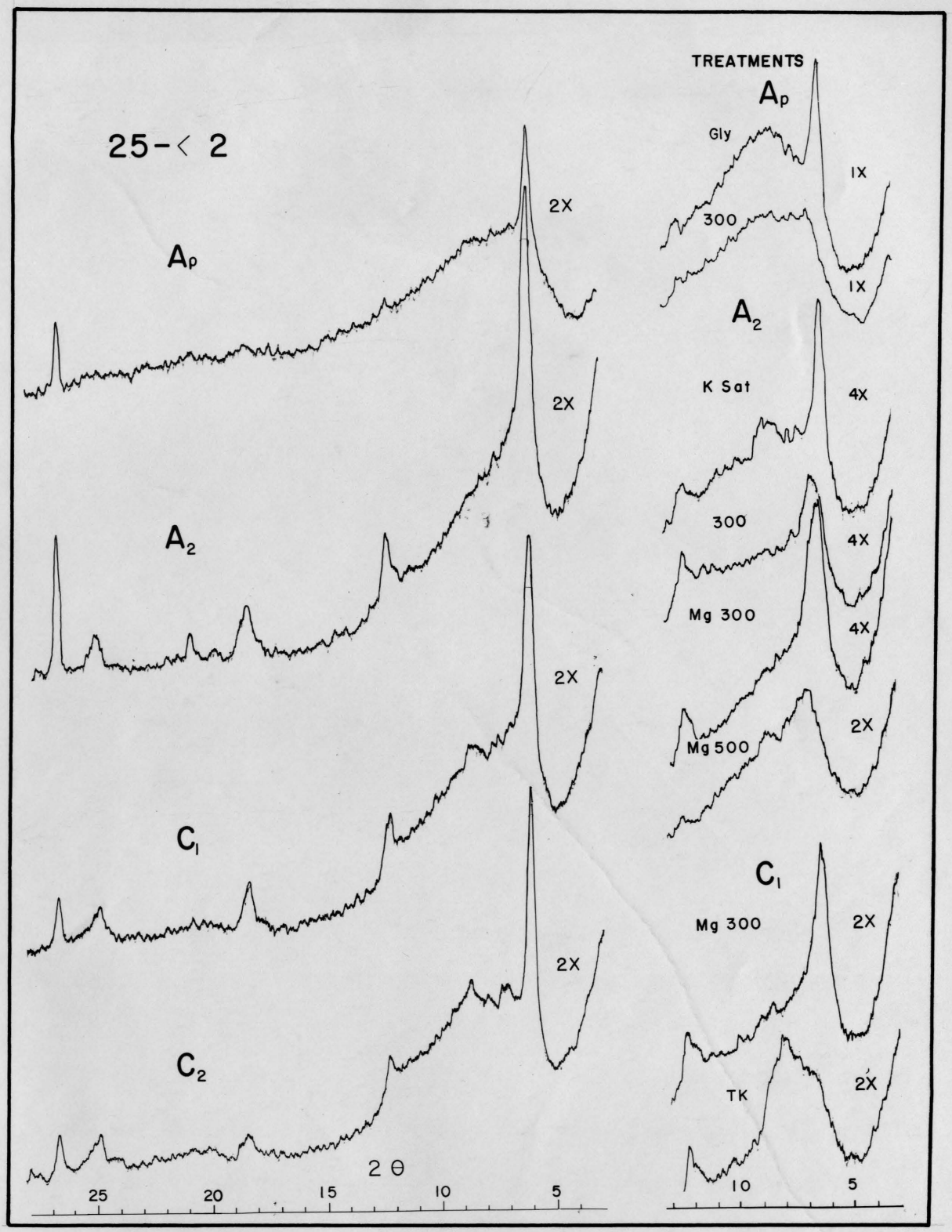


Figure 11 - This figure illustrates x-ray diffraction patterns of a Louisburg profile. The patterns on the right illustrate the response of these clays to heat and chemical treatments. The letters designating the treatments are the same as those used previously.

blendor treatment of friable rock again indicates that it probably f forms directly from the feldspar crystals or possibly from muscovite.

Louisburg-Appling-Cecil Catena

The Louisburg profile (sample 25) is more mature than a typical Louisburg soil. The profile is rather deep and has fair soil zonation. The soil is formed from weathered biotite granite, which was hydrothermally altered producing coarse-grained sericite.

The clay mineralogy of the profile is characterized by an intense vermiculite peak in all horizons (Fig. 11). The first order vermiculite reflection is very narrow and sharp. A peak at 4.28 A is probably the third order reflection. These data indicate that the mineral has exceptionally high crystallinity for a soil clay. Low intensity kaolin intensity is only 35 counts, but it increases to 200 counts in the subsoil and then remains nearly constant. A low illite peak occurs in the lower C horizons, and interstratified illite-vermiculite layers are abundant in all horizons. X-ray patterns for this profile are shown in Figure 11.

The vermiculitic clay shows the usual decrease in thermal stability with increasing depth. Both unsaturated and saturated vermiculite collapse more in the C horizon. However, the entire 14 A peak in the A horizon is completely destroyed by 300° C. heat, but a 10 A peak is not formed. Magnesium saturation increases the thermal stability of vermiculite (Fig. 11). Unsaturated vermiculite from the A_2 horizon collapses to 13.60 A at 300° C. but after Mg saturation the

peak remains at 14.25 A. In the C horizon unsaturated vermiculite collapses to 13.4 A after 300° C. heat and Mg saturated clay to 14.0 A. Potassium saturation of material from the A_2 horizon destroys about a quarter of the vermiculite peak and forms a diffuse peak at 10 A. Potassium saturation of the C horizon material collapses slightly more material to 10 A then it did in the surface layer. However, the greatest collapse occurs after leaching with NH_4F solution and K saturation. This treatment shifts the 14 A peak in the C horizon to a broad peak at about 10 A. Glycol saturation increases the intensity of the interstratified illite-vermiculite material in all horizons but not the intensity of the vermiculite peak.

A random mixed-layer illite-vermiculite peak occurs in the C_2 horizon of this profile. The peak occurs at 12.27 A in untreated specimens. After blendor treatment this reflection appears at 11.79 A and the intensity is increased (Fig. 10, sample 25).

Summary

The unusual formation of the intense 14 A vermiculite peak which has characteristics of rather good crystalline material is probably due to the nature of source material., The coarse grained potassium sericite and the altered biotite grains apparently serve as the source material. The low kaolin content of this profile is very surprising since feldspar is one of the major constituents of this rock. No explanation for this anomaly can be given. The presence of random

mixed-layer illite-vermiculite clay indicates the formation of vermiculite from 10 A material.

CHAPTER VIII

DISCUSSION OF SOIL FORMING FACTORS

Introduction

Many studies have been made and much has been written concerning the five soil forming factors. The general conclusions of these studies are best shown by the fact that the U. S Department of Agriculture bases its soil classification chiefly on climate and length of time the soil forming forces have been active. Nevertheless, results of this investigation indicate that the texture, structure and mineralogical composition of the parent rock are reflected in the physical appearance and mineralogical composition of all soils of the Virginia Piedmont. Topography also strongly influences the physical characteristics of the soil profiles and the weathering rate of the clay minerals, but has little effect on formation of clay minerals. The role of parent material and topography in the formation of soil clay minerals and soil morphology is discussed in the next section. Also included is a discussion of the effect of climate on the Blue Ridge and Piedmont soils.

Parent Material

Composition

An evaluation of the importance of parent material on the formation of Piedmont soils was one of the prime objectives of this investigation, for, as previously state, climate is generally accepted as

the only factor reflected in the properties of mature soils. Data collected in this study indicate that parent material is an important soil forming agent and that its importance increases as the parent rock becomes more basic in composition. In highly basic rocks composition may outweigh all other soil forming factors including other parent material factors such as rock structure and texture in determining the clay mineralogy of the soils.

The formation of montmorillonite is usually attributed to poor drainage (Grim 1953 and Goldschmidt 1958). The field of occurrence of poorly drained montmorillonitic Iredell soils adjacent to well drained Red-Yellow Podzolic soils suggests that poor drainage is a result and not the cause of their formation. The difference in drainage is most striking in Iredell soils developed on diabase dikes which cut granitic rocks. The granitic rocks weather to well drained kaolinitic Cecil soils. The Iredell soil, which has the same surface drainage, vegetation, and topography as the adjacent Red-Yellow Podzolic soil, is poorly drained and contains dense, sticky kaolin-montmorillonitic clays. The poor drainage is probably due to the high production of fine clay material and the formation of expandable clay minerals which retard the internal drainage. Apparently the restriction of drainage by this material produces a closed system in the subsoil, whose chemistry would be completely independent of composition of the surface water. It is only when surface drainage or the angle of slope becomes great enough to remove this impermeable layer, that parent material becomes

secondary in importance to topography and climate in the formation of soils from basic rocks.

Soils developed from granitic rocks are least affected by their parent material and weather to deep Red-Yellow Podzolic soils. The effect of parent rock composition is still evident in these soils. It is due largely to the type and amount of micaceous minerals. The strong influence of mica is a result of the different weathering rates of the two common mica minerals. Biotite not only weathers faster than muscovite but weathers to a different end product. Biotite weathers to vermiculite and muscovite probably alters to kaolinite.

Rock Structure and Texture

Another way that parent material influences the type of soil and soil clay minerals is through its rock structure and texture. These factors have some effect on soils developed from highly basic rocks but are more important in soils developed from rocks of intermediate to moderately basic composition. In metamorphic rocks drainage is greatest parallel to the rock foliation. In the Iredell catena soils developed on rocks with vertical foliation contain poorly drained clayey subsoils, but the subsoil is much thinner than it is in soils developed from the same rock with horizontal foliation. Rocks with this vertical structure occur in Nottoway County, The soil developed on them is mapped as the Mecklenburg soil.

The Helena soil, which is developed from hornblende-biotite schist, is probably the soil most strongly influenced by parent rock

structure. This soil, like the Iredell soils, has poor internal drainage and contains a dense clay layer, but is formed from a less calcic rock. The important factor in the formation of the soil appears to be the horizontal schistosity of the parent rock. The parallel orientation of the platly minerals must impede the internal drainage, and according to Jackson (1959) it's the permeability of the parent material that influences the soil clay minerals formed by chemical weathering. The close field association of Helena soil with deep red oxidized Fluvanna and Vance soils raises the possibility that these soils may develop from the same rock type, where the rock contains vertical foliation. This is speculation, since the parent rock of these soils could not be observed due to the great depth of weathering. However, this is an interesting problem for future work, for rock structure could explain why different soil types are often reported as forming from the same rock type.

Rock textures probably affect soil formation in the same way as rock structure. Open textures would increase internal drainage, and the rate of removal of bases. Sherman and Uehara (1956) believe that the rapid removal of bases favors kaolinization in the soil. Texture and mineralogical composition were cited by Cady (1950) as important controls in the formation of two North Carolina soils. He found that two very similar basic rocks on weathering gave different soil types. A well drained kaolin-vermiculitic Davidson soil formed from diorite rock material and a poorly drained kaolin-montmorillonitic Iredell soil

formed from meta-gabbro rock material. He believes that the texture and mineralogy of the diorite is conductive, when weathered, to the formation of a open structure which favors strong internal drainage.

Mineralogical Composition

Mineralogical composition as suggested by Cady may be an important soil forming factor. A rock containing minerals with different weathering stabilities would form fractures and holes upon weathering. Furthermore, a condition often cited by clay mineralogist as necessary for the formation of montmorillonite is, the simultaneous release of Ca and Mg ions from ferromagnesium silicates during the weathering of plagioclase feldspar. Thus it is possible that the chemical composition of the hornblende-epidote schist is not the most important factor in the formation of poorly drained Iredell type soils. The greater resistance of epidote to weathering compared to other calcium-aluminum silicates, such as plagioclase, may be an important factor. Epidote has about the same stability to weathering as hornblende, but calcic plagioclase weathers rapidly. It is possible that a hornblende-plagioclase schist, with the same chemical composition as a hornblende-epidote schist, could weather to a very different soil type. An indication of such weathering was observed in this study. A well foliated gneiss exposed in a road cut weathered to bright red, punky rock material. A sample of less weathered friable rock contained a texture and composition similar to the hornblende-epidote gneiss of sample 6. The only difference in composition appears to be the presence of

plagioclase in place of calcic epidote. It is interesting to note that when fresh, both rocks appear similar in hand specimen, and would probably be considered as the same rock by soil mappers.

