STRATIGRAPHY AND SOIL DEVELOPMENT IN UPLAND ALLUVIUM AND COLLUVIUM NORTH-CENTRAL VIRGINIA PIEDMONT

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ABSTRACT

A two-meter-deep pipeline ditch dug across north-central Virginia exposed saprolite, bedrock, and deposits of alluvium and colluvium. The colluvial mantle averaged approximately one meter deep except where it more than doubled in thickness along active and relict toeslopes. Shallow phyllitic bedrock was present in the ditch only under valley bottoms along large streams. Colluvium sharply truncated saprolitic structures which seldom showed evidence of soil creep. Alluvium lay in channels on erosional benches at several elevations between the highest divides and the floodplains. On certain intermediate-level benches, variations of soil color and percent clay in B horizons indicated significant age differences between alluvial and colluvial strata. Stratigraphic evidence of episodic colluviation existed at several locations with little indication of the timing or cause of slope instability. Several lines of evidence suggest that only a few tens of meters of relief formed in the study area during the Pleistocene.

INTRODUCTION

The stratigraphy of surficial deposits exposed in an excavation made by Colonial Pipeline Corporation across north-central Virginia proved to be surprisingly complex. This report outlines the distribution and stratigraphy of saprolite, alluvium and colluvium along the reach examined and the degree of soil development in each of these materials. Comparisons of these geologic and pedologic data with geomorphic models developed for surficial deposits in other Piedmont settings (e.g., Overstreet and others, 1968; Eargle, 1977; Dunford-Jackson, 1978; Darmon and Pols, 1982; Costa and Cleaves, 1984) demonstrate the usefulness of saprolite, colluvium, and alluvium in deciphering the history of a generally eroded landscape.

EXPOSURES AND THE GEOLOGIC SETTING

Pipeline construction through the study area often paralleled the strike of regional Piedmont structures. Where dug mechanically, the pipe ditch had vertical sides 2.0 meters deep and 1.5 meters apart. Shallow bedrock required blasting which left wider and deeper excavations. At any one location, the ditch was open approximately three weeks before the pipe was buried. Because of the time constraints, this study was confined to 22 kilometers of exposures within Culpeper and Orange counties (Figure 1). In the study area the route crossed a well-dissected upland underlain by light grey-to-tan phyllite (Wissahickon schist of Calver, 1963). Triassic sedimentary and volcanic rocks lie less than six kilometers to the west in the Culpeper basin; Cretaceous Coastal Plain deposits cap hills thirty kilometers to the east (Calver, 1963). Although phyllite was the only weathered bedrock exposed in the ditch, saprolite formed from small intrusions of felsic and mafic rocks commonly produced significant changes in soil texture and color over very short lateral distances. Although no faulting was apparent from surface features or displaced beds, slickensides present along some of the many high-angle fractures visible in both bedrock and saprolite may indicate recent fault activity.

Over 60 meters of relief exist where the Rappahannock and Rapidan Rivers cross the phyllitic upland in the study area. Third- and fourth-order stream
networks have thoroughly dissected the upland with a relatively high drainage density (8 km per sq. km) so that the resulting landscape has numerous short, steep slopes. Flat-topped terraces exist up to 20 meters above the level of most Rappahannock basin streams, according to Dunford-Jackson (1978).

