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-Saprolite-Landscape Relationships
Piedmont
Ridge Highland Regions
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M.H. Stolt, J.C. Baker, and T.W. Simpson

L. Andre Swiger, Dean and Director
College of Agriculture and Life Sciences
Virginia Agricultural Experiment Station
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061-0402

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SOIL-SAPROLITE-LANDSCAPE RELATIONSHIPS IN THE PIEDMONT AND BLUE RIDGE HIGHLAND REGIONS OF VIRGINIA

M.H. Stolt, J.C. Baker, and T.W. Simpson

ABSTRACT

Various methods and techniques were used to examine soil variability and soil-saprolite-landscape relationships in Virginia. Variability analysis indicates that for the overall study, most soil variability is attributable to differences between study sites or between horizons, with minimal amounts due to landscape position. Substantial lateral variability occurs within horizons, indicating a strong need for subsampling within horizons of the same pedon. Although some soil-saprolite transition horizons appear structureless in the field, soil micromorphology indicated evidence of pedogenic process within these horizons. Soil-saprolite transition horizons were designated as either BCt, BC, or CB, depending on the amount of oriented clay, and rates of change with depth of clay, DCB extractable Fe, and sand. Summit and backslope soils have essentially the same morphology and degree of profile development. Soil reconstruction indicates that sand weathering and clay eluviation/illuviation are the major soil-forming processes occurring within these soils. Footslope soils are less developed than are associated summit and backslope soils, with both depositional and pedologic processes contributing to soil formation and development. Saprolite thickness decreases from summit to footslope. Thicker saprolite at the summit is apparently related to the greater stability of the summit position compared to associated backslope and footslopes. Saprolite reconstruction indicates that between 20 and 36 % of the mass of the partially weathered rock, which is the precursor to saprolite, is lost during saprolite formation. Most of these losses are either Al or Si. Initial soil formation occurs at a faster rate than that of saprolite formation, but after substantial profile development, soil formation is reduced to a rate below that of saprolite formation, and saprolite accumulates below the solum.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Soils and associated landscapes are studied in order to understand landscape evolution, lateral water movement, relationships between landscape position and definable soil-map- unit boundaries, soil- forming processes, and degree of soil erosion. Most quantitative investigations of soil-landscape relationships have been undertaken in the midwest on young soils (Ruhe and Walker, 1968; Walker et al., 1968; Kleis, 1970; Huddleston and Riecken, 1973; Huddleston et al., 1975). Studies of well developed soils have been limited. In a typical well developed, upland-residual soil, the regolith consists of a solum and C and Cr horizons (saprolite) which over lie bedrock. Between the soil and saprolite lies a zone of transition. Understanding the genesis of the soil, saprolite, and associated landscape requires that each section of the regolith be examined across the landscape. One method commonly used to examine soil-forming processes is soil reconstruction. These techniques are employed to quantitatively measure gains and losses of the various soil constituents relative to those of the parent material (Marshall and Haseman, 1942; Brewer, 1976; Smeck and Wilding, 1980; Sudom and St. Arnaud, 1971; Wang and Arnold, 1973; Smeck et al., 1968; Smeck et al., 1981).

This research examined the gains, losses, transformations, and transfers of the soil constituents at the summit, backslope, and footslope landscape positions of soils located in the Piedmont and Blue Ridge Highlands regions of Virginia. The objectives were: 1) To describe and partition the variability within the soils studied. 2) To describe the zone of transition between soil and saprolite, and develop guidelines to separate BC horizons from Bt and C horizons formed in saprolite. 3) To evaluate the application of reconstruction analysis to studying relationships between soils, saprolite, and landscape position. 4) To characterize saprolite formed from gneissic rocks, and examine the genesis of these materials.

MATERIALS AND METHODS

Field Methods

More than fifty soil-landscape associations were examined in the Piedmont physiographic province and Blue Ridge Highlands region of Virginia in an attempt to find relatively undisturbed residual soils formed from uniform parent material. Reconnaissance sites were located in old churchyards, cemeteries, or homesteads in soils formed from gneissic or schistose rocks.

Soil and saprolite morphology at summit positions was examined with a bucket auger to a depth of 3.5 meters or lithic contact. Samples were collected from soils that showed evidence of residual nature, uniform parent material, and minimal cultural disturbance.

Four representative toposequences were chosen for detailed study. Soil pits were excavated at the summit, backslope, and footslope positions. Horizonation of four faces a meter apart on the long face of each pit wall (Figure 1) was examined. Bulk samples were collected from each of four faces labelled A, B, C, and D. Samples collected from the horizon just below the A horizon, the best expressed Bt horizon (determined by maximum clay content), and lowest C horizon accessible within the pit, were bagged separately. Samples obtained from the other horizons were combined to form a composite sample for each horizon, and bagged. Undisturbed clods were collected for bulk density and water retention measurements, and preparation of thin sections. Samples below the bottom of the soil pit were obtained with a bucket auger for sampling and description purposes. Bulk density clods for these C horizons were obtained using a modified bucket auger (Stolt et al., 1991). Rock samples were obtained from the bottom of the auger holes by chiseling the rock with a cold chisel welded to an auger extension, and collecting the samples with a bucket auger. Rock samples were also collected from nearby rock outcrops and footslope soils at Sites 1 and 2.

Laboratory Methods

Bulk samples were air-dried, ground, and passed through a 2 mm sieve. Particle size distribution (PSD) was determined by pipette (Gee and Bauder, 1986) with fine clay determined after centrifugation. Dithionite-citrate-bicarbonate (DCB) extractable Fe and Al were removed following the procedures of Holmgren (1967), and analyzed by inductively coupled plasma spectrometry (ICP). Elemental composition of rock and saprolite was determined by ICP after HF digestion (Bernas, 1968). Elemental Zr, Ti, Fe, Ca, and K of sand and silt fractions were determined from pellets using x-ray fluorescence (XRF) techniques. Silt and clay fractions were separated by gravimetric and centrifugation methods, and mineralogy examined following the procedures of Jackson (1956). Percent kaolinite and gibbsite were determined by differential scanning calorimetry (DSC) using poorly crystalline Georgia kaolinite and a Reynold's synthetic for kaolinite and gibbsite standards (Tan and Hajek, 1977). Percentages of the remaining minerals were estimated using relative peak areas. Bulk density and water retention values were determined following the procedures of Brasher et al. (1966). Thin sections were prepared from air-dried clods after impregnation with an epoxy resin. Thin sections were examined in plane-polarized (PPL) and cross-polarized (XPL) light. Micromorphological descriptions were made using the guidelines and

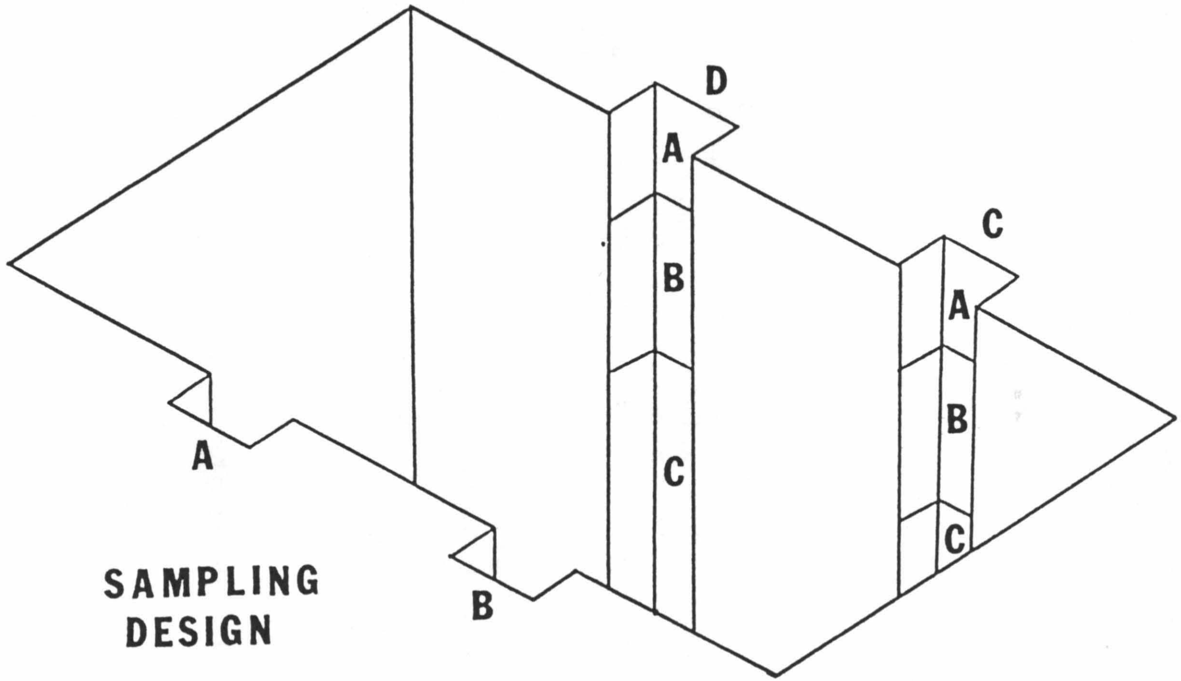

Figure 1. Diagram of sampling scheme within individual pedons (after Drees and Wilding, 1973).

terminology of Bullock et al. (1985). Estimations of percent oriented clay, coarse/fine ratios separated at 20 u (c/f_{20u} ratios), and voids were made from traverse line counts at 63X magnification. Reconstruction calculations were taken primarily from Brewer (1976). Thin sections, clay-free particle size analysis, regression techniques, and elemental composition were used to estimate the initial state and composition of parent materials that were not residual in nature.

Statistical Methods

The value for an individual variable (Y_{ijkl}) is explained by the ideal statistical model:

$$Y_{ijkl} = u + S_i + P_{ij} + H_{ijk} + E_{ijkl}$$

where u represents the population mean; S_i the effects due to site; P_{ij} the effects due to landscape position; H_{ijk} the effects due to horizon; and E_{ijkl} is that which is due to random error. Percent of the variability explained by each effect was estimated using a nested design (Webster, 1977). Percent of the total variance attributed to each component was estimated by dividing the variance attributed to the individual component by the total variance (SAS, 1985).

Analysis of variance was used to test if sample means of C horizons were significantly different between landscape positions. Significance of the differences was determined using an F test, and significantly different means were separated by least significant difference (LSD). Analysis of variance and LSD calculations were performed on a computer using SAS (SAS, 1985) programs.

RESULTS AND DISCUSSION

Study Site Descriptions

Study sites 1 and 2 are located in the Piedmont near the town of Lovingston, Nelson County, Va. (Figure 2). Residual soils (Tables 1 and 2) have formed in saprolite and weathered rock derived from a mica gneiss (Lovingston Formation, Bloomer and Werner, 1955). These sites are situated in woodlands of an old estate which dates back to the 1700s. Vegetation and soil morphology (Table 1) suggest that selective cutting has been the only

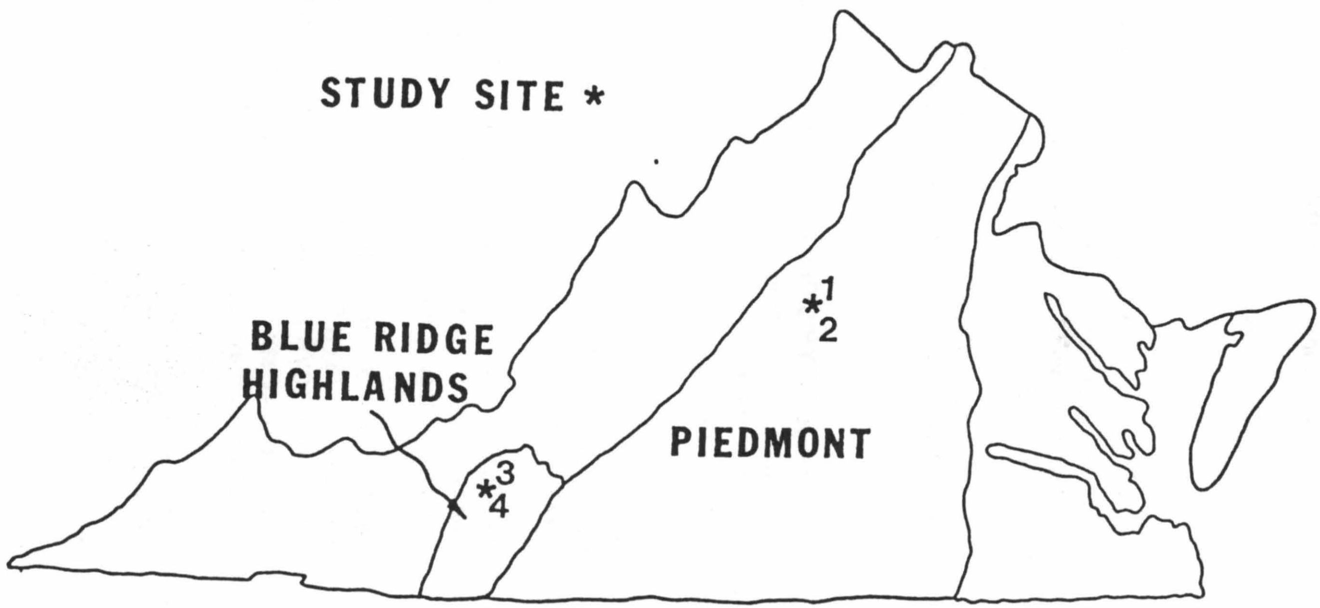

Figure 2. Location of study area and sites.

Table 1a. Profile description of the summit soil at Site 1.

Horizon	Depth	Description
	cm	
A	0-7	Dark Brown (10YR 3/3) fine sandy loam; weak, very fine to fine granular structure; very friable; many fine, medium, and coarse roots; abrupt wavy boundary; extremely acid.
E	7-16	Yellowish brown (10YR 5/8) fine sandy loam; weak, fine granular structure; friable; common fine and medium roots; clear wavy boundary; very strongly acid.
Bt1	16-31	Yellowish red (5YR 5/6) clay loam; moderate fine subangular blocky structure; friable; few fine and medium roots; common continuous clay films; gradual wavy boundary; very strongly acid.
Bt2	31-48	Red (2.5YR 5/6) clay; moderate medium subangular blocky structure; friable; few medium roots; many continuous clay films; gradual wavy boundary; very strongly acid.
Bt3	48-63	Red (2.5YR 4/6) clay; moderate medium subangular blocky; friable; few medium roots; many continuous clay films; clear wavy boundary; strongly acid.
Bt4	63-126	Red (2.5YR 4/6) sandy clay loam; common distinct yellowish red (5YR 5/8) and common prominent very pale brown (10YR 8/4) mottles; weak, fine sub angular blocky structure; friable; few continuous clay films; diffuse wavy boundary; strongly acid.
BC	126-170	Red (2.5YR 5/8) fine sandy loam; weak coarse subangular blocky structure; friable; few discontinuous clay films; gradual wavy boundary; moderately acid.

Table 1a (Site 1, summit) (cont.).

Horizon	Depth	Description
	cm	
C1	170-202	Variegated red (2.5YR 5/8), reddish yellow (5YR 6/8), strong brown 5/8), yellowish brown (10YR 5/6) fine sandy loam; structureless massive; friable; few clay flows; gradual boundary; moderately acid.
C2	202-245	Variegated red (2.5YR 5/8), reddish yellow (5YR 6/6), yellow (10YR 7/6) fine sandy loam; structureless massive; friable; few clay flows, gradual wavy bound ary; moderately acid.
C3	245-420	Variegated red (2.5YR 5/8), reddish yellow (5YR 6/6), yellow (10YR 7/6) fine sandy loam; structureless massive, friable; moderately acid.
C4	420-445	Variegated white (10YR 8/2), very pale brown (I0YR 7/4), very dark grayish brown (10YR 3/2) loamy fine sand; structureless massive; friable; moderately acid.
C5	445-485	Variegated very pale brown (I0YR 7/4) and grayish brown (10YR 3/2) loamy fine sand; structureless massive; friable; moderately acid.
C6	485-535	Variegated very pale brown (I0YR 7/4) and brownish yellow (I0YR 6/8) loamy fine sand; structureless massive; friable; moderately acid.
C7	535-620	Variegated light yellowish brown (I0YR 6/4) and brownish yellow (I0YR 6/8) loamy fine sand; structureless massive; friable; moderately acid.
C8	620-725	Variegated light yellowish brown (I0YR 6/4) and brownish yellow (I0YR 6/8) loamy fine sand; structureless massive; friable; moderately acid.
C9	725-750	Variegated light yellowish brown (I0YR 6/4) and brownish yellow (I0YR 6/8) loamy fine sand; structureless massive; friable; moderately acid.

Table 1a (Site 1, summit) (cont.)

Described from auger samples below 280 cm.

LOCATION: Nelson County, Virginia, on Oak Ridge Estate, 200 meters south of the Oak Ridge Catholic Church, in the woods.
VEGETATION: Oaks.
PARENT MATERIAL: Lovingston gneiss.
LANDSCAPE POSITION: Summit.
PHYSIOGRAPHY: Upland.
SLOPE: < 2%.
ELEVATION: 300 meters.
DRAINAGE: Well.
EROSION: None.
DESCRIBED BY: M.H. Stolt, J.C. Baker, S. Thomas, B. Legge, A.T. Stevens, and H. Behl.
DATE: 8/20/88.

Table 1b. Profile description of the backslope soil at Site 1.

Horizon	Depth	Description
	cm	
A	0-7	Dark brown (10YR 3/3) fine sandy loam; weak fine granular structure; very friable; many fine, medium, and coarse roots; abrupt wavy boundary; strongly acid.
E	7-28	Reddish yellow (7.5YR 6/8) fine sandy loam; weak moderate subangular blocky structure; very friable; common fine, medium, and coarse roots; 10-15% gravel size quartz; abrupt wavy boundary; moderately acid.
Bt1	28-43	Red (2.5YR 4/8) gravelly loam; few distinct yellowish red (5YR 5/6) mottles; weak moderate subangular blocky structure; friable; few fine and medium roots; common continuous clay films; 10-20% gravel size angular quartz; gradual wavy boundary; strongly acid.
Bt2	43-70	Red (2.5YR 4/6) clay; few distinct yellowish red (5YR 5/6) mottles; moderate medium subangular blocky structure; friable; few fine and medium roots; many continuous clay films; gradual wavy boundary; strongly acid.
Bt3	70-98	Red (2.5YR 4/6) clay; moderate medium subangular blocky structure; friable; few fine and medium roots; many continuous clay films; diffuse wavy boundary; moderately acid.
Bt4	98-130	Red (2.5YR 4/6) clay; few distinct reddish yellow (5YR 6/8) mottles; moderate coarse subangular blocky structure; friable; few fine and medium roots; common continuous clay films; diffuse wavy boundary; moderately acid.

Table 1b (Site 1, backslope) (cont.).

Horizon	Depth	Description
	cm	
BC	130-150	Red (2.5YR 4/6) loam; few distinct reddish yellow (5YR 6/6) and few prominent yellow (10YR 8/8) mottles; weak coarse subangular blocky structure; friable; few fine and medium roots; few discontinuous clay films; diffuse wavy boundary; moderately acid.
C1	150-187	Variegated red (2.5YR 4/6), light red (2.5YR 6/6), and dark brown (7.5YR 3/2) fine sandy loam; structureless massive; friable; few clay flows; diffuse wavy boundary; moderately acid.
C2	187-216	Variegated red (2.5YR 4/6), reddish yellow (5YR 6/8), and dark brown (7.5YR 3/2) fine sandy loam; structureless massive; friable; good rock structure; few clay flows; diffuse wavy boundary; moderately acid.
C3	216-275	Variegated red (2.5YR 4/6), reddish yellow (5YR 6/8), and dark brown (7.5YR 3/2) fine sandy loam; structureless massive; friable; good rock structure; few clay flows; diffuse wavy boundary; moderately acid.
C4	275-340	Variegated strong brown (7.5YR 4/6) and yellowish brown (10YR 5/8) loamy fine sand; structureless massive; friable; few discontinuous clay flows; moderately acid.
C5	340-430	Variegated reddish yellow (7.5YR 6/6) and yellowish red (5YR 5/8) loamy fine sand; structureless massive; friable; few discontinuous clay flows; moderately acid.

Table 1b (Site 1, backslope) (cont.).

Horizon	Depth	Description
	cm	
C6	430-450	Very pale brown (10YR 7/4) loamy fine sand; few distinct reddish yellow (5YR 6/8) and few prominent red (2.5YR 5/8) mottles; structureless massive friable; moderately acid.
Cr	450-460	Pale brown (10YR 6/3) which crushes to loamy fine sand.
Rock	460+	Mica Gneiss.

Described by auger samples below 275 cm.

LOCATION: Nelson County, Virginia, on Oak Ridge Estate, 250 meters south of the Oak Ridge Catholic Church, in the woods.
VEGETATION: Oaks.
PARENT MATERIAL: Lovingston gneiss.
LANDSCAPE POSITION: Backslope.
PHYSIOGRAPHY: Upland.
SLOPE: 18%.
ELEVATION: 291 meters.
DRAINAGE: Well.
EROSION: None.
DESCRIBED BY: M.H. Stolt, S. Thomas, B. Legge, A.T. Stevens, and H. Behl.
DATE: 8/20/88.

Table 1c. Profile description of the footslope soil at Site 1.

Horizon	Depth	Description
	cm	
A	0-10	Brown (10YR 4/3) fine sandy loam; weak fine granular structure; friable; many fine, medium, and coarse roots; clear wavy boundary; strongly acid.
AB	10-24	Strong brown (7.5YR 4/6) fine sandy loam; weak medium subangular blocky structure; friable; common fine, medium, and coarse roots; gradual wavy boundary; strongly acid.
Bw1	24-45	Strong brown (7.5YR 5/6) fine sandy loam; weak moderate subangular blocky structure; friable; common fine and medium roots; gradual wavy boundary; moderately acid.
Bw2	45-67	Strong brown (7.5YR 5/6) fine sandy loam; weak coarse subangular blocky structure; friable; few fine and medium roots; abrupt wavy boundary; moderately acid.
2Bt	67-100	Strong brown (10YR 5/6) gravelly sandy clay loam; few distinct red (2.5YR 5/8) and few faint reddish yellow (7.5YR 6/3) mottles; moderate fine subangular blocky structure; friable; few fine and medium roots; many discontinuous clay films; angular quartz stone line marks discontinuity; coarse fragments range from 1 to 36 percent; abrupt wavy boundary; moderately acid.
2Crt	100-135	Variegated reddish yellow (5YR 6/8), black (2.5YR 2/1), red (2.5YR 5/8), reddish yellow (7.5YR 6/8), pinkish grey (7.5YR 7/2), and pale brown (10YR 6/3) sandy clay loam; structureless massive; firm; thin 5-10 cm 2BC horizon above; abrupt wavy boundary; moderately acid.

LOCATION: Nelson County, Virginia, on Oak Ridge Estate, 300 meters south of Oak Ridge Catholic Church, in the woods.

Table 1b (Site 1, footslope) (cont.).

VEGETATION: Oaks.
PARENT MATERIAL: Local alluvium over residuum.
LANDSCAPE POSITION: Footslope.
PHYSIOGRAPHY: Upland.
SLOPE: 6%.
ELEVATION: 285 meters.
DRAINAGE: Moderately well.
EROSION: None.
DESCRIBED BY: M.H. Stolt, S. Thomas, Bruce Legge, A.T. Stevens, and H. Behl.
DATE: 8/21/88.

Table 2a. Profile description of the summit soil at Site 2.

Horizon	Depth	Description
	cm	
A	0-10	Dark yellowish brown (10YR 4/4) loam; moderate fine granular structure; very friable; common fine, medium, and coarse roots; abrupt wavy boundary; strongly acid.
E	10-17	Reddish yellow (7.5YR 6/6) loam; weak medium subangularblocky structure; friable; common fine, medium, and coarse roots; clear wavy boundary; strongly acid.
Bt1	17-37	Red (2.5YR 4/8) clay loam; few distinct yellowish red (5YR 5/6) mottles; moderate medium subangular blocky structure; friable; common coarse, and few fine and medium roots; common continuous clay films; gradual wavy boundary; strongly acid.
Bt2	37-57	Red (2.5YR 4/6) clay; moderate medium subangular blocky structure; friable; few fine, medium, and coarse roots; many continuous clay films; diffuse wavy boundary; strongly acid.
Bt3	57-97	Red (2.5YR 4/8) clay; moderate medium subangular blocky structure; friable; few fine and medium roots; many continuous clay films; diffuse wavy boundary; strongly acid.
BC1	97-123	Red (2.5YR 5/8) clay loam; few distinct pink (5YR 7/4) mottles; weak coarse subangular blocky structure; friable; few fine and medium roots; common discontinuous and few continuous clay films; diffuse wavy boundary; moderately acid.
BC2	123-160	Red (2.5YR 5/8) loam; few distinct pink (5YR 7/4) mottles; weak coarse subangular blocky structure to structureless massive; friable; few fine and medium roots; few discontinuous clay films; gradual wavy boundary; moderately acid.

Table 2a (Site 2, summit) (cont.).

Horizon	Depth	Description
	cm	
C1	160-186	Variegated red (2.5YR 4/6), reddish yellow (5YR 6/8) and reddish yellow (7.5YR 6/8) loam; structureless massive; friable; few fine and medium roots; many clay flows; diffuse wavy boundary; moderately acid.
C2	186-247	Variegated red (2.5YR 4/6), reddish yellow (7.5YR 6/8), and very dark greyish brown (10YR 3/2) fine sandy loam; structureless massive; friable; many clay flows; clear wavy boundary; moderately acid.
C3	247-280	Variegated red (2.5YR 5/8), reddish yellow (7.5YR 7/6), very pale brown (10YR 8/4), brownish yellow (10YR 6/8), and very dark greyish brown (10YR 3/2) loamy fine sand, structureless massive; friable; abrupt wavy boundary; moderately acid.
C4	280-320	Variegated reddish yellow (5YR 6/8), brownish yellow (10YR 6/8), very pale brown (10YR 7/3), and black (10YR 2/1) loamy fine sand; good rock structure; moderately acid.
C5	320-405	Variegated reddish yellow (7.5YR 6/8), very pale brown (10YR 8/4), brownish yellow (10YR 6/6), and black (10YR 2/1) loamy fine sand; moderately acid.
C6	405-450	Variegated strong brown (7.5YR 5/8), yellowish brown (10YR 5/8), very pale brown (10YR 2/1) loamy fine sand; moderately acid.
Rock	450 +	Mica gneiss

LOCATION: Nelson County, Virginia, on Oak Ridge Estate, 25 meters east of old theatre site in the woods.
VEGETATION: Oaks.
PARENT MATERIAL: Lovingston gneiss.

Table 2a (Site 2, summit) (cont.).

PHYSIOGRAPHY: Upland.
LANDSCAPE POSITION: Summit.
SLOPE: < 2%.
ELEVATION: 300 meters.
DRAINAGE: Well drained.
EROSION: None.
DESCRIBED BY: M. Stolt, S. Thomas, B. Legge, S. Cromer, A.T. Stevens, and H. Behl.
DATE: 8/25/88.

Table 2b. Profile description of the backslope soil at Site 2.

Horizon	Depth	Description
	cm	
A	0-8	Dark brown (7.5YR 4/4) loam; weak fine granular structure; very friable; many fine, medium, and coarse roots; clear wavy boundary; very strongly acid.
Bt1	8-35	Yellowish red (5YR 5/8) loam; weak medium subangular blocky structure; friable; common fine, medium, and coarse roots; common continuous clay films; gradual wavy boundary; very strongly acid.
Bt2	35-64	Red (2.5YR 4/6) clay; moderate medium subangular blocky structue; friable, few fine and medium roots; common continuous clay films; diffuse wavy boundary; strongly acid.
Bt3	64-92	Red (2.5YR 4/8) clay; moderate medium subangular blocky structure; friable; few fine and medium roots; common continuous clay films; clear wavy boundary; strongly acid.
Bt4	92-120	Red (2.5YR 4/8) clay; few distinct strong brown (7.5YR 5/8) mottles; moderate medium subangular blocky structure; few fine and medium roots; common continuous clay films; gradual wavy boundary; moderately acid.
2Bt5	120-148	Red (2.5YR 4/6) very gravelly clay; moderate medium subangular blocky structure; friable; common continuous clay films; angular quartz stone line (35% c.f.); abrupt wavy boundary; moderately acid.
2BC1	148-165	Red (2.5YR 4/6) clay loam; weak coarse subangular blocky structure; friable; few continuous clay films; gradual wavy boundary; moderately acid.

Table 2b (Site 2, backslope) (cont.).

Horizon	Depth	Description
	cm	
3BC2	165-187	Red (2.5YR 4/6) sandy clay loam; few distinct yellowish red (5YR 5/8) mottles; weak coarse subangular blocky structure; friable; few continuous clay films; gradual wavy boundary; strongly acid.
3C1	320-350	Variegated reddish yellow (7.5YR 7/8) and very pale brown (10YR 8/3) fine sandy loam; strongly acid.
3C2	350-370	Reddish yellow (5YR 6/8) fine sandy loam; moderately acid.
3Cr	370-390	Variegated red (2.5YR 5/8), black (N 2/0), and very pale brown (10YR 8/3) fine sandy loam; moderately acid.
Rock	390+	Mica gneiss.