Conclusions

Boundaries between different soil types are often very sharp. The controlling variable is evidently parent material. The parent material factor is itself composed of a number of variables which can influence soil formation. These variables are: chemical composition, mineralogical composition, rock structure, and rock texture. Chemical composition outweighs the other variables in very basic rocks. Mineralogical composition, particularly the type of mica, is very important in granitic rocks. Rock structure apparently controls the formation of Helena and Mecklenburg soils in the area studied.

Topography

Relief and surface drainage greatly influence the physical appearance of all soil profiles. In general they determine whether the soil is a zonal or azonal soil, but more specifically they control the depth of soil profile, the degree of profile development, the amount of differentiation between horizons, the extent of soil mottling, and the color of the profile. Topography also influences the rate of clay accumulation and the weathering sequence of clay minerals. Only in soils developed from biotite bearing rocks does it influence the formation of the primary clay minerals. In soils of the Louisa type

biotite does not have sufficient time to alter to vermiculite. Kaolinite is the only clay mineral in azonal soils of such catenas, whereas, the deeper, more mature members are characterized by highly vermiculitic profiles. Normally azonal soils contain the same clay minerals as the deeper and more mature zonal and intrazonal soils. Montmorillonite occurs in shallow strongly drained Bremo soils just as it does in deeper more poorly drained Iredell soils, but the amount and distribution of clay is different and controlled by relief and surface drainage. In the Bremo soil vermiculite occurs throughout most of the profile, but in Iredell soils it is restricted to the surface horizon.

One of the conclusions of this section is that relief and surface drainage are important factors in the development of the soils in the Piedmont and Blue Ridge areas. They control not only the gross soil features but also the weathering rate of the clay minerals.

Climate

Climate controls the type and degree of chemical weathering to which a soil is subjected. The close association between climate and soil formation is illustrated by the fact that the climatic zones of the earth have also been designated by soil group names. In the areas studied, the Gray-Brown Podzolic soils characterize the Blue Ridge climate and the Red-Yellow Podzolic soils characterize the Piedmont climate. The chief difference between the two climates is one of temperature. The Blue Ridge average yearly temperature is four degrees

lower than the Piedmont yearly average. The Blue Ridge has cooler summers. It also receives about one inch more precipitation than the Piedmont, but the distribution of rainfall is nearly the same in both areas. Since the climates are not very different, it is not surprizing that the same clay minerals develop from similar rocks in both climatic zones. Kaolin and vermiculite are the characteristic clay minerals developed in well drained soils, and montmorillonite is the typical clay mineral formed from highly basic rocks. Illite is not an important clay mineral in either climatic zone. However, there is a slight difference in the crystallinity of the clay minerals and the amount of kaolinite relative to vermiculite. The Blue Ridge soils appear to contain slightly sharper first order vermiculite peaks, (Compare Figures 9 and 11 to 2 and 4), and, the kaolin peak is often lower than the expected intensity. In the Louisburg soil (Fig. 11) the kaolinite peak is low and diffuse in all horizons, even though the soil is developed from a felsic rock. Both factors suggest that the Blue Ridge climate slightly favors the development of vermiculite over kaolinite and that vermiculite is slightly more resistant to weathering under this climate. These results are similar to those obtained by McLaughlin (1955), who studied the effect of climatic changes on New Zealand soils, but are far less conslusive since the temperature difference is smaller. McLaughlin was able to establish that increased temperature produced larger quantities of kaolinite and that cooler conditions favored the formation of hydrous mica.

CHAPTER IX

FORMATION OF CLAY MINERALS

Introduction

The literature concerning the alteration of primary silicates to soil clay minerals is extensive and often contradictory. Nearly all soil scientists agree that climate controls the end weathering products. Agreement is not nearly so complete concerning the intermediate states involved in the transformation of primary silicate minerals to clay minerals and the subsequent weathering of the clay minerals.

In general there are two schools of thought on the formation of clay minerals. The older concept is that a liquid or colloidal state exists between the primary silicates and the clay minerals. The theory is that clay minerals form from the hydrolysis of alumino-silicates and the formation of colloids which later react to give clay minerals. The second concept Simonson (1949), McLaughlin (1955), and Goldschmidt (1958) is that clay minerals are formed directly from the faces of primary silicates beneath the soil profile in the zone of rock decomposition. Later these clay minerals are destroyed in the upper horizons forming amorphous clay material.

The following is a discussion of the formation of clay minerals in the southern Blue Ridge and Piedmont soils. The major clay minerals are kaolin, vermiculite, and montmorillonite. The term kaolin here refers to the group of kaolin minerals since halloysite was not

distinguished from kaolinite. Illite and gibbsite? are also discussed. Each clay mineral is treated separately. The relationships between parent material, mode of transformation, time transformation, and location of formation in the profile are discussed for each mineral. Also included is a discussion of the weathering of these clay minerals to other clay products.

Montmorillonite

Montmorillonite has been extensively studied and many ideas on conditions needed for its formation have been proposed. Many workers state that the type and amount of cations controls the formation of the mineral. Grim (1953) and Kerr (1950) report that a high Ca content favors montmorillonite and prohibits the formation of kaolinite. Kerr states that the presence of Mg favors the formation of montmorillonite and that iron where it enters the lattice tends to accelerate its formation. The presence of K is found to retard its formation. Others found that drainage controls the formation of montmorillonite (Glenn 1960, Goldschmidt 1958, and Sherman and Uehara 1956). Sherman and Uehara concluded from their studies on weathered olivine basalts in Hawaii that where drainage is restricted to the extent that leaching of bases is inhibited montmorillonite forms. Rapid removal of the bases and lack of them favors kaolinization in the soil. Furthermore they found that there is no difference between a montmorillonite formed in a weathering environment with a high magnesium level and one developed under a high sodium level. They conclude that the

inherent properties of the crystal structure are responsible for its physical properties. Glenn and Goldschmidt independently reported that trioctahedral ferromagnesian mica weathers to vermiculite and then to montmorillonite if the drainage is poor. In this investigation all of these factors were found to affect the formation of montmorillonite and have been related to the primary cause of montmorillonite formation, the nature of the parent rock.

A high base content maintained by poor drainage appears to be the most important factor in the formation of montmorillonite, but as shown in the chapter on soil formation drainage is a secondary effect which is dependent on rock structure, texture, and composition. It is proposed here that montmorillonite formation depends on three related factors: occurrence of basic silicate minerals particularly rich in calcium and aluminum, which have nearly the same weathering stabilities and which occur in rocks with textures and structures that are not conducive to good drainage. The latter two factors were discussed in the previous chapter.

The association of calcium-aluminum silicate minerals with montmorillonitic soils indicates that such mineral compositions affect the formation of montmorillonite. Their importance in the formation can not be completely resolved since the chemical composition of the clay is not known. The aluminum content should be critical since the amount of aluminum substitution in the octahedral and tetrahedral positions controls the charge on the sheet structure. The calcium

ion probably helps to maintain the clay structure at a pH favorable to permit the proper substitution in the structure.

It is often cited in the literature that ferromagnesium minerals weather first to chlorite which in turn go to either vermiculite or montmorillonite, depending on the drainage conditions. Evidence of an intermediate chlorite stage was not found in this study. The data indicate that montmorillonite forms early in the profile, apparently directly on crystal faces of ferromagnesium minerals.

The early formation is suggested by the separation of montmorillonite from slightly weathered basic rock fragments by blendor treatment. Blending appears to remove the clay particles which were adhering to the rock fragments. Rosenberg (1953) found a similar occurrence of montmorillonite in the silt fraction of Iredell soils. Montmorillonite is usually found only in less than 2 micron fractions. Since dispersion of the aggregates was assumed to be complete, he concluded that it occurred either on partly weathered primary crystals or that it was adsorbed on the surfaces of associated quartz. He states that Sideri (1936) found clay could be so strongly adsorbed on quartz that treatment with 0.05N NaOH could not break the bonds. Quartz is not an abundant mineral in these rocks, but the first explanation agrees with data collected in this study.

The formation of three layer clay minerals from amphiboles requires only a minimum amount of alteration, since the amphiboles already consist of a two dimensional three layer structure. Formation of three dimensional sheets requires only the joining of amphibole

chains. That this occurs in nature is shown by the common occurrence of biotite flakes on the crystal faces of hornblende. The formation of an expandable 14 A lattice instead of a non-expandable lattice is difficult to explain without a chemical analysis of the clay minerals.

Vermiculite

Vermiculite and kaolinite occur in the surface horizons of all Blue Ridge and Piedmont samples. Heat and chemical treatment indicate that all the vermiculite is of the atypical variety (Rich and Obenshain, 1955). The vermiculite in this study formed from three different sources: (1) from montmorillonite in strongly leached surface horizons (Fig. 1, A_3 horizon). (2) from biotite by the gradual hydration of the mica structure with an intermediate 12 A mixed-layer clay mineral (Fig. 4). and (3) directly from amphibole minerals in the lower C horizons (Fig. 9).

The formation of vermiculite from montmorillonite in the A horizons is probably the result of removal of trivalent ions (iron and aluminum) from the octohedral position. In many montmorillonites these trivalent ions balance part of the negative charge caused by aluminum substitution in the tetrahedral position. Their removal would increase the negative charge on the sheets which could result in a non-expandable 14 A lattice.

The weathering of biotite to "typical" vermiculite has been well described by Walker (1950). He found that golden yellow biotite flakes in the lower horizons gave 10 A reflections. Dull brown

micaceous material higher in the profile gave only a 14 A peak. The dull brown is always associated with goethite. He states that during this alteration biotite loses iron, Mg, K, and Na and gains water. Ferrous iron is oxidized to its ferric state. In this study "atypical" vermiculite derived from biotite forms late in the profile. The first vermiculite peak appears in the upper C horizon and is low anddiffuse. Golden yellow biotite flakes are very common in the lower C horizon but as Walker found, they do not give a 14 A reflection. A decrease in number of visible mica flakes going up the profile is accompanied by an increase in intensity of the vermiculite peak, so that in the A horizon it is more intense than the kaolin reflection. The x-ray patterns are also characterized by a random mixed-layer illite-vermiculite peak which shifts toward the 14 A peak with decreasing depth in the profile. In blended samples from the lower C horizon only this peak and a weak mica peak occur.

The third source of vermiculite is amphibole minerals. Such vermiculite differs from the previous biotite vermiculite by its distribution and time of formation in the profile. It appears to form in the same manner as montmorillonite, directly from the primary silicate crystals. In soils developed from amphibole bearing rocks the vermiculite peak is very intense in the lowest horizons and in blended specimens of the friable rock. Furthermore, the intensity changes very little going upward in the profile (Fig. 9). These data suggest an early formation for vermiculite.

No conclusive evidence was found in this study to indicate that kaolinite is the end weathering product of the vermiculite. The increase in randomly interstratified clay material in the A horizons of some profiles suggests that vermiculite breaks down to this material but there is no evidence to indicate that it is going to kaolinite. Decrease in vermiculite peak intensity in the A horizon occurs chiefly in soils derived from amphibolites. The vermiculite developed from biotite does not appear to be effected by surface weathering. In fact the vermiculite peak in the A horizons of these soils is more intense and sharper than it was in the lower less strongly leached horizons, suggesting that it is still forming from biotite.