**METHODS**

During an initial investigation of the excavation, I identified 23 locations with unusually thick colluvium or alluvium that merited closer study. At eleven of these sites, I took samples, made profile descriptions using standard soil science techniques (Table 1), and constructed stratigraphic sections (e.g., Figure 2). In the laboratory, sand-silt-clay
<table>
<thead>
<tr>
<th>HORIZON</th>
<th>DEPTH</th>
<th>DESCRIPTION</th>
<th>PERCENT OF SAND-SILT-CLAY &lt;2 mm FRACTION</th>
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<tr>
<td>ALLOVUM ON INTERSTREAM DIVIDE (Site 6, No. 2; Elevation 104 ft)</td>
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<tr>
<td>Ap</td>
<td>0-20</td>
<td>Red (2.5YR 4/4) clay; very weak medium granular; friable; pH 5.1; abrupt smooth boundary</td>
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<td>B2t</td>
<td>20-40</td>
<td>Red (10YR 4/4) clay; moderate medium subangular blocky; firm; pH 4.8; continuous thick clay films; clear very boundary; colluvium</td>
<td>8-60-53</td>
</tr>
<tr>
<td>B3t</td>
<td>40-90</td>
<td>Red (2.5YR 4/4) clay; moderate coarse subangular blocky; pH 5.2; firm; continuous thick clay films; gradual irregular boundary; colluvium</td>
<td>15-36-49</td>
</tr>
<tr>
<td>II Bt</td>
<td>90-120</td>
<td>Red (2.5YR 4/4) sandy clay loam; weak medium subangular blocky; friable; pH 5.1; discontinuous very sandy clay loam; firm; many subangular to rounded quartz pebbles and cobbles; many thick clay films; clear very boundary; colluvium</td>
<td>49-21-30</td>
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<tr>
<td>III Bt</td>
<td>120-200+</td>
<td>Red (2.5YR 4/4) silt loam; very fine subangular blocky; friable; common yellow (10YR 6/8) mottles; common thick clay films; pH 5.1; saprolite</td>
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<th>HORIZON</th>
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<th>PERCENT OF SAND-SILT-CLAY &lt;2 mm FRACTION</th>
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<td>RELATIVELY OLD COLLUVIUM OVER ALLOVUM ON TERRACE, continued</td>
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<td>B3t</td>
<td>109-160</td>
<td>Strong brown (7.5YR 6/4) silt loam; moderate subangular blocky; firm; pH 4.8; many pale red (10YR 6/4) and white (10YR 7/4) mottles; common subangular quartz pebbles; many thick clay films; clear very boundary; colluvium</td>
<td>16-28-56</td>
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<tr>
<td>B3t</td>
<td>140-180</td>
<td>Strong brown (7.5YR 5/4) silt loam; moderate coarse subangular blocky; firm; pH 4.9; many subangular quartz pebbles; many thick clay films; clear irregular boundary; colluvium</td>
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<tr>
<td>II Bt</td>
<td>180-210+</td>
<td>Red (10YR 6/8) clay; strong medium angular blocky; extremely firm; pH 4.1; many brownish yellow (10YR 6/4) mottles; continuous very thick clay films; colluvium</td>
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<td>RELATIVELY YOUNG COLLUVIUM OVER ALLOVUM AND SAPROLITE ON TERRACE (Site 6, No. 8; Elevation 75 ft)</td>
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<td>Ap</td>
<td>0-21</td>
<td>Yellowish brown (10YR 4/4) silt loam; weak medium granular; friable; pH 4.7; few subrounded quartz pebbles; clear very boundary</td>
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<td>Very pale brown (10YR 2/4) loam; fine fine loamy to mesic; firm; pH 5.2; a few subrounded quartz pebbles; clear very boundary; colluvium</td>
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<td>75-93</td>
<td>Light brown (7.5YR 4/4) clay; strong medium angular blocky; firm; pH 4.9; common subangular quartz pebbles; many thick clay films; abrupt very boundary; colluvium</td>
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<td>Reddish brown (5YR 4/8) clay; strong medium subangular blocky; very firm; pH 4.6; light yellowish brown (10YR 7/4) mottles; continuous thick clay films; abrupt irregular boundary; colluvium</td>
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<td>IV Bt</td>
<td>134-155</td>
<td>Reddish brown (5YR 6/2) clay; sandy clay loam; very fine subangular blocky; friable; pH 4.8; many rounded to angular pebbles and cobbles of peat; schist; quartzite; granatons, red shale, basalts; continuous thick clay films; colluvium</td>
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<td>V Bt</td>
<td>155-200+</td>
<td>Yellowish brown (10YR 6/4) sandy clay loam; firm; pH 4.7; moderate subangular blocky; friable; pH 4.7; common thick clay films; colluvium</td>
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<td>Ap</td>
<td>0-10</td>
<td>Light brownish gray (10YR 6/4) sandy loam; weak fine granular; very friable; pH 5.2; abrupt smooth boundary; colluvium</td>
<td>23-34-43</td>
</tr>
<tr>
<td>B1t</td>
<td>10-210</td>
<td>Yellow (10YR 4/4) to yellowish brown (10YR 4/4) sandy clay loam to silt loam; loose; firm; a few rounded cobbles; to</td>
<td>53-31-16</td>
</tr>
<tr>
<td>B2t</td>
<td>210-400</td>
<td>Very dark grey brown (10YR 2/2) gravelly sandy loam; to gravelly loam; pH 4.9; continuous rounded pebbles and cobbles of peat; quartzite, basalt, red shale, and granatons; colluvium</td>
<td>41-54-5</td>
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*All Munsell colors are for moist samples*
Figure 2. Schematic cross-sections showing stratigraphy of surficial sediments at four sites (1 = saprolite; 2 = stony silty colluvium; 3 = stone-poor silty colluvium; 4 = fine-grained alluvium; 5 = sandy alluvium; 6 = sand and gravel alluvium). Dots denote position of measured soil profiles and stratigraphic sections; open dots, profiles described in Table 1. Exposures are 2 meters in height.