Described from auger samples below 275 cm.

LOCATION: Nelson County, Virginia, Oak Ridge Estate, 100 meters west of old theatre site in woods.
VEGETATION: Oaks.
PARENT MATERIAL: Colluvium over Lovingston gneiss.
PHYSIOGRAPHY: Upland.
LANDSCAPE POSITION: Backslope.
SLOPE: 7%.
ELEVATION: 296 meters.
DRAINAGE: Well drained.
EROSION: Slight.
DESCRIBED BY: M.H. Stolt, M. Genthner, S. Thomas, B. Legge, S. Cromer, A.T. Stevens, and H. Behl.
DATE: 8/25/88.

Table 2c. Profile description of the footslope soil at Site 2.

Horizon	Depth	Description
	cm	
A	0-11	Dark brown (10YR 3/3) loam; weak fine subangular blocky breaking to weak fine granular; very friable; many fine and medium roots; abrupt wavy boundary; strongly acid.
E	11-25	Yellowish brown (10YR 5/8) fine sandy loam; weak medium subangular blocky structure; friable; common fine and medium roots; clear wavy boundary; very strongly acid.
Bt1	25-37	Strong brown (7.5YR 4/6) loam; weak medium subangular blocky structure; friable; few and fine medium roots; common continuous clay films; clear wavy boundary; very strongly acid.
Bt2	37-61	Yellowish red (5YR 5/8) loam; weak medium subangular blocky structure; friable; few fine and medium roots; common continuous clay films; clear wavy boundary; strongly acid.
2BC	61-79	Yellowish red (5YR 4/6) fine sandy loam; few distinct strong brown (7.5YR 4/6) mottles; weak moderate subangular blocky structure; friable; few fine and medium roots; common continuous clay films; clear wavy boundary; strongly acid.
2C	79-90	Variegated reddish yellow (5YR 6/6 and 7/8), strong brown (7.5YR 5/8), dark brown (7.5YR 4/4), and brownish yellow (10YR 6/6) sandy clay loam; structureless massive; friable; clear wavy boundary; strongly acid.
2Cr	90-100	Variegated strong brown (7.5YR 5/8), yellowish brown (10YR 5/8), very pale brown (10YR 8/4), and black (10YR 2/1) that crushes to fine sandy loam; structureless massive; friable; good rock structure; abrupt wavy boundary.

Table 2c (Site 2 footslope) (cont.).

LOCATION: Nelson County, Virginia, on Oak Ridge Estate, 200 meters east of old theatre site in woods.
VEGETATION: Oaks.
PARENT MATERIAL: Local alluvium over Lovingston augen gneiss.
PHYSIOGRAPHY: Upland.
LANDSCAPE POSITION: Footslope.
SLOPE: 5%.
ELEVATION: 290 meters.
DRAINAGE: Moderately well.
EROSION: None.
DESCRIBED BY: M.H. Stolt, M. Genthner, S. Thomas, B. Legge, S. Cromer, A.T. Stevens, and H. Behl.
DATE: 8/24/88.

cultural disturbance affecting the summit and backslope soils. Summit soils have slopes < 2%. Slopes at the backslopes are 18% for Site 1, and 7% for Site 2. Footslope soils occur on landscapes sloping at 5 and 6 percent. Stone lines composed of angular quartz gravels occur within the footslope soil of Site 1 (Figure 3) and backslope and footslope soils of Site 2 (Figure 4). At the summit of Site 1, soil and saprolite extends to at least 8.5 m below the soil surface. Regolith thickness at the backslope is < 5 m, and < 1.5 m at the footslope. Depth to bedrock was not determined between summit and backslope, and a general trend is given by the dashed line. Saprolite is absent at the footslope. Saprolite at the summit of Site 2 extends to 5 m below the soil surface, and the thickness decreases down the landscape. Saprolite is absent at the footslope.

Study sites 3 and 4 occur in the Blue Ridge Highlands near the town of Pilot, Montgomery County, Va. Site 3 is located within the property of an old church and cemetery. Summit and backslope soils (Table 3) appear to be have undergone minimal cultural disturbance. The residual portion of the soils have formed in saprolite derived from an augen gneiss (Pilot Gneiss, Lewis 1975). The pedons sampled are located on landscape positions with slopes of 2 (summit), 18 (backslope), and 6 % (footslope). A stone line occurs across much of this landscape. Regolith thickness is over 11.5 m at the summit, and decreases down the landscape (Figure 5).

The toposequence at Site 4 occurs within mature oak woodlands. Summit and backslope soils, and the lower portion of the footslope soil (Table 4) have formed in saprolite, derived from a gneissic schist component of the Blue Ridge Complex (Dietrick, 1954). The summit is nearly level, and backslope and footslope have slopes of 14 and 6 %, respectively (Figure 6). A discontinuity occurs at the footslope position.

Soil-Saprolite Zone of Transition

In defining the limits between soil and nonsoil, the authors of Soil Taxonomy (Soil Survey Staff, 1975) commented that the lower limit of the soil is the most difficult to define. Difficulty arises in determining where the pedologic process stops and the geochemical begins. Pedologic refers to the formation of soil, whereas geochemical refers to, in the case of hard rock, the formation of saprolite. In most residual soils there is a zone of transition (termed transition zone) between parent material (saprolite) and soil. Micromorphology of lower B horizons and upper saprolite was examined in summit and backslope soils to better define the transition zone and determine the true soil parent material.

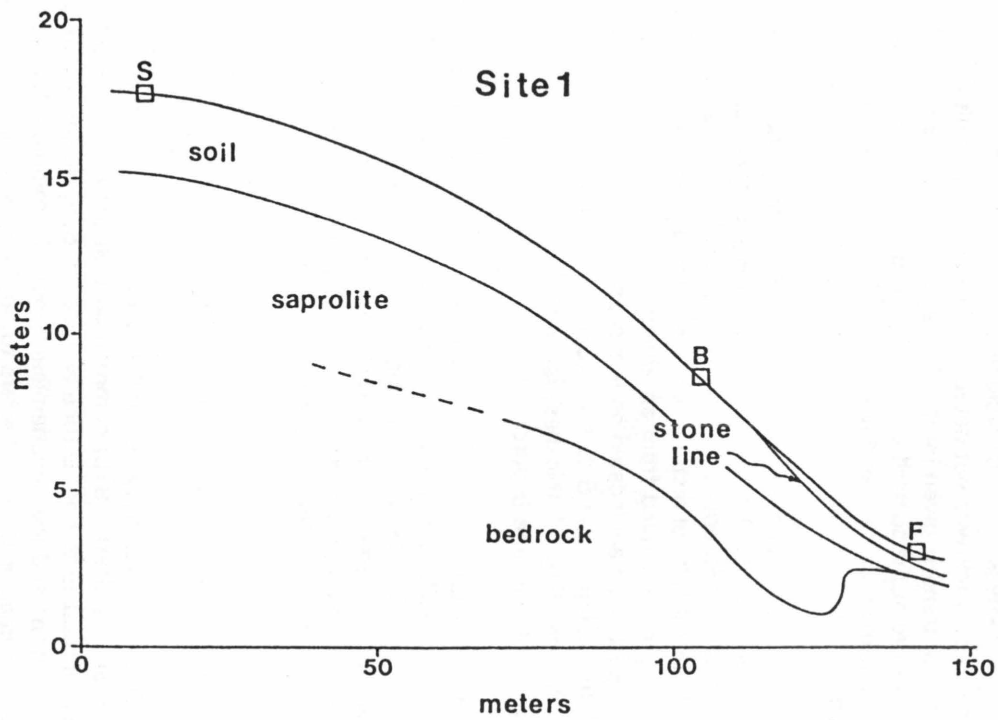

Figure 3. Cross section of Site 1. Vertical exaggeration is 5 times.

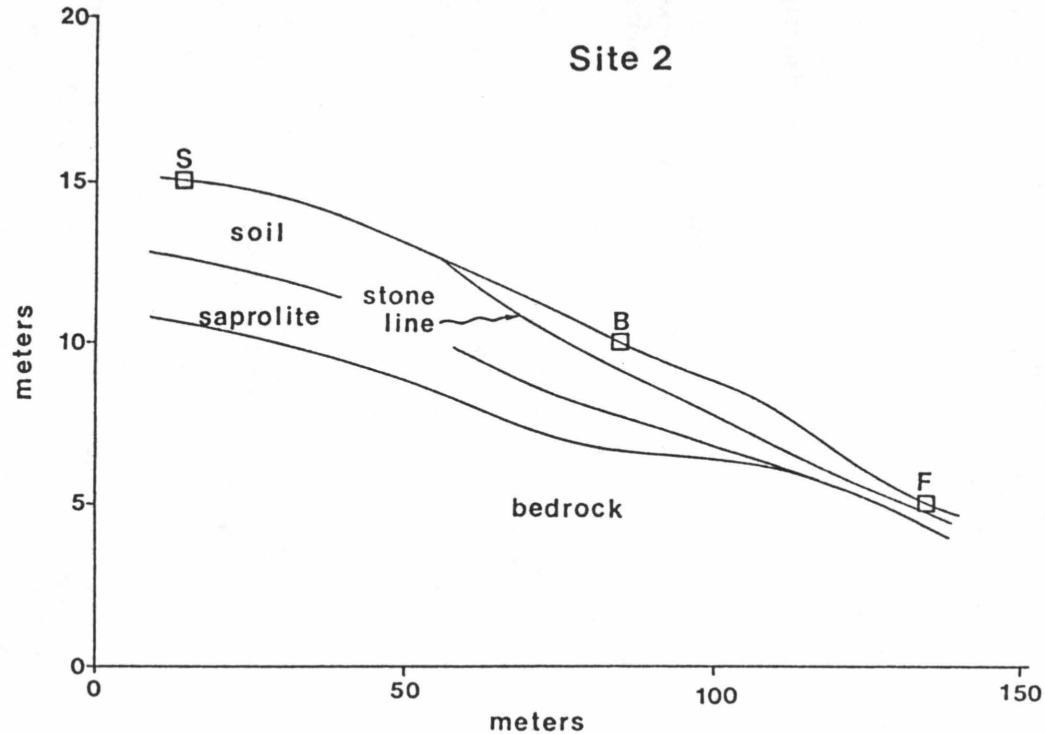

Figure 4. Cross section of Site 2. Vertical exaggeration is 5 times.

Table 3a. Profile description of the summit soil at Site 3.

Horizon	Depth	Description
	cm	
A	0-18	Very dark greyish brown (10YR 3/2) sandy loam; fine moderate granular structure; very friable; common fine and medium roots; clear smooth boundary; moderately acid.
E	18-28	Brown (7.5YR 4/2), with very dark greyish (10YR 3/2) earthworm crotovinas, sandy loam; weak medium subangular blocky structure; very friable; common fine, medium, and coarse roots; gradual wavy boundary; moderately acid.
BE	28-45	Strong brown (7.5YR 5/6) loam; common zones of dark brown (7.5YR 3/2); weak medium subangular blocky structure; friable; few fine, medium, and coarse roots; gradual wavy boundary; moderately acid.
Bt1	45-58	Strong brown (7.5YR 5/6) clay loam; few faint reddish yellow (7.5YR 6/6), yellowish red (5YR 5/6), and few distinct red (2.5YR 5/6) mottles; weak medium subangular blocky structure; friable; common continuous clay films; few fine and medium roots; gradual wavy boundary; moderately acid.
Bt2	58-83	Yellowish red (5YR 5/6) clay loam; common faint yellowish red (5YR 4/6), reddish yellow (5YR 6/6), and red (2.5YR 4/6) mottles; moderate medium subangular blocky structure; friable; many continuous clay films; few fine and medium roots; gradual wavy boundary; moderately acid.
Bt3	83-120	Yellowish red (5YR 5/6) clay loam; many distinct yellowish brown (10YR 5/6), many faint reddish yellow (5YR 6/6) and reddish brown (5YR 4/6) mottles; weak medium subangular blocky structure; friable; common continuous clay films; clear wavy boundary; moderately acid.

Table 3a (Site 3, summit) (cont.).

Horizon	Depth	Description
	cm	
BC	120-150	Variegated strong brown (7.5YR 5/6 and 4/6), reddish yellow (7.5YR 6/8), light yellowish brown (10YR 6/4), dark yellowish brown (10YR 4/6), black (N 2/0), and white (N 8/0) loam; weak coarse subangular blocky structure; friable; few continuous clay films; common Mn coatings; few augens; gradual wavy boundary; strongly acid.
C1	150-205	Variegated strong brown (7.5YR 5/6 and 4/6), reddish yellow (7.5YR 6/8), light yellowish brown (10YR 6/4), dark yellowish brown (10YR 4/6), black (N 2/0), and white (N 8/0) sandy loam; structureless massive; friable; few discontinuous clay films; many Mn coatings; common augens; gradual wavy boundary; strongly acid.
C2	205-310	Variegated strong brown (7.5YR 5/6 and 4/6), reddish yellow (7.5YR 6/8), light yellowish brown (10YR 6/4), dark yellowish brown (10YR 4/6), black (N 2/0), and white (N 8/0) sandy loam; structureless massive; friable; few discontinuous clay films; many Mn coatings; common augens; strongly acid.
C3	310-490	Variegated strong brown (7.5YR 5/6 and 4/6), reddish yellow (7.5YR 6/8), light yellowish brown (10YR 6/4), dark yellowish brown (10YR 4/6), black (N 2/0), and white (N 8/0) sandy loam; structureless massive; friable; few discontinuous clay films; many Mn coat-ings; common augens; strongly acid.
C4	490-610	Variegated strong brown (7.5YR 5/6 and 4/6), reddish yellow (7.5YR 6/8), light yellowish brown (10YR 6/4), dark yellowish brown (10YR 4/6), black (N 2/0), and white (N 8/0) sandy loam; structureless massive; friable; many Mn coatings; common augens; strongly acid.

Table 3a (Site 3, summit) (cont.).

Horizon	Depth	Description
	cm	
C5	610-780	Variegated strong brown (7.5YR 5/6, 4/6), reddish yellow (7.5YR 6/8), light yellowish brown (10YR 6/4), dark yellowish brown (10YR 4/6), black (N 2/0), white (N 8/0) sandy loam; structureless massive; friable; many Mn coatings; common augens; strongly acid.
C6	780-1145+	Variegated strong brown (7.5YR 5/6), reddish yellow (7.5YR 6/8), light yellowish brown (10YR 6/4), dark yellowish brown (10YR 4/6), black (N 2/0), and white (N 8/0) sandy loam; structureless massive; friable; many Mn coatings; common augens; strongly acid.

Described from auger samples below 240 cm. The BC horizon has structure breaks parallel to soil surface and normal to rock structure. Clay coatings occurred along these breaks.

LOCATION: Montgomery county, Virginia, 10 meters east of the entrance to High Rock Church.
VEGETATION: Oaks.
PARENT MATERIAL: Augen gneiss (Blue Ridge Complex).
LANDSCAPE POSITION: Summit.
PHYSIOGRAPHY: Upland.
SLOPE: < 2%.
ELEVATION: 725 meters.
DRAINAGE: Well.
EROSION: None.
DESCRIBED BY: M.H. Stolt, B.R. Stewart, and H. Behl.
DATE: 3/14/89.

Table 3b. Profile description of the backslope soil at Site 3.

Horizon	Depth	Description
	cm	
A	0-18	Dark yellowish brown (10YR 3/4) sandy loam; moderately fine granular structure; very friable; many medium and coarse roots; clear wavy boundary; moderately acid.
E	18-41	Yellowish Brown (10YR 5/4) and dark yellowish brown (10YR 4/4) sandy loam; weak medium subangular blocky structure parting to weak thin platy; very friable; common fine and medium roots; gradual wavy boundary; strongly acid.
EB	41-58	Dark brown (7.5YR 4/4) sandy clay loam; few faint dark yellowish brown (10YR 3/4) and brown (7.5YR 5/4) zones due to mixing; few distinct red (2.5YR 5/8) mottles; weak medium subangular block structure; friable; common fine roots; gradual wavy boundary; moderately acid.
Bt1	58-75	Yellowish red (5YR 5/8) clay loam; common faint light red (2.5YR 6/8), red (2.5YR 4/8), and strong brown (7.5YR 5/8) mottles; moderate medium subangular blocky structure; friable; common continuous clay films; common fine roots; gradual wavy boundary; strongly acid.
2Bt2	75-106	Yellowish red (5YR 5/8) clay loam; common faint light red (2.5YR 6/8), red (2.5YR 4/8), brown (7.5YR 5/4) mottles; moderate medium subangular blocky structure; friable; many continuous clay films; common fine roots; thin discontinuous stone line of quartz from 85-90 cm; diffuse wavy boundary; strongly acid.

Table 3b (Site 3, backslope) (cont.).

Horizon	Depth	Description
	cm	
2Bt3	106-128	Yellowish red (5YR 5/8) sandy clay loam; many faint red (2.5YR 5/8), light red (2.5YR 6/8 and 6/6), and strong brown (7.5YR 5/8) mottles; weak medium subangular blocky structure; friable; common continuous clay films; few fine roots; observable rock structure; common Mn coatings; clear wavy boundary; strongly acid.
2BC	128-150	Yellowish red (5YR 5/8) sandy loam/sandy clay loam; many faint red (2.5YR 5/8) and many distinct pinkish grey (5YR 6/2) mottles; weak coarse subangular blocky structure; friable; common continuous clay films; few fine roots; common Mn coatings; clear wavy boundary; strongly acid.
2C1	150-200	Variegated reddish brown (5YR 5/4), light reddish brown (2.5YR 6/4), reddish brown (2.5YR 5/4), light brownish grey (10YR 6/2), white (10YR 8/2), and brownish yellow (10YR 6/8) sandy loam; structureless massive; friable; few continuous clay films; few fine roots; many Mn coatings; diffuse wavy boundary; moderately acid.
2C2	200-260	Variegated reddish brown (5YR 5/4), light reddish brown (2.5YR 6/4), reddish brown (2.5YR 5/4), light brownish grey (10YR 6/2), white (10YR 8/2), and brownish yellow (10YR 6/8) sandy loam; structureless massive; friable; few continuous clay films; few fine roots; many Mn coatings; diffuse wavy boundary; moderately acid.
2C3	260-300	Variegated reddish brown (5YR 5/4), light reddish brown (2.5YR 6/4), reddish brown (2.5YR 5/4), light brownish grey (10YR 6/2), white (10YR 8/2), and brownish yellow (10YR 6/8) sandy loam; structureless massive; friable; few continuous clay films; few fine roots; many Mn coatings; moderately acid.

Table 3b (Site 3, backslope) (cont.).

Horizon	Depth	Description
	cm	
2Cr	300-390	Variegated reddish brown (5YR 5/4), light reddish brown (2.5YR 6/4), reddish brown (2.5YR 5/4), light brownish grey (10YR 6/2), white (10YR 8/2), and brownish yellow (10YR 6/8) sandy loam; structureless massive; friable; few continuous clay films; few fine roots; many Mn coatings; moderately acid.
Rock	390+	Augen gneiss.

Described from auger samples below 260 cm. Evidence of tree thrown in the pit (D-face). The Bt1, Bt2, and Bt3 horizons were very thin along this face.

LOCATION: Montgomery County, Virginia, 20 meters south of the High Rock Church.
VEGETATION: Oaks and pines.
PARENT MATERIAL: Augen gneiss (Blue Ridge Complex).
LANDSCAPE POSITION: Backslope.
PHYSIOGRAPHY: Upland.
SLOPE: 18%.
ELEVATION: 715 meters.
DRAINAGE: Well.
EROSION: None.
DESCRIBED BY: M.H. Stolt, B.R. Stewart, and H. Behl.
DATE: 3/16/89.

Table 3c. Profile description of the footslope soil at Site 3.

Horizon	Depth	Description
	cm	
A	0-11	Dark yellowish brown (10YR 3/4) sandy loam; weak fine subangular blocky to weak fine granular structure; friable; many fine and medium, and common coarse roots; abrupt smooth boundary; strongly acid.
E	18-30	Yellowish brown (10YR 5/6) sandy loam; common zones of A horizon material; weak medium subangular blocky structure; friable; few medium and fine roots; gradual wavy boundary; strongly acid.
BE	30-44	Yellowish brown (10YR 5/8) loam; weak medium subangular blocky structure; friable; few fine roots; abrupt smooth boundary; strongly acid.
2Bt1	44-75	Yellowish red (5YR 5/8) clay loam; red (2.5YR 5/8) and very dark grey (10YR 3/1) mottles; moderate medium subangular blocky structure; friable; many continuous red (7.5YR 5/8) clay films; few fine roots; stone line of olive brown (2.5YR 4/4) schist at upper boundary; gradual wavy boundary; strongly acid.
2Bt2	75-108	Yellowish red (5YR 5/8) sandy clay loam; few faint reddish yellow (7.5YR 6/8) and few distinct red (2.5YR 4/8) mottles; weak coarse subangular blocky structure; friable; common continuous red (2.5YR 4/8) clay films; many of the clay films were parallel to the surface and normal to the rock structure; few fine roots; abrupt wavy boundary; strongly acid.
2Bt3	108-120	Yellowish red (5YR 5/6) clay; weak medium subangular blocky structure parting along rock faces; friable; many continuous red (2.5YR 4/8) clay films; common fine and medium roots; abrupt wavy boundary; strongly acid.

Table 3c (Site 3, footslope) (cont.).

Horizon	Depth	Description
	cm	
2BC	120-145	Brownish yellow (10YR 6/8) sandy loam; common faint light yellowish brown and common prominent red (2.5YR 5/6) mottles; weak coarse subangular blocky structure parting along rock faces; friable; common continuous strong brown (7.5YR 4/6) clay films; few fine roots; few black (10YR 2/1) Mn coatings; common white (5YR 8/1) augens; gradual wavy boundary; strongly acid.
2C1	145-190	Variegated light yellowish brown (10YR 6/4), yellow (10YR 7/8), black (10YR 2/1), yellowish red (5YR 5/8), and white (5YR 8/1) sandy loam; structureless massive; friable; few fine roots; common Mn coatings; many augens; gradual wavy boundary; strongly acid.
2C2	190-295	Variegated yellowish brown (10YR 5/6), very dark brown (10YR 2/2), reddish yellow (7.5YR 7/8), yellowish red (5YR 4/6), and white (5YR 8/1) sandy loam; structureless massive; friable; few fine roots; common Mn coatings; many augens; strongly acid.
2Cr	295-310	Variegated yellowish brown (10YR 5/6), very dark brown (10YR 2/2), reddish yellow (7.5YR 7/8), yellowish red (5YR 4/6), and white (5YR 8/1) sandy loam; structureless massive; friable; few fine roots; common Mn coatings; many augens; strongly acid.
Rock	310+	Augen gneiss.

Described from auger samples below 220 cm. The thickness of the 2Bt3 varies from 8-20 cm. The 2Bt3 horizon was totally absent along the C and D faces. Thin zones of weathered schist (2-3 cm thick) were present in the 2C1 and 2C2 horizons. A blue quartz stone line was observed in the C and D faces within the 2Bt horizon, but could not be located in the A and B faces.

Table 3c (Site 3, footslope) (cont.).

LOCATION: Montgomery County, Virginia, 50 meters south of High Rock Church.
VEGETATION: Black locust.
PARENT MATERIAL: Colluvium over augen gneiss.
LANDSCAPE POSITION: Footslope.
PHYSIOGRAPHY: Upland.
SLOPE: 6%.
ELEVATION: 700 meters.
DRAINAGE: Well.
EROSION: None.
DESCRIBED BY: M.H. Stolt, M. Matt, M. Baker, and H. Behl.
DATE: 6/2/89.

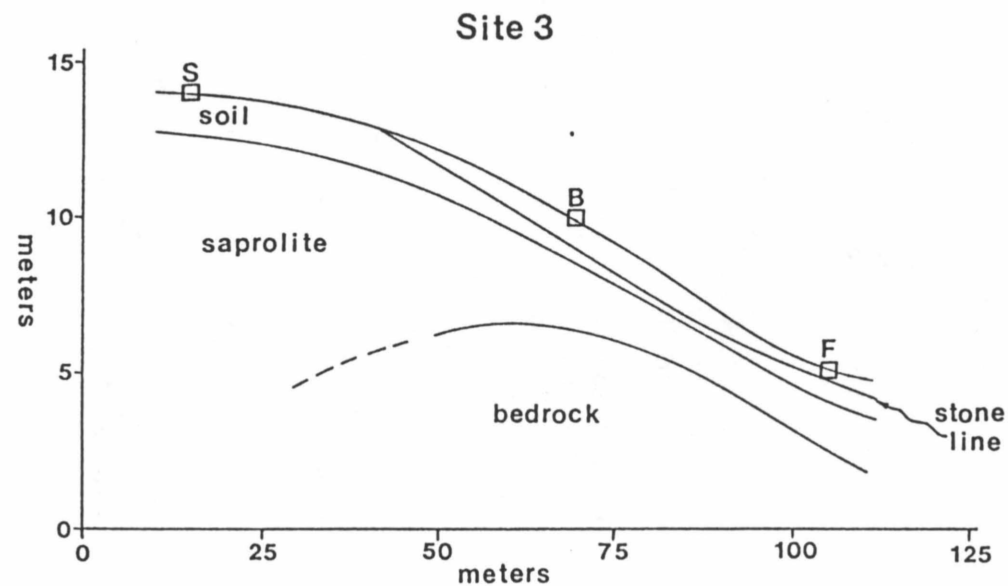

Figure 5. Cross section of Site 3. Vertical exaggeration is 4.5 times.

Table 4a. Profile description of the summit soil of Site 4.

Horizon	Depth	Description
	cm	
A	0-7	Dark brown (10YR 3/3) silt loam; weak fine granular structure; friable; many fine and medium roots; clear wavy boundary; extremely acid.
E	7-18	Very pale brown (10YR 7/4) silt loam; weak medium subangular block structure parting to weak thin platy; friable; common fine and medium roots; gradual wavy boundary; extremely acid.
BE	18-28	Strong brown (7.5YR 5/8) silty clay loam; weak medium subangular block structure; friable; common fine and medium roots; few continuous clay films; gradual wavy boundary; very strongly acid.
Bt1	28-54	Yellowish red (5YR 5/8) silty clay loam; moderate medium subangular blocky structure; friable; many continuous clay films; few fine and medium roots; gradual wavy boundary; very strongly acid.
Bt2	54-72	Red (2.5YR 5/6) clay; common distinct light grey (5YR 7/1) and reddish yellow (7.5YR 7/8) mottles; weak medium subangular blocky structure; friable; common continuous clay films; few fine and medium roots; some evidence of rock structure; gradual wavy boundary; strongly acid.
BC1	72-96	Red (2.5YR 5/8) silt loam; many distinct light grey (5YR 7/1) and reddish yellow (7.5YR 7/8) mottles; weak medium subangular blocky structure; friable; common continuous clay films; evidence of rock structure; gradual wavy boundary; strongly acid.

Table 4a (Site 4, summit) (cont.).

Horizon	Depth	Description
	cm	
BC2	96-114	Red (2.5YR 5/8) silt loam; many distinct white (N 8/0) and reddish yellow (7.5YR 7/8) mottles; weak medium subangular blocky structure; friable; common continuous clay films; evidence of rock structure; gradual wavy boundary; strongly acid.
C1	114-176	Variegated red (2.5YR 5/8), reddish yellow (5YR 7/8) and white (N 8/0) loam; rock controlled structure; friable; few continuous clay films; common Mn coatings; contains a 10-20 cm zone of hard but weathered phyllite; clear wavy boundary; strongly acid.
C2	176-265	Variegated red (2.5YR 5/8), reddish yellow (5YR 7/8) and white (N 8/0) loam; rock controlled structure; friable; few continuous clay films; common Mn coatings; thin zone of hard but weathered phyllite at the base of the horizon; clear wavy boundary; moderately acid.
C3	265-330	Variegated light red (2.5YR 6/6), reddish yellow (5YR 7/8) and white (N 8/0) silt loam; rock controlled structure; friable; few continuous clay films; common Mn coatings; strongly acid.
C4	330-445	Reddish yellow (7.5YR 6/8) sandy loam; many distinct yellowish red (5YR 5/8) and white (N 8/0) mottles; rock controlled structure; friable; moderately acid.
C5	445-525	Brownish yellow (10YR 6/8) sandy loam; many distinct yellowish red (5YR 5/8) and white (N 8/0) mottles; rock controlled structure; friable; moderately acid.
C6	525-580	Brownish yellow (10YR 6/8) sandy loam; many distinct yellowish red (5YR 5/8) and white (N 8/0) mottles; rock controlled structure; friable; moderately acid.

Table 4a (Site 4, summit) (cont.).