Kaolinite

Kaolinite is the most abundant clay mineral in Piedmont soils. It not only occurs in all soil profiles but also in every soil horizon. Kaolinite is undoubtly the clay mineral most favored under these climatic conditions. The chief source of kaolinite is plagioclase feldspar. Sand (1952) established that under optimum leaching conditions plagioclase went directly to halloysite and that under moderate leaching conditions to sericite which then went to kaolinite. Cady (1950) in his work on Iredell soils in North Carolina found that plagioclase weathered to halloysite. Bates (1962) reports a similar weathering sequence of plagioclase to halloysite in basic rocks in Hawaii. Goldschmidt (1958) states that under poor drainage and in

the presence of Mg and Fe feldspars go to montmorillonite instead of kaolinite. There is no indication in this study that feldspar weathers to montmorillonite. In all poorly drained montmorillonitic soils developed from feldspathic rocks, kaolinite is a major clay mineral. The kaolinite reflection is weak only in soils developed from rocks with a low feldspar content, such as hornblende-epidote schist, and even in these soils the reflection is weak only in the lower horizons.

The early occurrence of kaolinite suggests that it forms directly from the primary crystals. Evidence for this formation is the sharp increase in kaolin content produced by blending friable rock material. In this material there is very little free clay material prior to blending. Blending appears to remove kaolin particles which were adhering to the rock fragments. Theoretical evidence for the formation of clay minerals directly from feldspar crystal faces is cited by De Vore (1958). He believes that the discontinuity caused by the faces on feldspar crystals leave unsaturated tetrahedra. He states that it is theoretically possible for sheet structure clay minerals to form directly on these faces.

Potassium feldspar also weathers to kaolinite but probably alters first to illite. The intermediate illite phase is suggested by the common occurrence of a 10 A reflection in the C horizons of microcline-rich parent rocks. The 10 A material is not normal illite since it often expands to a broad band centered at 12 A after glycol

saturation. Plagioclase feldspar showed no evidence of passing through this intermediate phase.

The formation of kaolinite from muscovite is not resolved for soils of the southern Blue Ridge and Piedmont. Two end products for muscovite have been proposed by different soil investigators. Sand (1956) found that muscovite in the rocks of this area alter directly to kaolinite. Hathaway (1955) and Rich (1958) have shown that muscovite in the same region has altered to dioctahedral vermiculite and that there are no indications that vermiculite is an intermediate phase in the formation of kaolinite. Data collected in this study are not conclusive for either idea but favor weathering of muscovite to kaolinite.

Kaolinite is essentially the only clay mineral in soils developed from quartz-muscovite schist (Cecil soil). In such rocks quartz and muscovite make up 90 percent of the rock. The remainder is composed of albite and a small amount of biotite. Vermiculite is present in the soil but the peak is low and diffuse. Illite is present and is more abundant than in any other Piedmont soil, but is still only a minor clay mineral. The intense kaolinite peak and near absence of other clay minerals suggest that muscovite weathers to kaolinite. The low vermiculite peak can be attributed to the biotite content of the rock, and the illite peak is not intense enough to account for all the muscovite in the parent rock. The conflicting results on muscovite weathering may be due to a difference in grain size of the mica. In the study made by Rich on the Wissahickon schist the muscovite is very fine-grained, whereas in this investigation and in the work by Sand the muscovite is medium- to coarse-grained.

10 A Material

Illite occurs in minor amounts in all soils developed from micaceous rocks. The most intense peaks occur in the A and lower C horizons. Blendor treatment always increases the amount of 10 A clay in the specimens. The increase is probably due to the break down of larger mica flakes. The presence of abundant illite in the A horizon could be due to collapse of vermiculite by K saturation from organic material or the increase could be due to the breaking up of mica particles into clay size material by prolonged weathering.

On the basis of heat and chemical treatment two other types of 10 A material were differentiated. In the C horizons of a few soils a 10 A peak was expanded by glycol treatment to a band centered around 12 A. The material is not as thermally stable as normal illite. In other soils a 10 A peak is formed after glycol treatment. The formation of the peak is accompanied by a decrease in the amount of interstratified kaolin-illite material. This material appears to be associated with plagioclase feldspar and could be caused by halloysite. However, the latter two clay minerals are not very important in Piedmont weathering since they occur only in as low intensity peaks in a few horizons.

Gibbsite

Gibbsite is considered a common weathering product in areas which are subjected to long term chemical weathering. It is often reported as an abundant weathering product of basic rocks (Cady 1950).

Gibbsite is usually identified by DTA curves. In x-ray diffraction patterns the most intense peak occurs at 4.84 A. This d spacing coincides with the third order vermiculite reflection, but in soil vermiculite this reflection is usually absent, so that a peak at 4.84 A could be attributed to gibbsite. In this study a reflection at 4.84 A occurs in some soils but is best developed in the B_1 and B_2 horizons in soils formed from micaceous rocks. In a few specimens an intense reflection occurs when the first order vermiculite peak is rather low and diffuse, indicating that the 4.84 A peak is probably a gibbsite reflection.

SUMMARY

The purpose of this investigation was to obtain data on the clay mineralogy of selected Piedmont and Blue Ridge soils, and to relate these data to the parent rock petrography, topography, and climate, in order to better evaluate the role of these factors in soils formed under prolonged chemical weathering.

The investigation entailed the study of 29 soil profiles from 10 Piedmont and Blue Ridge soil catenas, which were formed from 13 different rock types. The profiles collected in the Piedmont province came from Prince Edward and Nottoway Counties. In the Blue Ridge soils were sampled in Grayson and Carrol Counties.

Soils developed from different rock types can be distinguished on the basis of color, texture, degree of contrast between horizons, and depth to fresh rock. On the basis of clay mineralogy they can be distinguished by the distribution, amount, and type of clay minerals. Light-gray to yellow-brown colors, poor drainage, massive clayey subsoils, and sharp boundaries between horizons are characteristic of soils developed from basic rocks. The occurrence of fresh rock at very shallow depths is also a typical feature of such soils. The existence of fresh rock near the surface in the highly weathered Piedmont is probably due to the retardation of internal drainage by the high content of fine clay and the expandable clay minerals. In general dark red to brown-red colors, deep well drained profiles, and mature soil textures are characteristic of soils formed from

intermediate basic rocks. Bright red, well-drained, micaceous soils are typical of soils formed from felsic micaceous rocks. The rate of weathering of these rocks exceeds that of soil formation by three or four times.

The effect of parent material on clay mineral formation and soil morphology was found to be a complex function of several variables. The variables are: chemical composition, mineralogical composition, rock texture, and rock structure. In soils developed from basic rocks which do not have structures or textures conducive to the formation of strong internal drainage the characteristic clay minerals are kaolin and montmorillonite. In all other soils and in the surface horizon of these soils, the major clay minerals are kaolin and vermiculite. Surprisingly, illite is not an abundant clay mineral in any soil profile, even in soils developed from micaceous rocks.

The most important mechanism for clay mineral formation is apparently directly from the crystal faces of the silicate minerals. Illuviation probably occurs in the upper horizons but accounts for only a small percentage of the clay minerals. Direct mineral alteration is shown by the presence of intense reflections in the lower C horizons and by the formation of sharp peaks after blendor treatment of saprolitic rock material. The source materials of vermiculite and montmorillonite were determined in this study. All ferromagnesium silicate minerals are believed to weather to 14 A clay minerals. The distribution of the clay and the intensity of the peaks is controlled by the rate of weathering of the silicate minerals. Vermiculite formed from biotite does not reach its maximum peak intensity until

the A horizon, whereas vermiculite formed from amphiboles has an intense peak in the lower horizon. The formation of montmorillonite verses vermiculite is controlled by the four parent material variables listed above. Drainage was found to be a secondary control in montmorillonite formation and not the primary cause.

The chief source of kaolin clay is from the weathering of feldspars. Muscovite may also be a source of kaolin since most kaolinitic soils are associated with muscovite-quartz schists. The near absence of other clay minerals in soils developed form such rocks suggests a possible muscovite source for the kaolinite. However, these rocks are difficult to work with since they weather to great depths and a study of their weathering products must include a great thickness of material, whereas, in more basic rocks the complete cycle of weathering often occurs in less than 6 feet.

Topography was found to affect the degree of profile development, color and soil texture. It also controls the rate of clay mineral accumulation and weathering. The climates of the Blue Ridge and Piedmont are most favorable for the formation of kaolin clay minerals. However, while the results are inconclusive, kaolinite formation is apparently favored more under the Piedmont climate. Vermiculite peaks are intense in nearly all Blue Ridge profiles, and kaolinite peaks are low in intensity even in soil formed from granitic rocks.

The main contributions of this investigation have been to establish that parent rock has an important effect on soils formed under prolonged chemical weathering; and to provide for the first time a

detailed petrographic description of source rocks for a number of Piedmont and Blue Ridge soils. This has led to the formation of several new soil catenas and the reorganization of several others. The study has also contributed new clay mineral data for several Piedmont and Blue Ridge soils.

FUTURE WORK

Many questions have been raised by this study and much work still remains to be done. While the factors conducive to the formation of montmorillonite have been determined, the changes in crystal chemistry which led to the formation of an expandable 14 A structure have not been determined. The role of texture, rock structure, and mineralogical composition have not been completely delineated in soil formation. These factors may be particularly important in the formation of the Vance and Fluvanna soils in the Piedmont area studied and possibly the Rabun soil in the Blue Ridge area. From literature references the Orange and Davidson soils of the northern Piedmont may also be controlled by texture, rock structure, and mineralogy. The relationship of poorly drained Worsham soils to granitic rock catenas is still unclear but it appears that it may be an alluvial soil with no relationship to the parent rock.

These are just a few of the questions which remain to be answered concerning Piedmont soil and clay mineral formation. Unfortunately many answers must await a sampling program in which core drilling is employed so that a continuous profile can be obtained down to and including fresh parent rock.

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APPENDIX I

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PIEDMONT PROFILES

Code for Mineralogical Data Reported in Tables

Abbreviation of Mineral Names

Kaol - kaolin minerals

Verm - vermiculite

Mont - montmorillonite

Designation of Interstratified Minerals

K/I - interstratified kaolin and illite

I/V - interstratified illite and vermiculite

K/V - interstratified kaolin and vermiculite

Indication of Quantity

The relative intensity in counts per second is listed for the first order reflection of each mineral. The intensities were measured from the base of the peak corrected to general background intensity.

Designation of Treatments

B - indicates blendor treatment

M - indicates mixing with a Fisher laboratory mixture.

APPENDIX I-A

CATENAS DEVELOPED ON MAFIC ROCKS

IREDELL CATENA

Sample #2 BREMO LOAM, ERODED HILLY PHASE (12 to 25% slope)

The following a profile in a road cut one mile east of the junction of State Highways 307 and 628 in Nottoway County.

A — 0 to 10 inches, dark grayish-brown, very friable loam.

B — 10 to 17 inches, yellow brown, friable, fine, heavy loam to light fine sandy clay loam; when wet slightly sticky, weak, fine to medium subangular blocky structure.

C_1 — 17 to 20 inches, mottled, strong brown, yellow brown, black, and yellow, friable loam soil material; contains a large amount of weathered hornblende gneiss fragments.

C_2 — 20 inches, strong brown, yellow red, black, yellow brown, white and olive brown, partly weathered hornblende gneiss rock material.

The parent rock is steeply dipping, well-foliated, dark greenish-black, medium to fine-grained hornblende schist. Hornblende, granular epidote, quartz and plagioclase (An 37) are the essential minerals. Biotite is also present and is closely associated with hornblende Colorless, granular epidote and minor amounts of sphene (largely altered to leucoxene) are intergrown with hornblende. Magnetite and pyrite are present as accessory minerals. A mode of the thin sections contains the following:

Hornblende	Epidote	Quartz	Plagioclase	Biotite	Accessory
43.3%	21.0	12.4	18.0	5.1	1.0

CLAY MINERALOGY

Relative intensities of first order reflection profile #2.