a. Site 5, 2.9 km southwest of Rappahannock River; 108 to 100 m elevation.
b. Site 21, 7.6 km southwest of Rapidan River; 113 to 100 m elevation.
c. Site 4, 1.0 km southwest of Rappahannock River; 97 to 84 m elevation.
d. Site 12, 0.5 km northeast of Rapidan River; 97 to 65 m elevation.

Soil pH ratios were measured with hydrometer techniques and by sieving at half-phi intervals. Water pH values were obtained with a Corning probe.

DISTRIBUTION OF SURFICIAL MATERIALS

Saprolite

Saprolite overprinted with a pedogenic solon comprised roughly 20% of the ditch exposures. Saprolite is the isovolumetric residuum formed at shallow depths by geochemical alterations of easily weatherable rocks; further pedologic alterations active close to the surface form the solon by decomposing even the most resistant primary minerals (Newell and others, 1980). Under the highest, gently sloping divides, residual soils (solon
plus saprolite) were often thicker than the exposures were deep (2 meters) and showed no visible stratification or stonelines. On particularly steep slopes where geologic and cultural erosion had removed the solum, saprolite lay at the surface. Encroachment of the clay-enriched solum into the low-density saprolite occasionally followed planes of weakness such as foliation and sheet joints that formed before saprolitization. Exposures of slightly weathered or fresh bedrock commonly showed 5 cm thick clay skins filling these cracks as much as 4 meters below the surface.

Shallow bedrock was exposed in the Culpeper ditch only beneath large streams near the base of long or steep slopes descending to those streams. The few strongly convex slope segments in the landscape generally were controlled by the location of shallow bedrock or saprolite thinly blanketed with colluvium and were present on the downhill side of gently sloping benches or terraces close to the valley bottom.

Colluvium

Stony, silty colluvium blanketed more than 60% of the landscape cut by the trench with a very uniform 0.5 to 1.0 meter thickness (Figure 2a). The abrupt base of the colluvium appeared as a change in color, texture, or stoniness that truncated saprolite, bedrock or alluvium. At the bottom of the colluvium and below, few veins, dikes, or foliations showed signs of warping caused by soil creep.