Horizon	Depth	Description
	cm	
C7	580-655	Brownish yellow (10YR 6/8) sandy loam; many distinct yellowish red (5YR 5/8) and white (N 8/0) mottles; rock controlled structure; friable; moderately acid.
C8	655-790	Brownish yellow (10YR 6/8) sandy loam; many distinct yellowish red (5YR 5/8) and white (N 8/0) mottles; rock controlled structure; friable; strongly acid.
C9	655-850	Brownish yellow (10YR 6/8) sandy loam; many distinct yellowish red (5YR 5/8) and white (N 8/0) mottles; rock controlled structure; friable; moderately acid.

Notes: Described from auger samples below 285 cm. Quartz vein at 850 cm.

LOCATION: Montgomery County, Virginia, Harrison Farm, off Rt 612, first block of woods south of the farmhouse.
VEGETATION: Oaks.
PARENT MATERIAL: Gneissic schist (Blue Ridge Complex).
LANDSCAPE POSITION: Summit.
PHYSIOGRAPHY: Upland.
SLOPE: $< 2\%$.
ELEVATION: 715 meters.
DRAINAGE: Well.
EROSION: None.
DESCRIBED BY: M.H. Stolt, C. Ogg, and H. Behl.
DATE: 10/25/88.

Table 4b. Profile description of the backslope soil at Site 4.

Horizon	Depth	Description
	cm	
A	0-9	Dark brown (10YR 3/3) silt loam; weak fine granular structure; friable; many fine and medium roots; clear wavy boundary; extremely acid.
A2	9-16	Dark yellowish brown (10YR 4/6) silt loam; weak fine granular structure; friable; common fine and medium roots; clear wavy boundary; very strongly acid.
Bt1	16-27	Reddish brown (5YR 5/4) silt loam; weak medium subangular blocky structure; friable; few fine roots; common continuous clay films; gradual wavy boundary; very strongly acid.
Bt2	27-48	Yellowish red (5YR 5/8) clay loam/clay; moderate medium subangular blocky structure; friable; many continuous clay films; few fine and medium roots; gradual wavy boundary; strongly acid.
Bt3	48-63	Red (2.5YR 5/6) clay loam; common distinct light yellowish (10YR 6/4) mottles; moderate medium subangular blocky structure; friable; many continuous clay films; few fine and medium roots; clear wavy boundary; strongly acid.
BC1	63-81	Red (2.5YR 5/8) and light yellowish brown (10YR 6/4) loam; many prominent black (10YR 2/1) and white (5Y 8/1) mottles; weak medium subangular blocky structure; friable; common continuous clay films; evidence of rock structure; gradual wavy boundary; strongly acid.
BC2	81-96	Light yellowish brown (10YR 6/4) sandy loam; many prominent white (N 8/0) and many distinct reddish yellow (7.5YR 7/8) mottles; rock controlled structure; friable; few fine roots; few discontinuous red (2.5YR 4/8) clay films; gradual wavy boundary; moderately acid.

Table 4b (Site 4 backslope) (cont.).

Horizon	Depth	Description
	cm	
C1	96-144	Variegated red (2.5YR 5/8), reddish yellow (5YR 7/8), pale brown (10YR 6/3), black (10YR 2/1) and white (N 8/0) loam; rock controlled structure; friable; few fine roots; gradual wavy boundary; moderately acid.
C2	144-170	Variegated red (2.5YR 5/8), reddish yellow (5YR 7/8), pale brown (10YR 6/3), black (10YR 2/1) and white (N 8/0) loam; rock controlled structure; friable; few fine roots; clear wavy boundary; moderately acid.
C3	170-241	Variegated red (2.5YR 5/8), reddish yellow (5YR 7/8), light yellowish brown (10YR 6/4), black (10YR 2/1) and white (N 8/0) sandy loam; rock controlled structure; friable; few fine roots; clear wavy boundary; moderately acid.
C4	241-360	Light yellowish brown (10YR 6/4) sandy loam; many prominent white (5Y 8/1), and black (10YR 2/1), and many distinct strong brown (7.5YR 5/8) and reddish yellow (7.5 YR 5/8) mottles; rock controlled structure; friable; moderately acid.
C5	360-410	Light yellowish brown (10YR 6/4) silt loam; many prominent white (5Y 8/1), and black (10YR 2/1), and many distinct strong brown (7.5YR 5/8) and reddish yellow (7.5YR 5/8) mottles; rock controlled structure; friable; moderately acid.
C6	410-580	Light yellowish brown (10YR 6/4) silt loam; many prominent white (5Y 8/1), and black (10YR 2/1), and many distinct strong brown (7.5YR 5/8) and reddish yellow (7.5 YR5/8) mottles; rock controlled structure; friable; moderately acid.

Table 4b (Site 4 backslope) (cont.).

Horizon	Depth	Description
	cm	
C7	410-610	Yellowish brown (10YR 5/4) silt loam; many prominent white (5Y 8/1), and black (10YR 2/1), and many distinct strong brown (7.5YR 5/8) and reddish yellow (7.5 YR 5/8) mottles; rock controlled structure; friable; moderately acid.

Notes: Described from auger samples below 280 cm. Quartz vein at 610 cm.

LOCATION: Montgomery County, Virginia, Harrison Farm, off Rt. 612, first block of woods south of the farmhouse.
VEGETATION: Oaks and pines.
PARENT MATERIAL: Gneissic schist (Blue Ridge Complex).
LANDSCAPE POSITION: Backslope.
PHYSIOGRAPHY: Upland.
SLOPE: 14%.
ELEVATION: 707 meters.
DRAINAGE: Well.
EROSION: None.
DESCRIBED BY: M.H. Stolt and H. Behl.
DATE: 10/28/88.

Table 4c. Profile description of the footslope soil at Site 4.

Horizon	Depth	Description
	dm	
A	0-18	Brown (10YR 4/3) gravelly silt loam; weak medium granular structure; friable; 29% angular quartz gravels; common fine and medium roots; clear wavy boundary; very strongly acid.
BA	18-32	Brown (10YR 4/3) and strong brown (7.5YR 5/6) gravelly silt loam; weak medium subangular blocky structure; friable; 29% angular quartz gravels; common fine and medium roots; gradual wavy boundary; very strongly acid.
Bt1	32-47	Strong brown (7.5YR 5/6) gravelly silt loam; moderate medium subangular blocky structure; friable; common fine and medium roots; 22% angular quartz gravels; common continuous clay films; gradual wavy boundary; strongly acid.
Bt2	47-73	Strong brown (7.5YR 5/6) gravelly loam; common distinct yellow (10YR 7/8) mottles; moderate medium subangular blocky structure; friable; 16% angular quartz gravels; few fine and medium roots; many continuous clay films; gradual wavy boundary; strongly acid.
2Bt3	73-105	Strong brown (7.5YR 5/6) loam; common distinct yellow (10YR 7/8) mottles; weak medium subangular blocky structure; friable; few fine and medium roots; common continous clay films; clear wavy boundary; strongly acid.
2BC1	105-163	Variegated very pale brown (10YR 8/3), yellow (10 YR 7/6), and light gray (10YR 7/1) loam; weak coarse subangular blocky structure; friable; few fine and medium roots; common continuous clay films; gradual wavy boundary; strongly acid.

Table 4c (Site 4, footslope) (cont.).

Horizon	Depth	Description
	cm	
2BC2	163-192	Variegated very pale brown (10YR 8/3) yellow (10YR 7/6), light gray (10YR 7/1), and black 10YR 2/1) loam; rock controlled structure; friable; gradual wavy boundary; strongly acid.
2C1	192-285	Light yellowish brown (10YR 6/4) sandy loam; many prominent light gray (10YR 7/1), black (10YR 2/1), and very pale brown (10YR 8/3) mottles; rock controlled structure; firm; moderately acid.
2C2	285-335	Strong brown (7.5YR 5/6) sandy loam; many prominent light gray (10YR 7/1), black (10YR 2/1), and very pale brown (10YR 8/3) mottles; rock controlled structure; friable; moderately acid.
2C3	235-455	Strong brown (7.5YR 5/6) sandy loam; many prominent light gray (10YR 7/1), black (10YR 2/1), and very pale brown (10YR 8/3) mottles; rock controlled structure; friable; moderately acid.
2C4	455-515	Brownish yellow (10YR 6/6) sandy loam; many prominent light gray (10YR 7/1), black (10 YR 2/1), and very pale brown (10YR 8/3) mottles; rock controlled structure; friable; moderately acid.
2C5	515-555	Yellowish brown (10YR 5/4) sandy loam; many prominent light gray (10YR 7/1), black (10YR 2/1), and very pale brown (10YR 8/3) mottles; rock controlled structure; friable; moderately acid.
2Cr	555-600	Yellowish brown (10YR 5/4) sandy loam; many prominent light gray (10YR 7/1), black (10YR 2/1), and very pale brown (10YR 8/3) mottles; rock controlled structure; firm; moderately acid.
Rock	600+	Gneissic schist.

Table 4c (Site 4, footslope) (cont.).

Notes: Described from auger samples below 285 cm.

LOCATION: Montgomery County, Virginia, Harrison Farm, off Rt. 612, first block of woods south of the farmhouse.
VEGETATION: White pines.
PARENT MATERIAL: Colluvium over gneissic schist residium (Blue Ridge Complex).
LANDSCAPE POSITION: Footslope.
PHYSIOGRAPHY: Upland.
SLOPE: 6%.
ELEVATION: 697 meters.
DRAINAGE: Well.
EROSION: None.
DESCRIBED BY: M.H. Stolt and H. Behl.
DATE: 10/29/88.

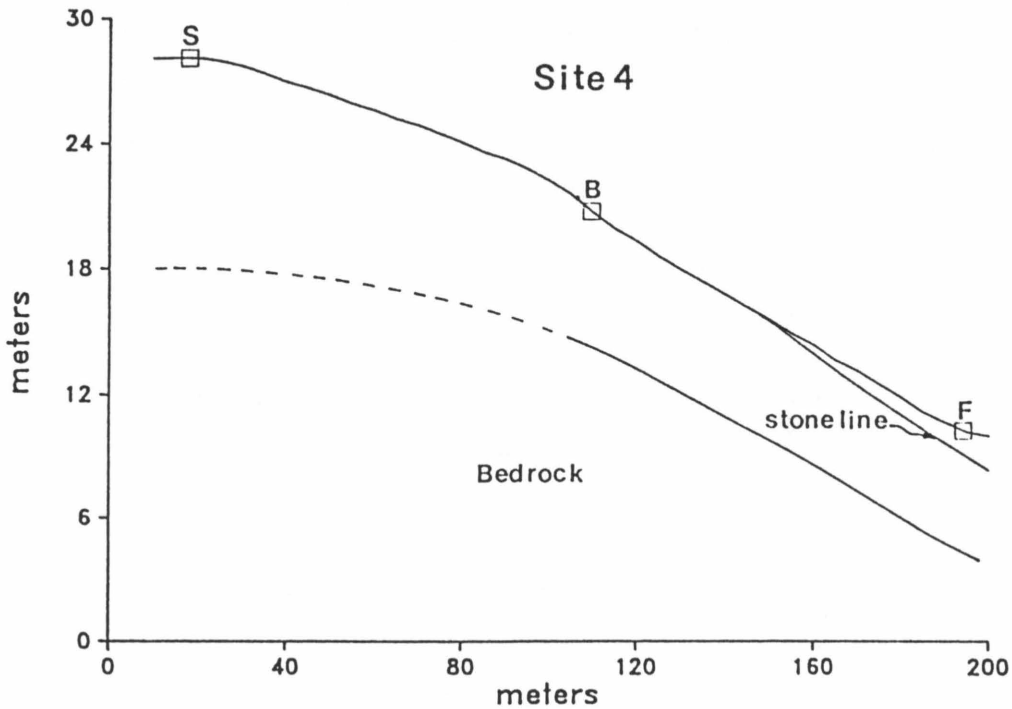

Figure 6. Cross section of Site 4. Vertical exaggeration is 7 times.

Field descriptions indicate that the transition zone is relatively thin (20-44 cm), and soil horizonation is fairly simple (Tables 1-4). Micromorphology (Table 5) and laboratory results (Table 6), however, suggest that in some cases the transition zone is much thicker and several horizons are present. The clay content of the summit BC horizon at Site 1 is 19%, and 4.5% occurs as oriented clay coatings. In the field, the BC horizon shows evidence of rock structure as parent material mottles. In addition, a substantial decrease in clay relative to the maximum (52 vs 19%) occurs. Based on these data, the horizon was renamed BCt.

Although the C1 and C2 horizons of the summit pedon of Site 1 were described as structureless massive in the field, both oriented clay and some weak subangular blocky microstructure were observed in thin section. These features are indicative of pedogenic process, and these horizons should not be considered C horizons. In order to evaluate the correlation between micromorphology and lab data, percent sand, total clay, DCB extractable Fe, and sand Zr were plotted with depth. Slopes of sand, clay, and DCB Fe lines for the summit pedon at Site 1 suggest two separate trends (Figure 7). The first trend shows an area of transition between the argillic horizon and saprolite in which substantial change occurs. Clay data suggest that the first transition zone occurs between the Bt3 and BC horizon. Percent sand, and to a lesser degree percent DCB Fe, suggests the first transition ends at the CB horizon. Below this point very little change occurs with depth. The BC horizon falls within the first trend because rates of change with depth are occurring at approximately the same rate as the other B horizons. The CB horizon occurs within the boundaries of the second trend because changes with depth are occurring in a similar manner to those in the C horizon.

Pedons in the Blue Ridge Highlands have thinner transition zones between soil and saprolite than those in the Piedmont (Figure 8). In the summit pedon of Site 3, the BC horizon shows 5% oriented clay, and was designated a BCt horizon. Evidence of pedologic process such as oriented clay and subangular blocky microstructure are absent from the C1 and C2 horizons, so their horizon designations were left as those given in the field.

Micromorphology and laboratory observations and results indicate that many of the horizons that were labelled in the field as C horizons are actually transition horizons. The following recommendations apply to making field descriptions of soil-saprolite transition horizons, and saprolite C horizons: 1) Percent clay should not decrease following the first C horizon. 2) C horizons should lack subangular blocky microstructure and illuvial clay in small macrovoids as observed in a hand lens. Clay flows are allowed in C horizons if they are restricted to large macropores along relic fissure cracks or similar non-pedologic breaks in the massive saprolite. 3) Horizons with moderate evidence

Table 5. Selected micromorphological properties and characteristics.

Horizon	Depth	Oriented Clay	Planar Voids	Packing voids	20_{um} c:f ratio	Micro-structure
	cm	%	%	%		
Site 1 Summit						
Bt3	48-63	16.2	7.5	0.0	0.3	Str SBK
Bt4	63-126	11.2	3.2	0.0	0.6	Str/Mod SBK
BC	126-170	4.5	1.3	1.0	0.9	Wk SBK/RC
C1	170-202	0.7	0.0	6.0	1.5	RC/Wk SBK
C2	202-245	1.4	0.6	3.1	1.9	RC/Wk SBK
C3	245-420	0.3	0.0	6.7	2.7	RC

Table 5 (cont.). Selected micromorphological properties and characteristics.

Horizon	Depth	Oriented Clay	Planar Voids	Packing voids	20_{um} c:f ratio	Micro-structure
	cm	%	%	%		
Site 3 Summit						
Bt3	83-120	9.1	4.6	0.0	0.4	Mod SBK
BC	120-150	4.9	2.7	0.0	0.6	Wk SBK/RC
C1	150-205	0.0	2.5	0.6	0.8	RC/crack
C2	205-310	0.0	0.3	0.0	0.3	RC/crack

Abbreviations include: Wk-weak, Mod-moderate, Str-strong, SBK-subangular blocky, RC-rock controlled, porph-porphyric.

Table 6. Selected physical and chemical properties.

Horizon	Depth	Sand	Clay	Fine Clay	DCB-Fe	Bulk Density
	cm	%	%	%	%	g/cm^3
Site 1 Summit						
Bt3	48-63	33	52	24	2.60	1.28
Bt4	63-126	51	30	14	2.32	1.37
BC	126-170	60	19	9	2.10	1.47
C1	170-202	67	8	3	1.20	1.38
C2	202-245	74	8	3	0.92	1.34
C3	245-420	76	6	2	0.84	1.30
Site 3 Summit						
Bt3	83-120	40	36	17	3.69	1.49
BC	120-150	58	9	4	2.02	1.43
C1	150-205	66	5	1	1.82	1.40
C2	205-310	59	4	1	1.74	1.37

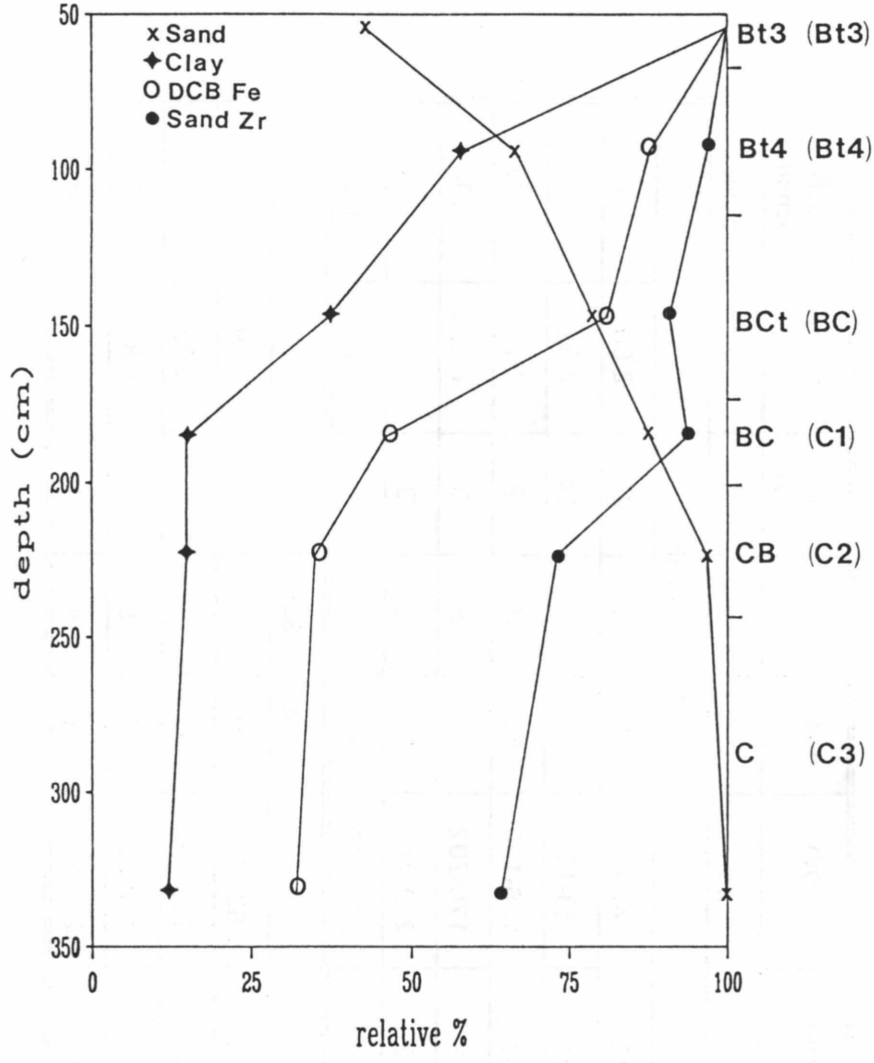

Figure 7. Percent sand, clay, DCB Fe, and sand Zr with depth in the summit pedon of Site 1. Soil horizonation was determined after laboratory results. Field horizonation is given in the parentheses.

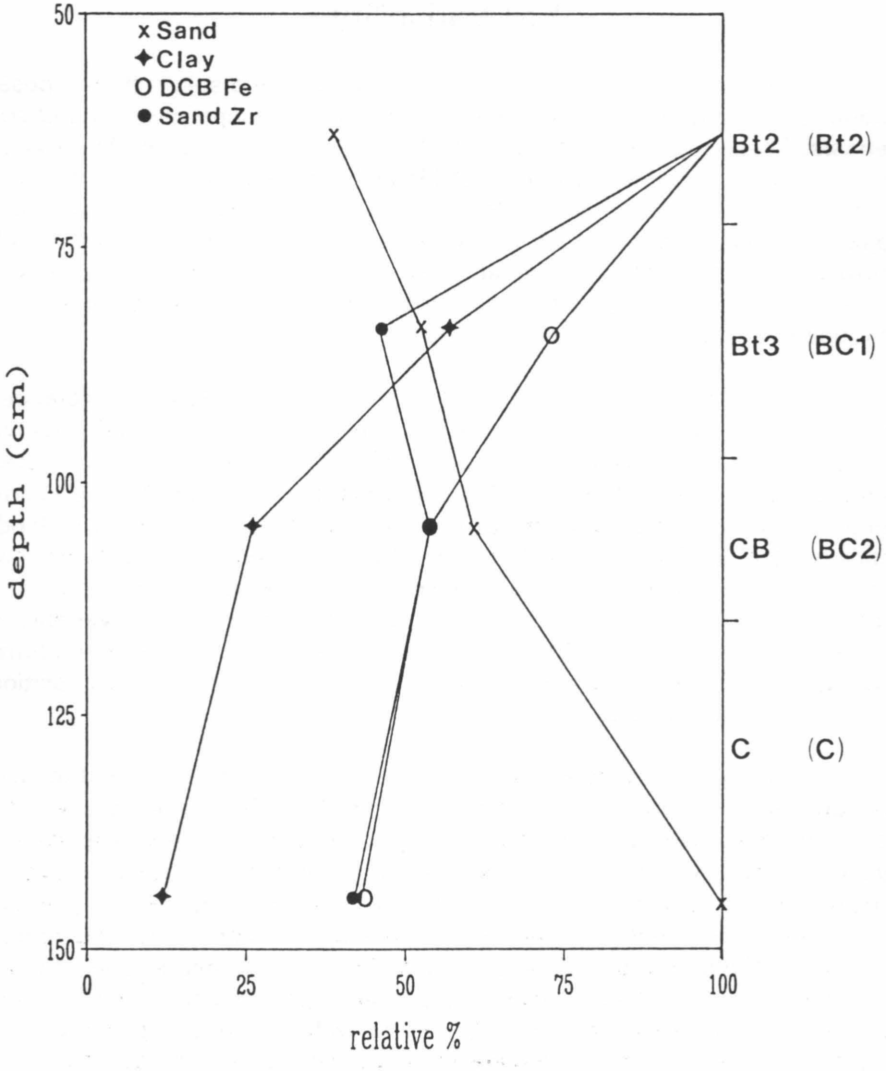

Figure 8. Percent sand, clay, DCB Fe, and sand Zr with depth in the summit pedon of Site 4. Soil horizonation was determined after laboratory results. Field horizonation is given in the parentheses.

of rock structure should be labelled a transition horizon, even if the horizon meets the clay requirements as part of the argillic horizon.

Soil Variability

The overall focus of this study was to examine soils within toposequences to evaluate the relationships between landscape position and soil genesis. These relationships can often be hidden or confounded by random soil variability. In order to examine soil-landscape relationships using reconstruction and other techniques, differences related to random variability must be recognized and separated from the measurable differences associated with factors such as parent material, pedogenesis, or landscape position. Therefore, soil variability was examined to evaluate the sources and degree of random variability in the soils studied.

Total variability within this study can be attributed to differences between study sites, landscape positions, horizons, and variability within horizons due to lateral variability, and sampling and lab error. Using a nested design, the sources of the variability and amount contributed by each component, were estimated. Percent of the total variability contributed by landscape position is minimal to totally absent (Table 7). These data suggest that for upland soils in which study sites are spread between different regions and parent materials, landscape position contributes little to the total variability. Therefore, for studies of upland soils on a fairly large scale, parent material and regional climate factors are much more important than landscape position for explaining soil development.

None of the variables show > 66% of the variability related to site, and only sand Zr and Ti, and total silt show > 50% related to site. The various sand and silt fractions show an equal amount of variability explained by site and horizon. Therefore, even though the soils examined occur in two different regions, and parent materials vary from mica gneiss to gneissic schist, soils and parent materials appear very similar. Total, fine, and coarse clay, sand, DCB extractable Fe and Al, and silt Zr, Ti, Fe, and K, and sand Fe are the variables in which variability is explained primarily by horizon. These results are expected for moderately well to well developed upland soils in which weathering and illuviation are the major soil-forming processes.

Table 7. Percent of the total variability explained by site, position, horizon, and error.

Variable	Site	Position	Horizon	Error
	------------------------%----------------------			
VCo Sand	43	0	48	9
Co Sand	49	0	44	7
Med Sand	46	0	46	8
Fine Sand	49	0	46	5
VF Sand	44	0	53	3
Co Silt	47	0	42	11
Fine Silt	47	0	46	7
Co Clay	4	0	93	3
Fine Clay	4	0	92	4
Sand	17	0	78	5
Silt	56	0	34	10
Clay	4	0	93	3
DCB Fe	2	0	91	7
DCB Al	5	0	88	7
Sand Zr	58	2	26	13
Silt Zr	26	0	44	29
Sand Ti	66	2	19	14
Silt Ti	13	3	78	6
Sand Fe	8	0	73	19
Silt Fe	0	0	92	8
Sand K	41	7	28	25
Silt K	5	0	69	26

Variability of Residual Parent Materials Among Landscape Positions

Residual parent materials within sites appear very similar. In order to better describe the similarities and differences of the parent material, particle size and elemental composition data from the C horizons were analyzed using analysis of variance. For Site 1, sand Zr and silt Ti (Table 8) are the only elemental fractions that are significantly different at the three landscape positions. The other elemental fractions and all of the particle size fractions (Table 9) are statistically equivalent across the landscape, or only one position shows some variation. The C horizons in Site 2 appear very uniform across the landscape with no means significantly different between all three landscape positions, and few differing between any two landscape positions (Tables 8 and 9).

The C horizons at Site 3 are saprolite formed from an augen gneiss. Sand fractions are rich in K, and silt fractions rich in Fe (Table 8). Sand Fe is the only elemental fraction that differs significantly between the three landscape positions. The other elemental fractions are very similar. Although the various sand and silt fractions appear fairly uniform across the landscape, total sand and silt are significantly different between the three positions (Table 9). These data suggest that some variation in the particle size fractions occurs between landscape positions, but the elemental composition and therefore mineralogy of the silt and sand fractions are essentially the same.

The residual parent material for the soils at Site 4 is saprolite formed from a gneissic schist. Silt Ti, Fe, and K, as well as fine silt, differ significantly between the three landscape positions (Table 8). The other elemental and particle size fractions are similar. These data suggest that the mineralogy of silt fractions may vary slightly depending upon the landscape position.

Variability Within Horizons

Variability within horizons of the same pedon, or lateral variability, was examined for 3 horizons within each pit. These included the horizon just below the A horizon, the most expressed B horizon, and the lowest C horizon accessible within the soil pits. Variability is reported as coefficients of variation (CVs).

The highest mean CV for each particle size fraction occurs in the C horizon (Table 10). In 7 out of 10 DCB and elemental parameters, the C

Table 8. Sample means of elemental sand and silt fractions of the residual parent material at each landscape position. Sample means with different letters are signigicantly different at the .05 level.

Position	S Zr	Si Zr	S Ti	Si Ti	S Fe	Si Fe	S K	Si K
	%	%	%	%	%	%	%	%
Site 1								
Summit	0.03a	0.16a	0.30a	0.40a	1.88a	2.55a	4.54a	3.03a
Backslope	0.10b	0.10a	0.66b	0.70b	4.74b	4.49b	4.15a	3.21a
Footslope	0.19c	0.12a	0.66b	1.00c	2.62a	3.54b	4.19a	2.85a
Site 2								
Summit	0.18a	0.01a	1.03a	0.60a	5.11a	3.15a	3.74a	3.97a
Backslope	0.14b	0.02a	1.04a	0.69a	4.48a	3.31ab	3.87a	4.12a
Footslope	0.15ab	0.42b	0.69a	0.67a	4.36a	3.86b	5.05a	2.58b

Table 8 (cont.). Sample means of elemental sand and silt fractions of the residual parent material at each landscape position. Sample means with different letters are signigicantly different at the .05 level.

Position	S Zr	Si Zr	S Ti	Si Ti	S Fe	Si Fe	S K	Si K
	%	%	%	%	%	%	%	%
Site 3								
Summit	0.08a	0.02a	0.95a	0.47a	0.91a	5.32ab	5.15a	2.72a
Backslope	0.06a	0.02a	1.03a	0.33a	1.57b	4.25a	5.08a	2.75a
Footslope	0.06a	0.02a	1.17a	0.30a	2.27c	6.06b	4.90a	2.55a
Site 4								
Summit	0.04ab	0.02a	0.96a	0.48a	1.29a	1.72a	3.59a	1.92a
Backslope	0.03a	0.02a	1.03ab	0.87b	2.89b	5.33b	4.51b	2.83b
Footslope	0.05b	0.02a	1.23b	0.75c	2.85b	4.27c	3.13a	2.31c

Table 9. Sample means of elemental sand and silt fractions of the residual parent material at each landscape position. Sample means with different letters are signigicantly different at the .05 level.