Horizon	Kaol.	Verm.	Mont.	K/V	K/I	I/V	Quartz
A	150	450	-	90	-	-	200
B	400	350	50	-	-	-	-
C_1	300	400	-	-	-	-	-
C_2	500	475	25	-	-	-	-
D	400	-	275	-	-	-	-

IREDELL CATENA

Sample #1 MECKLENBURG LOAM, UNDULATING PHASE (2 to 7% slope)

The following describes a profile of this soil covered by grassland, 30 yards east of the junction of State Highways 307 and 628 in Nottoway County.

A_p 0 to 9 inches, grayish-brown (10YR 4/2 moist), very friable loam; weak, very fine to fine, granular structure; few angular quartz pebbles and many small and medium roots; clear, smooth boundary.

B_2 9 to 20 inches, yellowish-brown (10YR 5/6), firm clay; moderate, medium to fine, angular blocky structure; plastic and sticky when wet, extremely hard when dry; distinct clay films; contains a few fine roots.

B_3 20 to 26 inches, mottled strong brown, yellow brown, black, dark grayish-brown, yellow red, and olive brown, firm, plastic, slightly sticky clay with a high content of very fine sand; weak, coarse to medium, angular blocky structure; few very fine to medium roots; gradual, wavey boundary.

C 26 to 33 inches, mottled black, olive brown, strong brown, and yellow brown, friable fine sandy loam soil material; structure controlled by the weathered rock; clear, smooth boundary.

B_2 33 to 35 inches, mottled strong brown, yellow brown, light gray, and gray, extremely stick and extremely plastic, translocated clay.

R 35 to 35 1/8 inches, dark red, very hard iron pan.

The parent rock is steeply dipping, well-foliated, dark greenish-black, fine-grained hornblende schist. Dark green hornblende and quartz are the chief constituents; plagioclase (An 40) and granular eipdote are also present. Magnetite, sphene, and leucoxene occur as accessory minerals. A mode of the thin section contains the following:

Hornblende	Quartz	Epidote	Plagioclase	Accessory
63.0%	22.2%	6.0	5.4	2.3

CLAY MINERALOGY

Relative intensities of first order reflections of profile #1.

Horizon	Kaol.	Verm.	Mont.	K/V	K/I	I/V	Quartz
A_p	210	350	-	-	-	-	150
B_2	425	-	200	-	-	-	-
B_3	700	-	300	-	-	-	-
C	250	-	250	-	-	-	-

IREDELL CATENA

Sample #6 ZION FINE SANDY LOAM, UNDULATING PHASE (2 to 7% slope)

The following describes a profile in a railroad cut 200 yards south of the junction of State Highway 47 and County road 699 in Prince Edward County.

A_p 0 to 7 inches, brown to dark brown, friable, fine sandy clay loam; weak, very fine granular structure; contains many medium size roots; gradual, wavy boundary.

A_3 7 to 10 inches, brown, friable, fine sandy loam; weak, fine granular structure; contains a few fine roots and many small black concretions; sharp, smooth boundary.

B_2 10 to 15 inches, yellowish-brown, plastic, slightly sticky clay extremely hard when dry; weak, coarse, subangular blocky structure.

B_3 15 to 22 inches, brown, plastic clay; distinct mottles of grayish-white, and black; weak, coarse, subangular blocky structure; sticky when wet extremely hard when dry.

C 22 to 27 inches, mottled, black, olive green, yellowish-brown gray and black green, friable, sandy clay; very weak, medium, subangular blocky structure; structure of parent material is noticeable; slightly sticky and plastic when wet.

C_{1x} 27 to 27 1/2 inches, mottled, white, grayish-white and gray; highly plastic, massive clay; sticky when wet; occurs along the boundary between C and D, and as vertical veins in the D horizons.

C_4 27 1/2 to 41 inches, light green, dark green, and white, loose, fine sandy hornblende schist rock material.

The parent material is moderately dipping, well-foliated, dark greenish-black, fine-grained hornblende schist (1/4 to 1/2 mm). Dark green hornblende and granular epidote are the chief constituents. Weathered plagioclase (An ?) and quartz are also present. Sphene and apatite occur as accessory minerals. A mode of the thin section contains the following:

Hornblende	Epidote	Quartz	Plagioclase
62%	28	5	5

CLAY MINERALOGY

Relative intensities of first order reflections of profile #6.

Horizon	Kaol.	Verm.	Mont.	K/I	I/V	K/V	Quartz
A_p	200	320	20	-	-	-	90
A_3	340	240	140	-	-	-	-
B_2	600	-	300	-	-	-	-
B_3	600	-	540	-	-	-	-
C_1	520	-	320	-	-	-	-
C_4	50	-	-	-	-	-	-

IREDELL CATENA

Sample #4 IREDELL SANDY LOAM, ROLLING PHASE (7 to 12% slope)

The following describes a profile exposed in a road cut in Nottoway County, one mile east of the junction of State Highways 307 and County road 628. The profile is covered by a forest of mixed hardwoods.

A — 0 to 5 inches, light grayish-brown, sandy loam; possibly mixed with adjoining soils which have slumped down slope.

B_1 — 5 to 13 inches, yellowish-brown, very plastic, and very sticky when wet, extremely hard when dry; massive clay.

B_2 — 13 to 22 inches, mottled yellow brown, light brownish-yellow and yellowish-red, massive, extremely plastic and sticky clay; red and light yellowish-brown mottles increase in number and size with depth; contains black concretions and black mineral films.

C_1 — 22 to 30 inches, mottled, light yellowish-brown, brown, dark reddish-brown, gray, grayish-white and bluish-black, firm plastic, sticky clay; weak, subangular blocky structure, which is strongly influenced by the rock structure.

D_1 — 30 inches +, mottled, light yellowish-brown, brown, reddish-brown and blue black; concentricly weathered, diabase rock material.

The parent material is very fined grained (1/4 mm) olivine diabase, composed chiefly of laboradorite (An 56-66), interstitial augite and olivine which is strongly altered to bowlingite, magnetite, and chlorite. The rock occurs as a dike which is probably less than 10 feet in width. A mode of the thin section contains the following:

Plagioclase	Augite	Olivine	Chlorite	Accessories Bowlingite Magnetite
50%	30%	11%	3.0%	6.2%

CLAY MINERALOGY

Relative intensities of first order reflections of profile #4.

Horizon	Kaol.	Verm.	Mont.	K/I	I/V	K/V	Quartz
A	400	-	175	-	-	-	40
B_1	600	-	175	-	-	-	-
B_2	500	-	220	-	-	-	-

IREDELL CATENA

Sample #11 IREDELL FINE SANDY LOAM, UNDULATING PHASE (2 to 7% slope)

The following describes a profile in a railroad cut just below the bridge on County road 671 on the Charlotte-Prince Edward County line.

18 inches, mixed soil material which was deposited on the profile during cleaning of the roadbed.

A_p 0 to 5 inches, brown, very friable, fine sandy loam; with faint mottles of black and yellow brown; weak, fine, granular structure; many medium size roots, sharp, smooth boundary.

A_3 5 to 8 inches, grayish-brown, friable, fine sandy loam; weak, fine, granular structure; clear, smooth boundary.

B_1 8 to 32 inches, yellow brown, plastic sticky clay; moderate, medium, angular blocky structure; hard when dry.

B_2 32 to 60 inches, olive brown to greenish-gray, with faint mottles of brown and gray, when wet extremely plastic and sticky clay; weak, coarse, subangular blocky to massive; extremely hard when dry; sharp, smooth boundary.

C_1 60 to 65 inches, parent material mottles of brown, greenish-brown and white; very plastic, heavy clay; weak, fine, granular structure.

C_2 65 to 85 inches, parent material mottles of dark yellow, greenish-yellow, brown and white, soft punky plastic clay; relic structure of parent diabase rock.

C_3 85 to 96 inches +, parent material mottles of dark orange, brown light green and white, soft, slightly plastic, clay; relic structure of parent diabase rock.

The parent rock is a dark green, coarsed-grained olivine diabase. The main constituents are laboradorite (An 50-70), augite, and olivine. The olivine is strongly altered to magnetite, bowlingite, serpentine, and iddingsite. A very small amount of quartz is also present, probably formed during the alteration of olivine. A mode of the thin sections contains the following:

Leboradorite	Augite	Olivine	Serpentine	Accessory
60.5%	20.4	1.4	8.0	10.0

CLAY MINERALOGY

Relative intensities of first order reflection of profile #11.

Horizon	Kaol.	Verm.	Mont.	K/I	I/V	K/V	Quartz
A_p	400	100	100	-	-	-	10
A_3	500	110	90	-	-	-	50
B_1	1000	-	400	-	-	-	-
B_2	1050	-	1700	-	-	-	-
C_1	850	-	1200	-	-	-	-
C_2	575	-	600	-	-	-	-
C_3	1100	-	760	-	-	-	-

IREDELL CATENA

Sample #12 IREDELL FINE SANDY LOAM, UNDULATING PHASE (2 to 7% slope)

The following describes a profile of this soil covered by grassland, 30 yards east of the junction of State Highways 307 and 628 and ten from sample 1 in Nottoway County.

A_p 0 to 7 1/2 inches, light grayish-brown, very friable loam; weak, fine granular structure; clear, smooth boundary.

B_2 7 to 18 1/2 inches, mottled, brown, black, green and olive, firm clay; moderate, medium, angular blocky structure; extremely hard when dry and plastic and sticky when wet.

B_{2m} 18 1/2 to 26 inches, mottled, yellowish-brown, gray, black and olive green, massive clay; extremely plastic and sticky when wet.

C 26 to 30 inches, green, yellow, white, and yellow brown friable to firm, highly weathered, sandy, hornblende gneiss.

C_x 30 inches, mottled, yellow brown, dark brown and black plastic clay occurs at the boundary between C and D.

The parent material is steeply dipping, well-foliated, greenish-black hornblende schist. The rock was so friable that no thin section could be made. However, the sample was taken very near to sample #1 and appears to have a similar composition. It therefore probably contains hornblende, gramular epidote, quartz, and plagioclase.

CLAY MINERALOGY

Relative intensities of first order reflections of profile #12.

Horizon	Kaol.	Verm.	Mont.	K/I	I/V	K/V	Quartz
A	200	250	-	-	-	-	80
B_2	500	-	250	-	-	-	-
B_3	575	-	250	-	-	-	-
C	350	-	240	-	-	-	-

IREDELL CATENA

Sample #29 IREDELL FINE SANDY LOAM, UNDULATING ERODED PHASE.

The following describes a profile of this soil covered by a forest of pines along Country road 664, 3/4 mile north of the junction of County roads 664 and 668 in Prince Edward County.

A — 0 to 4 1/2 inches, light greenish-gray, very sandy clay loam; very fine, granular structure; contains a large amount of organic material.

B — 4 1/2 to 8 inches, gray mottled, yellow brown, olive, brown, and dark green, plastic, sticky, clay loam; moderate, coarse, angular blocky structure; contains a few black hornblende grains.

C_1 — 8 to 11 1/2 inches, mottled, brown, yellow-brown, and olive, friable clay; mixed with partly weathered green and black hornblende gneiss rock fragments.

C_2 — 11 to 26 inches, green, black and white hornblende gneiss rock material mixed with veins and plugs of brown and yellow brown, plastic, sticky clay.

The parent material is gently dipping, well-foliated, fine-grained hornblende schist, composed of about 55 percent hornblende and about 25 percent epidote. The other less resistance minerals have already been removed by weathering. The epidote is the nonferrian variety of zoisite. The crystal are lath shaped and commonly have anomalous blue interference colors.

CLAY MINERALOGY

Relative intensities of first order reflections of profile #29.

Horizon	Kaol.	Verm.	Mont.	K/V	K/I	I/V	Quartz
A	250	275	-	90	-	-	75
B	425	225	75	-	-	-	15
C_1	600	200	100	-	-	-	-
C_2	450	100	100	-	-	-	-

APPENDIX I-B

CATENAS DEVELOPED ON INTERMEDIATE ROCKS

HELENA CATENA

Sample #31 HELENA FINE SANDY LOAM, UNDULATING PHASE (0 to 5% slope)

The following describes a profile of this soil covered by grassland along County road 664 just north of the junction of County roads 664 and 668 in Prince Edward County.