The colluvium was derived principally from phyllite and schist saprolite and from quartz veins. Within a colluvial mass, angular blocks of phyllite were present only near the saprolite-colluvium interface at the uphill end of the deposit. Pebbles of subangular quartz less than 5 cm in diameter studded the fine-grained matrix and appeared in stone lines extending up to 10 meters in thin discontinuous beds parallel to the hillslope. Occasionally an irregularly-thick bed of vein quartz fragments lined the base of the colluvium. No buried soils were noted within the colluvium wedges although certain reaches of the exposure did have distinct breaks in colluvial texture (e.g., stone-poor silty colluvium over stony silty colluvium, Figure 2a).

Deposition of colluvium at the sites studied was both episodic in time and migratory in location. Where the pipeline route crossed the paths of first-order valleys, shallow channel-fill sequences often appeared in the exposures. At one site (Figure 2c) two small channels were filled with massive colluvium that contained fewer angular quartz pebbles and less soil development than the underlying material. Material in channels at another site (Figure 2d) graded laterally between thin, bedded alluvium and massive stony colluvium. In its uphill exposures this colluvium had a silty matrix with abundant angular quartz pebbles throughout and numerous blocks of phyllite near its base. Thin lenses of sand and rounded pebbles composed of non-local rock types were increasingly abundant further downhill so that the sediments in the lower margin of the channel appeared fluvial in character. In the top of the channel above this variable unit lay a uniformly massive colluvial bed with a quartz stoneline at its base. The thick deposits below this channel-fill sequence also made an interbedded transition from colluvium to alluvium.

Alluvium and Related Colluvium

Usually thick accumulations of colluvium and alluvium lay on some summits, on terraces and benches, and on concave valley bottoms. At the crests of two major interfluvies stony deposits filled channels 1.0 to 1.5 meters deep and no more than 8 meters wide at their tops (Figure 2a). Each deposit was identified as alluvium because of the partially rounded pebbles in thin beds at their bases and the diminishing quantity of sand in successively higher layers above the gravel. Beneath the summits and terraces, the deposits and underlying saprolite were impregnated with
pedogenic clay throughout their exposures and stained with reddish iron oxides. Soil survey and geomorphic reports (e.g., Carter and others, 1971; Elder and Pettry, 1975; Dunford-Jackson, 1978) indicate that such divide-capping alluvium is common in the Piedmont of Virginia; some of these deposits lie at elevations considerably higher than encountered in this study. Presumably an exhaustive search for potential hilltop channels would locate more examples than were encountered along this pipeline ditch.

The thickest colluvium and alluvium beds present along side-slopes were most often beneath and uphill from gently-sloping benches 5 to 12 meters above the modern floodplain. In a few locations side-slopes cut across buried benches of saprolite and alluvium without changing slope. Figures 2b-d illustrate the varied stratigraphy encountered in this landscape position. Wedges of reddish-brown clay-rich colluvium commonly buried fining-upwards sequences of alluvium, also heavily weathered. At several sites, small channels cut into these beds were filled with younger, less weathered slope debris. All of these saprolite-supported bench deposits were older and higher than the modern valley-bottom alluvium.

The alluvium beneath side-slopes and benches contained rounded and subrounded pebbles and cobbles of quartz, quartzite, green stone, red shale, schist and gneiss which graded upwards through beds of stone-free sand and silty clay. The thickness of the alluvium varied according to the size of the nearest stream but ranged from 1 to 3 meters. Many of the non-quartz gravel clasts were very friable due to post-depositional weathering; quartz pebbles commonly had iron-rich rims up to 8 mm thick. In places thin pedogenic clay skins and iron- and magnanese-rich oxides coated alluvial gravels and sands up to 2 meters below the surface.

Where exposed by the pipeline ditch, the deposits in the low terraces and floodplains along major streams consisted of relatively unweathered fluvial sequences. Basal gravels containing vein quartz, quartzite, and gneiss with minor amounts of red shale, greenstone, and basalt lay upon unweathered bedrock. Beds of poorly-sorted sand and silt blanketed the gravels. Although water in the excavation usually obscured the total thickness of these fluvial sediments, some sequences exceeded 4 meters in measured thickness and rose to more than 3 meters above their parent stream.