Position	cfS	cfVCS	cfCS	cfMS	cfFS	cfVFS	cfSi	cfCSi
	%	%	%	%	%	%	%	%
				Site 1				
Summit	83a	7a	17a	13a	28a	18a	17a	19a
Backslope	76a	3b	8b	10a	32a	23b	24a	14b
Footslope	77a	11a	15a	11a	25b	15a	23a	9a
				Site 2				
Summit	66a	2a	5a	7a	30a	22a	34a	14a
Backslope	62a	1a	4a	6a	28a	22a	38a	14a
Footslope	71a	4a	8b	8b	28a	22a	29a	15a

Table 9 (cont.). Sample means of elemental sand and silt fractions of the residual parent material at each landscape position. Sample means with different letters are signigicantly different at the .05 level.

Position	S Zr	Si Zr	S Ti	Si Ti	S Fe	Si Fe	S K	Si K
	%	%	%	%	%	%	%	%
Site 3								
Summit	62a	15a	18a	9a	13ab	7a	38a	8a
Backslope	69b	19a	18a	9a	15b	7a	31b	7a
Footslope	74c	26b	21b	9a	12a	5b	26c	5b
Site 4								
Summit	56a	19a	13a	5ab	10a	8a	4a	18a
Backslope	58a	17a	13a	6b	11a	11b	4a	22a
Footslope	50a	14a	11a	5a	11a	10b	5a	18a

Table 10. Range and average coefficients of variation for particle size fractions by horizon.

Horizon	Sand	CS	FS	VFS	Silt	CSi	Clay	FC
	-----	-----	-----	-----	%	-----	-----	-----
				Range				
E	1-8	2-12	1-11	1-11	1-15	6-32	3-36	5-63
Bt	4-18	5-64	2-22	4-14	2-29	4-43	1-45	3-75
C	1-17	7-47	3-65	1-19	1-46	8-70	9-79	18-128
				Average				
E	3	6	4	6	4	15	11	24
Bt	9	18	9	10	11	18	10	15
C	10	21	17	10	15	22	38	60
$\bar{x}$	8	16	10	9	10	19	22	34

horizon has the highest mean CV value (Table 11). These data suggest that for nearly all components, the C horizon is the most variable. These trends are expected for well developed soils. Surface and Bt horizons have undergone substantial change and ordering due to pedogenesis and weathering, and therefore these horizons show much less variability than associated C horizons.

Management of variability is an important aspect of any soils study. One method to manage variability within a study is by increasing the sample size. This effect can be seen in these two equations:

$$CV = SD/\bar{x}$$

$$SD = \{ (X-\bar{x})^2/N\}^{1/2} \qquad \text{(Zar, 1984)}$$

Coefficients of variation are dependent upon the sample size because the CV is a function of the standard deviation (SD). Therefore, by subsampling within horizons, the average variability about the mean, described by the CV, is reduced. These results clearly demonstrate the need for multiple sampling of horizons in soils research. Multiple sampling however, increases the amount of laboratory analysis. Composites of each horizon can be formed by mixing equivalent amounts of the multiple samples. Laboratory measurements of composite samples of each horizon will be equivalent to means calculated from multiple sampling and analysis.

Evaluation of Parent Material Uniformity

Parent material unconformities were recognized in the field at the footslope position of each study site. Material at the surface was identified as colluvium or local alluvium that had moved down slope. Similar materials and discontinuities occur at the backslopes of Sites 2 and 3. No indication of lithologic discontinuities could be found in the field for the other six pedons. To determine if colluvial or alluvial additions have significantly affected these soils, parent material uniformity was examined.

The most common methods for distinguishing lithologic discontinuities are examination of clay-free particle size distributions, sand:silt ratios, Ti:Zr ratios, and index mineral (or their elemental equivalent) trends with depth. Confidence intervals (CIs) were calculated for ratios of sand:silt and Ti:Zr for horizons in which lateral variability was examined (Table 12). Sand and silt Zr, and clay-free sand distributions, were also plotted with depth (Fig. 9 and 10). Site 1 from the Piedmont and Site 4 from the Blue Ridge Highlands will be discussed in detail in regard to parent material uniformity.

Table 11. Range and average coefficient of variation by horizon for elemental components and DCB extractable Fe.

Horizon	DCB-Fe	S Zr	Si Zr	S Ti	Si Ti	S Fe	Si Fe	S K	Si K
	%	%	%	%	%	%	%	%	%
					Range				
E	7-37	5-24	3-18	0-41	3-7	4-116	1-24	2-14	4-18
Bt	2-39	9-111	8-42	2-45	4-18	9-46	3-19	1-26	2-13
C	8-43	6-38	5-128	2-82	3-41	4-59	2-26	3-44	0-14
					Average				
E	13	12	11	10	5	43	11	7	8
Bt	11	27	23	16	8	24	11	10	6
C	23	20	52	21	16	25	9	14	10
$\bar{x}$	16	20	29	16	10	29	10	11	8

Table 12. Confidence intervals for means of sand:silt (S:Si), coarse sand:coarse silt (CoS:CoSi), silt Ti:Zr (Si Ti:Zr), sand Ti:Zr (S Ti:Zr), and weighted Ti:Zr (wt. Ti:Zr) ratios.

Horizon	depth	S:Si	CoS:CoSi	Si Ti:Zr	S Ti:Zr	wt. Ti:Zr
	cm					
Site 1 Summit						
E	7-16	1.8-2.1	1.2-1.6	2.8-5.2	1.7-6.8	3.1-5.0
Bt3	48-63	1.8-2.5	0.9-2.1	3.5-5.1	5.2-9.0	4.1-6.3
C1	245-420	1.4-9.5	0.1-4.2	2.0-4.2	7.3-12.5	5.1-6.9
Site 1 Backslope						
E	7-28	1.7-1.9	0.9-1.1	3.9-7.7	1.2-2.2	2.5-4.3
Bt3	70-98	0.9-1.9	0.3-1.6	4.1-7.9	2.3-5.9	3.5-6.0
C1	216-275	2.5-4.1	0.2-1.1	4.9-15.3	3.8-9.1	5.0-7.8
Site 1 Footslope						
AB	10-24	1.7-1.9	0.8-1.7	4.7-5.5	0.3-3.5	2.6-4.2
2Bt	67-100	1.9-2.5	1.1-1.6	5.0-9.0	1.3-3.1	2.4-4.9
2Crt	100-135	2.0-4.9	1.3-2.2	2.9-17.6	0.1-8.1	1.0-9.8

Table 12 (cont.). Confidence intervals for means of sand:silt (S:SI), coarse sand:coarse silt (CoS:CoSi), silt Ti:Zr (Si Ti:Zr), sand Ti:Zr (S Ti:Zr), and weighted Ti:Zr (wt. Ti:Zr) ratios.

Horizon	depth	S:Si	CoS:CoSi	Si Ti:Zr	S Ti:Zr	wt. Ti:Zr
	cm					
Site 4 Summit						
E	7-18	0.4-0.5	0.3-0.4	8.4-15.4	8.3-11.3	7.6-14.6
Bt2	54-72	0.4-0.7	0.3-0.6	12.6-22.8	4.4-19.7	5.9-22.1
C2	176-245	0.7-1.9	0.5-0.9	17.4-40.6	16.3-26.6	15.0-26.8
Site 4 Backslope						
A2	9-16	0.3-0.4	0.2-0.4	21.4-37.8	15.8-18.8	21.2-28.2
Bt2	27-48	0.3-0.7	0.2-0.4	23.2-65.2	12.0-18.6	23.0-27.2
C3	170-241	1.0-1.8	0.4-0.8	29.1-61.1	21.5-41.5	26.9-43.9
Site 4 Footslope						
BA	18-32	0.3-0.6	0.4-0.6	11.4-27.4	17.0-25.0	16.3-24.2
Bt2	47-73	0.4-0.6	0.4-0.7	17.0-48.6	11.5-37.9	16.4-40.7
2C1	192-285	0.5-1.6	0.2-1.0	28.4-77.2	18.3-28.9	23.0-36.2

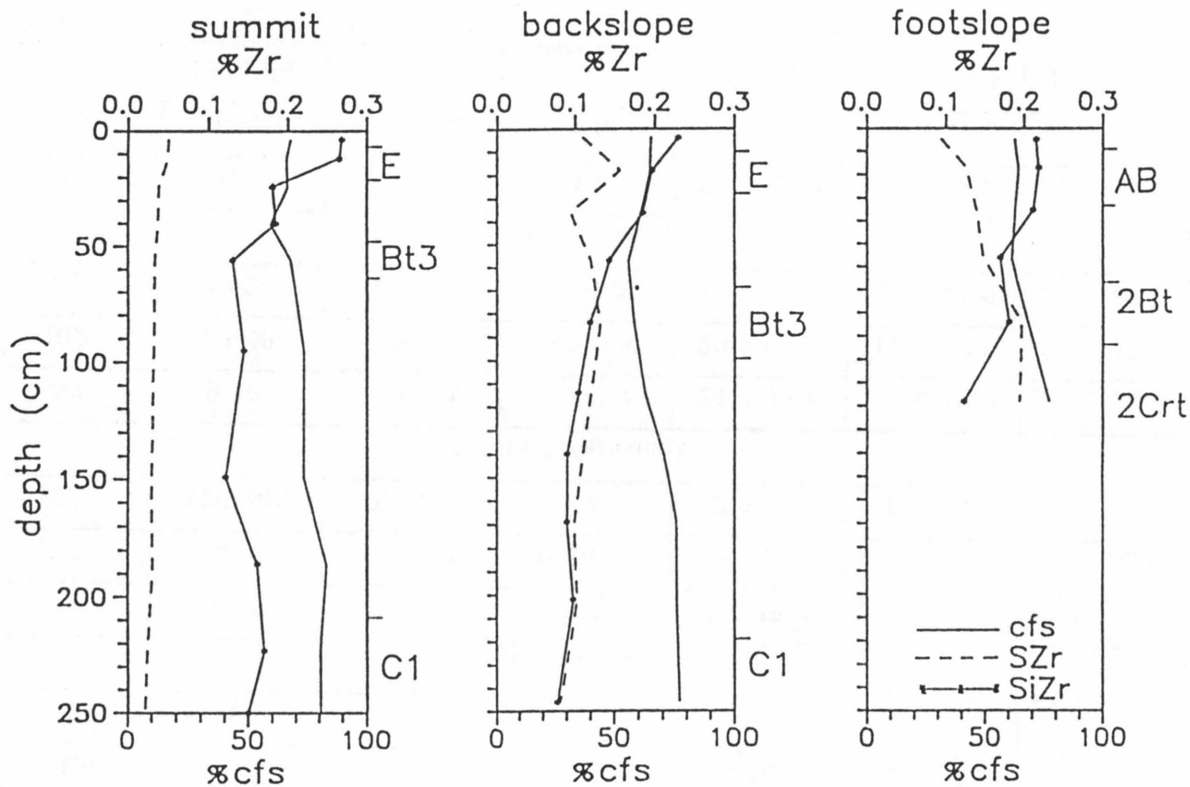

Figure 9. Sand Zr (SZr), silt Zr (SiZr), and clay-free sand (cfs) with depth for the summit, backslope, and footslope pedons at Site 1.

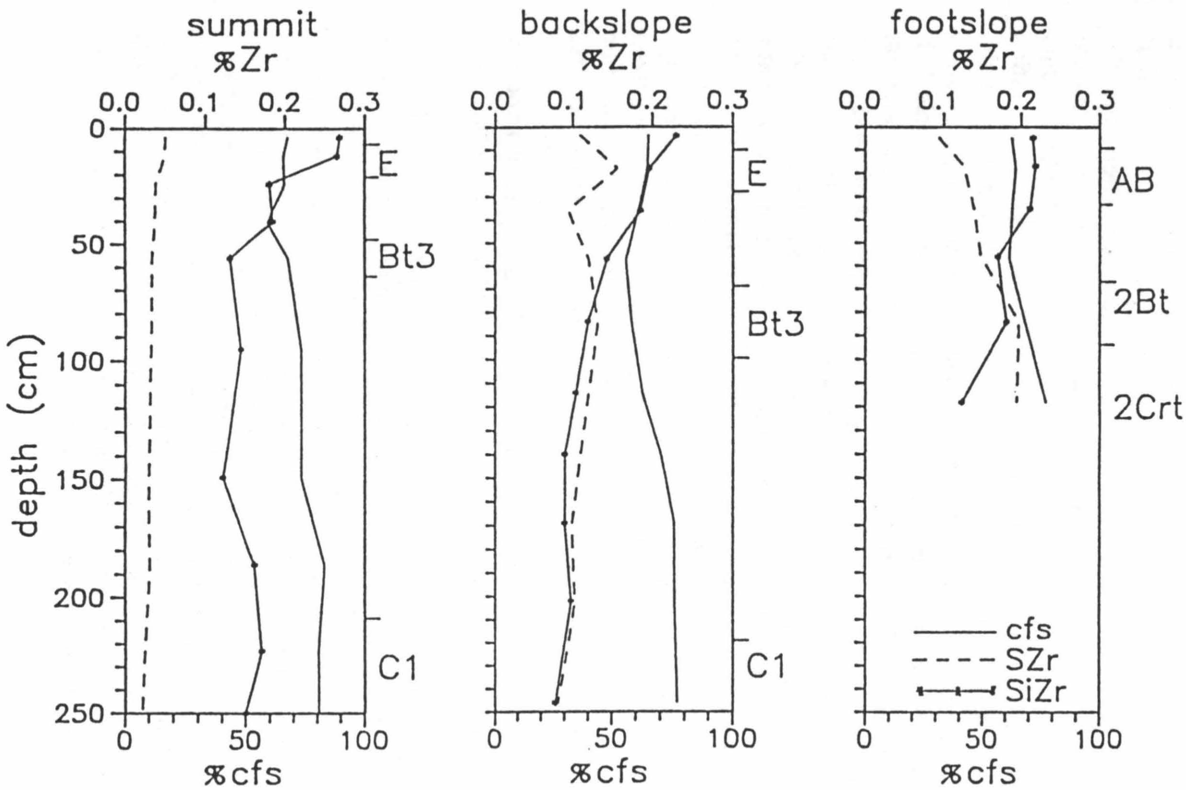

Figure 10. Sand Zr (SZr), silt Zr (SiZr), and clay-free sand (cfs) with depth for the summit, backslope, and footslope pedons at Site 4.

Clay-free sand, and sand and silt Zr distributions of the summit and backslope soils, show similar trends with depth. Clay-free sand decreases from the surface horizon to the argillic horizon, and then increases approaching the C material (Fig. 9 and 10). Sand and silt Zr, although somewhat variable, decreases from the surface horizons into the argillic horizon. Below the argillic horizon minimal change in Zr occurs with depth. Several explanations can account for the differences in rates and direction of change with depth for clay-free sand and Zr. These explanations are the presence of a lithologic discontinuity, considerable variability in parent material composition, or differential weathering within the profile. Confidence intervals of sand:silt, coarse sand:coarse silt, silt Ti:Zr, and sand Ti:Zr ratios of the near surface (E or A2) and Bt horizons within each pedon, with the exception of the sand Ti:Zr ratio in the Site 1 backslope, overlap, indicating that sample means are not significantly different at the 0.05 level (Table 12). The primary assumption in examining clay-free PSD is that sand and silt fractions are immobile and weather at similar rates. Movement of sand or silt in these soils is unlikely. Thin sections of the parent materials show that quartz, mica, and feldspar are the most common silt and sand size minerals. Silt mineralogy of the summit and backslope soils of Site 1 shows a dramatic decrease in quartz from the A horizons to the Bt3 horizons (Table 13). In acid environments mica and feldspar weather much faster than quartz, so that in this soil environment quartz is being concentrated in the surface horizons. Clay-free PSD data suggest that the larger quartz grains weather at a slower rate than do silt fractions. Weathering of quartz is primarily a desilication process. Sand has a smaller surface area than silt, so that weathering rates and desilication are greater for silt than for sand size quartz (Drees et al., 1989). These data suggest that for soils composed of a diversity of minerals, clay-free PSD may not be a reliable index of parent material uniformity.

Changes in the distribution of Zr with depth do not always indicate a change in parent material, but may indicate a less weathered environment. Although there is some variability, concentration of Zr can be observed in the upper 50 to 100 cm of the summit and backslope profiles (Fig. 9 and 10). In the soil Zr is found almost exclusively in the form of the mineral zircon, which is resistant to weathering and stable in the soil environment (Brewer, 1976; Milnes and Fitzpatrick, 1989). As other mineral forms weather from coarser fractions, zircon is concentrated. The Zr trends suggest that weathering is most active within the upper 50 to 100 cm of the soils, and corresponds to the zone where clay-free sand decreases from the A to Bt horizons. This trend supports the explanation that the differences in rates or direction of change with depth of clay-free sand are primarily due to weathering.

Table 13. Silt (2-50u) mineralogy for Site 1.

Horizon	KLN	QTZ	MIC	GIB	FLD	HIV	INT
	%	%	%	%	%	%	%
Summit							
A	17	40	4	-	27	11	1
E	17	34	4	1	24	19	1
Bt1	24	22	10	1	22	20	t
Bt2	26	22	15	1	19	15	t
Bt3	26	18	18	1	16	10	t
Bt4	32	17	20	t	17	13	t
BCt	29	16	23	-	18	10	3
BC1	31	16	27	-	18	8	t
BC2	22	17	30	-	18	12	t
C1	18	16	32	-	21	12	t

Table 13 (cont.). Silt (2-50u) mineralogy for Site 1.

Horizon	KLN	QTZ	MIC	GIB	FLD	HIV	INT
	%	%	%	%	%	%	%
Backslope							
A	7	47	5	t	30	10	t
E	9	47	4	1	28	10	1
Bt1	17	35	80	1	25	13	1
Bt2	25	28	11	t	22	12	1
Bt3	30	21	13	t	19	16	1
Bt4	38	17	15	-	15	15	t
BCt	35	18	18	t	18	10	t
BC1	32	17	23	2	16	10	t
BC2	29	18	28	-	15	10	t
C1	19	16	33	-	20	11	t

Table 13 (cont.). Silt (2-50u) mineralogy for Site 1.

Horizon	KLN	QTZ	MIC	GIB	FLD	HIV	INT
	%	%	%	%	%	%	%
Footslope							
A	8	36	9	t	26	20	t
AB	9	35	9	t	26	20	t
Bw1	13	24	11	t	24	25	2
Bw2	11	25	18	t	19	25	t
2Bt	16	21	25	t	15	20	2
2Cr	31	10	30	t	12	15	1

Abbreviations: KLN = kaolinite, QTZ = quartz, MIC = mica, GIB = gibbsite, FLD = feldspar, HIV = hydroxy interlayer vermiculite, INT = randomly interstatified, t = trace.

Confidence intervals for total sand:silt ratios for the Bt3 and C1 horizons of the backslope of Site 1 do not overlap, indicating significant differences in the means between these two horizons. Distributions of clay-free sand, and sand and silt Zr, show minimal changes with depth between the Bt3 and C1 horizons. The Bt3 horizon shows considerable more weathering of the silt fraction, as evidenced by the higher concentration of mica and lower concentration of quartz and kaolinite in the C1 horizon (Table 13). These data, as well as the distributions of clay-free sand and Zr with depth, suggest that differences between the Bt3 and C1 horizon, are minimal in respect to parent material uniformity.

Confidence intervals for total sand:silt ratios and sand Ti:Zr ratios for the Bt2 and C3 horizons backslope soil at Site 4 do not overlap, suggesting significant differences in the means. The greatest difference in rates of change with depth for clay-free sand occurs at 72 cm (Figure 10), which is within the BCt horizon. Evidence of relict rock structure can be observed within this horizon indicating, the residual nature of this horizon and those below. Saprolite from these soils has formed from a gneissic schist. Thin zones (10-40 cm thick) of a more schistose, almost phylite like material, are common in these soils. These zones lie parallel to the rock structure, and show less weathering than the primary parent materials. These thin strata may explain the differences in total sand:silt ratios and sand Ti:Zr ratios between the Bt2 and C3 horizons.

Discontinuities were recognized in the field at the top of the 2Bt horizon in the Site 1 footslope (Fig. 9) and the base of the Bt2 horizon of the Site 4 footslope (Fig. 10). Distributions of Zr and clay-free sand, and confidence intervals of sand:silt or Ti:Zr ratios, are not able to establish the presence of these discontinuities. In most cases local alluvium or colluvium is initially derived from the same parent rock as is the residual portion of the soil, and therefore has a very similar composition. These data and observations clearly demonstrate the difficulty in recognizing a discontinuity in colluvium or local alluvium without field evidence.

Soil Reconstruction

Soil reconstruction techniques were employed to determine the changes that have occurred during pedogenesis. These changes are measured as gains and losses of the various soil constituents relative to those of the parent material. Saprolite was used as the parent material for the summit and backslope soils of Site 1, which are residual in nature. Physical and chemical properties of the A-Bw2 horizons of the footslope soil are similar to those of the A horizon of the backslope soil. Therefore, A horizon material from the backslope soil was used as the parent material for reconstruction of the A-Bw2 horizons of the footslope soil at Site 1. Parent rock at the base of the footslope was used as parent material for the 2Bt and 2Crt horizons.

Soil development in the upper four horizons of the footslope soil at Site 1 is restricted to a cambic horizon. This development can be observed as a slight gain in DCB Fe with depth (Table 14).

Reconstruction analysis for the 2Bt and 2Crt of the footslope soil indicated losses of elemental constituents, and gains in the < 2 mm fraction. The parent rock of these two horizons has a bulk density of 2.41 g/cm^3, and apparently slightly weathered. Clay films occur in both the 2Bt and 2Crt horizons. Thus, gains in clay are not entirely due to physical weathering of rock to clay size particles. Losses in elemental Fe are greater than gains in DCB-extractable Fe, and may indicate that Fe is being lost from the system.

Gains and losses of soil constituents for the summit and backslope soils at Site 1 are very similar (Table 14). The greatest losses occur in the sand fraction, indicating that sand weathering is the major process occurring in these soils. Losses of sand decrease with depth, indicating that weathering also decreases with depth. Although these losses occur in both the summit and backslope soils, noticeably less sand losses occur at the backslope soil surface.

Losses of total silt occur in the A and E horizons, but minimal change in silt content occurs below the E horizons. In the upper horizons, the weathering of sand to silt is probably occurring at a slower rate than that of silt to clay, and loss of silt is occurring. Below the E horizons, however, sand and silt weathering likely occurs at similar rates.

Total and fine clay show the largest gains. Maximum gains occur in the argillic horizon, indicating that illuviation is the second most important soil-forming process occurring in these soils. Gains and losses of clay in A and E horizons are within an acceptable range in error of 0, indicating that a state of equilibrium between clay eluviation and weathering of larger particles to clay and fine clay has been reached in these two horizons.

Although the gains are much smaller, the DCB extractable Fe and Al show similar trends to the clay fractions. Maximum gains in DCB Fe and DCB Al occur in the same horizon as the maximum gains in clay. These results are expected as DCB Fe is generally found in close association with the clay fractions.

Table 14. Gains and losses of selected physical, chemical, and elemental constituents for the summit, backslope, and footslope soils of Site 1.

Horizon	Depth	Volume factor	DCB Fe	DCB Al	Ti	Fe	K	Sand	Silt	Clay	Fine Clay
	cm		---------g/100 cm³---------								
					Summit						
A	0-7	.51	-1.32	-.04	-.26	-5.00	-7.83	-133	-18	1	2
E	7-16	.38	-1.86	-.04	-.35	-6.62	-10.37	-186	-23	-5	-2
Bt1	16-31	.55	.75	.24	-.09	-4.02	-6.13	-115	-2	31	12
Bt2	31-48	.81	3.23	.45	-.13	-2.54	-4.52	-81	-1	57	26
Bt3	48-63	1.43	3.85	.47	-.04	-.94	-1.49	-27	4	61	29
Bt4	63-126	.98	2.06	.26	-.06	-1.26	-2.24	-31	1	34	17
BCt	126-170	.87	1.83	.20	-.04	-1.26	-1.66	-27	4	20	11
BC1	170-202	.91	.46	.07	-.01	-.61	-1.20	-17	-5	3	2
BC2	202-245	.92	.04	.01	-.01	-.06	-.56	-9	-2	3	1
C	245-420	1.00	.00	.00	.00	.00	.00	0	0	0	0

Table 14 (cont). Gains and losses of selected physical, chemical, and elemental constituents for the summit, backslope, and footslope soils of Site 1.

Horizon	Depth	Volume factor	DCB Fe	DCB Al	Ti	Fe	K	Sand	Silt	Clay	Fine Clay
	cm		-----------------	-----------------	-----------------	-----------------	g/100 cm^3	-----------------	-----------------	-----------------	-----------------
					Backslope						
A	0-7	.48	-4.50	-.17	-1.88	-12.90	-4.36	-110	-11	-2	-3
E	7-28	.46	-4.67	-.31	-2.14	-13.54	-5.10	-119	-22	-9	-8
Bt1	28-43	.64	-2.01	-.06	-1.31	-9.46	-3.12	-77	3	22	5
Bt2	43-70	.94	1.65	.22	-.84	-5.63	-2.08	-57	6	52	22
Bt3	70-98	1.27	4.18	.47	-.64	-3.66	-1.61	-40	-5	73	35
Bt4	98-130	1.05	3.22	.26	-.73	-3.72	-1.49	-38	4	50	26
BCt	130-150	1.00	1.57	.12	-.69	-2.93	-.97	-28	0	31	14
BC1	150-187	.81	-.41	-.05	-.86	-3.11	-.65	-22	-4	6	4
BC2	187-216	.86	-.50	-.09	-.73	-2.33	-.70	-24	-6	4	1
C	216-275	1.00	.00	.00	.00	.00	.00	0	0	0	0

Table 14 (cont). Gains and losses of selected physical, chemical, and elemental constituents for the summit, backslope, and footslope soils of Site 1.

Horizon	Depth	Volume factor	DCB Fe	DCB Al	Ti	Fe	K	Sand	Silt	Clay	Fine Clay
	cm		-----g/100 cm^3-----								
Footslope											
A	0-10	1.35	.19	.03	.05	.01	.38	3	5	3	1
AB	10-24	.82	.21	-.06	-.08	-.18	-.07	-4	-1	-5	-3
Bw1	24-45	.75	.35	-.07	.00	.04	-.40	-11	-1	-2	-2
Bw2	45-67	.74	.64	-.08	.09	.15	-.30	-7	3	-1	-3
2Bt	67-100	1.19	2.83	.31	-.95	-11.94	-3.94	76	35	34	10
2Crt	100-135	1.12	4.34	.43	-.87	-10.56	-3.31	98	29	38	13
Rock		1.00	.00	.00	.00	.00	.00	0	0	0	0
A-Bw2-pm		1.00	.00	.00	.00	.00	.00	0	0	0	0

Elemental constituents for the summit and backslope soils of Site 1 show decreasing losses with depth. These losses support the particle size weathering trends. Losses of Fe and Ti are larger, and losses of K smaller, in the backslope soil than in the summit soil. These data suggest that the mineral composition of the silt and sand fractions may be slightly different between landscape positions. Parent material thin sections show quartz, feldspar, muscovite, and biotite as the primary sand and silt-sized minerals. Biotite is generally Fe rich and has been shown to have some Ti substitutions. Since the backslope had greater Ti and Fe losses, the backslope soil may contain slightly more biotite than the summit soil. Although some Fe may be lost from the silt and sand fractions to clay size particles, most is probably released during the oxidation and weathering of biotite. Losses of elemental Fe in the summit and backslope soils are slightly higher than gains in DCB Fe. The losses may indicate that some Fe released from primary minerals is being leached from the soil system.

Gains and losses of soil constituents at the summit and backslope of Site 2 are very similar to those positions at Site 1, and will not be discussed in detail. A bisequel soil occurs at the footslope of Site 2. This soil is similar to the footslope pedon at Site 1, except that an argillic horizon occurs above the discontinuity. Although the materials for the upper soil had moved from upslope, and are local alluvial or colluvial materials, a good match for these materials in the backslope or summit soils was difficult to find. Therefore, parent materials for these horizons were estimated using several assumptions and regression techniques. Parent materials generally contain less clay than the horizons which developed in the materials. Clay contents of the footslope E horizon and saprolite at the summit are 11 and 5 %, respectively. Therefore, clay content was assumed to be 10%. Silt and sand contents were based on the sand:silt ratios of the upper horizons, and adjusted for clay content. To estimate the percent DCB Fe and Al, and elemental constituents, regression techniques were employed. Zirconium accumulates at the surface and decreases with depth; thus Zr contents of the parent materials were set at .02% less than the lowest Zr content in the upper four horizons.

Losses of sand are greatest at the surface and decrease with depth (Table 15). These losses are less than half of those observed for the backslope soil. Gains of clay occur in the argillic horizon, indicating clay illuviation is an important process in these soils. The gains are smaller than those at the backslope, and suggest, with support of the sand losses, that footslope soils are substantially less developed than associated backslope and summit soils. Weathering trends occur for both Fe and K supporting the conclusion that sand and possibly silt particles are weathering. Gains in DCB extractable Fe also occur in the argillic horizons.