A_p 0 to 9 inches, grayish-tan, very friable sandy loam; very fine, granular structure; contains a few angular quartz grains.

B_1 9 to 13 inches, yellow brown, silty loam with faint mottles of dark brown; fine granular structure; contains a few angular quartz fragments.

B_2 13 to 30 inches, yellow brown with faint, fine mottles of brown and gray; firm plastic, slightly sticky clay; moderate, medium angular blocky structure; contains a number of small silver mica flakes and a few granular quartz grains.

C_1 30 to 33 inches+, highly weathered, brownish-green, hornblende mica schist rock material.

The parent material is a highly weathered greenish-brown, medium-grained biotite-hornblende schist. The rock has well developed schistosity and marked alignment of the biotite flakes. Common minerals are quartz, plagioclase (An 33), biotite and hornblende. Almost all of the biotite has weathered to vermicular biotite.

The hornblende has not been altered by the weathering processes. Magnetite is generally closely associated with the biotite. A small amount of magnetite has been altered to brownish-red limonite. Epidote is present only in accessory amounts. The rock was too highly weathered to make an accurate point. In the field it had nearly horizontal foliation.

CLAY MINERALOGY

Relative intensities of first order reflections of profile #31.

Horizon	Kaol.	Verm.	Mont.	K/I	I/V	K/V	Quartz
A	100	150	-	-	-	100	-
B_1	800	575	-	-	-	-	-
B_2	1200	50	125	-	-	-	-
C_1	850	-	175	-	-	-	-

LLOYD CATENA

Sample #14 BREMO LOAM, ERODED STEEP PHASE (12 to 25% slope)

The following describes a profile in a road cut 2 tens of a mile south of Spring Creek on County Road No. 664 in Prince Edward County.

A — 0 to 3 1/2 inches, brown, friable sandy loam; fine, granular structure; contains a number of angular pebbles.

C_1 — 3 1/2 to 11 inches, reddish-brown, friable fine sandy loam; fine, granular structure; contains a few fragments of partly weathered amphibole gneiss.

C_3 — 11 to 28 inches, dark red, friable sandy clay loam; fine granular structure, largely controlled by the foliation of the parent material;

D_1 — 28 inches +, red, white, black and brownish-red highly weathered, hard rock material; feldspar grains are weathered, yellowish-white.

The parent material is a strongly weathered yellow-white, medium-grained, garnet-amphibolite gneiss. The rock contains mainly pleochroic dark green to grayish-white hornblende intergrown with colorless cummingtonite, quartz and plagioclase (An 26). Both amphiboles have well developed fine cross cutting striations which are parallel to (001) and make a 76° angle with the (110) cleavage. Magnetite is very abundant and is closely associated with the amphiboles. Garnet porpyroblasts 2 mm across, partly weathered to limonite, are common. No point count was made of the slides due to the high degree of weathering, but the rock contains about 20% hornblende, 35% plagioclase, 35% quartz, and about 10% cummingtonite.

CLAY MINERALOGY

Horizon	Kaol.	Verm.	Illite	K/I	I/V	K/V	Quartz
A	200	175	-	-	-	70	45
C_1	260	230	-	-	-	80	-
C_3	220	130	-	-	-	70	-
D_2	100	100	40	-	-	115	-

LLOYD CATENA

Sample #16 LLOYD CLAY LOAM, ERODED UNDULATING PHASE (2 to 7% slope)

The following describes a profile in a road cut 1/2 mile north of the junction of County roads 664 and 665 along County road 665 in Prince Edward County.

A_p 0 to 5 1/2 inches, reddish-brown, friable clay loam; fine, granular structure; contains many small roots.

A_3 5 1/2 to 11 inches, light reddish-brown, friable loam; fine, granular to weak, medium, subangular block structure.

B_1 11 to 18 inches, reddish-brown, firm clay loam; moderate, medium, subangular blocky structure.

B_2 18 to 41 inches, dark red, firm clay; medium, angular blocky structure; common, prominent clay films.

C 41 inches +, mottled, dark red and yellowish-red, friable weathered soil material; no definite structure.

The parent material is gently dipping green and white very fine-grained garnet amphibolite gneiss; composed mainly of amphibole, quartz and plagioclase (An ?). The highly weathered nature of the rock makes the positive identification of the amphiboles impossbile. However a hornblende-actinolite amphibole can be identified on the bases of its pleochroism (green to light grey) and inclined extinction ($20^{o} < c$). A second amphibole with less pleochroism (thick section) and a lower extinction angle may indicate the presence of the cummingtonite-grunerite series. The rock was too highly weathered to determine the mode but consists of about 55 percent amphibole, 25 percent quartz and 20 percent plagioclase.

CLAY MINERALOGY

Horizon	Kaol.	Verm.	Illite	K/I	I/V	K/V	Quartz
A_p	130	75	25	75	75	-	-
A_3	250	170	-	75	100	-	-
B_1	375	120	-	-	-	100	-
B_2	420	100	-	-	-	70	-
C	420	100	-	-	-	70	-

LLOYD CATENA

Sample #28 LLOYD CLAY LOAM, ERODED ROLLING PHASE (12 to 25% slope)

The following describes a profile of this soil in a pasture field, 1/2 mile east, northeast of the Prince Edward-Charlotte County line.

A — 0 to 8 inches, dark reddish-brown, friable clay loam; fine, granular structure; contains many small highly weathered rock fragments.

C_1 — 8 to 15 inches, reddish-brown, friable clay loam; fine, granular structure; contains many weathered basic rock fragments, some of which are 3 cm across.

C_3 — 15 to 22 inches +, reddish-brown, friable soil material; fine, granular structure, contains many large partly weathered garnet amphibole gneiss rock fragments.

The parent material is gently dipping, yellowish-white and dark green, coarse-grained garnet amphibolite gneiss. The main constituents are pleochroic dark green to light yellow green hornblende, weakly pleochroic brownish-gray to gray cummingtonite, and garnet. All minerals in the slide are either altered to or coated with brown limonite. Other less abundant minerals are quartz, magnetite and chlorite. The latter two are closely associated with cummingtonite. Epidote is present only in accessory amounts. Cummingtonite was identified on the bases of its strong birefringence, large positive 2V, gray color, low extinction angle and well developed cross cutting striations which make an angle of 76° with the (110) cleavage. The rock was too highly weathered to make an accurate point count but consists of about 30 percent cummingtonite, 30 percent hornblende, 20 percent limonite, 10 percent garnet, 6 percent chlorite, magnetite, and quartz.

Clay Mineralogy

Relative intensities of first order reflections of profile #28.

Horizon	Kaol.	Verm.	Illite	K/I	I/V	K/V	Quartz
A_p	235	70	-	75	30	-	35
BC	105	250	-	-	-	70	25
C_1	270	140	-	-	-	70	-
C_3	250	90	-	100	40	-	-

APPENDIX I-C

CATENAS DEVELOPED FROM SILICIC ROCKS.

MADISON CATENA

Sample #8 LOUISA SANDY LOAM, ERODED HILLY PHASE (12 to 20% slope)

The following describes a profile in a road cut, 40 yards south of the South Fork of Spring Creek on County Road 663 in Prince Edward County.

A_p 0 to 16 inches, brown to dark brown, friable sandy clay loam; weak, fine granular structure; contains a few small golden and black mica flakes; many medium to fine roots.

C_1 16 to 23 inches, mottled, brown, yellow brown and dark brown, friable fine sandy clay loam; weak, fine granular structure; a few shiny mica flakes; contains mottles of dark brown material inherited from the rock.

C_2 23 to 30 inches, dark brown friable highly weathered rock material with mottles of olive green and black; contains many small black mica flakes.

C_3 30 to 120 inches, dark brown and white, friable coarse sandy biotite gneiss rock material; feldspar grains up to 5 mm.

The parent material is highly weathered, mottled yellow white to dark brown, medium-grained, biotite gneiss. The rock is composed chiefly of plagioclase (An 28), quartz, and biotite (1/8 by 1/4 mm). Light yellow granular epidote, which is usually associated with biotite, is also common. Muscovite, magnetite, and garnet are minor accessory minerals. The garnet crystals are altered to yellow red limonite along fractures and on the crystals faces. The rock is too highly weathered to make a modal analysis but contains about 40 to 45 percent plagioclase, 35 to 40 percent quartz, 10 percent biotite, and 2 to 5 percent epidote.

CLAY MINERALOGY

Relative intensities of first order reflections of profile #8.

Horizon	Kaol.	Verm.	Illite	K/I	I/V	K/V	Quartz
A_1	540	220	25	100	115	-	20
C_1	270	240	-	70	100	-	35
C_2	275	210	110	100	100	-	-
C_3	240	110	120	70	70	-	-

MADISON CATENA

Sample #13 LOUISA FINE SANDY LOAM, SEVERELY ERODED HILLY PHASE (12 to 25% slope)

The following describes a profile in a road cut, 3 tens of a mile north of Spring Creek on County Road No. 664 in Prince Edward County.

A — 0 to 2 1/2 inches, brown, friable clay loam; very fine to fine granular structure; many fine and medium roots.

B — 2 1/2 to 12 inches, reddish-brown, friable clay loam; weak, medium, subangular blocky structure; contains a few small mica flakes.

C_1 — 12 to 18 inches, red, friable clay loam; fine, granular structure; mica flakes are common.

C_3 — 18 to 39 inches, parent material mottles of red, black, and light yellow, friable sandy loam; structure controlled by the foliation of the rock; contains many biotite and muscovite flakes.

The parent material is light brown and yellow white, friable, highly weathered biotite-muscovite gneiss. The rock contains quartz, coarse-grained feldspar, biotite, muscovite, and chlorite. The rock has horizonal foliation and strong lineation of the mica flakes. A modal analysis could not be made of this rock.

CLAY MINERALOGY

Relative intensities of first order of profile #13.

Horizon	Kaol.	Verm.	Illite	K/I	I/V	K/V	Quartz
A	440	20	60	80	60	-	40
B_2	470	40	60	80	50	-	-
C_1	375	40	5	90	-	-	-
C_3	390	-	40	50	-	40	-
C_4	200	50	30	80	-	70	-

MADISON CATENA

Sample #30 WILKES SANDY LOAM, ERODED HILLY PHASE (7 to 12% slope)

The following describes a profile of this soil on County road 664, 1 mile south of the junction of County roads 664 and 665 in Prince Edward County.

A_p 0 to 4 inches, very light reddish-brown, very friable sandy loam; very fine, granular structure.

B_2 4 to 15 inches, yellowish-red to red, firm, clay loam; fine, subangular blocky structure; contains 2 to 5% silver mica flakes.

B_3 15 to 23 inches, brownish-red to red, friable silty clay loam; weak, subangular blocky to platy structure of the parent material; contains many silver mica flakes.

C_1 23 to 31 inches, brown and red friable rock material; structure controlled by the foliation of the rock; contains partly weathered white feldspar grains up to 2 cm, many small biotite flakes, and a few quartz grains.

C_2 31 inches +, light grayish-tan, very friable muscovite-biotite gneiss rock material.

The parent material is a black and white, medium-grained, biotite-muscovite gneiss. The chief constituents are quartz, plagioclase, microcline, muscovite, and biotite. The biotite flakes are fine-grained (1/8 by 1/2) and closely associated with coarser muscovite flakes (3 mm). Minor accessory minerals are epidote which is closely associated with biotite, pyrite, magnetite and limonite. The rock was too highly weathered to make a modal analysis but is composed of about 35-40 percent quartz, 20-25 percent plagioclase, 15-20 percent muscovite, 5-10 percent biotite, and 5-10 percent microcline.

Relative intensities of first order reflections of profile #30.