**RELATIVE AGE DATA**

The relative ages of surficial deposits are established by stratigraphic relationships, geomorphic positions, and soil development criteria. Depositional and erosional boundaries clearly exposed in the ditch indicate the relative ordering of many geomorphic events. The indices of weathering available for this study (B horizon structures, thicknesses, colors, and clay contents; degree of clast weathering) might suggest the timing of those events.

The principle of geomorphic ascendancy dictates that the hilltop channels were the oldest deposits found in the study area. Formed by small streams which left an armor of relatively insoluble quartz pebbles and sand, the channel-fills now sit in an inverted topographic position. The very high clay content (65%) in the once-sandy alluvium, the reddish-brown to red (2.5 YR to 10R) soil colors (Table 1), and the landscape position of the channels imply a great age for the deposits. B horizon thicknesses were difficult to assess because the topsoil and some subsoil horizons had been eroded.

If this relative age interpretation for the hilltop channels is correct, the alluvium on the sideslopes and benches should be measureably less weathered than the hilltop channel alluvium. It seems clear that the observed benches of bedrock (saprolite) which lie at 75 meters elevation were once part of a valley floor system (Terrace Level 3 of Dunford-Jackson, 1978), much younger than the higher channels at 104 and 128 meters elevation. With the available soils data, though, it is difficult to
distinguish the hilltop alluvium from the terrace deposits. On the side-
slopes and benches the full depth of B horizon clay penetration was at least
200 cm but may have been as deep as 400 cm; maximum clay contents were
comparable (50-60%) at like depths in similar materials. Although soil
colors were somewhat less reddish in the bench deposits (SYR to 2 SYR) than
in the hilltop channels, this color distinction may be the result of
differing histories of soil drainage conditions. Relative measures of
pebble weathering were not useful in establishing relative ages because the
hilltop channels contained nothing except vein quartz. Thicknesses of iron
oxide rinds on rounded quartz pebbles ranges from 0 to 8 mm in both
landscape settings; therefore, due to the lack of time, numerous systematic
measurements of these rinds were not taken. Future research may find such
data valuable, however.

Even though the soil data on the two sets of weathered alluvium did not
suggest marked differences in age, contrasting soil characteristics between
the bench alluvium and overlying colluvium did indicate some variations in
age. In Figure 2b, the colluvial wedge was weathered to the same degree as
the underlying alluvium; similar weathering criteria were found in the
colluvial and alluvial facies represented in the oldest strata of Figure 2d
and the oldest alluvium of Figure 2c. However, the massive colluvium shown
in Figure 2c seemed significantly less weathered than the alluvium at that
site. In deposits of similar texture, the alluvium had better developed
blocky structure plus more and thicker clay films than the overlying
colluvium. The stonelike and clear boundary at the base of the colluvium
plus the change in clay content also indicate that the colluvium buried a
paleosol formed on the alluvium.

Young colluvium filling the swales cut into these older bench deposits
was less weathered than the underlying materials. Not all of the young
swale fills were equally weathered at every site. Some of the deposits
apparently accumulated in the recent past, judging by their high content of
disseminated organic matter in the moderately well-drained sites; others had
filled now-relict drainageways presently truncated by swales following new
slope directions. All of these younger colluvial masses had more brown
hues, lower clay percentages, and thinner B horizons than stratigraphically
older deposits at the same site.

Compared to the bench and sideslope deposits, the valley bottom
sediments were virtually unweathered. The amounts of clay present rarely
exceed 15% even in the finest floodplain sediments; the lack of soil
structures suggested that the clay in these deposits was non-pedogenic.
Brown colors (10YR) indicated a minor amount of oxidation in these soils but
for all practical purposes the gravels were unaltered. The freshness of
these class contrasted with the moderately weathered, friable gneiss and
basalt pebbles found in older alluvial gravels.