Table 15. Gains and losses of selected physical, chemical, and elemental constituents for the Site 2 footslope.

Horizon	Depth	Volume factor	DCB Fe	DCB Al	Ti	Fe	K	Sand	Silt	Clay	Fine Clay
	cm		g/100 cm^3								
Footslope											
A	0-11	.71	-.32	-.01	.16	-6.37	-3.05	-46	-14	2	-1
E	11-25	.64	-.28	-.10	.41	-5.82	-3.05	-39	-11	-4	-3
Bt1	25-37	.78	1.00	.07	.59	-3.93	-1.63	-23	1	14	4
Bt2	37-61	.76	2.02	.15	.46	-2.95	-1.77	-21	-11	24	8
2BC	61-79	.70	3.87	.21	-1.73	-11.74	-6.22	71	40	25	8
2C	79-90	.91	3.10	.16	-1.33	-6.36	-3.56	84	31	33	12
2Cr	90-100	.84	2.97	.08	-1.49	-5.88	-2.69	110	26	25	14
Rock	100+	1.00	.00	.00	.00	.00	.00	0	0	0	0
A-Bt2 pm		1.00	.00	.00	.00	.00	.00	0	0	0	0

Parent rock was used as parent material for the residual horizons (2Bt2 to 2Crt). Larger gains in sand occur with increasing depth, indicating that weathering of sand continues after initial weathering of rock to soil. Losses in sand are accompanied by increases in silt. Gains in silt decrease with depth. Losses of elemental constituents show decreasing losses with depth. These trends support the previous conclusions that sand weathers after initial rock weathering.

Site 4 occurs in a mature oak woodlands in the Blue Ridge Highlands. Although the primary parent materials for these soils is saprolite derived from a gneissic schist, thin zones of a more schistose material occur within the saprolite. To reduce effects this variation may have on soil reconstruction results, data for the C horizons sampled in the soil pit were averaged. Weathering trends observed for elemental Ti and fine silt in the summit soil are not evident in the backslope soil. Losses of sand and silt are also less in the backslope soil. Sand, silt, and elemental Fe and K show weathering trends with depth (Table 16). Slight variations in silt gains and losses occur in the lower horizons in both the summit and backslope soils. These variations are attributed to stratification in the parent rock.

Gains in clay occur in the surface horizons of the summit and backslope soils. Saprolite contains more than 45 % silt, with over half occurring as fine silt. These data suggest that fine silt is weathering to clay at a faster rate than clay eluviation. Thus, equilibrium between particle weathering and clay illuviation may be dependent upon the original particle size distribution. The backslope soil does not have an eluvial horizon, and clay contents of the A1 and A2 horizons are greater than those of the summit A horizon. Therefore, the surface horizon of this soil is likely disturbed. The absence of the most weathered horizons may explain the differences in losses between the summit and backslope soils, or they may be attributed to less weathering at the backslope landscape position.

The footslope soil at Site 4 is a bisequel soil with a solum thickness nearly twice that of the summit and backslope soils. The upper 73 cm is colluvium that overlies residual soil material and saprolite. The procedures previously discussed for estimation of the footslope parent material at Site 2 were used to estimate the original parent materials of these horizons. Reconstruction results for the colluvial and residual portions of these soils suggest minimal changes with depth except for the clay fractions (Table 16). Upper horizon parent materials are most likely material derived from the surface and upper argillic horizons of a soil that occurred upslope. These materials were substantially weathered prior to deposition; therefore particle weathering should be minimal and clay illuviation the major soil-forming process. Gains of clay and DCB Fe in the argillic horizon indicate that eluviation and illuviation

Table 16. Gains and losses of selected physical, chemical, and elemental constituents for the summit, backslope, and footslope soils of Site 4.

Horizon	Depth	Volume factor	DCB Fe	DCB Al	Ti	Fe	K	Sand	Silt	Clay	Fine Clay
	cm		g/100 cm^3								
Summit											
A	0-7	.49	-4.45	-.15	-1.00	-4.38	-6.06	-112	-74	14	5
E	7-18	.41	-4.63	-.13	-1.19	-5.12	-7.15	-131	-84	13	3
BE	18-28	.49	-2.72	.09	-.81	-3.99	-5.39	-110	-55	33	10
Bt1	28-54	.80	1.52	.44	-.44	-1.78	-2.46	-59	-20	53	21
Bt2	54-72	.78	2.36	.56	-.61	-1.48	-2.17	-56	-28	58	27
Bt3	72-96	1.14	1.91	.34	-.13	.31	-.10	-19	16	31	16
BC	96-114	1.05	.26	.09	.04	.85	.57	-22	16	11	6
C1-C3	114-330	1.00	.00	.00	.00	.00	.00	0	0	0	0
Backslope											
A	0-9	1.01	-.32	.09	-.33	-4.85	-3.20	-54	-18	20	6
A2	9-16	.85	-.33	.15	-.30	-5.61	-3.69	-67	-17	24	7
Bt1	16-27	.69	.43	.25	-.51	-6.58	-4.17	-84	-13	32	11
Bt2	27-48	1.14	3.31	.55	-.21	-2.42	-1.50	-35	-2	55	26
Bt3	48-63	1.23	1.74	.11	-.23	-1.31	-.36	-15	-3	40	23
BCt	63-81	.78	.85	.14	-.47	-2.83	-1.69	-28	-30	19	12
BC	81-96	.92	.52	.07	-.33	-1.65	-.85	-10	-13	6	3
C1-C3	96-241	1.00	.00	.00	.00	.00	.00	0	0	0	0

Table 16 (cont). Gains and losses of selected physical, chemical, and elemental constituents for the summit, backslope, and footslope soils of Site 4.

Horizon	Depth	Volume factor	DCB Fe	DCB Al	Ti	Fe	K	Sand	Silt	Clay	fine Clay
	cm		----------g/100 cm^3----------								
					Footslope						
A	0-18	.88	-.20	-.02	-.26	-.88	-.70	-4	-12	7	1
AB	18-32	.66	-.85	-.06	-.53	-1.12	-1.07	-10	-26	-4	-2
Bt1	32-47	.72	.22	-.02	-.46	-.78	-.63	-9	-14	2	2
Bt2	47-73	1.12	2.36	.02	.25	.72	.94	13	16	19	5
2Bt3	73-105	1.30	2.31	-.01	.48	-1.08	.04	-8	14	35	10
2BCt	105-163	1.21	2.20	-.10	-.28	-.81	.16	2	-6	28	15
2BC	163-192	.98	-.15	.07	-.40	-1.82	-1.00	-32	-9	14	6
2C1	192-285	1.00	.00	.00	.00	.00	.00	0	0	0	0
A-Bt2 pm		1.00	.00	.00	.00	.00	.00	0	0	0	0

were active processes in this soil. These gains are about half as much as the gains in clay in the summit and backslope argillic horizons at Site 4.

Soil-Landscape Relationships

Field descriptions from reconnaissance efforts and profile descriptions of representative study pedons indicate that summit and backslope soils have very similar profile morphology. Although backslopes are most often thought of as an erosional landscape position, backslope soils that occur in mature woodlands, with slopes of up to 18%, are as stable as those soils occurring on summits. Some evidence of erosion was observed in two backslope soils. These effects, however, probably resulted from cultural practices. Two of the four backslope soils studied had lithologic discontinuities with substantial material present above stone lines. These data suggest that backslopes can also occur as depositional landscape positions.

All footslope soils examined were bisequel. The upper soil material is composed of colluvial or local alluvial sediments that were transported downslope. Footslope soils show less profile development than do associated summit and backslope soils. These differences in profile development are substantial in the Piedmont. Clay distributions of the summit and backslope soils at Site 1 are very similar (Figure 11). The maximum clay content is between 55 and 60 %, and the slope of the lines toward and away from the clay maximum are nearly identical. Clay distribution of the footslope soil, however, shows evidence of a bisequel soil, with a lower clay content than the summit and backslope soils. Differences in morphology and profile development also occur between Blue Ridge Highland footslope soils and associated summit and backslope soils. These differences are not as evident as those in the Piedmont (Figure 12). The maximum clay content of the footslope soil is only slightly less than that of associated summit and backslope soils.

Auger descriptions made at 5 m intervals between study pedons indicate that differences in profile morphology are not apparent between landscape positions until the concave portion of the lower landscape (Figures 3-6). These results suggest that if differences in morphology exist between summit and backslope soils developed in gneissic or schistose materials with slopes of < 18%, these differences can be related to either man-induced erosion or differences in parent materials, rather than landscape position.

Reconstruction analysis indicates that sand weathering and clay illuviation are the major soil-forming processes occurring in these soils. Surface and near-surface horizons of summit soils show slightly more losses of sand than do associated backslope soils, suggesting that backslope soils are slightly

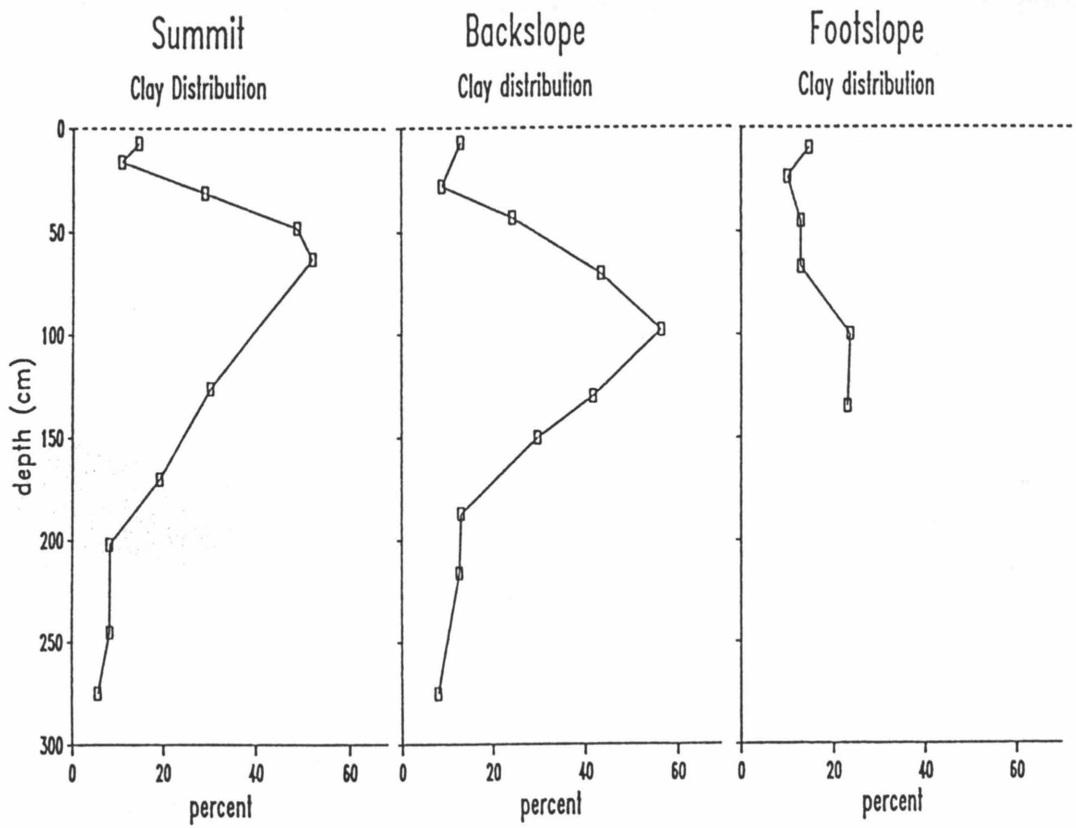

Figure 11. Clay distribution of the summit, backslope, and footslope soils, at Site 1.

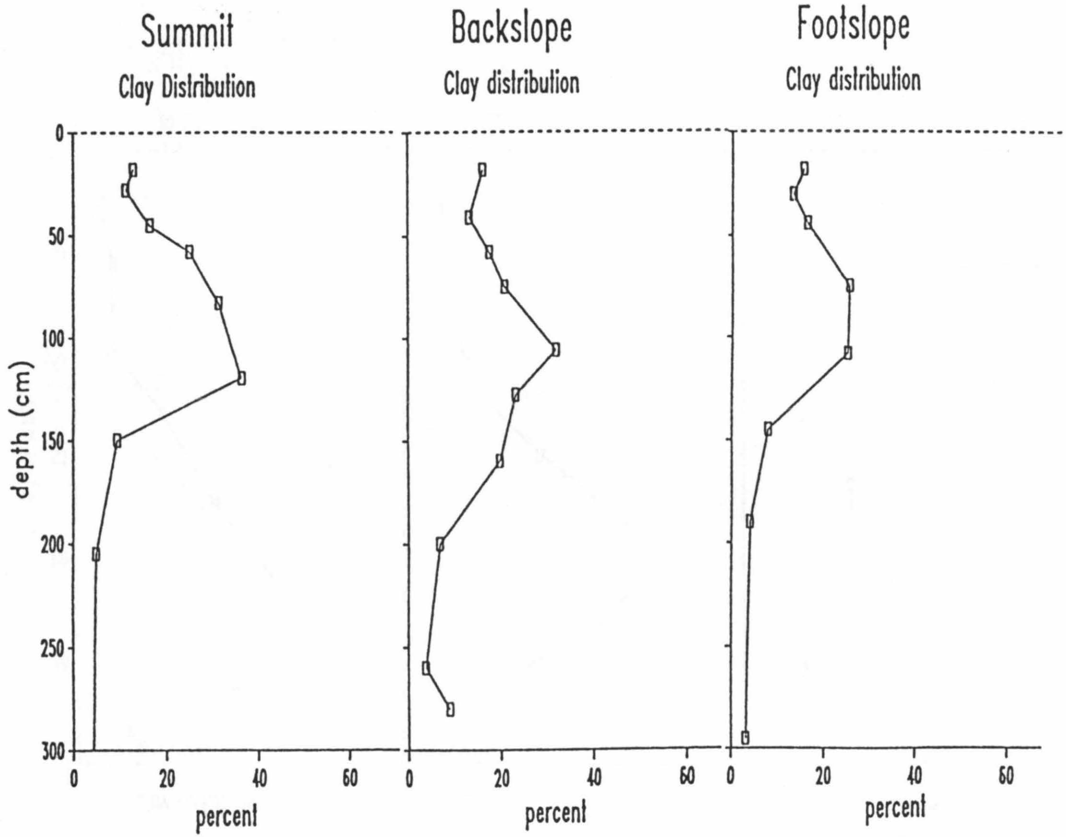

Figure 12. Clay distribution of the summit, backslope, and footslope soils, at Site 3.

less weathered than the summit soils. Two of the backslope soils studied, however, show evidence of disturbance and erosion due to cultural practices that would reduce the amount of losses at the soil surface. Losses of sand are less in footslope soils than in associated summit or backslope soils. Sand weathering is the major soil-forming process occurring within footslope soils formed from weathered rock, saprolite, or transported material that was primarily saprolite or weathered rock. Horizons of footslope soils which have formed in local alluvium, however, show minimal losses of sand. The local alluvium parent materials for these horizons were derived from the surface or upper argillic horizons upslope, and were substantially weathered prior to deposition.

After sand weathering, clay illuviation is the most important soil-forming process at each landscape position. Gains in clay are essentially the same in the argillic horizons of both summit and backslope soils. Gains in clay in footslope Bt horizons, however, are about one half as much as those within summit and backslope argillic horizons. These reconstruction results support the conclusions that summit and backslope soils are very similar. Soil-forming processes in these soils, and the present rates at which these processes occur, are essentially the same. Footslope soils are less developed and the rates of soil-forming processes are dependent upon the type of parent material. Both depositional and pedogenic processes control the development of soils occurring at footslope landscape positions.

Mineralogy

Quartz, mica, and feldspar are the most common mineral grains observed in thin section. Alteration of quartz is slight ($<$2.5%), and occurs in pellicular and irregular linear patterns. Feldspar grains show pellicular, parallel, and cross-linear alterations (Figure 13). Alterations are generally less than 25%. Mica grains show slight ($<$ 2.5%) to total parallel linear alteration (Figure 14). Pellicular alteration is also prevalent in mica grains. In order to examine the alteration products of the mica and feldspar grains, and establish both weathering trends and landscape position relationships, silt and clay mineralogy was examined using x-ray diffraction (XRD) techniques.

Summit and backslope soils of Site 1 have similar silt mineralogy (Table 13). In both soils, silt-sized quartz has accumulated in the surface and upper Bt horizons. Quartz is resistant to weathering and becomes concentrated in the upper horizons. Feldspar shows a similar accumulation in the upper horizons. These results suggest that feldspar, although often thought of as a weatherable mineral, may be relatively stable in these soil environments. The secondary minerals that have formed from the weathering of feldspar are most likely kaolinite and gibbsite. Kaolinite is one of the most

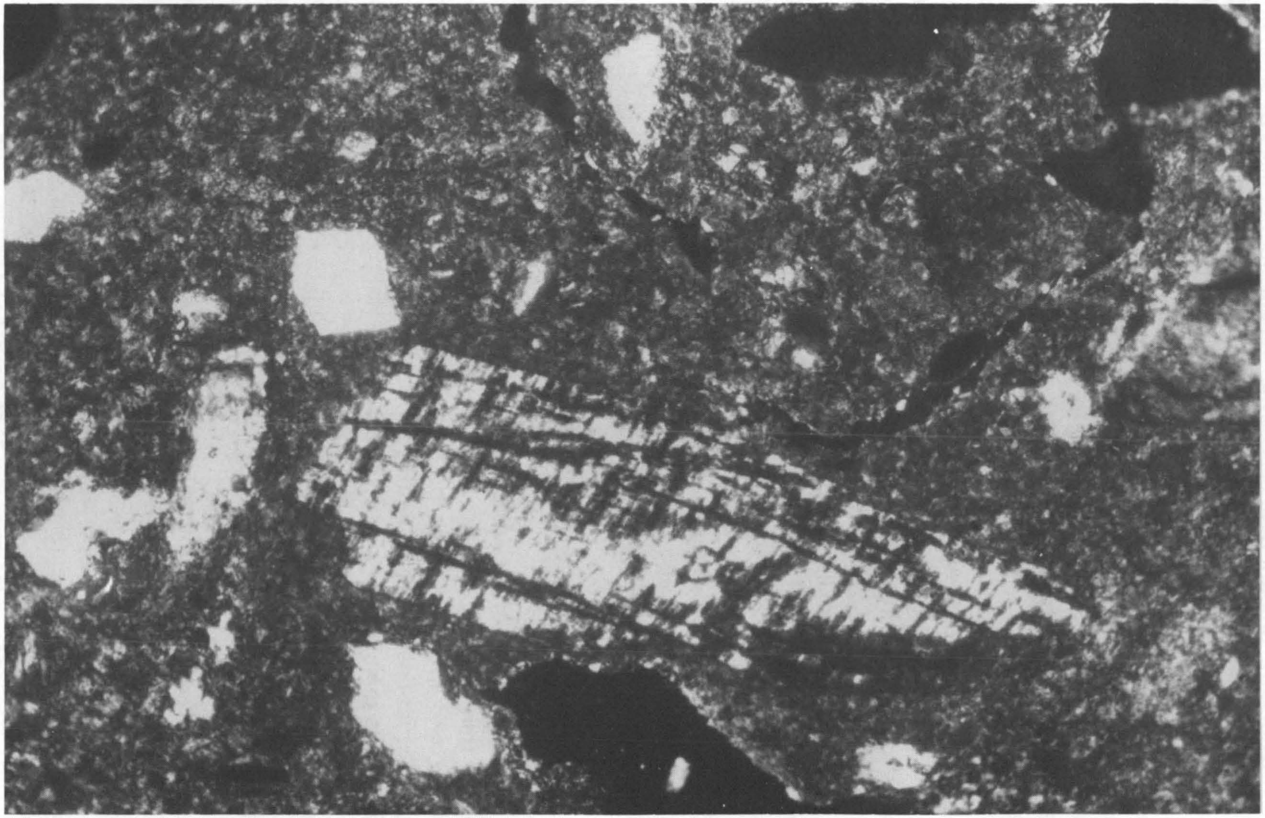

Figure 13. Cross-linear alteration of a feldspar grain. Micrograph was taken under cross-polarized light at 100X magnification. Frame length is 1.5 mm.

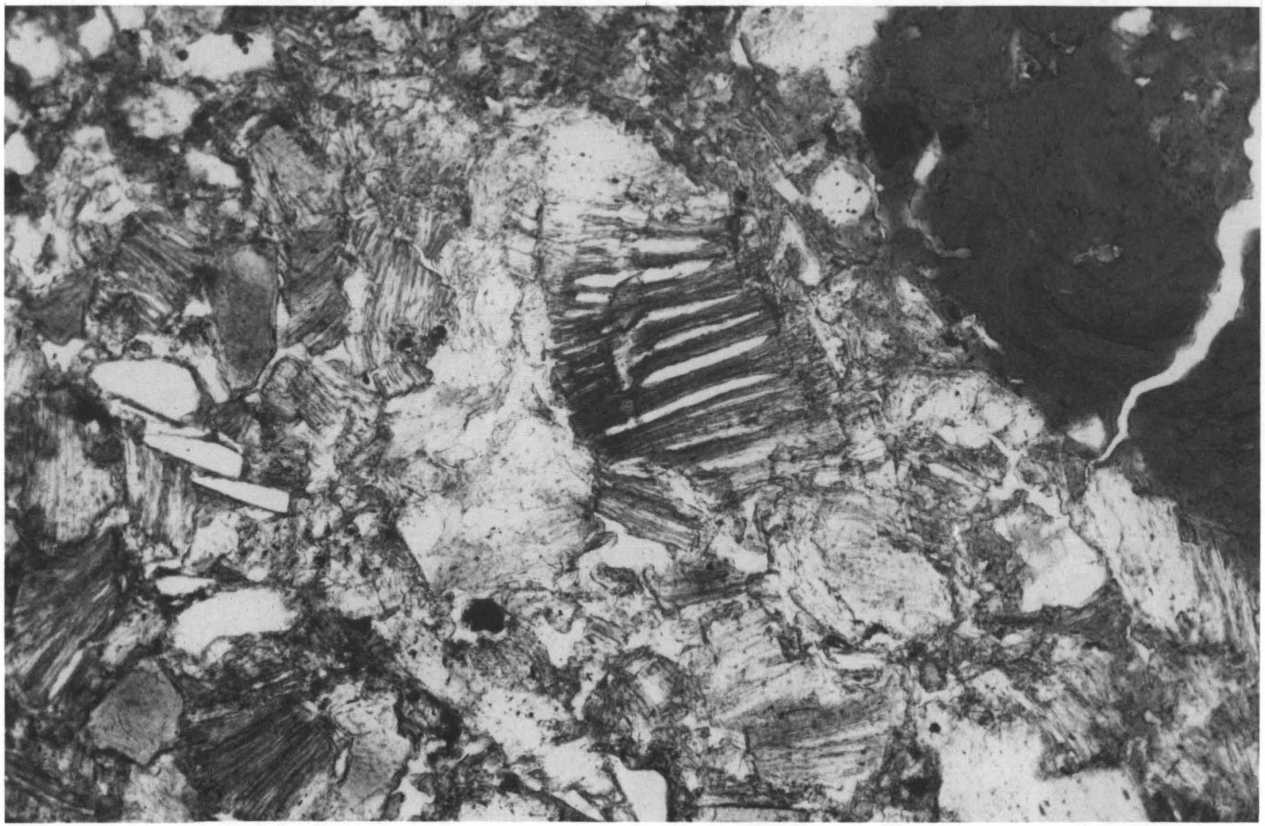

Figure 14. Parallel-linear alteration of a mica grain. Micrograph was taken under plane-polarized light at 100X magnification. Frame length is 1.5 mm.

abundant silt minerals in these soils, and traces of gibbsite occur in the surface and argillic horizons. Gibbsite probably occurs as coatings on the silt grains.

Mica alteration and weathering occur with depth. Both muscovite and biotite are observed in the thin sections of saprolite. These micas are apparently weathering to form kaolinite, HIV, or interstratified minerals. Most of the losses of Fe and K observed in the reconstruction analysis of these soils are probably related to mica weathering, especially biotite.

Except for HIV content, silt mineralogy of the upper four horizons of the footslope soil is very similar to that of the backslope surface and upper argillic horizons. These horizons have formed in recently deposited material which likely underwent substantial weathering prior to deposition. As a result, trends in mineral content with depth in the footslope soil are absent. The 2Bt and 2Crt horizons have formed directly from bedrock. The mineralogy of the 2Crt is very similar to that of the summit and backslope BC horizons, a fact which may indicate that substantial mineral alteration occurs during the early stages of bedrock weathering and soil formation.

Similar amounts of clay-sized kaolinite occur in the summit and backslope argillic horizons (Table 17). Contents of clay-sized kaolinite in the surface horizons of the backslope soil, however, are noticeably less than the kaolinite content of the summit surface horizons. Similar trends were observed for silt-sized kaolinite. One explanation for these differences may be related to Si removal. Leaching and eluviation are more active in the surface horizons of the backslope soil, which occurs on an 18% slope. Thus, water not only moves downward through the backslope profile, but also laterally through the surface horizons. In this manner, kaolinite formation is limited by silica removal. The highest amounts of gibbsite in the Site 1 profiles are found in the backslope surface horizons, supporting the conclusion that silica has been removed from these horizons. Less kaolinite occurs in the lower solum of the backslope soil than in the same horizons of the summit soil. These differences are slight and may indicate that the lower solum of the backslope is less weathered, or slight differences occur in the content of primary minerals which weather to kaolinite.

Mica contents are relatively low at the surface and do not increase substantially until the BC and C horizons. After kaolinite, HIV is the most abundant clay-sized mineral in these soils. The highest amounts of HIV occur in the surface horizons, indicating that HIV and kaolinite are the most important weathering products of mica, and that HIV may be as stable in the surface horizons as kaolinite under the present soil conditions. Measurable amounts of secondary chlorite occur in the surface horizons of the backslope

Table 17. Clay (<2.0u) mineralogy of Site 1.

Horizon	KLN	QTZ	GT	GIB	MIC	FLD	HIV	INT	CHL	HEM
	%	%	%	%	%	%	%	%	%	%
Summit										
A	43	4	-	2	7	3	40	t	t	-
E	39	6	-	2	6	3	43	t	t	t
Bt1	48	3	-	4	4	-	42	t	t	t
Bt2	58	-	t	4	5	-	29	t	t	2
Bt3	60	-	t	3	4	t	26		t	4
Bt4	60	-	t	4	7	t	25	-	t	2
BCt	61	-	1	2	6	4	22	-	t	3
BC1	62	-	2	1	10	1	17	-	t	4
BC2	59	-	2	1	12	2	19	t	t	4
C1	58	1	2	t	18	2	15	t	t	4

Table 17 (cont.). Clay (<2.0u) mineralogy of Site 1.

Horizon	KLN	QTZ	GT	GIB	MIC	FLD	HIV	INT	CHL	HEM
	%	%	%	%	%	%	%	%	%	%
Backslope										
A	28	11	-	4	5	3	45	t	3	-
E	31	13	-	4	5	5	36	5	3	-
Bt1	33	8	t	4	5	4	40	3	t	-
Bt2	47	2	t	3	4	2	34	3	t	2
Bt3	54	t	2	2	4	-	28	3	t	3
Bt4	59	t	1	1	5	2	34	t	-	4
BCt	60	t	1	1	2	-	30	t	-	5
BC1	58	-	1	1	5	1	28	1	-	4
BC2	54	-	1	t	15	1	24	t	-	4
C1	49	-	-	-	20	t	26	t	-	4

Table 17 (cont.). Clay (<2.0u) mineralogy of Site 1.

Horizon	KLN	QTZ	GT	GIB	MIC	FLD	HIV	INT	CHL	HEM
	%	%	%	%	%	%	%	%	%	%
Footslope										
A	29	9	-	3	4	3	49	t	2	-
AB	29	10	-	3	5	4	45	2	2	-
Bw1	38	11	-	1	6	6	34	1	3	-
Bw2	44	9	-	2	4	5	28	t	6	-
2Bt	56	5	2	t	7	4	18	t	4	t
2Cr	57	1	2	t	7	t	30	t	-	t

Abbreviations: KLN = kaolinite, QTZ = quartz, GT = goethite, GIB = gibbsite, MIC = Mica, HIV = hydroxy interlayer vermiculite, INT = randomly interstratified, FLD = feldspar, CHL = chlorite, HEM = hematite.

soil. In cases where both secondary chlorite and HIV are found, HIV is generally considered to be an intermediate between mica and secondary chlorite (Barnhisel and Bertsch, 1989).

Most of the clay-sized quartz and feldspar of the summit and backslope soils occurs in the surface and upper argillic horizons. As weatherable minerals decrease in the sand and silt fractions, quartz and feldspar grains become more evident. These trends are observed in the silt mineralogy of these two soils. Apparently, after most of the weatherable minerals are removed, only quartz and feldspar are left to undergo physical breakdown to clay-sized material.

Morphology of the summit and backslope soils in the Piedmont fit the concept of the Hayesville series (clayey, oxidic, Typic Hapludult). Mineralogy of the control section of the soils studied, however, does not meet the requirements of the oxidic class. These soils should be classified into the kaolinitic mineralogy class.