Horizon	Kaol.		Verm.		Illite		K/V		K/I		I/V		Quartz
	B	M	B	M	B	M	B	M	B	M	B	M	
A_p	600	480	540	200	130	30	-	80	120	-	200	70	40
B_2	900	1200	140	140	20	-	100	100	-	-	-	30	-
B_3	325	460	100	40	70	20	-	40	150	-	-	-	-
C_1	850	300	120	60	50	20	80	100	-	-	-	80	-
C_2	450	-	-	-	140	40	-	-	190	100	-	100	-

MADISON CATENA

Sample #7 MADISON LOAM, ERODED HILLY PHASE (12 to 20% slope)

The following describes a profile in a road cut, 40 yards north of South Fork of Spring Creek and 1/2 mile south of County Road 663 in Prince Edward County.

A_p 0 to 12 inches, brown to light brown, slightly hard, silty clay loam; very fine, granular structure; contains a few angular quartz pebbles.

A_3 12 to 17 inches, light brown, slightly hard, clay loam; very fine, granular structure; contains a few pebbles size quartz grains and a few shiny mica flakes.

B 17 to 43 inches, yellow brown and reddish-brown, friable clay loam; weak, fine granular structure, partly controlled by the parent material; many partly weathered quartz and feldspar fragments; contains a few golden mica flakes.

C_2 43 to 55 inches, yellow brown to light brown (wet), friable sandy clay; structure controlled by parent material; soil is smooth and slick, contains many partly weathered mica gneiss rock fragments.

C_3 55 to 80 inches, highly weathered brownish-yellow and white biotite and muscovite gneiss rock material; contains many small mica flakes.

The parent material is very highly weathered reddish-white, very coarse-grained biotite gneiss, composed mainly of microcline, quartz, and biotite. The rock is too highly weathered to make a thin section, but a megascopic examination indicates that it consists chiefly microcline, quartz and contains about 5 percent biotite.

CLAY MINERALOGY

Relative intensities of first order reflections of profile #7.

Horizon	Kaol.	Verm.	Illite	K/I	I/V	K/V	Quartz
A_p	135	180	20	-	-	80	50
A_3	120	120	-	-	-	80	135
B_1	325	150	100	-	-	75	-
C_2	460	50	80	150	80	-	75
C_3	300	50	60	140	40	-	-

MADISON CATENA

Sample #3 MADISON SANDY LOAM, ROLLING PHASE (7 to 12% slope)

The following describes a profile in a new road cut, two miles south of the junction of U. S. 460 and County Road 603 in Nottoway County.

A_p 0 to 8 inches, brown to dark brown, very friable sandy loam; (medium to coarse sand); fine to very fine, granular structure; many large and medium size roots and a few fine roots; clear, smooth boundary.

B_1 8 to 12 inches, yellowish-red (5YR 4/6), friable, slightly hard slightly sticky, sandy clay loam; weak to moderate, medium, subangular blocky structure; small mica flakes are common.

B_2 12 to 20 inches, red (25YR 4/6), with thin reddish-brown clay films; firm to friable, sticky, light clay loam; moderate, medium, subangular blocky structure; contains 15 to 20% small shiny mica flakes; gradual, smooth boundary.

B_3 20 to 26 inches, red, friable, highly micaceous, silt loam to loam; coarse, weak angular blocky structure, that is largely rock controlled.

C_1 26 to 34 inches, red (25 YR 4/6-5/6), with mottles of yellow red, black, and white; highly micaceous, sandy loam soil material; structure is the same as the parent rock; contains 30% mica flakes and a few pebbles size quartz grains.

C_2 34 to 44 inches, mottled with parent material, mottles of yellow red, reddish-yellow, and black, sandy loam soil material; containing 50 to 70% black and gold micaceous material; structure is controlled by the rock.

C_3 44 to 60 inches, brownish-yellow (10YR 6/5), strong brown (7.5YR 5/6) and black, very friable, highly weathered, micaceous rock material.

C_4 60 to 80 inches, highly weathered, white, black and brownish-yellow, friable sandy loam; micaceous rock material; small pebbles of quartz are common.

The parent material is gently dipping, well-foliated, mottled black to white, coarse-grained biotite gneiss composed chiefly of quartz and plagioclase (An 30). Other minerals are microcline (3 to 6 mm), biotite (2 to 3 mm) and granular, yellowish-green epidote which is closely associated with biotite. Calcite, sphene, pyrite, magnetite, and hornblende are present in very minor amounts. The latter generally has alteration rims of biotite. A mode of the thin sections contains the following:

Quartz	Plagioclase	Microcline	Biotite	Epidote	Accessory
46%	33%	10%	8%	2%	1%

CLAY MINERALOGY

Relative intensities of first order reflections of profile #3.

Horizon	Kaol.		Verm.		Illite		K/V		I/V		K/V		Quartz
	B	M	B	M	B	M	B	M	B	M	B	M	
A_p	640	250	475	275	-	-	-	-	-	-	140	75	70
B_1	940	325	200	150	-	-	100	-	170	-	-	100	60
B_2	660	310	70	100	-	-	-	-	-	-	90	120	-
B_3	520	270	-	-	-	-	160	100	-	-	-	-	-
C_1	800	220	120	60	-	20	-	125	60	-	200	-	-
C_2	600	200	40	50	60	-	100	110	100	-	-	-	-
CC_3	650	130	100	-	-	-	125	-	-	-	-	100	-
C_4	100	200	-	-	-	-	100	-	200	-	-	125	-

MADISON CATENA

Sample #10 MADISON FINE SANDY LOAM, UNDULATING PHASE (2 to 7% slope)

The following describes a profile in a railroad cut, 1/4 mile south of County Road No. 671 in west Charlotte County.

A_p 0 to 22 inches, yellowish-white, very friable sandy loam; weak very fine granular structure; contains many coarse, medium and fine roots; clear, wavy boundary.

B_1 22 to 32 inches, yellowish-brown, friable clay, with a few faint medium, size mottles of reddish-brown; weak, fine, subangular blocky structure; quartz pebbles are common.

B_2 32 to 43 inches, dark yellowish-brown, frim clay, with faint medium, size mottles of dark reddish-brown; moderate, medium subangular blocky structure; contains a few quartz pebbles.

B_3 43 to 60 inches, dark yellowish-brown, firm clay with many distinct, coarse red mottles; moderate, medium, angular blocky structure.

C_1 60 to 92 inches, prominent coarse mottles of red, yellow, yellow brown and brownish-red, very firm clay; weak, fine, subangular blocky structure.

C_2 92 to 138 inches, dark red, firm clay, with parent material mottles of white and yellowish-white; weak platy structure controlled by the structure of the parent rock.

C_3 138 to + inches, red, soft friable soil material continuing specks and thin layers of yellowish-white, clay (relic feldspar); structure controlled by the parent rock; contains many extremely fine grained golden mica flakes.

The parent material is gently dipping, grayish-white and black, fined-grained (1/2 mm) biotite gneiss. The rock has a finely banded gneissic structure and pronounced foliation. Plagioclase (An 30), quartz, and biotite (1/4 by 1/5 mm) are the essential minerals. Pleochroic light yellow to colorless epidote is closely associated with the biotite, and a colorless epidote occurs in the feldspar.

Muscovite (1/2 by 1 mm) and small garnet grains (1/2 mm) are also present. Other minor accessory minerals are magnetite and zircon. A point count of the thin section gives the following values:

Plagioclase (AN 30)	Quartz	Biotite	Epidote	Muscovite
47.6%	31.1%	18.2%	2.2%	2.6%

Espenshade and Potter (1960) have published a chemical analysis for a biotite gneiss mineralogy, sampled less than a mile from this profile. The analysis is given on page 38 number V, p. 102.

SiO_2	64.85
Al_2O_3	14.86
Fe_2O_3	2.31
FeO	3.70
MgO	2.03
CaO	4.31
Na_2O	3.44
K_2O	2.58
H_2O -	0.07
H_2O +	0.84
TiO_2	0.68
CO_2	0.01
P_2O_5	0.14
F	0.04
MnO	0.14
TOTAL	100.00
Less O for F	.02
TOTAL	99.98

CLAY MINERALOGY

Relative intensities of first order reflections of profile #3.

Hor.	Kaol.			Verm.			Illite			K/I			I/V			K/V			Quartz
	<2 Mm	2 Bm	4 Bm	2 Mm	2 Bm	4 Bm	2 Mm	2 Bm	4 Bm	2 Mm	2 Bm	4 Bm	2 Mm	2 Bm	4 Bm	2 Mm	2 Bm	4 Bm	2 Mm
A_p	150	400	200	230	800	340	-	-	170	60	350	150	125	450	240	-	-	-	180
B_1	300	400	280	400	800	390	-	60	80	-	400	150	-	480	200	80	-	-	110
B_2	200	200	380	325	340	400	-	-	60	-	100	130	-	200	200	50	-	-	70
B_3	200	180	200	300	260	300	-	20	-	-	140	100	-	200	180	70	-	-	20
C_1	380	600	650	180	200	240	-	-	-	-	-	-	-	-	-	50	180	180	-
C_2	510	800	1000	80	120	140	-	-	-	40	160	-	-	80	-	-	-	80	-
C_3	350	300	260	20	-	-	-	-	-	80	150	-	20	200	-	-	-	-	-
C_4	100	-	400	-	-	-	-	-	-	75	-	-	100	-	-	-	-	120	-

CECIL CATENA

Sample #5 LOUISBURG FINE SANDY LOAM, ROLLING PHASE (7 to 12% slope)

The following describes a profile in a road cut in Nottoway County, one mile east of the junction of State Highways 307 and 628.

A_p 0 to 6 inches, dark grayish-brown (10 YR 4/2), fine sandy loam; weak, very fine, granular structure; contains small, medium, size roots; 5 to 10% angular quartz fragments, ranging in size from 1/4 to 2 inches across.

A_3 6 to 11 inches, yellowish-brown (5 YR 5/6), faintly mottled, strong brown and brownish-yellow, friable, slightly sticky sandy loam, with a fairly high content of clay; weak, fine granular structure; gradual, smooth boundary.

C_1 11 to 22 inches, brownish-yellow (10 YR 6/5), faintly mottled with yellowish-red, strong brown, and light gray, slightly sticky sandy loam.

C_2 22 to 32 inches, mottled, white, light gray, yellow-brown, strong brown, and gray, highly weathered pegmatite rock material; contains strata and pugs of gray plastic clay, quartz stringer at the bottom of the horizon contains the same clay strata and pugs; clear, smooth boundary.

C_{21} - (The strata and pugs of gray plastic clay), mottled, brown, gray, white and reddish-brown, sticky, very plastic, massive clay.

C_3 32 to 48 inches, brownish-yellow, yellow, white and yellow red, coarse sandy loam; highly weathered pegmatite rock material.

The parent material is a fine-grained pegmatite (1/2 mm) composed chiefly of quartz, microcline, and plagioclase (An 18). Biotite and muscovite are also present. Epidote is a minor accessory mineral. A mode of the thin section contains the following:

Quartz	Microcline	Plagioclase	Biotite	Muscovite
70%	15%	12%	2%	1%

CLAY MINERALOGY

Relative intensities of first order reflection of profile #5.

Horizon	Kaol.	Verm.	Mont.	K/I	I/V	K/V	Quartz
A_p	200	300	-	-	-	90	230
A_3	200	180	-	-	-	30	100
C_1	270	300	-	-	-	90	-
C_2	800	280	200	-	-	-	-
C_3	280	-	-	-	-	-	-

CECIL CATENA

Sample #15 LOUISBURG LOAM, ERODED STEEP PHASE (12 to 15% slope)

The following describes a profile in a road cut 4 tens of a mile south of Spring Creek on County Road 664 in Prince Edward County.

A — 0 to 6 inches, brown, friable loam; fine granular structure; contains a few mica flakes; many small roots and small angular rock fragments.

C_1 — 6 to 9 inches, reddish-brown, sandy clay loam; fine, granular structure; contains a few mica flakes.

C_3 — 9 to 23 inches, yellowish-brown, friable to firm, coarse sandy loam; structure controlled by the parent rock material; contains a large number of greenish-yellow, to black mica flakes and angular quartz grains.