**DISCUSSION**

Colluvium is widespread in the unglaciated Piedmont (e.g., Cain, 1944;
Conley and Drummond, 1965; Overstreet and others, 1968; Eargle, 1977;
Ciołkosz and others, 1979; Newell and others, 1980; Darmody and Foss,
1982). Most authors consider the saprolite, which mantles bedrock in the
Piedmont, to be the source of the silty matrix and angular stone fragments
found in most colluvium, although Darmody and Foss (1982) argued that a
significant amount of the silty colluvium in the Maryland Piedmont is
reworked loess. Darmody and Foss cited lithologic breaks visible within
the colluvium that matched changes in stoniness and clay mineralogy to
substantiate the loessal hypothesis. In Culpeper County, Virginia, only a
few sites with such lithologic distinctions were noted along the 22
kilometers examined. Although future studies may confirm the reworking of
loess into the colluvium in Virginia, the available stratigraphic data do
not suggest that the loess was thick or well preserved.
The colluvium cover in the Piedmont is generally thought to be thin especially when compared to 18-meter-thick colluvial wedges in the inner Coastal Plain of Georgia (Newell and others, 1980). However, Eargle (1977) reported 3 to 6 meters of colluvium in swales and on sideslope benches in South Carolina while thicknesses of 1 to 30 meters have been cited in Pennsylvania’s Piedmont (Ciolek and others, 1979). The massive colluvium found during the present study exceeded 2 meters only where it lay upon active or relict toeslopes.

Alluvium is as widespread as colluvium and saprolite in some Piedmont areas (e.g., Eargle, 1977). In north-central Virginia, though, alluvium formed the parent material for soils in only approximately 10% of all ditch exposures; colluvium, 60%. The relatively sparse distribution of alluvium in Culpeper and Orange Counties is interesting given the numerous terrace deposits noted by Dunford-Jackson (1978) in the same areas. This dearth may be due to the large number of steep slopes along the pipeline route caused by the incision and close proximity of Rapidan and Rappahannock Rivers (Stan Dunford-Jackson, personal communication, 1980). These slopes probably induced more stripping of surficial sediments along the narrow divides in the study area than occurred elsewhere in the region.

Several features found to be common in the South Carolina and North Carolina Piedmont were not present in the Virginia pipeline exposures. Near Spartanburg, South Carolina, Eargle (1977) discovered large numbers of colluvial masses burying both weathered alluvium and mats of organic debris up to 3 meters thick. During the Pleistocene, these deposits filled steep-sided swales carved into the saprolite. The massive colluvium proved resistant to subsequent re-entrainment and forced valleys to develop in the adjacent saprolite thereby forming benches of valley-fill materials. Surficial materials and stratigraphic situations similar to these in South Carolina also exist along small streams in central North Carolina (Overstreet and others, 1968; Whittlecar, 1984). Neither organic mats nor substantial colluvium- armored benches were seen along the ditch in north-central Virginia. As noted in Figure 2 colluvium did bury alluvium along relict toeslopes in north-central Virginia, yet because of the relative thinness of most colluvial deposits when compared to the size of adjacent streams, any effect of the observed colluvial masses upon the location of stream incision is believed to have been minimal. Perhaps the lack of visible organic mats was due to the limited exposure afforded by the pipeline excavation in poorly-drained materials, in contrast to the deep gully walls used by some earlier workers. Most sites examined were sufficiently drained to oxidize any carbonaceous sediments. The only "organic deposits" found along the pipeline route filled broad depressions that occasionally appeared only on one side of the ditch. Artifacts, highly-disturbed stratification, and charred stumps confirmed the reports of local residents that the apparent "channels" were disposal pits dug during construction of the original pipeline in the 1960s.