Clay mineralogy of the A through Bw2 horizons of the footslope soil is very similar to that of the upper horizons of the backslope soil. Kaolinite and HIV contents are noticeably different between the A and AB horizons, and between the two Bw horizons. The similar trend that occurs for silt-sized quartz may indicate parent material stratification. Clay mineralogy of the footslope 2Bt and 2Crt horizons is very similar to that of the summit and backslope Bt and BC horizons. Much of the clay in the 2Bt and 2Crt horizons occurs as clay films or coatings. The high kaolinite content may indicate that the soil that occurred above these horizons prior to truncation was moderately well developed.

Silt and clay mineralogy of the soils at Site 3 are similar to the mineralogy of the soils at Site 1, and many of the same weathering mechanisms and transformations are believed to have occurred (Tables 18 and 19). Mineralogy and trends in mineral content are similar at all three landscape positions. In both the silt and clay fractions, quartz and feldspar have accumulated in the surface horizons, and amounts decrease with depth. As previously discussed, quartz is resistant to weathering and becomes concentrated in the upper horizons. Feldspar, although often thought of as a weatherable mineral, may be relatively stable in these soil environments. Mica contents increase with depth. Kaolinite, HIV, and a randomly interstratified component appear to have resulted from the weathering and transformation of mica. In the silt fraction, HIV contents vary between horizons, showing no obvious trends with depth. In the clay fraction, however, HIV contents are highest in the surface and decrease with depth. Significant amounts of secondary chlorite also occur in the surface horizon clay fractions. Gibbsite, however,

Table 18. Silt (2-50u) mineralogy of Site 3.

Hor.	KLN	QTZ	MIC	FLD	HIV	INT
	%	%	%	%	%	%
			Summit			
A	5	45	8	29	10	3
E	5	38	5	32	17	3
BE	4	40	5	32	17	2
Bt1	8	33	12	25	16	3
Bt2	11	25	12	25	24	3
Bt3	12	23	14	25	20	6
BC	13	22	25	20	18	2
C1	10	20	30	20	18	2
			Backslope			
A	4	45	8	32	10	t
E	4	42	5	25	22	2
BE	8	40	6	24	19	3
Bt1	10	40	7	24	18	1
Bt2	11	35	10	23	21	t
Bt3	17	28	9	24	21	1
BC	19	20	15	21	24	1
C1	20	14	20	23	20	3

Table 18 (cont.). Silt (2-50u) mineralogy of Site 3.

Hor.	KLN	QTZ	MIC	FLD	HIV	INT
	%	%	%	%	%	%
			Footslope			
A	4	41	5	35	14	t
E	3	40	6	32	17	2
BE	7	34	10	29	11	1
2Bt1	15	27	62	27	23	2
2Bt2	10	21	9	28	30	2
2BC	7	16	17	25	28	2
2C1	8	15	25	21	30	1

Abbreviations: KLN = kaolinite, QTZ = quartz, MIC-mica, FLD = feldspar, HIV = hydroxy interlayered vermiculite, INT = randomly interstratified.

Table 19. Clay (<2.0u) mineralogy of Site 3.

Horizon	KLN	QTZ	GIB	MIC	FLD	HIV	CHL	INT
	%	%	%	%	%	%	%	%
				Summit				
A	20	5	-	5	5	55	10	-
E	19	5	-	6	5	55	10	-
BE	29	5	t	5	5	45	10	-
Bt1	43	2	t	8	5	40	t	-
Bt2	48	1	t	10	4	36	t	-
Bt3	52	t	-	10	3	34	t	-
BC	39	t	-	35	t	26	-	-
C1	30	t	-	45	t	26	-	-
				Backslope				
A	21	6	t	4	7	51	10	-
E	15	6	t	4	7	57	10	-
BE	44	5	-	7	5	34	5	-
Bt1	42	5	-	7	5	40	t	-
Bt2	43	3	-	7	3	43	t	-
Bt3	54	2	-	7	2	34	t	-
BC	45	1	-	7	t	46	-	-
C1	50	2	-	16	5	26	-	12

Table 19 (cont.). Clay (<2.0u) mineralogy of Site 3.

Horizon	KLN	QTZ	GIB	MIC	FLD	HIV	CHL	INT
	%	%	%	%	%	%	%	%
				Footslope				
A	24	7	-	5	5	50	9	t
E	23	7	-	5	6	49	10	t
BE	35	91	-	7	6	32	11	t
2Bt1	45	5	-	9	4	35	2	t
2Bt2	47	5	-	10	2	35	t	t
2BC	35	3	-	20	t	41	t	-
2C1	25	3	-	35	1	35	t	-

Abbreviations: KLN=kaolinite, QTZ=quartz, GIB=gibbsite, MIC=Mica, HIV=hydroxy interlayer vermiculite, INT=randomly interstratified, FLD=feldspar, CHL=chlorite.

occurs only in trace amounts even though considerable amounts of Al are present in the soil system, as indicated by high amounts of Al-interlayered minerals.

Saprolite Characterization and Genesis

An estimated 95 percent of the Inner Piedmont belt is overlain by saprolite (Overstreet et al., 1968). Thus saprolite is arguably the most prevalent soil parent material in the Piedmont. Saprolite morphology and genesis were examined at Sites 1, 2, and 3. Most of the saprolite shows variegated colors related to parent material. The primary colors of the upper saprolite are the same as the matrix color of the argillic or transition horizon above the saprolite, and apparently result from oxidized Fe. Saprolite with reduced colors (5Y 6/2) occurs above the bow-shaped form of the bedrock between the backslope and footslope positions at Site 1 (Figure 3). All of the saprolite is structureless massive, and friable in consistence. The Cr horizons are generally thin (0-20 cm thick, except for the backslope of Site 3, which was 90 cm thick), and firm in consistence.

Bulk density values vary between C horizons and range from 1.19 to 1.74 g/cm^3. The 26 C horizons sampled have an average bulk density of 1.39 g/cm^3 (Table 20). Unweathered rock collected from outcrops nearby have bulk density values of approximately 2.6 g/cm^3. Therefore, the loss in mass during the formation of C horizon saprolite from fresh unweathered rock ranges from 33 to 54 %, with an average loss of 47% of the original mass. Average bulk density values for the Cr horizons, partially weathered rock chiselled from the bottom of the auger holes, and slightly weathered rock at the base of the footslope soils at Sites 1 and 2 were 1.8, 2.1, and 2.4 g/cm^3, respectively. These data suggest that bulk densities of the saprolite do not necessarily increase with depth, but there is a gradation between C horizon saprolite and completely unweathered bedrock.

Particle size distribution is fairly constant within saprolite of a given pedon, and does not vary more than 6% for any one fraction (Tables 20 and 21). Sand is the dominant particle size fraction, with clay contents in most cases < 5%.

Saprolite DCB-Fe values vary with depth, showing no clear trends (Table 22). Silica and Al are by far the major elemental components (Table 21). Elemental Fe increases with depth in most cases, and is the only component that shows a trend indicative of weathering with depth. These data, along with the oxidized colors observed in the field, suggest that oxidation of Fe is an important process occurring during and after initial formation of saprolite. With the exception of Si and Al, the highest levels of

Table 20. Particle size distribution and bulk density values of saprolite.

Horizon	Depth	B.D.	Sand	Silt	CoSi	FSi	Clay	CoC
	cm	g/cm^3	%	%	%	%	%	%
Site 1 Summit								
C1	245-420	1.30	76.2	18.3	11.5	6.8	5.5	4.0
C2	420-445	1.29	75.0	23.0	16.3	6.7	2.0	1.1
C3	445-485	1.28	80.4	17.5	10.9	6.6	2.1	1.5
C4	485-535	1.30	82.1	17.7	12.1	5.6	.2	.2
C5	535-620	1.26	77.7	21.2	11.2	10.0	1.1	.6
C6	620-725	1.40	85.7	13.3	8.3	5.0	1.0	.4
C7	725-750+	1.40	81.8	16.8	9.7	7.1	1.4	1.4

Table 20 (cont.). Particle size distribution and bulk density values of saprolite.

Horizon	Depth	B.D.	Sand	Silt	CoSi	FSi	Clay	CoC
	cm	g/cm³	%	%	%	%	%	%
Site 1 Backslope								
C1	216-275	1.36	71.0	21.1	12.5	8.6	7.9	4.4
C2	275-340	1.19	82.5	14.8	7.5	7.3	2.7	1.9
C3	340-430	1.40	76.4	19.8	12.4	7.4	3.8	2.9
C4	430-450	1.41	80.6	17.7	10.5	7.2	1.7	1.3
Cr	450-460	1.82	74.1	23.6	14.2	9.4	2.3	2.3
Rock	460+	2.06						

Table 20 (cont). Particle size distribution and bulk density values of saprolite.

Horizon	Depth	B.D.	Sand	Silt	CoSi	FSi	Clay	CoC
	cm	g/cm^3	%	%	%	%	%	%
Site 2 Summit								
C1	247-280	1.62	80.8	17.1	12.8	4.3	2.1	1.3
C2	280-320	1.74	80.2	18.2	13.3	4.9	1.6	1.1
C3	320-405	1.31	85.1	13.1	6.9	6.2	1.8	1.4
C4	405-450	1.37	83.2	15.1	8.3	6.8	1.7	1.2
Rock	450+	2.11						
Site 2 Backslope								
3C1	320-350	1.30	68.3	24.6	11.8	12.8	7.1	5.2
3C2	350-370	1.30	70.4	20.0	10.4	9.6	9.6	6.5
3Cr	370-390	1.81	74.4	21.4	12.5	8.9	4.2	2.1
Rock	390+	2.09						

Table 20 (cont.). Particle size distribution and bulk density values of saprolite.

Horizon	Depth	B.D.	Sand	Silt	CoSi	FSi	Clay	CoC
	cm	g/cm^3	%	%	%	%	%	%
Site 3 Summit								
C1	150-205	1.40	65.5	29.6	6.2	23.4	4.9	3.8
C2	205-310	1.38	58.8	36.9	7.5	29.4	4.3	3.1
C3	310-490	1.37	61.3	34.1	6.0	28.1	4.6	3.8
C4	490-610	1.42	60.7	35.1	6.3	28.8	4.2	3.7
C5	610-780	1.47	65.0	32.4	8.7	23.7	2.6	2.5
C6	780-1145+	1.47	62.8	33.1	7.0	26.1	3.9	3.9
Site 3 Backslope								
C1	150-200	1.43	65.8	27.4	6.9	20.5	6.8	4.5
C2	200-260	1.46	70.5	25.6	7.5	18.1	3.9	2.4
C3	260-300	1.42	64.8	29.2	6.8	22.4	6.0	4.0
Cr	300-390	1.83	75.6	22.2	7.3	14.9	2.2	2.2
Rock	390+	2.08						

Table 21. Saprolite sand distribution.

Horizon	Depth	Sand	VCS	CS	MS	FS	VFS
	cm	%	%	%	%	%	%
Site 1 Summit							
C1	245-420	76.2	3.0	13.5	10.2	28.9	20.6
C2	420-445	75.0	5.5	9.0	12.6	29.6	18.3
C3	445-485	80.4	4.4	16.7	13.1	27.7	18.5
C4	485-535	82.1	3.6	20.4	14.2	26.7	17.2
C5	535-620	77.7	10.1	17.1	8.9	23.9	17.7
C6	620-725	85.7	9.3	21.2	12.5	27.7	15.0
C7	725-750+	81.8	2.7	15.8	13.3	33.1	16.9
Site 1 Backslope							
C1	216-275	71.0	4.1	8.5	8.6	28.9	20.9
C2	275-340	82.5	8.9	18.6	10.7	24.4	19.9
C3	340-430	76.4	9.4	13.7	8.7	25.8	18.8
C4	430-450	80.6	16.8	18.8	9.6	21.7	13.7
Cr	450-460	74.1	6.9	11.7	10.2	27.4	17.9

Table 21 (cont.). Saprolite sand distribution.

Horizon	Depth	Sand	VCS	CS	MS	FS	VFS
	cm	%	%	%	%	%	%
Site 2 Summit							
C1	247-280	80.8	3.1	10.1	10.8	35.7	21.1
C2	280-320	80.2	3.1	9.3	9.0	35.7	23.1
C3	320-405	85.1	5.5	12.3	10.3	37.7	19.3
C4	405-450	83.2	5.4	10.9	9.1	37.1	20.7

Table 21 (cont.). Saprolite sand distribution.

Horizon	Depth	Sand	VCS	CS	MS	FS	VFS
	cm	%	%	%	%	%	%
Site 3 Summit							
C1	150-205	65.5	17.9	19.5	8.9	12.9	6.3
C2	205-310	58.8	15.0	17.0	8.3	12.4	6.1
C3	310-490	61.3	14.5	16.7	10.9	12.8	6.4
C4	490-610	60.7	14.3	16.3	8.9	14.5	6.7
C5	610-780	65.0	16.1	18.1	9.5	14.8	6.5
C6	780-1145 +	62.8	18.7	14.0	8.6	14.8	6.7
Site 3 Backslope							
C1	150-200	65.8	17.7	16.5	8.5	15.0	8.1
C2	200-260	70.5	19.6	18.0	9.3	15.3	8.3
C3	260-300	64.8	17.8	17.1	8.6	14.3	7.0
Cr	300-390	75.6	21.3	22.0	10.8	15.2	6.3

Table 22. Selected elemental and DCB extractable values for saprolite and parent rock.

Horizon	Depth	Ca	Al	Fe	Mg	Si	Ti	Na	DCB Fe
	cm	%	%	%	%	%	%	%	%
Site 1 Summit									
C1	245-420	.14	8.41	1.23	.11	30.51	.16	.22	.84
C2	420-445	.16	8.67	.82	.12	30.74	.06	.21	.29
C3	445-485	.17	10.06	.96	.09	21.65	.17	.66	.51
C4	485-535	.07	9.72	2.46	.31	28.58	.73	.21	.60
C5	535-620	.07	9.12	1.80	.15	30.66	.21	.35	.89
C6	620-725	.04	9.85	2.13	.15	29.63	.20	.78	.39
C7	725-750+	.00	2.99	3.11	.13	27.78	.30	.67	.48

Table 22 (cont.). Selected elemental and DCB extractable values for saprolite and parent rock.

Horizon	Depth	Ca	Al	Fe	Mg	Si	Ti	Na	DCB Fe
	cm	%	%	%	%	%	%	%	%
Site 1 Backslope									
C1	216-275	.00	11.70	3.19	.19	26.44	.52	.18	1.95
C2	275-340	.03	9.38	1.75	.11	29.25	.16	.16	.53
C3	340-430	.06	9.63	1.88	.11	30.84	.16	.31	.32
C4	430-450	.11	9.87	2.04	.16	29.85	.14	1.23	.13
Cr	450-460	.18	9.76	2.39	.24	29.04	.30	1.83	.46
Rock	460+	.45	9.66	3.89	.42	26.69	.46	2.27	.29

Table 22 (cont.). Selected elemental and DCB extractable values for saprolite and parent rock.

Horizon	Depth	Ca	Al	Fe	Mg	Si	Ti	Na	DCB Fe
	cm	%	%	%	%	%	%	%	%
Site 2 Summit									
C1	247-280	.01	9.57	3.18	.22	26.23	.45	.19	.30
C2	280-320	.17	10.72	3.51	.89	26.93	.38	1.59	.24
C3	320-405	.40	7.99	3.38	.38	27.51	.45	.47	.67
C4	405-450	.01	8.90	3.65	.54	24.83	.54	.21	.63
Rock	450+	.28	9.84	4.19	1.3	23.39	.65	1.41	.45
Site 2 Backslope									
3C1	320-350	.15	10.02	.89	.12	29.65	.14	.21	.70
3C2	350-370	.12	10.66	1.57	.11	27.65	.18	1.65	.82
3Cr	370-390	.05	9.59	4.34	.58	25.45	.60	1.03	.43
Rock	390+	1.51	10.75	2.88	1.1	28.56	.39	2.91	.10

Table 22 (cont.). Selected elemental and DCB extractable values for saprolite and parent rock.

Horizon	Depth	Ca	Al	Fe	Mg	Si	Ti	Na	DCB Fe
	cm	%	%	%	%	%	%	%	%
Site 3 Summit									
C2	205-310	.13	9.73	1.11	.07	29.66	.15	.31	1.96
C3	310-490	.01	9.77	2.88	.14	27.72	.74	.32	1.98
C4	490-610	.01	9.72	3.19	.13	25.58	.72	.19	2.50
C5	610-780	.00	10.54	2.77	.15	25.52	.63	.15	1.77
C6	780-1145 +	.00	9.05	3.55	.14	26.50	1.03	.17	3.02
Site 3 Backslope									
C2	200-260	.00	9.97	2.31	.08	26.11	.71	.32	1.69
C3	260-300	.08	9.73	1.46	.20	26.73	.52	.78	1.36
Cr	300-390	.60	9.37	1.33	.22	28.49	.33	.74	.65
Rock	390 +	.95	9.75	2.58	.29	27.85	.28	1.00	.92

most other elements are found in the rock samples. Consistent trends with depth for these elements, however, are not apparent. After saprolite formation, chemical weathering and dissolution apparently occur at similar rates regardless of the depth of the saprolitic horizon. These results are supported by the particle size data, which show no changes with depth.

Gains and losses of the elemental components were examined on an area basis, and losses totalled for each pedon (Table 23). Total losses range from 20 to 36 %. The average bulk density values for the 15 C and Cr horizons, and 4 rock samples examined in Table 22 are, 1.49 and 2.09 g/cm^3, respectively. Therefore, the average loss of constituents for the saprolite of these 4 soils is 29%. This value is essentially the same as the losses measured using reconstruction calculations (Table 23). The average bulk density value of unweathered rock sampled from outcrops near these soils is 2.6 g/cm^3, indicating that approximately 20% of the mass is lost during weathering of fresh rock to partially weathered rock, which is the precursor of saprolite. Therefore, although the elemental forms lost during weathering of fresh rock to partially weathered rock may differ from those lost during saprolite formation, greater total losses occur during saprolite formation. Between 73 and 82 % of these losses are the result of losses of Al and Si.

The Cr horizons in most summit and backslope soils are thin (< 20 cm) or nearly absent. This thin transition zone between partially weathered rock and saprolite indicates that the formation of saprolite from partially weathered rock is a relatively fast process, compared to the rates of change following initial formation of saprolite. At the footslope positions Cr horizons are also recognized above bedrock, but C saprolite does not always occur above these horizons. Clay coatings indicative of clay illuviation occur in the fissure cracks of the Cr horizon at the footslope of Site 1. Thus, there appear to be two types of Cr horizons. One type is overlain by saprolite and has formed through chemical weathering. The other type is not a precursor to C saprolite, and has evolved through physical and chemical weathering, and in some cases shows pedogenic alteration.

The occurrence of Cr horizons without saprolite indicates that initially soil formation is occurring at a faster rate than saprolite formation, and at a similar rate to physical and chemical rock weathering. This stage of development can be observed between time zero (t_0) and t_1 (Figure 15), where only soil and rock occur in the system. After initial soil formation and mineral weathering, saprolite forms at a faster rate than soil does, and saprolite begins to accumulate below the solum (after t_1). Following an extended period of time, the amount of energy necessary to further the degree of profile development is greater than the amount in the soil system, and the soil reaches a state of equilibrium (after t_2). Saprolite continues to form, although most

Table 23. Gains and losses of elemental and DCB extractable constituents on an area basis.

Horizon	Depth	CaO	Al_2O_3	FeO	MgO	SiO_2	TiO_2	Na_2O	DCB Fe_2O_3	Total Losses
	cm	----------------	----------------	----------------	----------------	$g/100\ cm^2$	----------------	----------------	----------------	%
Site 1 Backslope										
C1	216-275	-77	-445	-278	-60	-2110	-24	-353	173	
C2	275-340	-82	-1073	-495	-79	-2465	-82	-394	3	
C3	340-430	-108	-1092	-622	-106	-1997	-109	-515	-19	
C4	430-450	-22	-226	-132	-21	-485	-25	-79	-12	
Cr	450-460	-9	-40	-47	-7	-40	-7	-18	-3	
Rock	460+	0	0	0	0	0	0	0	0	
Total		-297	-2876	-1574	-273	-7098	-246	-1360	27	27

Table 23 (cont.). Gains and losses of elemental and DCB extractable constituents on an area basis.

Horizon	Depth	CaO	Al_2O_3	FeO	MgO	SiO_2	TiO_2	Na_2O	DCB Fe_2O_3	Total Losses
	cm	----------------g/100 cm^2----------------								%
Site 2 Summit										
C1	247-280	-25	-260	-136	-125	-266	-31	-112	-20	
C2	280-320	-15	-78	-130	-72	6	-43	-3	-28	
C3	320-405	-4	-1480	-480	-303	-1717	-101	-253	-3	
C4	405-450	-74	-1344	-459	-299	-2279	-89	-325	-5	
Rock	450+	0	0	0	0	0	0	0	0	
Total		-118	-3163	-1097	-799	-4256	-264	-693	-55	26

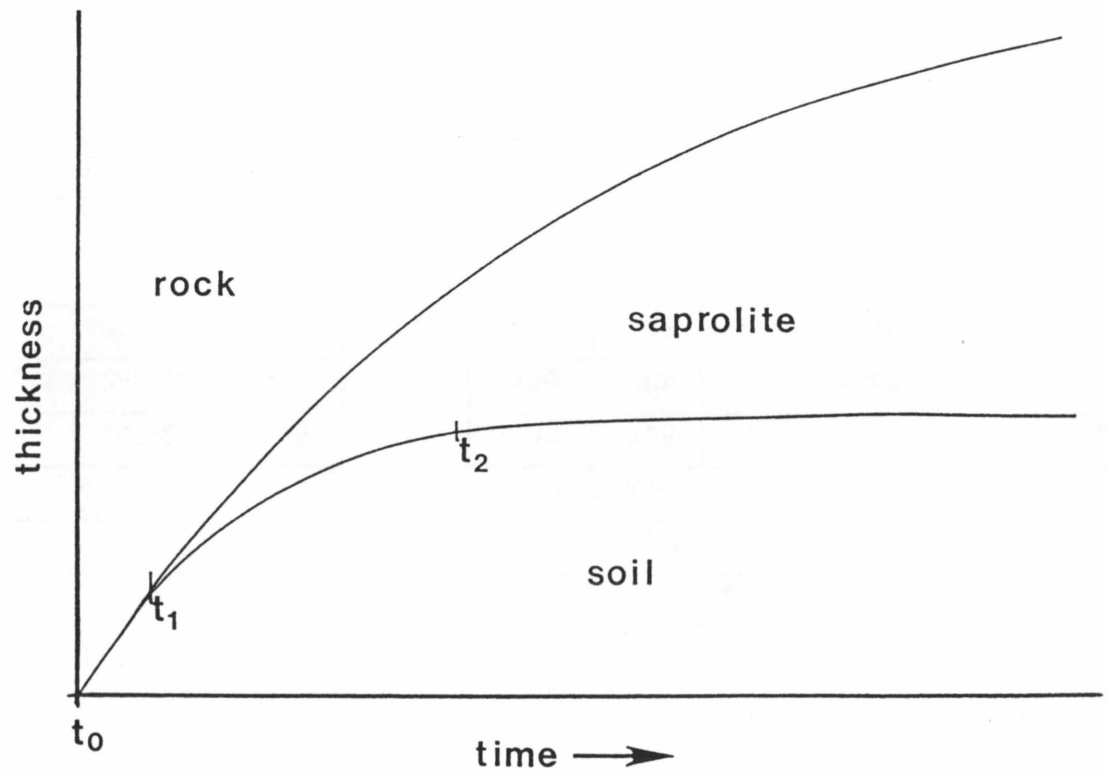

Figure 15. Diagram of the relationships between soil and saprolite thickness with time.

likely at a slower rate than when the partially weathered rock was at a shallower depth. This rate of saprolite formation, represented by the curve of the rock-saprolite boundary in Figure 15, will differ depending upon the rock type and mineralogy.

Soil-saprolite-landscape relationships

In the three toposequences studied, the forms of the bedrock and present landscape are very similar between the backslope and footslope positions. Between summit and backslope, however, the present landscape does not always conform to the shape of the bedrock (Figures 3, 4, and 5). Saprolite is much thicker at the summit of Site 1 than at the summit of Site 2. These sites are less than a kilometer apart and both summit and backslope soils have essentially the same profile morphology and thickness. Therefore, differences in saprolite thickness between summit and backslope soils at Sites 1, and between the summits at Sites 1 and 2, are not related to soil type or thickness. Minor differences in the mineralogy or degree of metamorphism of the parent rock at the summit of Site 1 could have caused this material to weather at a faster rate than the rock at the summit of Site 2. The upper landscape at Site 2 was apparently unstable at some period, as indicated by the thickness of the material above the stoneline (Figure 4), during which a considerable amount of soil and saprolite may have been removed. As a result, summit and backslope soils at Site 2 have about equal amounts of saprolite. Evidence for substantial displacement of soil material from the upper landscape of Site 1 is lacking. Saprolite thickness is much greater at the summit than at the backslope, indicating that the summit position is relatively stable in comparison to the backslope at Site 1 and summit and backslope at Site 2.

At Site 3 the soils at each landscape position are very similar. Significant differences in saprolite thickness occur between the summit and backslope landscape positions. The stone line across most of the landscape (Figure 5) indicates a period of landscape instability. The erosional period, represented by the stone line and depositional material at the backslope and footslope, did not appear to have substantially affected the thickness of the summit regolith.

Footslope soils at Sites 1 and 2 are void of saprolite, and saprolite thickness at the footslope of Site 3 is about 1.5 m. Footslope soils at Sites 1 and 2, which occur at the head of drainageways, are probably eroding at least as fast as the saprolite is forming.

Pavich (1986) estimated that the rate of saprolite formation in the Piedmont of Virginia is at least 4 m per million years. The thickness of the regolith at the backslopes of the soils examined in this study is < 5 m. Therefore, if the rate of saprolite formation is at least 4 m per million years, the current forms of the Piedmont and Blue Ridge Highland landscapes are only 1 to 2 million years old.

SUMMARY AND CONCLUSIONS

In this research, various methods and techniques were used to examine soil-saprolite-landscape relationships from several perspectives. Soil micromorphology indicated that although horizons appear structureless-massive in the field, many of these horizons have undergone considerable alteration due to pedogenesis, and are in fact transition horizons. As a result, the solum thicknesses of many soils, especially those in the Piedmont, are much thicker than commonly thought.

Distinguishing soil-saprolite transition horizons from C horizons in the field is a difficult task. To better describe the transition and associated saprolite C horizons in the field, these guidelines should be followed: 1) Percent clay should not decrease below the C1 horizon. 2) C horizons should lack subangular blocky microstructure or illuvial clay in small macrovoids. 3) Horizons that show moderate evidence of rock structure should be labelled a transition horizon, even if the horizon meets the criteria as part of the argillic horizon. Micromorphology and laboratory data suggest 3 types of transition horizons. Horizons labelled BCt are those with subangular blocky structure, evidence of rock structure, and substantial oriented clay. Those horizons labelled BC contain some subangular blocky microstructure, and increases or decreases in sand, clay, or DCB-Fe contents with depth, more like those observed in B than those seen in C horizons. Transition horizons labelled CB are very similar to C horizons, except that CB horizons show some evidence of pedogenesis.

Most of the overall soil variability can be attributed to differences between study sites or between horizons. Total variability explained by landscape position is minimal, indicating that in soil studies that occur over several regions, landscape position is not as important soil-forming factor as parent material or regional climate. Substantial variability occurs within horizons of the same pedon. The most variability occurs within C horizons. These data indicate a strong need for subsampling within horizons of the same pedon to reduce the variability about the population mean.

Many studies have indicated that backslopes are erosional positions; and therefore these soils are less developed than are associated summit soils. These observations suggest that differences in profile morphology between summit and backslope soils are most likely related to differences in parent materials or man-induced erosion.

Reconstruction analysis is a valuable tool in studying soil-landscape relationships. These techniques indicate that both summit and backslope soils undergo the same soil-forming processes. The most important soil-forming processes are sand weathering and clay eluviation/illuviation. Footslope soils are less developed than are associated summit and backslope soils, and both depositional and pedologic processes contribute to soil formation and development.

Greater amounts of saprolite occur at summit positions than at associated backslope and footslopes. These differences in saprolite thickness are apparently related to the relative stability of the summit, compared to associated backslope and footslope positions. Significant losses of primarily Al and Si occur during the chemical weathering of partially weathered rock to saprolite. Initial saprolite formation occurs at a faster rate than saprolite changes following formation . Initial soil development occurs at a faster rate than saprolite formation, but after substantial profile development, soil formation occurs at a slower rate than saprolite formation, and saprolite begins to accumulate below a soil. Soil formation may finally reach a rate where the energy needed to further profile development is greater than the amount in the soil system, and soil development is minimal. Saprolite however, continues to form and accumulate under the soil.