The parent material is well-foliated, gently dipping, light yellow brown, coarsed-grained, muscovite schist. Quartz and muscovite are the main constituents. The muscovite contains small granular epidote grains. Plagioclase (An 15) and biotite partly weathered to vermiculite are also present. Magnetite, limonite and sphene occur in minor amounts. A mode of the thin section contains the following:

Quartz	Muscovite	Plagioclase	Biotite	Holes*
47%	43%	1%	5%	7%

*The 7 percent holes are probably the result of the weathering of plagioclase.

CLAY MINERALOGY

Relative intensities of first order reflection of profile #15.

Horizon	Kaol.	Verm.	Illite	K/V	K/I	I/V	Quartz
A	500	100	-	-	40	-	-
C_{12}	550	75	-	-	80	-	-
C_3	540	75	-	-	100	-	-
C_4	150	-	20	90	-	-	-

CECIL CATENA

Sample #9 CECIL FINE SANDY LOAM, ERODED UNDULATING PHASE (2 to 7% slope)

The following describes a profile covered by grassland, 40 yards east of the Norfolk and Western railroad bridge on Country Road 671, Prince Edward County.

A_p 0 to 3 inches, dark brown (wet), friable sandy loam, weak, fine granular structure; faint mottles of yellow brown in the lower part; angular vein quartz fragments are common; contains many small roots.

AB 3 to 6 inches, mottled brown, yellow brown and red brown, friable clay loam; weak, medium, subangular blocky structure.

B 6 to 12 inches, mottled, brown, reddish-brown, light yellow brown and light brown, (wet) slightly sticky and plastic, heavy sandy clay loam; moderate, medium, subangular blocky structure; contains a few silver mica flakes and a few angular vein quartz fragments.

C 12 to 28 inches +, mottled reddish-yellow and reddish-brown, friable sandy soil material; structure is controlled by the parent rock; both small and large mica flakes are common; angular vein quartz fragments are common.

The parent material is moderately dipping, highly schistose, gray, medium-to coarse-grained muscovite schist. The mica flakes are strongly alined and are bent into microfolds. The schist is so strongly weathered that only a porous structure of quartz and muscovite remains. Due to this advanced weathering stage, the mode for this rock could not be determined. However, it contains about 45 percent muscovite, 40 percent quartz, 1 or 2 percent biotite and the rest of the slide is holes which were probably originally feldspar minerals.

CLAY MINERALOGY

Relative intensities of first order reflections of profile #9.

Horizon	Kaol.	Verm.	Illite	K/I	I/V	K/V	Quartz
A_p	400	180	-	-	-	100	75
AB	350	200	30	-	-	80	75
B_2	675	150	20	70	-	-	50
C	480	180	-	-	-	75	50

CECIL CATENA

Sample #26 CECIL FINE SANDY LOAM, ROLLING PHASE (2 to 7% slope)

The following describes a profile of this soil in a railroad cut, 1/2 mile north of County Road No. 761 and 1 1/4 miles north east of the junction of this road with State Highway 47 in Prince Edward County.

A_p 0 to 7 inches, layer of light red mixed material containing many large angular vein quartz fragments.

B_1 7 to 12 inches, red, friable to slightly hard, sandy clay loam; weak to moderate, fine, subangular blocky structure; contains a few large angular quartz fragments.

B_2 12 to 35 inches, red, firm clay loam; moderate, fine, subangular blocky structure; contains a few mica flakes.

B_3 35 to 50 inches, red, firm to friable, clay loam; moderate, medium, subangular blocky structure; tending to weakly platy structure of the parent rock; golden mica flakes are common.

C_1 50 to 73 inches, red, to light red, highly micaceous, firm silty clay loam; weak, fine, subangular blocky structure with noticeable platy structure of the parent material; a few small yellow and yellow-green mottles.

C_2 73 to 101 inches +, dark red, with parent material mottles of yellowish-white, white and greenish-yellow, friable very highly micaceous, soil material; structure controlled by the parent rock; the mottles increase in size and number with depth.

The parent material is a light gray, coarse-grained muscovite-biotite mica gneiss. The rock is too friable to make a thin section but appears to contain mainly coarse-grained muscovite and quartz; biotite and feldspar appear to be less abundant. The rock is mapped by Espenshade and Potter (1960) as a muscovite-quartz gneiss. They state that the typical mica gneiss of this area contains coarse muscovite, quartz, plagioclase (An 5-15), and microcline in some of the more gneissic varieties.

CLAY MINERALOGY

Relative intensities of first order reflections of profile #26.

Hor.	Kaol.			Verm.			Illite			K/I			I/V			K/V			Quartz
	<2 Mm	2 Bm	4 Bm	2 Mm	2 Bm	4 Bm	2 Mm	2 Bm	4 Bm	2 Mm	2 Bm	4 Bm	2 Mm	2 Bm	4 Bm	2 Mm	2 Bm	4 Bm	<2 Mm
A_p	900	440	400	170	260	260	-	30	140	160	120	110	100	175	170	-	-	-	50
B_1	1100	520	590	180	300	300	-	100	130	200	140	100	70	200	200	-	-	-	90
B_2	1700	600	900	190	190	240	-	50	45	140	-	-	-	-	-	-	120	120	30
B_3	1450	600	900	160	150	160	-	10	15	100	100	-	--	160	-	-	-	140	-
C_1	1400	380	400	140	140	140	40	40	30	140	-	-	-	-	-	-	140	130	-
C_2	800	260	280	140	-	-	40	50	50	-	140	150	-	180	150	100	-	-	-
C_4	-	380	280	-	-	-	-	-	-	-	150	170	-	150	200	-	-	-	-

ALLUVIAL MATERIAL

Sample #18, WORSHAM SANDY LOAM, UNDULATING PHASE (0 to 5% slope)

The following describes a profile in a railroad cut two tens of a mile south of County Road 671 along the Prince Edward-Charlotte County line.

A — 0 to 9 inches, grayish-white, friable sandy loam; weak, fine, granular structure.

A_3 — 9 to 14 inches, light yellow, friable sandy loam; few, distinct mottles of brownish-yellow; weak, fine, granular structure; contains a few quartz pebbles.

B_1 — 14 to 20 inches, yellowish-brown, friable sandy clay loam; few, distinct mottles of brown and red; moderate, medium, subangular blocky structure; quartz pebbles are common.

B_2 — 20 to 47 inches, gray, firm clay; distinct mottles of brownish-yellow and red; weak, coarse, angular blocky structure to platy structure; few angular quartz pebbles.

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RESIDUAL MATERIAL

C_1 — 47 to 53 inches, pale greenish-gray, massive, sandy clay; slightly sticky and plastic when wet; contains yellowish-white specks of parent material.

C_2 — 53 to 83 inches, light greenish-yellow, friable sandy soil material; structure controlled by the foliation of the parent rock.

C_4 — The parent material is gently dipping, well-foliated, light green, medium-grained, micaceous gneiss composed mainly of quartz, plagioclase (An 24), and biotite. Dark green pleochroic hornblende is also common. Epidote is present only in accessory amounts. The rock was too highly weathered to make a modal analysis but contains about 40 percent quartz, 35 percent plagioclase, 15 percent biotite and 5 percent hornblende.

CLAY MINERALOGY

Relative intensities of first order reflections of profile #18.

Horizon	Kaol.	Verm.	Mont.	K/V	K/I	I/V	Quartz
A_p	175	150	-	-	60	85	100
A_3	475	225	-	-	-	90	100
B_1	750	200	-	-	-	-	70
B_2	1300	350	50	-	-	-	-
C_1	1500	-	2400	-	-	-	-
C_2	1000	-	2400	-	-	-	-
C_4	150	-	600	-	-	-	-

APPENDIX II

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BLUE RIDGE PROFILES

APPENDIX II-A

CATENAS DEVELOPED FROM MAFIC ROCKS

ELBERT CATENA

Sample #22, ELBERT SILT LOAM: VERY POORLY DRAINED, UNDULATING PHASE (2% slope)

The following describes a profile on the old airport grounds, 5 miles south of Galax on State Highway 89 in Carroll County. The profile occurs at an elevation of 2,580 feet and is 50 yards west of sample 21.

A 0 to 10 inches, dark grayish-brown to black, very friable silt loam; very fine, granular structure; contains much high percentage of organic matter.

B 10 to 16 inches, gray, mottled, with yellow brown and strong brown, friable, slightly plastic, slightly sticky and slick, silty clay loam; moderate, fine to medium, blocky structure; noticeable mica flakes on cut surface.

BM 16 to 36 inches, mottled dark gray, light gray, yellow, black, strong brown and brownish-yellow; slick, extremely plastic and extremely sticky clay; massive (structureless); noticeable white shiny mica flakes; clay becomes heavier and more sticky with depth.

The parent material is massive greenish-gray, ultramafic rock composed mainly of chlorite, talc, and tremolite. Magnetite, olivine, and serpentine are also common. The chlorite and talc occur as radial, bent, fibrous aggregates which are cut by very long (30 to 40 mm) euhedral tremolite crystals. The crystals have a completely random distribution and orientation. Large olivine crystals are nearly completely altered to serpentine and magnetite. A mode of the thin section contains the following:

Chlorite-Talc	Tremolite	Magnetite	Serpentine	Olivine
41%	34%	9%	10%	6%

CLAY MINERALOGY

Relative intensities of first order reflections of profile #22.

Horizon	7A Chl.	14A Chlorite	Mont.	Talc
A_p	800	740	-	470
B	1425	700	-	400
B_{1m}	1200	1480	340	250
B_{2m}	1000	1000	1250	500

CATOCTIN-RABUN CATENA

Sample #20, CATOCTIN SILT LOAM, GENTLY SLOPING PHASE (2 to 7% slope)

The following describes a profile in a road cut, 7 miles east of Galax on U. S. Highway 58 in Carroll County. The profile occurs at an elevation of 2,300 feet.

A — 0 to 12 inches, brown to dark brown, heavy silt loam; weak, fine granular structure; containing 1 to 2 percent greenstone rock fragments, 1/4 to 1 inches across.

BC — 12 to 18 inches, brown, friable silt loam; weak, fine, subangular blocky structure; which crushes readily to a fine granular structure.

C — 18 to 22 inches, brown to reddish-brown, silt loam; weak, fine, granular structure; mixed with 50 to 70 percent partly weathered platly greenstone fragments.

The parent material is dark green, very fine-grained hornblende schist (Greenstone). The main constituent is fine-grained (1/16 by 1/4 mm) pleochroic dark green to pale yellow hornblende. The hornblende crystals are lath shaped and have pronounced parallel orientation. These laths make up about 65 percent of the rock. The remainder is composed of fine-grained quartz about 20 percent, plagioclase probably of andesine composition 10 percent, and light yellow epidote 5 percent. Magnetite and biotite are minor accessory minerals. The specimen is too highly weathered to determine a mode.

CLAY MINERALOGY

Relative intensities of first order reflections of profile #20.

Horizon	Kaol.	Verm.	Illite	K/I	I/V	K/V	Quartz
A	350	800	-	-	-	-	-
BC	200	500	-	-	-	90	-
C	250	980	-	-	-	-	-
C_4	120	250	-	-	-	150	-

CATOCTIN-RABUN CATENA

Sample #21, RABUN SILTY CLAY LOAM, UNDULATING PHASE (0 to 7% slope)

The following describes a profile on the old airport grounds, 5 miles south of Galax on State Highway 89 in Carroll County. The profile occurs at an elevation of 2,590 feet.

A_p 0 to 4 inches, reddish-brown, friable heavy silty clay loam; weak, fine, graular structure; contains many fine roots.

B_2 4 to 10 inches, reddish-brown to red, friable silty clay; weak, fine to medium, subangular blocky structure.

B_3 10 to 18 inches, mottled, red, brown and yellow, friable silty clay loam; weak, fine, angular blocky structure; structure partly controlled by parent rock; moderately micaceous; contains white and black chlorite and talc flakes.