Many recent studies indicate that changes in soil profile development can indicate the relative age of some landscape features (e.g., Gile, 1970; Bockheim, 1980; Whittlecar and others, 1982; Birckeland, 1984; Foss and Segovia, 1984; Mills and Wagner, 1985). However it is very difficult to assign absolute ages to weathered deposits by using soil criteria exclusively (Vreken, 1984). Rate and types of soil-forming processes on a single hillslope can vary dramatically according to landscape position, drainage, slope angle or parent material. Soils on stable uplands or interfluves will tend to be overprinted with soil characteristics formed under climatic or geomorphic conditions different from the present. Furthermore, under a monogenetic environment the rates of change for many soil characteristics are non-linear and should not be used to calculate soil age without additional relative dating information. Firm chronologic control is only established by correlating a soil with dated sedimentary sequences or well-established geomorphic surfaces. Even with such control,
great caution should be used when extending soil-age comparisons away from the area of empirical reference chronosequences to different climatic or geologic situations (Vreeken, 1984). With the potential for so many problems in interpretation, soil age estimates are rarely better than "order of magnitude" in precision.

Any use of soil development data to indicate relative age must be supported by a combination of geomorphic, stratigraphic, sedimentologic, or petrographic information. For example, a clear distinction must be drawn between the age of a geomorphic surface and the sediments and soils underlying that surface (Ruhe, 1969; Daniels and others, 1971). Almost all slopes in the Piedmont are composed of one or more erosion surfaces which can truncate geologic structures, sedimentary sequences and soil profiles. Fortunately, because alluvial point bar deposits exhibit fining-upwards sequences approximately equal in thickness to the depth of the river channel (Wolman and Leopold, 1957), it is possible to estimate the amount of deposit stripped from a given terrace surface. In the study area the degree of erosion on alluvial deposits generally increases with elevation. The youngest valley-bottom sediments showed no apparent erosion; the hilltop channel fills were severely eroded with half or more of the original deposits missing. Alluvial sequences on intermediate-level terraces were nearly complete beneath old colluvial masses close to the valley side but moderately to severely eroded elsewhere. Although the amount of erosion was less than one meter on most of these terrace deposits, the tops of fining-upwards sequences were rarely expressed as low-gradient surfaces. The range of soil development upon a single terrace level can be understood only with knowledge of the site's sediments and stratigraphy.

The study of Rappahannock River basin done by Dunford-Jackson (1978) relied upon elevation analyses and recognition of sedimentary sequences as well as differences in soil development to distinguish six alluvial surfaces present within 120 meters of relief. Increasing soil development was indicated by more red hues, greater clay percentages in the B horizon, and total solum thicknesses. The alluvial benches at 75 meter elevations in the study area correspond to Dunford-Jackson's Terrace Level 3. On surfaces at this elevation, Dunford-Jackson reported up to 80% clay in B horizons with 2.5YR colors. Stream deposits on major interstream divides contained up to 90% clay and 10R colors throughout. As indicated in Table 1, clay contents in the hilltop and alluvial deposits described earlier in this paper contained only 50-60% clay, more like soils Dunford-Jackson described on younger, lower surfaces. These differences in soil clay content could be due to variations in parent material or to the erosion of horizons at the sites I studied. Soil colors and pH values found in the pipeline exposures generally match those predicted by Dunford-Jackson (1978) although his soil pH values showed significant decreases at the base of the B horizon that were not found in the ditch profiles.