REFERENCES

Barnhisel, R.I. and P.M. Bertsch. 1989. Chlorites and hydroxy-interlayered vermiculite and smectite. In Minerals in the Soil Environments, J.B. Dixon and S.B. Weed (eds.) Soil Sci. Soc. Am., Madison Wisc. Agronomy, 1:729-788.

Becker, G.F. 1895. A reconnaissance of the goldfields of the Southern Appalachians. U.S. Geol. Survey 16th Annual Report, pp. 289-290. USGS, Washington, D.C.

Bernas, B. 1968. A new method for decomposition and comprehensive analysis of silicates by atomic absorption spectrometry. Anal. Chem. 40:1682-1686.

Bloomer, R.O., and H.J. Werner. 1955. Geology of the Blue Ridge region in central Virginia. Geol. Soc. Am. Bull. 66:579-606.

Brasher, B.R., D.P. Franzmeier, V. Valais, and S.E. Davidson. 1966. Use of saran resin to coat natural soil clods for bulk density and water retention measurements. Soil Sci. 101: 108.

Brewer, R. 1976. Calculations of soil formation. In Fabric and mineral analysis, pp. 63-87. Krieger Publ., NY.

Bullock, P., N. Federoff, A. Jongerius, G. Stoops, T. Tursina, and U.Babel. 1985. Handbook for thin section description. Wolverhampton, England: Waine Research Publications.

Dietrich, R.V. 1954. Geology of the Pilot Mountain area of Virginia. Bull. Engr. Exp. Sta. #91. Blacksburg, Va., Virginia Tech, Engrineering Station. 32 pp.

Drees, L.R. and L.P. Wilding. 1973. Elemental variability within a sampling unit. Soil Sci. Soc. Am. Proc. 37: 82-87.

Drees, L.R., L.P. Wilding, N.E. Smeck and A.L. Senkayi. 1989. Silica in soils: quartz and disordered silica polymorphs. In Minerals in the Soil Environments, J.B. Dixon and S.B. Weed (eds.). Soil Sci. Soc. Am., Madison Wisc.. Agronomy 1: 913-974.

Gee, G.W., and J.W. Bauder. 1986. Particle size analysis. In Methods of Soil Analysis, Part 1, A. Klute (ed.). Agronomy 9:383-409.

Holmgren, G.G.S. 1967. A rapid citrate-dithionite extractable iron procedure. Soil Sci. Soc. Am. Proc. 31: 210-211.

Huddleston, J.H. and F.F. Riecken. 1973. Local soil-landscape relationships in western Iowa: I. Distribution of selected physical and chemical properties. Soil Sci. Soc. Am. Proc. 37: 264-270.

Huddleston, J.H., J.A. Walsh, D. Jowett, and F.F. Riecken. 1975. Local soil-landscape relationships in western Iowa: II. Quantification of pedologic and geologic effects. Soil Sci. Soc. Am. Proc. 39: 908-913.

Jackson, M.L. 1956. Soil chemical analysis, advanced course. Madison, Wisc. M.L. Jackson.

Kleis, H.J. 1970. Hillslope sedimentation and soil formation in northeastern Iowa. Soil Sci. Soc. Am. Proc. 24: 289-290.

Lewis, S.E. 1975. Geology of the southern part of Riner quadrangle, Montgomery and Floyd Counties, Va. M.S. Thesis. Raleigh, N.C.: North Carolina State University. 106 pp.

Marshall, C.E., and J.F. Haseman. 1942. The quantitative evaluation of soil formation and development by heavy mineral studies: a Grundy silt loam study. Soil Sci. Soc. Am. Proc. 7: 448-453.

Milnes, A.R. and R.W. Fitzpatrick. 1989. Titanium and zirconium minerals. In Minerals in the Soil Environments, J.B. Dixon and S.B. Weed (eds.). Soil Sci. Soc. Am., Madison, Wisc. Agronomy 1:1131-1208.

Overstreet, W.C., A.M. White, J.W. Whitlow, P.K. Theobald, P.W. Caldwell, and N.P. Cuppels. 1968. Fluvial monazite deposits in the Southeastern United States. U.S. Geol. Survey Prof. Paper. No. 568. USGS, Washington D.C. 85 pp.

Pavich, M.J. 1986. Processes and rates of saprolite production and erosion on a foliated granitic rock of the Virginia Piedmont. In Rates of chemical weathering of rocks and minerals. S.M. Coleman and D.P. Diether (eds.). Orlando, Fla.: Academic Press.

Ruhe, R.V., and P.H. Walker. 1968. Hillslope models and soil formation: I. Open systems. Trans. 9th Intl. Congr. Soil Sci. 4: 551-560.

SAS Institute. 1985. SAS user's guide: Statistics. 5th ed. Cary, N.C.: SAS Inst.

Smeck, N.E. and L.P. Wilding. 1980. Quantitative evaluation of pedon formation in calcareous glacial deposits in Ohio. Geoderma 24: 1-16.

Smeck, N.E., L.P. Wilding, and N. Holowaychuk. 1968. Genesis of argillic horizons in Celina and Morley soils of western Ohio. Soil Sci. Soc. Am. Proc. 32: 550-556.

Smeck, N.E., A. Ritchie, L.P. Wilding, and L.R. Drees. 1981. Clay accumulation in sola of poorly drained soils of western Ohio. Soil Sci. Soc. Am. J. 45: 95-102.

Soil Survey Staff. 1975. Soil Taxonomy. A basic system of soil classification for making and interpreting soil surveys. USDA-SCS Agric. Handb. 436. Washington, DC. U.S. Goverment Printing Office.

Stolt, M.H., J.C. Baker, and T.W. Simpson. 1991. Bucket auger modification for obtaining undisturbed samples of deep saprolite. Soil Sci. 151:179-182.

Sudom, M.D. and R.J. St. Arnaud. 1971. Use of quartz, zirconium and titanium as indices in pedologic studies. Can J. Soil Sci. 51: 385-396.

Tan, K.H., and B.F. Hajek. 1977. Thermal analysis of soils. In Minerals in soil environments, J.B. Dixon and S.B. Weed (eds.). Soil Sci. Soc. Am., Madison, Wisc. Agronomy, 1:865-884.

Walker, P.H., G.F. Hall, and R. Protz. 1968. Soil trends and variability across selected landscapes in Iowa. Soil Sci. Soc. Am. Proc. 32: 97-101.

Wang, C. and R.W. Arnold. 1973. Quantifying pedogenesis for soils with discontinuities. Soil Soc. Am. Proc. 37: 271-278.

Webster, R. 1977. Quantitative and numerical methods in soil classification and survey. Oxford, U.K. Clarendon Press.

Wilding, L.P., and L.R. Drees. 1983. Spatial variability and pedology. In Pedogenesis and soil taxonomy. I. Concepts and interactions. L.P. Wilding, N.E Smeck, and G.F. Hall (eds.) Amsterdam. Elsevier Science Publishers.

Zar, J.H. 1984. Biostatistical Analysis. Englewood Cliffs, N.J.: Prentice Hall.

APPENDICES

Appendix A. Additional soils data for Site 1.

Table A-1. Base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the summit pedon.

Table A-2. Variability in base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the summit pedon.

Table A-3. Base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the backslope pedon.

Table A-4. Variability in base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the backslope pedon.

Table A-5. Base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the footslope pedon.

Table A-6. Variability in base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the footslope pedon.

Table A-7. Sand distributions of the Site 1 pedons.

Table A-8. Particle size distribution and textural class of the Site 1 pedons.

Table A-1. Base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the summit pedon at Site 1. .

Horizon	pH	Ca	Mg	K	H	Al	B.S.	DCB Fe	B.D.
		meq/100 g					%		g/cm^3
A	4.44	0.30	0.11	0.28	13.20	3.15	4.97	0.78	0.84
E	4.85	0.19	0.02	0.18	4.80	1.71	7.52	0.79	1.32
Bt1	4.88	0.30	0.07	0.26	6.20	2.55	9.22	1.81	1.52
Bt2	4.97	0.25	0.76	0.40	11.00	2.85	11.36	3.35	1.37
Bt3	5.17	0.19	1.24	0.44	9.00	2.28	17.20	3.60	1.28
BC	5.50	0.30	0.03	0.20	3.20	2.05	14.21	2.32	1.37
C1	5.56	0.24	0.03	0.20	4.35	1.58	9.75	2.10	1.47
C2	5.67	0.24	0.02	0.13	3.00	1.65	11.50	1.20	1.38
C3	5.63	0.20	0.04	0.11	3.20	1.45	9.86	0.92	1.34
C4	5.84	0.18	0.03	0.08	1.40	0.55	17.16	0.84	1.30
C5	5.86	0.18	0.16	0.11	1.60	0.95	21.95	0.29	1.29
C6	5.87	0.16	0.23	0.11	2.00	0.85	20.00	0.51	1.28
C7	5.78	0.16	0.48	0.14	3.20	1.75	19.60	0.60	1.30
C8	5.95	0.14	0.23	0.13	1.60	0.65	23.81	0.89	1.40

Table A-2. Variability in base saturation (B.S.), pH, DCB extractable Fe, and exchangeable cations of the summit pedon at Site 1. Horizons labelled A, B, C, or D were sampled from separate faces within soil pit.

Horizon	pH	Ca	Mg	K	H	Al	B.S.	DCB Fe
		----------meq/100 g----------					-----%-----	
E-A	4.86	0.20	0.02	0.19	4.40	1.50	18.52	0.65
E-B	4.77	0.20	0.01	0.15	5.00	1.75	6.72	0.80
E-C	4.79	0.18	0.02	0.20	5.00	1.95	7.41	0.78
E-D	4.98	0.16	0.03	0.17	4.80	1.65	6.98	0.91
Bt3-A	5.18	0.20	1.43	0.53	11.60	2.35	15.70	4.02
Bt3-B	5.10	0.20	1.23	0.42	10.80	2.45	14.62	3.66
Bt3-C	5.20	0.18	0.99	0.40	5.00	2.25	23.90	3.45
Bt3-D	5.18	0.16	1.30	0.41	8.60	2.05	17.86	3.25
C1-A	5.59	0.28	0.03	0.14	6.20	1.65	12.33	0.90
C1-B	5.53	0.26	0.02	0.17	4.60	2.05	8.91	1.80
C1-C	5.69	0.20	0.04	0.26	2.40	0.95	17.24	0.80
C1-D	5.59	0.20	0.02	0.21	4.20	1.65	9.29	1.28

Table A-3. Base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the backslope pedon at Site 1.

Horizon	pH	Ca	Mg	K	H	Al	B.S.	DCB Fe	B.D.
		meq/100 g					%		g/cm^3
A	5.48	3.59	0.72	0.27	11.20	0.35	29.02	0.64	1.17
E	5.71	0.38	0.14	0.16	2.00	0.58	25.37	0.68	1.61
Bt1	5.34	0.41	0.42	0.22	4.60	1.35	18.58	1.33	1.62
Bt2	5.36	0.74	1.70	0.43	9.40	1.60	23.39	3.05	1.47
Bt3	5.57	0.88	1.95	0.55	8.70	1.35	27.98	4.32	1.45
Bt4	5.67	0.30	1.06	0.41	8.60	1.75	17.07	3.96	1.45
BC	5.64	0.05	0.52	0.42	6.60	2.10	13.04	3.04	1.39
C1	5.64	0.05	0.29	0.36	5.80	2.05	10.77	1.95	1.46
C2	5.60	0.05	0.27	0.31	4.90	2.21	11.39	1.95	1.32
C3	5.48	0.06	0.29	0.29	7.60	2.65	7.77	1.95	1.19
C4	5.65	0.06	0.19	0.20	4.80	1.15	8.57	0.53	1.40
C5	5.75	0.05	0.29	0.17	1.40	1.20	26.70	0.32	1.41
C6	5.90	0.07	0.09	0.19	2.00	0.45	14.89	0.13	1.41

Table A-4. Variability in base saturation (B.S.), pH, DCB extractable Fe, and exchangeable cations of the backslope pedon at Site 1. Horizons labelled A, B, C, or D were sampled from separate faces within soil pit.

Horizon	pH	Ca	Mg	K	H	Al	B.S.	DCB Fe
		-----	-----	meq/100 g	-----	-----	-----	% -----
E-A	5.80	0.43	0.15	0.16	2.20	0.45	25.17	0.69
E-B	5.58	0.31	0.13	0.14	1.60	0.75	26.61	0.74
E-C	5.74	0.42	0.18	0.16	1.80	0.45	29.69	0.64
E-D	5.70	0.34	0.08	0.17	2.20	0.65	21.15	0.64
Bt3-A	5.60	0.69	2.02	0.57	9.00	1.45	26.71	4.28
Bt3-B	5.46	0.78	1.95	0.56	7.80	1.45	29.67	4.02
Bt3-C	5.58	1.19	2.18	0.54	9.40	1.05	29.38	4.76
Bt3-D	5.64	0.85	1.65	0.53	8.60	1.45	26.05	4.22
C2-A	5.50	0.05	0.30	0.31	7.00	2.60	8.62	2.75
C2-B	5.60	0.05	0.26	0.32	3.60	1.85	14.89	1.45
C2-C	5.66	0.07	0.20	0.25	4.00	1.75	11.50	1.02
C2-D	5.63	0.04	0.30	0.35	5.00	2.65	12.13	2.58

Table A-5. Base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the footslope pedon at Site 1.

Horizon	pH	Ca	Mg	K	H	Al	B.S.	DCB Fe	B.D.
		meq/100 g					%		g/cm^3
A	5.40	2.61	0.68	0.31	9.60	0.50	27.27	0.76	1.03
AB	5.50	0.94	0.31	0.26	7.50	0.51	16.76	0.83	1.43
Bw1	5.60	0.65	0.27	0.24	7.40	0.45	13.55	0.93	1.52
Bw2	5.70	0.79	0.35	0.26	6.20	0.40	18.42	1.05	1.64
2Bt	5.71	1.56	0.96	0.32	8.30	0.30	25.49	2.24	1.45
3Cr	5.68	1.95	1.35	0.36	8.80	0.35	29.37	2.90	1.65

Table A-6. Variability in base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the footslope pedon at Site 1. Horizons labelled A, B, C, or D were sampled from separate faces within soil pit.

Horizon	pH	Ca	Mg	K	H	Al	B.S.	DCB Fe
		meq/100 g					%	
AB-A	5.30	0.55	0.24	0.23	5.40	0.85	15.89	0.73
AB-B	5.56	0.99	0.39	0.34	8.40	0.35	17.00	0.89
AB-C	5.54	1.01	0.26	0.18	8.00	0.45	15.35	0.88
AB-D	5.66	1.22	0.33	0.28	8.20	0.35	18.25	0.82
2Bt-A	5.72	2.57	1.52	0.38	10.40	0.25	30.06	3.38
2Bt-B	5.67	0.98	0.56	0.29	7.40	0.30	19.83	1.61
2Bt-C	5.74	1.65	1.06	0.33	7.40	0.30	29.12	2.49
2Bt-D	5.70	1.04	0.72	0.29	8.00	0.35	20.40	1.49
3Cr-A	5.64	2.19	1.53	0.36	8.80	0.45	31.68	2.61
3Cr-B	5.76	2.22	1.49	0.40	8.80	0.25	31.84	3.47
3Cr-D	5.64	1.43	1.03	0.33	8.80	0.35	24.07	2.62

Table A-7. Sand distribution of Site 1 pedons.

Horizon	Depth	Total Sand	VCo	Co	M	F	VF
	cm	%	%	%	%	%	%
			Summit				
A	0-7	58.2	4.1	13.7	11.1	20.2	9.3
E	7-16	59.1	3.6	13.2	10.4	20.4	11.5
Bt1	16-31	43.9	2.9	9.6	8.0	14.4	9.0
Bt2	31-48	30.7	2.5	7.0	5.2	9.6	6.4
Bt3	48-63	32.8	2.7	7.1	5.2	9.6	8.2
Bt4	63-126	51.3	3.8	10.4	8.3	16.0	12.8
BCt	126-170	59.6	5.3	12.2	9.0	18.5	14.6
BC	170-202	66.7	6.7	15.4	9.4	19.6	15.6
CB	202-245	74.1	4.2	14.2	10.4	26.5	18.8
C1	245-420	76.2	3.0	13.5	10.2	28.9	20.6

Appendix A-7 (cont). Sand distribution of Site 1 pedons.

Horizon	Depth	Total Sand	VCo	Co	M	F	VF
	cm	%	%	%	%	%	%
			Backslope				
A	0-7	56.6	3.5	9.7	10.1	22.3	11.0
E	7-28	56.4	4.3	10.0	7.9	22.0	12.2
Bt1	28-43	45.9	3.2	7.7	8.1	17.6	9.3
Bt2	43-70	31.5	1.9	4.9	4.9	11.8	8.0
Bt3	70-98	24.7	1.1	2.5	3.6	9.4	8.1
Bt4	98-130	36.7	2.0	4.6	4.8	13.7	11.6
Bt5	130-150	49.5	2.3	6.6	7.1	19.9	13.6
BCt	150-187	66.0	3.6	8.5	9.0	26.1	18.8
CB	187-216	66.6	2.8	7.6	8.4	27.6	20.2
C1	216-275	71.0	4.1	8.5	8.6	28.9	20.9
			Footslope				
A	0-10	53.4	2.1	10.2	10.3	20.2	10.6
AB	10-24	57.9	2.6	11.8	11.5	21.6	10.4
Bw1	24-45	54.6	2.6	9.7	10.5	20.4	11.4
Bw2	45-67	53.7	3.1	9.7	10.0	20.0	10.9
2Bt	67-100	52.4	3.6	9.8	9.7	19.4	9.9
2Cr	100-135	59.6	8.4	11.9	8.8	19.2	11.3

Table A-8. Particle size distribution and textural class (Tex) of Site 1 pedons.

Horizon	Depth	Sand	Silt	CoSi	Clay	Tex
	cm	%	%	%	%	%
			Summit			
A	0-7	58.2	27.6	7.7	14.2	SL
E	7-16	59.1	30.5	9.8	10.4	fSL
Bt1	16-31	43.9	27.4	8.5	28.7	CL
Bt2	31-48	30.7	21.1	5.9	48.2	C
Bt3	48-63	32.8	15.7	5.1	51.5	C
Bt4	63-126	51.3	18.6	9.6	30.1	SCL
BCt	126-170	59.6	21.4	10.7	19.0	fSL
BC	170-202	66.7	15.1	6.3	10.3	fSL
CB	202-245	74.1	17.9	10.1	8.0	fSL
C1	245-420	76.2	18.3	11.5	5.5	fSL

Appendix A-8 (cont). Particle size distribution and textural class (Tex) of Site 1 pedons.

Horizon	Depth	Sand	Silt	CoSi	Clay	Tex
	cm	%	%	%	%	%
			Backslope			
A	0-7	56.6	30.5	9.1	12.9	fSL
E	7-28	56.4	34.8	11.9	8.8	fSL
Bt1	28-43	45.9	29.9	5.9	24.2	L
Bt2	43-70	31.5	25.1	6.5	43.4	C
Bt3	70-98	24.7	18.9	4.3	56.4	C
Bt4	98-130	36.7	21.6	8.2	41.7	C
Bt5	130-150	49.5	20.8	6.9	29.7	L
BCt	150-187	66.0	21.1	14.1	12.9	fSL
CB	187-216	66.6	20.9	12.0	12.5	fSL
C1	216-275	71.0	21.1	12.5	7.9	fSL
			Footslope			
A	0-10	53.4	32.0	9.8	14.6	fSL
AB	10-24	57.9	32.1	9.8	10.0	fSL
Bw1	24-45	54.6	32.5	9.3	12.9	fSL
Bw2	45-67	53.7	33.4	9.7	12.9	fSL
2Bt	67-100	52.4	24.1	7.3	23.5	SCL
2Cr	100-135	59.6	17.5	6.8	22.9	SCL

Appendix B. Additional soils data for Site 2.

Table B-1. Base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the summit pedon.

Table B-2. Variability in base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the summit pedon.

Table B-3. Base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the backslope pedon.

Table B-4. Variability in base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the backslope pedon.

Table B-5. Base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the footslope pedon.

Table B-6. Variability in base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the footslope pedon.

Table B-7. Sand distributions of the Site 2 pedons.

Table B-8. Particle size distribution and textural class of the Site 2 pedons.

Table B-1. Base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the summit pedon at Site 2.

Horizon	pH	Ca	Mg	K	H	Al	B.S.	DCB Fe	B.D.
		meq/100 g					%		g/cm^3
A	5.14	1.10	0.75	0.30	12.80	1.65	14.38	1.49	1.18
E	5.03	0.14	0.27	0.20	9.30	1.48	7.09	1.10	1.57
Bt1	5.12	0.36	1.04	0.29	10.60	1.55	13.75	3.09	1.54
Bt2	5.25	0.31	1.82	0.34	12.60	1.35	16.39	4.75	1.38
Bt3	5.50	0.06	1.15	0.30	12.35	1.35	10.89	5.80	1.42
BC1	5.58	0.08	0.54	0.22	10.00	1.75	7.75	5.04	1.52
BC2	5.58	0.09	0.42	0.16	6.60	1.75	9.22	4.30	1.50
C1	5.56	0.09	0.42	0.12	7.60	2.00	7.65	2.99	1.39
C2	5.49	0.10	0.35	0.08	5.10	1.63	7.78	1.90	1.37
C3	5.58	0.11	0.06	0.08	3.40	0.35	6.85	0.30	1.62
C4	5.60	0.10	0.05	0.05	6.00	0.25	3.23	0.24	1.74
C5	5.82	0.11	0.15	0.13	2.60	0.60	13.04	0.67	1.31
C6	5.83	0.11	0.05	0.10	2.60	0.55	9.09	0.35	1.37
C7	5.88	0.11	0.23	0.14	3.60	0.80	11.76	0.45	

Table B-2. Variability in base saturation (B.S.), pH, DCB extractable Fe, and exchangeable cations of the summit pedon at Site 2. Horizons labelled A, B, C, or D were sampled from separate faces within soil pit.

Horizon	pH	Ca	Mg	K	H	Al	B.S.	DCB Fe
		meq/100 g					%	
E-A	5.17	0.09	0.26	0.25	9.00	1.45	6.25	0.87
E-B	4.94	0.08	0.21	0.16	9.40	1.65	4.57	1.20
E-C	5.01	0.14	0.27	0.19	8.60	1.35	6.52	1.11
E-D	5.00	0.23	0.33	0.18	10.00	1.45	6.89	1.22
Bt3-A	5.48	0.04	1.25	0.34	13.60	1.25	10.70	5.90
Bt3-B	5.50	0.04	1.14	0.27	11.40	1.35	11.28	5.95
Bt3-C	5.51	0.06	1.14	0.30	11.60	1.25	11.45	5.73
Bt3-D	5.50	0.08	1.07	0.27	12.80	1.55	9.99	5.48
C2-A	5.50	0.11	0.28	0.07	5.40	2.00	7.85	2.13
C2-B	5.41	0.10	0.39	0.08	5.00	1.25	10.23	1.87
C2-C	5.53	0.10	0.46	0.08	5.40	1.75	10.60	1.96
C2-D	5.52	0.10	0.27	0.08	4.60	1.50	8.91	1.68

Table B-3. Base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the backslope pedon at Site 2.

Horizon	pH	Ca	Mg	K	H	Al	B.S.	DCB Fe	B.D.
		meq/100 g					%		g/cm^3
A	5.00	1.10	0.51	0.31	14.20	1.55	11.91	0.48	1.01
Bt1	4.99	0.27	0.26	0.23	8.15	1.55	8.53	1.57	1.54
Bt2	5.18	0.67	1.00	0.34	6.80	1.65	22.81	3.73	1.53
Bt3	5.45	1.22	1.30	0.40	9.15	1.13	24.19	5.03	1.37
Bt4	5.74	1.02	1.05	0.30	6.80	0.75	25.85	5.40	1.44
2Bt5	5.60	0.47	0.57	0.19	6.00	1.05	17.01	4.08	1.56
3BC1	5.60	0.28	0.42	0.19	5.40	1.55	13.88	3.91	1.45
3BC2	5.52	0.21	0.36	0.16	5.80	1.85	11.18	1.98	1.46
3C1	5.42	0.04	0.32	0.15	5.25	2.25	8.85	1.71	1.45
3C2	5.34	0.03	0.35	0.15	4.00	2.15	11.70	1.31	1.32
3C3	5.40	0.06	0.10	0.09	3.60	1.25	6.49	0.70	1.30
3C4	5.60	0.07	0.04	0.20	2.60	0.95	10.65	0.82	1.30
3Cr	5.66	0.03	0.04	0.18	1.40	0.75	16.17	0.43	

Table B-4. Variability in base saturation (B.S.), pH, DCB extractable Fe, and exchangeable cations of the backslope pedon at Site 2. Horizons labelled A, B, C, or D were sampled from separate faces within soil pit.

Horizon	pH	Ca	Mg	K	H	Al	B.S.	DCB Fe
		----------meq/100 g				----------	----%----	
Bt1-A	5.05	0.18	0.14	0.23	7.20	1.35	7.10	1.13
Bt1-B	4.96	0.16	0.16	0.20	8.20	1.55	5.96	1.37
Bt1-C	5.00	0.27	0.23	0.22	7.20	1.25	9.09	1.34
Bt1-D	4.94	0.45	0.52	0.28	10.00	2.05	11.11	2.43
Bt3-A	5.36	1.52	1.38	0.44	8.40	1.00	28.45	4.93
Bt3-B	5.28	0.63	1.09	0.29	8.40	1.70	19.31	4.07
Bt3-C	5.55	0.78	1.12	0.39	10.80	1.05	17.49	5.76
Bt3-D	5.60	1.96	1.61	0.48	9.00	0.75	31.03	5.33
3C1-A	5.36	0.04	0.20	0.14	5.00	2.45	7.06	1.27
3C1-B	5.54	0.50	0.64	0.19	4.80	1.85	21.70	1.82
3C1-C	5.42	0.02	0.30	0.13	6.80	2.55	6.21	2.31
3C1-D	5.34	0.04	0.15	0.12	4.40	2.15	6.58	1.42

Table B-5. Base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the footslope pedon at Site 2.

Horizon	pH	Ca	Mg	K	H	Al	B.S.	DCB Fe	B.D.
		meq/100 g					%		g/cm^3
A	5.10	1.64	0.78	0.47	13.20	1.20	17.96	1.03	1.17
E	5.06	0.19	0.12	0.24	7.85	1.68	6.55	1.00	1.43
Bt1	5.07	0.31	0.50	0.28	6.60	1.70	14.17	1.57	1.53
Bt2	5.21	0.52	0.91	0.34	7.30	1.43	19.51	2.22	1.55
2BC	5.32	0.63	1.31	0.39	8.40	1.25	21.71	3.17	1.46
2C	5.33	0.52	1.20	0.33	7.73	1.32	20.96	2.51	1.47
2Cr	5.49	0.14	0.68	0.24	8.60	1.20	10.97	2.22	1.62

Table B-6. Variability in base saturation (B.S.), pH, DCB extractable Fe, and exchangeable cations of the footslope pedon at Site 2. Horizons labelled A, B, C, or D were sampled from separate faces within soil pit.

Horizon	pH	Ca	Mg	K	H	Al	B.S.	DCB Fe
		meq/100 g					%	
E-A	5.00	0.07	0.06	0.19	7.00	1.80	4.10	0.88
E-B	5.18	0.41	0.21	0.35	6.60	1.20	12.81	0.96
E-C	5.05	0.18	0.15	0.24	10.60	1.70	5.10	1.05
E-D	5.02	0.08	0.07	0.19	7.20	2.05	4.51	1.09
Bt2-A	5.22	0.31	1.25	0.34	6.40	1.45	22.89	2.70
Bt2-B	5.04	0.39	0.45	0.32	7.20	1.95	13.88	1.88
Bt2-C	5.26	0.65	0.78	0.34	7.60	1.15	18.89	1.87
Bt2-D	5.30	0.74	1.16	0.35	7.80	1.15	22.39	2.43
2C-A	5.36	0.22	1.12	0.38	8.00	1.45	17.70	2.54
2C-B	5.30	0.35	1.26	0.45	8.00	1.15	20.48	3.13
2C-C	5.32	0.98	1.22	0.17	7.20	1.35	24.76	1.87
2Cr-A	5.52	0.05	0.59	0.27	8.60	1.25	9.57	1.28
2Cr-B	5.46	0.22	0.76	0.20	8.60	1.15	12.07	3.16

Table B-7. Sand distribution of Site 2 pedons.

Horizon	Depth	Total Sand	VCo	Co	M	F	VF
	cm	%	%	%	%	%	%
			Summit				
A	0-10	46.7	2.5	5.9	7.5	21.0	9.8
E	10-17	46.7	2.3	5.7	7.7	20.9	10.1
Bt1	17-37	32.1	1.3	3.6	4.9	14.2	8.1
Bt2	37-57	21.5	0.8	1.8	2.7	9.4	6.8
Bt3	57-97	22.8	0.6	1.6	2.4	9.7	8.5
Bt4	97-123	38.9	2.6	4.1	4.8	15.5	11.9
BCt	123-160	37.8	0.5	1.6	3.4	17.6	14.7
BC	160-186	44.7	0.9	2.7	4.2	20.4	16.6
CB	186-247	62.6	2.3	5.0	6.6	28.0	20.7
C1	247-280	80.8	3.1	10.1	10.8	35.7	21.1

Appendix B-7 (cont). Sand distribution of Site 2 pedons.