C_1 18 to 24 inches, red brown, friable silty clay loam; with white yellow and greenish-yellow, mottles of parent material; fine, granular structure; overall structure controlled by parent rock; slick and smooth when rubbed; contains fragments of green soapstone.

C_2 24 to 30 inches, light reddish-brown to dark red brown, friable silt loam; weak, fine, granular structure; contains 20 to 30 percent yellowish-green soapstone fragments.

The parent material is light green very fine-grained, chloritic soapstone. The rock is composed almost entirely of radial, bent, fibrous, aggregates of chlorite and talc. Less common are long bladed euhedral crystals of tremolite which weather to reddish-brown limonite. Magnetite is the only accessory mineral. A mode of the section contains the following:

Chlorite and Talc	Tremolite
91%	9%

CLAY MINERALOGY

Relative intensities of first order reflections of profile #21.

Horizon	7 Ch	Talc	14 Chlorite	Talc/chl
A_p	180	400	470	90
B_2	100	220	300	150
B_3	40	270	250	-
C_1	30	170	125	-
C_2	50	185	170	-

CATOCTIN-RABUN CATENA

Sample #24, RABUN SILT LOAM, ERODED STEEP PHASE (20 to 45% slope)

The following describes a profile of this soil in a road cut on County Road 660, one mile east of Carsonville in Grayson County. The profile occurs at an elevation of 2,420 feet.

A — 0 to 4 inches, dark reddish-brown, friable silt loam, moderate, fine, granular structure.

B — 4 to 16 inches, red to dark red, friable to slightly firm, slightly sticky and plastic clay; moderate, fine to medium, subangular blocky structure.

B_3 — 16 to 26 inches, yellowish-red, friable slightly slick, heavy silt clay loam; weak, fine to medium, subangular blocky structure; contains a few mica flakes.

C_1 — 26 to 35 inches, mottled with parent material mottles of red, yellow red, strong brown, black, yellow, white, and reddish-yellow, very friable, silt loam soil material; massive (structureless).

C_2 — 35 to 120 inches, mottled with parent material mottles of red, yellow red, strong brown, black, yellow, white, and reddish-yellow, with white and black mottles increasing with depth, and red and brown mottles decreasing; friable silt loam; non plastic and non sticky clay; structure controlled by parent material.

C_3 — 120 inches +, white, black, yellow, strong brown and yellow red, highly weathered hornblende diorite rock material; the black mottles are partly weathered coarse-grained hornblende.

The parent material is steeply dipping, well-foliated, white and black, medium to coarse-grained biotite-hornblende gneiss. The main constituent is highly sericitized plagioclase (An ?). Other common minerals are: hornblende, red-brown biotite and quartz. The biotite is weathered and slightly expanded perpendicular to the cleavage. Minor accessory minerals are: euhedral apatite, chlorite (as alterations rims on biotite), magnetite and hematite. A mode of the thin sections contains the following:

Sericite (Plagioclase)	Hornblende	Biotite	Quartz	Accessory	Holes*
41%	26.8%	14.2%	11.0%	2.6%	5%

*The five percent holes represent minerals removed during weathering and in this case probably plagioclase.

CLAY MINERALOGY

Horizon	Kaol.	Verm.	Illite	K/I	I/V	K/V	Quartz
A	310	280	-	-	-	100	-
B	230	110	10	-	-	60	-
B_3	420	130	25	-	-	110	-
C_1	215	-	20	100	50	50	-
C_2	300	-	10	210	150	-	-
C_3	100	-	40	90	60	-	-

APPENDIX II-B

CATENAS DEVELOPED FROM INTERMEDIATE ROCKS

EUBANKS CATENA

Sample #23, EUBANKS LOAM, ERODED HILLY (12 to 25% slope)

The following describes a profile of this soil in a road cut on County Road No. 660, 1 1/4 mile west of Riverside and 1/5 mile north of New River in Grayson County. The profile occurs at an elevation of 2,300 feet.

A — 0 to 7 inches, brown, very friable loam with a high content of silt and grit; fine granular structure; many fine roots.

B_1 — 7 to 13 inches, yellowish-red, friable clay loam; fine subangular blocky structure.

B_2 — 13 to 32 inches, red (25 YR 5/6), friable to slightly firm, light clay loam to heavy clay loam; moderate, fine to medium, subangular blocky structure.

B_3 — 32 to 42 inches, red, mottled with brownish-yellow, yellow red, reddish-yellow, and white; friable, light clay loam to heavy silt loam, with a high content of sand; weak, angular and subangular blocky structure, tending toward platy structure.

C_1 — 42 to 58 inches, yellow red, mottled with parent material mottles of white, green, red and yellow grown, friable coarse sandy clay; structure is that of the parent rock; contains partly weathered white feldspar crystals, 5 by 15 mm across; green mottles occur as bands and appear to be the epidote veins of the parent material.

C_2 — 58 inches +, brownish-yellow, mottled with parent material mottles of white, yellow, green, brown and reddish-brown; friable sandy rock material; structure is that of the parent rock; contains feldspar, quartz and epidote in their original position.

The parent material is pink and green, coarse-grained, augen gneiss composed chiefly of large pink microcline phenocrysts enclosed by dark green veins of epidote. Other important minerals are quartz which occurs both as anhedral crystals and as fine grain vein quartz, vein epidote, and highly sericitized albite (An 9). Magnetite and vermicular biotite are also present. A mode of the thin section contains the following:

Microcline	Quartz	Epidote	Albite	Biotite & Magnetite
41%	30%	13%	10%	4%

CLAY MINERALOGY

Relative intensities of first reflections of profile #23.

Horizon	Kaol.	Verm.	Illite	K/V	I/V	K/I	Quartz
A	400	550	-	90	70	-	100
B_1	880	600	-	-	200	90	100
B_2	760	400	-	90	-	-	90
B_3	680	280	-	90	-	-	50
C_1	280	20	-	-	200	140	10
C_2	60	-	50	-	-	200	-

APPENDIX II-C

CATENAS DEVELOPED FROM SILICIC ROCKS

Sample #19, TALLADEGA SILT LOAM, GENTLY SLOPING (0 to 7% slope)

The following describes a profile in a road cut, 2 miles southwest of Hillside on U. S. Highway 58 in Carroll County. The profile occurs at an elevation of 2,400 feet above sea level.

A_p 0 to 7 inches, brown, very friable highly micaceous, silt loam; weak, very fine, granular structure.

B 7 to 12 inches, yellow red to strong brown, friable highly micaceous, silt loam; weak, medium to coarse, subangular blocky structure.

C_1 12 to 20 inches, yellow red, very friable, very highly micaceous, silt loam; fine, granular structure; smooth and slick when rubbed between the fingers.

C_2 20 to 70 inches, reddish-brown to strong brown, friable highly weathered biotite gneiss rock material; containing many black, gold, silver and brown mica flakes.

The parent material is steeply dipping, well-foliated, medium to coarse-grained, biotite-muscovite schist. The rock consists of quartz, muscovite, biotite, microcline, and plagioclase (An 15). The plagioclase crystals occur as large subhedral crystals which are commonly poikilitic. The inclusions represent fine grain equivalents of nearly every mineral in the rock. The most common inclusions are: biotite, muscovite, quartz, calcite, and zircon. Muscovite and biotite are intergrown, and the muscovite is coarser grained (Mus. 1 by 4 mm - biotite 1/2 by 2 mm). Calcite, apatite, magnetite, and zircon are present as minor accessory minerals. A mode of the thin sections contain the following:

Quartz	Muscovite	Biotite	Microcline	Plagioclase	Accessory
50%	18%	13%	8%	11%	1%

CLAY MINERALOGY

Relative intensities of first reflections of profile #19.

Horizon	Kaol.	Verm.	K/I	I/V	K/V	Quartz
A_p	550	220	110	190	-	-
B	1400	160	100	160	-	-
C_1	390	-	100	200	-	-
C_2	420	200	70	140	-	-

LOUISBURG-APPLING-CECIL CATENA

Sample #25, LOUISBURG SANDY LOAM, ERODED HILLY PHASE (12 to 25% slope)

The following describes a profile of this soil 1/5 mile northwest of Carsonville on County Road 660 in Grayson County. The profile occurs at an elevation of 2,650 feet.

A_p 0 to 4 inches, grayish-brown to dark grayish-brown, very friable sandy loam; weak, fine, granular structure; contains a few gravel size quartz fragments.

A_2 4 to 12 inches, pale brown, very friable sandy loam; contains slightly more gravel size quartz then the above horizon.

BC 12 to 20 inches, yellow brown, very friable sandy loam; very weak, medium, subangular blocky structure, that crushes to fine and medium, granular structure; gravel size granite rock fragments are common.

C_1 20 to 33 inches, brownish-yellow (10 YR 6/6), very friable slightly compact, coarse sandy loam soil material; structure is that of the parent rock.

C_2 33 to 45 inches, highly weathered black, white, gray yellow, and yellow brown; coarse-grained granitic rock material.

The parent rock is a light gray medium-grained granite composed of strained anhedral quartz, plagioclase (An 18), and microcline some of which is coarsely perthitic, and sericite. Most of the plagioclase is fresh but some grains are altered to coarse-grained sericite (1/32 mm), which occurs in aggregate masses. Sericite also occurs in cross-cutting veins which have altered the biotite to irregular masses of light yellow weakly pelochroic material. Coarse sericite plates are also common on many quartz crystals. Magnetite is the only accessory mineral. A mode of the thin sections contains the following:

Quartz	Microcline	Plagioclase	Sericite	RelictBiotite
52%	25%	12%	8%	3%

CLAY MINERALOGY

Horizon	Kaol.	Verm.	Illite	K/I	I/V	K/V	Quartz
A_p	35	470	-	-	225	-	160
A_2	200	780	-	80	180	-	300
BC	200	1200	-	100	200	-	200
C_1	170	700	40	-	-	100	-
C_2	150	650	100	-	-	150	-

ABSTRACT

X-ray diffraction studies of 29 Virginia Blue Ridge and Piedmont soil profiles and petrographic examinations of the parent rocks reveal that even after prolonged chemical weathering, physical and mineralogical differences exist between soil types which are due largely to changes in the parent rock, and to a lesser extent changes in the topography.

Soils developed from different source rocks can be distinguished on the basis of color, texture, degree of contrast between horizons, and depth to fresh rock. The clay minerals of such soils differ in their distribution, amount and kind. The role of parent material in soil and clay mineral formation is a complex function of several variables: (1) chemical composition (2) mineralogical composition (3) rock texture and (4) rock structure. Soils developed from calcium-aluminum rich rocks or from basic rocks which have structures or textures not conducive to good drainage are characterized by kaolin and montmorillonite clay minerals and by dense plastic, poorly drained, clayey subsoils. In all other soils and in the surface horizon of these soils, the major clay minerals are kaolin and vermiculite.

Topography affects the degree of profile development, color, and soil texture and controls the rate of clay mineral accumulation and weathering. The climates of the Blue Ridge and Piedmont are most favorable to the formation of kaolin minerals. However, greater amounts of kaolinite appear to be formed in the warmer Piedmont climate and more vermiculite in the cooler Blue Ridge climate.

The most important mechanism for clay mineral formation is probably by direct alteration of the primarily silicate minerals. The distribution of these clays in the profile is determined by the weathering stability of the primary silicate. All ferromagnesium silicates weather to 14 A clay minerals. An intermediate 14 A chlorite phase was not observed. The most common product is vermiculite. The formation of montmorillonite is controlled by the four parent material factors listed above. Hornblende and augite are the chief source materials of montmorillonite. Biotite possibly weathers to montmorillonite if the internal drainage is strongly retarded. Montmorillonite weathers to vermiculite in the surface horizons. Kaolinite forms early in the profile during the weathering of feldspar. Medium- to coarse-grained muscovite is also a source of kaolinite. There was no evidence found to indicate that kaolinite is a weathering product of the 14 A clay minerals. Illite occurs in minor amounts in a few micaceous profiles but appears to be the result of mechanical break-down of larger mica particles.