Horizon	Depth	Total Sand	VCo	Co	M	F	VF
	cm	%	%	%	%	%	%
			Backslope				
A	0-8	42.8	2.1	5.2	6.6	18.5	10.4
Bt1	8-35	39.4	1.8	4.8	6.9	16.6	9.3
Bt2	35-64	28.7	1.2	3.1	4.6	12.3	7.5
Bt3	64-92	21.2	0.9	2.2	3.1	8.4	6.6
Bt4	92-120	29.6	1.2	2.6	4.0	13.0	8.8
2Bt5	120-148	38.3	2.8	4.5	6.3	16.0	8.7
3Bt6	148-165	35.7	2.6	4.1	4.8	15.5	8.7
3BCt	165-187	46.0	1.5	4.5	4.9	19.1	16.0
3BC	187-245	52.8	1.2	3.7	5.4	24.0	18.5
3CB	245-320	56.1	6.3	8.2	5.7	19.7	16.2
3C1	320-350	68.3	13.1	13.3	7.4	20.3	14.2
			Footslope				
A	0-11	48.1	3.1	6.9	7.9	19.3	10.9
E	11-25	53.0	3.0	7.9	8.5	21.4	12.2
Bt1	25-37	46.0	2.2	5.4	7.0	19.0	12.4
Bt2	37-61	47.9	4.1	7.6	6.4	18.3	11.6
2BC	61-79	48.4	2.5	5.2	6.1	23.1	18.9
2C	79-90	56.8	2.7	6.0	6.4	21.7	17.1
2Cr	90-100	68.2	2.8	8.6	8.2	28.9	19.8

Table B-8. Particle size distribution and textural class (Tex) of Site 2 pedons.

Horizon	Depth	Sand	Silt	CoSi	Clay	Tex
	cm	%	%	%	%	%
			Summit			
A	0-10	46.7	33.8	7.2	19.5	L
E	10-17	46.7	39.1	7.8	14.2	L
Bt1	17-37	32.1	34.2	4.5	33.7	CL
Bt2	37-57	21.5	23.4	2.2	55.1	C
Bt3	57-97	22.8	23.3	4.0	53.9	C
Bt4	97-123	38.9	30.3	7.4	37.9	CL
BCt	123-160	37.8	36.6	11.0	25.6	L
BC	160-186	44.7	38.4	12.8	16.8	SCL
CB	186-247	62.6	32.5	13.9	4.9	fSL
C1	247-280	80.8	17.1	12.8	3.8	LfS

Appendix B-8 (cont). Particle size distribution and textural class (Tex) of Site 2 pedons.

Horizon	Depth	Sand	Silt	CoSi	Clay	Tex
	cm	%	%	%	%	%
			Backslope			
A	0-8	42.8	34.9	8.3	22.3	L
Bt1	8-35	39.4	37.1	7.4	23.5	L
Bt2	35-64	28.7	28.4	5.0	42.9	C
Bt3	64-92	21.2	20.6	10.8	51.2	C
Bt4	92-120	29.6	20.2	4.3	50.2	C
2Bt5	120-148	38.3	15.1	4.5	46.6	C
3Bt6	148-165	35.7	26.6	9.5	37.7	CL
3BCt	165-187	46.0	29.5	8.1	24.5	SCL
3BC	187-245	52.8	31.6	12.1	15.6	fSL
3CB	245-320	56.1	27.2	11.6	16.7	fSL
3C1	320-350	68.3	24.6	11.8	7.1	fSL
			Footslope			
A	0-11	48.1	35.6	10.7	16.3	L
E	11-25	53.0	36.0	10.6	11.0	fSL
Bt1	25-37	46.0	34.4	8.9	19.6	L
Bt2	37-61	47.9	26.2	8.9	25.9	L
2BC	61-79	48.4	27.4	14.5	16.8	fSL
2C	79-90	56.8	21.0	11.6	22.2	SCL
2Cr	90-100	68.2	16.2	10.5	15.7	fSL

Appendix C. Additional soils data for Site 3.

Table C-1. Base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the summit pedon.

Table C-2. Variability in base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the summit pedon.

Table C-3. Base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the backslope pedon.

Table C-4. Variability in base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the backslope pedon.

Table C-5. Base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the footslope pedon.

Table C-6. Variability in base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the footslope pedon.

Table C -7. Sand distributions of the Site 3 pedons.

Table C-8. Particle size distribution and textural class of the Site 3 pedons.

Table C-1. Base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the summit pedon at Site 3.

Horizon	pH	Ca	Mg	K	H	Al	B.S.	DCB Fe	B.D.
		meq/100 g					%		g/cm^3
A	6.00	7.61	0.41	0.56	6.40	0.45	57.28	0.74	1.29
E	5.47	1.74	0.25	0.27	6.30	0.93	26.40	1.21	1.48
BE	6.03	1.90	0.19	0.24	3.60	0.35	39.29	1.28	1.61
Bt1	5.58	2.90	0.16	0.26	4.60	0.35	41.92	2.02	1.64
Bt2	6.12	3.09	0.80	0.41	4.50	0.56	48.86	3.06	1.54
Bt3	6.00	0.75	0.70	0.37	9.20	2.65	16.52	3.69	1.49
BC1	5.28	0.11	0.20	0.20	7.20	3.15	6.61	2.02	1.43
C1	5.22	0.17	0.09	0.10	5.20	3.15	7.80	1.82	1.40
C2	5.34	0.04	0.34	0.20	6.40	3.10	8.31	1.96	1.38
C3	5.53	0.10	0.40	0.18	5.00	2.93	11.97	1.98	1.37
C4	5.66	0.34	1.42	0.16	8.20	2.95	18.97	1.51	1.42
C5	5.75	0.45	1.44	0.16	4.60	2.15	30.83	1.77	1.47
C6	5.72	1.50	2.14	0.21	6.20	2.35	38.31	3.02	1.47

Table C-2. Variabilty in base saturation (B.S.), pH, DCB extractable Fe, and exchangeable cations of the summit pedon at Site 3. Horizons labelled A, B, C, or D were sampled from separate faces within soil pit.

Horizon	pH	Ca	Mg	K	H	Al	B.S.	DCB Fe
		meq/100 g					%	
E-A	5.34	0.98	0.07	0.27	6.40	1.05	17.10	1.13
E-B	5.23	0.69	0.02	0.23	9.00	2.15	9.46	1.44
E-C	5.64	3.19	0.08	0.32	5.00	0.15	41.79	1.15
E-D	5.67	2.08	0.81	0.29	4.80	0.35	34.52	1.11
Bt2-A	6.28	3.22	0.86	0.38	3.20	0.30	58.22	2.88
Bt2-B	5.70	1.81	0.66	0.46	5.00	1.45	36.95	3.31
Bt2-C	6.30	3.53	0.85	0.42	4.80	0.20	50.00	2.96
Bt2-D	6.19	3.80	0.84	0.36	5.00	0.30	50.00	3.09
C3-A	5.36	0.13	0.10	0.18	6.20	2.95	6.20	3.02
C3-B	5.73	0.13	0.68	0.21	4.60	2.65	18.15	1.80
C3-C	5.54	0.07	0.41	0.17	3.60	2.55	15.29	1.60
C3-D	5.50	0.08	0.40	0.19	5.60	3.55	10.69	1.51

Table C-3. Base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the backslope pedon at Site 3.

Horizon	pH	Ca	Mg	K	H	Al	B.S.	DCB Fe	B.D.
		----------meq/100 g----------					----%----		g/cm^3
A	5.60	1.94	0.40	0.26	10.00	0.95	20.63	1.25	1.35
E	5.52	1.16	0.24	0.17	5.50	0.60	22.21	1.20	1.58
BE	5.72	1.99	0.16	0.13	4.20	0.65	35.19	2.18	1.66
Bt1	5.32	1.71	0.41	0.12	3.80	1.75	37.09	1.86	1.60
2Bt2	5.47	1.39	0.82	0.18	8.10	2.50	22.78	2.73	1.53
2Bt3	5.52	0.62	1.03	0.25	6.20	4.05	23.46	2.55	1.57
2BC	5.41	0.67	0.30	0.23	10.80	4.05	10.00	2.74	1.50
2C1	5.65	0.54	0.67	0.20	7.40	3.00	16.00	1.89	1.43
2C2	5.64	0.35	0.55	0.19	6.80	2.60	13.81	1.36	1.46
2C3	5.79	0.47	0.56	0.16	5.55	2.50	17.66	1.36	1.42

Table C-4. Variability in base saturation (B.S.), pH, DCB extractable Fe, and exchangeable cations of the backslope pedon at Site 3. Horizons labelled A, B, C, or D were sampled from separate faces within soil pit.

Horizon	pH	Ca	Mg	K	H	Al	B.S.	DCB Fe
		----------meq/100 g----------					----%----	
E-A	5.72	1.90	0.23	0.13	3.80	0.15	37.29	1.10
E-B	5.42	0.95	0.20	0.19	6.20	0.75	17.77	1.21
E-C	5.42	0.96	0.23	0.16	6.20	0.95	17.88	1.39
E-D	5.50	0.84	0.29	0.19	5.80	0.55	18.54	1.10
2Bt2-A	5.40	1.07	0.88	0.21	9.20	3.05	19.01	2.61
2Bt2-B	5.62	1.39	0.88	0.17	7.80	2.15	23.83	2.82
2Bt2-D	5.40	1.71	0.70	0.15	7.20	2.35	26.23	2.75
2C3-A	5.66	0.53	0.78	0.17	4.40	3.35	25.17	1.19
2C3-B	5.89	0.33	0.37	0.13	4.40	1.75	15.87	1.24
2C3-C	5.90	0.53	0.59	0.18	7.40	2.45	14.94	1.48
2C3-D	5.72	0.49	0.49	0.17	6.00	2.45	16.08	1.52

Table C-5. Base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the footslope pedon at Site 3.

Horizon	pH	Ca	Mg	K	H	Al	B.S.	DCB Fe	B.D.
		meq/100 g					%		g/cm³
A	4.99	1.65	0.39	0.27	14.60	1.45	13.66	1.00	1.39
E	5.17	0.39	0.24	0.17	7.90	1.95	9.20	1.24	1.61
BE	5.05	0.77	0.59	0.17	8.00	1.95	16.05	1.82	1.71
2Bt1	5.17	0.98	1.30	0.17	9.80	3.90	20.00	2.57	1.61
2Bt2	5.38	0.50	1.17	0.22	14.20	5.05	11.75	2.73	1.57
2Bt3	5.30	0.39	1.63	0.35	19.35	6.20	11.75	5.54	1.54
2BC	5.18	0.14	0.84	0.17	11.60	4.55	9.02	2.54	1.53
2C1	5.35	0.27	0.79	0.20	9.00	4.25	12.28	2.06	1.60
2C2	5.35	0.62	0.87	0.16	8.10	3.49	16.92	1.95	1.63

Table C-6. Variability in base saturation (B.S.), pH, DCB extractable Fe, and exchangeable cations of the footslope pedon at Site 3. Horizons labelled A, B, C, or D were sampled from separate faces within soil pit.

Horizon	pH	Ca	Mg	K	H	Al	B.S.	DCB Fe
		------meq/100 g				------	------%	------
E-A	5.22	0.44	0.31	0.15	8.00	1.95	10.11	1.35
E-B	5.20	0.35	0.18	0.17	7.20	2.05	8.86	1.33
E-C	5.16	0.40	0.24	0.22	8.60	2.05	9.09	1.12
E-D	5.10	0.38	0.22	0.13	7.80	1.75	8.56	1.14
2Bt1-A	5.17	1.01	1.26	0.18	12.40	3.90	16.50	2.75
2Bt1-B	5.17	0.58	1.10	0.16	10.80	4.60	14.56	2.62
2Bt1-C	5.07	0.59	1.11	0.15	9.20	4.45	16.74	2.39
2Bt1-D	5.25	1.75	1.73	0.17	6.80	2.75	34.93	2.51
2C2-A	5.28	1.29	1.20	0.16	12.20	3.75	17.85	2.65
2C2-B	5.56	0.67	0.73	0.19	6.80	2.85	18.95	1.67
2C2-C	5.17	0.24	0.79	0.15	8.80	3.75	11.82	1.82
2C2-D	5.37	0.26	0.77	0.17	4.60	3.60	20.69	1.62

Table C-7. Sand distribution of Site 3 pedons.

Horizon	Depth	Total Sand	VCo	Co	M	F	VF
	cm	%	%	%	%	%	%
			Summit				
A	0-18	58.3	10.0	16.3	9.7	15.5	6.8
E	18-28	50.9	6.8	14.2	8.6	14.6	6.7
BE	28-45	46.8	5.4	12.9	8.5	13.7	6.3
Bt1	45-58	40.9	5.3	10.8	7.1	12.1	5.6
Bt2	58-83	36.2	6.3	8.9	5.8	10.0	5.2
Bt3	83-120	40.0	7.2	11.2	6.7	9.9	5.0
BCt	120-150	57.9	12.2	17.4	8.4	13.3	6.6
C1	150-205	65.5	17.9	19.5	8.9	12.9	6.3

Appendix C-7 (cont). Sand distribution of Site 3 pedons.

Horizon	Depth	Total Sand	VCo	Co	M	F	VF
	cm	%	%	%	%	%	%
			Backslope				
A	0-18	45.4	7.8	14.5	7.4	10.8	4.9
E	18-41	46.3	6.0	13.6	8.0	12.8	5.9
EB	41-58	44.4	9.0	12.0	6.9	11.4	5.1
Bt1	58-75	42.7	8.0	11.8	6.8	11.4	4.7
2Bt2	75-106	38.5	8.5	9.6	5.7	9.9	4.8
2Bt3	106-128	50.5	15.7	11.3	5.8	11.3	6.4
2BCt	128-160	44.6	11.4	6.8	5.2	13.5	7.7
2C1	160-200	65.8	17.7	16.5	8.5	15.0	8.1
			Footslope				
A	0-18	51.0	13.4	14.7	7.4	10.7	4.8
E	18-30	49.1	9.7	13.9	7.9	12.2	5.4
BE	30-44	48.0	10.9	12.9	7.2	11.7	5.3
2Bt1	44-75	41.2	9.0	11.0	6.0	10.2	5.0
2Bt2	75-120	47.9	15.0	13.5	6.2	9.0	4.2
2BC	120-145	66.5	18.6	20.0	9.2	13.2	5.5
2C1	145-190	70.1	23.1	20.5	9.1	12.4	5.0

Table C-8. Particle size distribution and textural class (Tex) of Site 3 pedons.

Horizon	Depth	Sand	Silt	CoSi	Clay	Tex
	cm	%	%	%	%	%
			Summit			
A	0-18	58.3	28.9	7.0	12.8	SL
E	18-28	50.9	37.9	7.3	11.2	L
BE	28-45	46.8	36.9	7.5	16.3	L
Bt1	45-58	40.9	34.3	4.9	24.8	L
Bt2	58-83	36.2	32.6	4.5	31.2	CL
Bt3	83-120	40.0	23.8	3.4	36.2	CL
BCt	120-150	57.9	32.8	7.1	9.3	SL
C1	150-205	65.5	29.6	6.2	4.9	SL

Appendix C-8 (cont). Particle size distribution and textural class (Tex) of Site 3 pedons.

Horizon	Depth	Sand	Silt	CoSi	Clay	Tex
	cm	%	%	%	%	%
			Backslope			
A	0-18	45.4	38.5	6.5	16.1	L
E	18-41	46.3	40.5	6.9	13.2	L
EB	41-58	44.4	38.0	7.8	17.6	L
Bt1	58-75	42.7	36.4	5.9	20.9	L
2Bt2	75-106	38.5	29.5	3.5	32.0	CL
2Bt3	106-128	50.5	26.3	5.4	23.2	L
2BCt	128-160	44.6	35.6	14.1	19.8	L
2C1	160-200	65.8	27.4	6.9	6.8	SL
			Footslope			
A	0-18	51.0	33.7	5.7	15.3	L
E	18-30	49.1	37.8	6.1	13.1	L
BE	30-44	48.0	35.9	5.9	16.1	L
2Bt1	44-75	41.2	33.5	5.0	25.3	L
2Bt2	75-120	47.9	27.1	5.5	25.0	L
2BC	120-145	66.5	25.7	5.8	7.8	SL
2C1	145-190	70.1	25.9	5.7	4.0	SL

Appendix D. Additional soils data for Site 4.

Table D-1. Base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the summit pedon.

Table D-2. Variability in base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the summit pedon.

Table D-3. Base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the backslope pedon.

Table D-4. Variability in base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the backslope pedon.

Table D-5. Base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the footslope pedon.

Table D-6. Variability in base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the footslope pedon.

Table D-7. Sand distributions of the Site 4 pedons.

Table D-8. Particle size distribution and textural class of the Site 4 pedons.

Table D-1. Base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the summit pedon at Site 4.

Horizon	pH	Ca	Mg	K	H	Al	B.S.	DCB Fe	B.D.
		----------meq/100 g				----------	-----%-----		g/cm^3
A	4.12	0.51	0.49	0.64	18.60	4.55	8.10	1.25	1.09
E	4.32	0.08	0.20	0.28	11.20	3.25	4.76	1.73	1.34
BE	4.65	0.06	0.23	0.22	8.80	3.55	5.48	2.07	1.50
Bt1	5.00	0.02	0.72	0.20	11.60	4.45	7.50	3.49	1.45
Bt2	5.13	0.04	0.46	0.19	12.20	4.90	5.35	4.12	1.49
BC1	5.40	0.04	0.25	0.14	7.60	4.65	5.35	4.02	1.48
BC2	5.60	0.04	0.20	0.11	5.40	3.55	6.09	2.97	1.36
C1	5.30	0.04	0.23	0.10	2.40	2.45	13.36	2.18	1.37
C2	5.59	0.03	0.27	0.08	2.70	1.45	12.05	1.74	1.36
C3	5.34	0.02	0.38	0.09	3.80	1.75	11.42	2.04	1.34
C4	5.48	0.02	0.72	0.12	3.80	1.95	18.45	2.43	1.34
C5	5.80	0.02	0.72	0.15	3.80	1.75	18.98	3.90	1.39
C6	5.90	0.03	0.66	0.16	2.00	1.55	29.82	0.56	1.41
C7	5.60	0.14	0.84	0.13	3.40	1.45	24.61	1.07	1.41
C8	5.30	0.65	0.82	0.18	1.80	1.15	47.83	1.40	1.41

Table D-2. Variability in base saturation (B.S.), pH, DCB extractable Fe, and exchangeable cations of the summit pedon at Site 4. Horizons labelled A, B, C, or D were sampled from separate faces within soil pit.

Horizon	pH	Ca	Mg	K	H	Al	B.S.	DCB Fe
		---meq/100 g---					---%---	
Bt2-A	5.15	0.04	0.44	0.18	12.20	4.65	5.13	4.12
Bt2-B	5.15	0.04	0.46	0.17	12.60	5.05	5.05	3.83
Bt2-C	5.13	0.03	0.35	0.20	12.20	4.85	4.54	4.30
Bt2-D	5.09	0.03	0.59	0.20	11.80	5.05	6.50	3.82
C2-A	5.48	0.02	0.29	0.08	2.20	1.45	15.06	2.35
C2-B	5.76	0.02	0.20	0.08	2.20	1.35	12.00	1.46
C2-D	5.54	0.04	0.31	0.08	3.80	1.45	10.17	2.31

Table D-3. Base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the backslope pedon at Site 4.

Horizon	pH	Ca	Mg	K	H	Al	B.S.	DCB Fe	B.D.
		meq/100 g					%		g/cm^3
A1	4.21	0.83	0.59	0.35	22.20	5.95	7.38	1.61	0.95
A2	4.49	0.09	0.23	0.26	14.80	4.18	3.77	1.63	1.14
Bt1	4.80	0.04	0.54	0.22	7.00	3.65	10.26	2.09	1.50
Bt2	5.07	0.04	1.28	0.40	11.85	3.75	12.68	3.36	1.47
Bt3	5.33	0.04	0.66	0.35	10.00	3.25	9.50	2.30	1.42
BC1	5.52	0.02	0.48	0.25	8.00	2.95	8.57	2.16	1.50
BC2	5.58	0.02	0.44	0.18	6.60	2.65	8.84	1.76	1.45
C1	5.70	0.04	0.48	0.16	5.00	2.15	11.97	1.28	1.51
C2	5.77	0.02	0.51	0.18	5.40	1.95	11.62	1.43	1.48
C3	5.97	0.04	0.50	0.18	4.20	2.00	14.63	1.07	1.45
C4	5.62	0.04	0.59	0.21	4.40	1.95	16.03	0.79	1.54
C5	5.92	0.02	0.57	0.21	4.20	2.25	16.00	0.75	1.37
C6	5.53	0.02	0.81	0.20	6.60	2.65	13.50	0.75	1.54
C7	5.63	0.03	0.64	0.19	5.60	2.05	13.31	0.95	
Cr	5.80	0.28	0.99	0.23	8.20	2.25	15.46	1.77	

Table D-4. Variability in base saturation (B.S.), pH, DCB extractable Fe, and exchangeable cations of the backslope pedon at Site 4. Horizons labelled A, B, C, or D were sampled from separate faces within soil pit.

Horizon	pH	Ca	Mg	K	H	Al	B.S.	DCB Fe
		meq/100 g					%	
A2-A	4.50	0.10	0.19	0.23	12.00	3.85	4.15	1.59
A2-B	4.44	0.20	0.26	0.25	16.20	4.75	4.20	1.56
A2-C	4.50	0.09	0.22	0.26	15.40	4.45	3.57	1.83
A2-D	4.51	0.08	0.25	0.29	15.60	4.65	3.82	1.52
Bt2-A	4.95	0.05	1.12	0.44	10.40	3.75	13.41	2.90
Bt2-B	5.10	0.04	1.27	0.35	13.40	3.95	11.02	3.49
Bt2-C	4.97	0.04	1.35	0.43	11.00	3.65	14.20	3.22
Bt2-D	5.25	0.03	1.40	0.38	12.60	3.65	12.56	3.84
C3-A	6.00	0.04	0.54	0.19	5.80	2.15	11.72	1.39
C3-B	6.05	0.04	0.49	0.18	2.20	1.85	24.40	0.84
C3-C	6.06	0.04	0.52	0.18	4.60	2.05	13.86	1.09
C3-D	5.76	0.02	0.51	0.17	4.20	1.95	14.29	0.97

Table D-5. Base saturation (B.S.), pH, DCB extractable Fe, bulk density (B.D.), and exchangeable cations of the footslope pedon at Site 4.

Horizon	pH	Ca	Mg	K	H	Al	B.S.	DCB Fe	B.D.
		meq/100 g					%		g/cm^3
A	4.87	0.64	0.43	0.26	11.60	2.65	10.29	2.29	1.34
BA	4.86	0.34	0.28	0.15	12.20	2.65	5.94	2.34	1.49
Bt1	5.42	0.48	0.39	0.13	8.60	2.75	10.42	2.75	1.53
Bt2	5.27	0.16	0.62	0.24	10.10	3.45	9.17	3.09	1.59
2Bt3	5.24	0.13	0.51	0.25	10.20	3.95	8.03	3.04	1.59
2BC1	5.36	0.04	0.31	0.18	9.00	3.75	5.56	3.27	1.50
2BC2	5.10	0.07	0.35	0.17	9.40	4.25	5.91	2.46	1.30
C1	5.81	0.03	0.31	0.16	6.20	3.00	7.46	2.14	1.53
C2	5.70	0.03	0.62	0.26	14.00	5.25	6.10		

Table D-6. Variability in base saturation (B.S.), pH, DCB extractable Fe, and exchangeable cations of the footslope pedon at Site 4. Horizons labelled A, B, C, or D were sampled from separate faces within soil pit.

Horizon	pH	Ca	Mg	K	H	Al	B.S.	DCB Fe
		meq/100 g					%	
Bt2-A	5.24	0.14	0.67	0.21	9.60	3.35	9.60	3.17
Bt2-C	5.44	0.13	0.62	0.25	10.20	3.45	8.93	3.01
Bt2-D	5.12	0.20	0.57	0.27	10.40	3.55	9.09	3.09
C1-A	5.70	0.02	0.26	0.16	6.20	2.75	6.63	1.86
C1-B	5.88	0.04	0.38	0.18	8.00	3.35	6.98	1.94
C1-C	5.74	0.05	0.31	0.16	5.20	2.95	9.09	2.88
C1-D	5.90	0.02	0.30	0.15	5.60	2.95	7.74	1.88

Table D-7. Sand distribution of Site 4 pedons.

Horizon	Depth	Total Sand	VCo	Co	M	F	VF
	cm	%	%	%	%	%	%
			Summit				
A	0-7	23.6	6.8	5.6	3.0	4.4	3.8
E	7-18	24.8	6.0	6.1	3.5	5.2	4.0
BE	18-28	18.5	3.7	4.5	2.7	4.1	3.5
Bt1	28-54	17.0	5.3	3.5	1.8	3.3	3.1
Bt2	54-72	20.0	5.5	4.2	2.1	4.2	4.0
Bt3	72-96	26.5	5.5	5.4	2.6	5.7	7.3
CB	96-114	30.6	6.1	6.0	3.0	6.4	9.1
C1	114-176	50.7	14.0	11.1	4.9	10.0	10.7

Appendix D-7 (cont). Sand distribution of Site 4 pedons.

Horizon	Depth	Total Sand	VCo	Co	M	F	VF
	cm	%	%	%	%	%	%
			Backslope				
A1	0-9	22.3	7.3	4.9	2.5	4.1	3.5
A2	9-16	19.2	4.3	4.9	2.6	4.2	3.2
Bt1	16-27	17.8	2.3	4.2	3.1	4.7	3.5
Bt2	27-48	21.4	5.0	4.6	2.4	4.9	4.5
Bt3	48-63	33.1	7.7	8.2	3.4	6.9	6.9
BCt	63-81	46.3	16.1	9.7	4.2	8.4	7.9
CB	81-96	50.6	16.6	10.6	4.5	9.4	9.5
C1	96-144	47.2	9.7	10.6	5.2	10.8	10.9
			Footslope				
A	0-18	23.1	8.4	5.7	2.8	3.9	2.3
AB	18-32	24.2	5.1	6.5	3.5	5.4	3.7
Bt1	32-47	21.8	5.8	5.4	2.9	4.5	3.2
Bt2	47-73	25.2	8.0	5.5	3.0	5.1	3.6
2Bt3	73-105	30.9	11.0	6.4	3.3	5.9	4.3
2BC1	105-163	42.5	12.5	11.5	5.0	8.3	5.2
2BC2	163-192	34.3	10.2	7.5	3.0	6.9	6.7
2C1	192-285	48.7	13.3	10.7	4.5	10.6	9.6

Table D-8. Particle size distribution and textural class (Tex) of Site 4 pedons.

Horizon	Depth	Sand	Silt	CoSi	Clay	Tex
	cm	%	%	%	%	%
			Summit			
A	0-7	23.6	56.1	15.9	20.3	SiL
E	7-18	24.8	58.4	15.0	20.3	SiL
BE	18-28	18.5	53.9	11.6	27.6	SiL
Bt1	28-54	17.0	43.1	9.3	39.9	SiCL
Bt2	54-72	20.0	37.8	9.3	42.2	C
Bt3	72-96	26.5	50.0	19.2	23.5	SiL
CB	96-114	30.6	58.3	24.6	11.1	SiL
C1	114-176	50.7	44.5	22.3	4.8	SiL

Appendix D-8 (cont). Particle size distribution and textural class (Tex) of Site 4 pedons.

Horizon	Depth	Sand	Silt	CoSi	Clay	Tex
	cm	%	%	%	%	%
			Backslope			
A1	0-9	22.3	54.0	14.0	23.7	SiL
A2	9-16	19.2	57.2	14.9	23.6	SiL
Bt1	16-27	17.8	58.8	13.0	23.4	SiL
Bt2	27-48	21.4	40.3	11.4	38.3	CL
Bt3	48-63	33.1	37.7	14.6	29.2	CL
BCt	63-81	46.3	39.6	17.7	14.1	L
CB	81-96	50.6	43.8	19.6	5.6	SL
C1	96-144	47.2	51.4	25.6	1.4	SiL
			Footslope			
A	0-18	23.1	50.5	11.1	26.4	SiL
AB	18-32	24.2	53.5	12.4	22.3	SiL
Bt1	32-47	21.8	54.2	10.4	24.0	SiL
Bt2	47-73	25.2	48.9	10.3	25.9	SiL
2Bt3	73-105	30.9	44.7	11.2	24.4	L
2BC1	105-163	42.5	36.1	11.7	21.4	L
2BC2	163-192	34.3	50.9	15.3	14.8	SiL
2C1	192-285	48.7	47.9	17.8	5.5	SL

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