Several lines of evidence suggest that the deposits on the 75 meter benches may date from at least the early Pleistocene or before. Dunford-Jackson (1978) obtained estimates of terrace age by projecting the Piedmont terrace levels down-valley and correlating them with Coastal Plain terraces. He suggested that the widespread Terrace Level 3 formed at the same time as the "Coharie" terrace, one of several Coastal Plain surfaces thought to be pre-Pleistocene in age (e.g., Hack, 1955). Markewich, Pavich, and Gonzales (1983), who studied soils in dated sandy Coastal Plain deposits, found that thickness of the total soil, thickness of the B horizon, clay content, and various elemental ratios in secondary soil minerals increase with time of soil development. They found that soils in many deposits one million years old were 2-to-4 meters thick and had over 40% clay in the B horizon, whereas 60,000-to-500,000 year old soils contained 15-25% clay. Other studies in Virginia (Pavich and Obermeier, 1977; Pavich and Markewich, 1979; Pavich, in press) suggest that a 4-meter thick mantle of saprolite can form in crystalline bedrock during a million years of landscape stability. Sheet
joints and potholes preserved on the saprolite beneath the 75 meter terraces in the present study strongly suggest that saprolite developed after the alluvium was deposited. Comparison of the sola and saprolite on the benches with those described in reports cited above indicates that the bench soils formed over a span of at least 500,000 years and perhaps much longer. Therefore an early Pleistocene date, or even Pliocene as suggested for these surfaces by Dunford-Jackson (1978), seems possible.

In north-central Virginia, bedrock rarely appeared in the 2-meter deep ditch at more than 10 meters elevation above the nearest large stream. The presence of unweathered bedrock only beneath incised valley bottoms in the Piedmont, also noted in Georgia (Newell and others, 1980) and in Maryland (Costa and Cleaves, 1984), indicates that stream erosion has removed regolith there more rapidly than saprolite can reform. Thus, based upon the rate of saprolite formation mentioned earlier, this active fluvial erosion occurred during the late Pleistocene in the lower portions of major valleys of the Rappahannock River system.

Although some authors expect to find only one generation of soil development in the Piedmont (e.g., Newell and others, 1980), buried paleosols are reported from several locations in the Piedmont and Blue Ridge (e.g., Overstreet and others, 1968; Eargle, 1977; Mills, 1977, 1982). Because a well-developed soil profile only forms upon a relatively stable surface, Ciolkosz and others (1979) concluded that the presence of buried paleosols in colluvium implies episodic periods of slope instability alternating with times of stable slopes. Mills (1977) came to the same conclusion based upon three traceable slope deposits exhibiting different degrees of weathering in the South Carolina Blue Ridge. Using discriminant analyses of weathering phenomena from 135 sites in that area, Mills (1982) provided further support for repeated episodes of rapid colluviation.

Climatic change is often cited as the reason for such episodic slope instability. Ciolkosz and others (1979) used indirect evidence of widespread periglacialization in Pennsylvania (Marchand and others, 1978) to argue for frost-acentuated solifluction during the Pleistocene. Citing reports of spruce-fir pollen from colluvium and from organic mats buried beneath colluvium, several authors have suggested that cooler Pleistocene climates induced rapid colluviation in the Piedmont of the Carolinas (Cain, 1944; Whitehead and Barghoorn, 1962; Overstreet and others, 1968; Eargle, 1977; also see Pewe, 1984).

In north-central Virginia, the different degrees of weathering between alluvial deposits at several sites and the buried paleosols on some alluvium indicate that along the pipeline traverse more colluvium was deposited during some periods than others. Two explanations are possible for the stratigraphy observed in the ditch. Because of the possible shifts in the positions of valleys and toeslopes in the study area due to progressive landscape erosion, the hillslope colluvium might have changed its accumulation areas through time (e.g., Newell and others, 1980) even while its rate of activity remained relatively constant. If this were true, any arbitrarily-chosen traverse may encounter only parts of the entire colluvial sequence present in the landscape thereby giving an illusion of apparent pulsations in slope stability. The evidence gathered in the present study is insufficient to refute this "steady down-wasting" interpretation. On the other hand, studies in the Piedmont cited above suggest that Pleistocene climate changes strongly affected the rates of hillslope processes in the region. Some observations and conclusions in this report may support an interpretation of the superimposed colluvial wedges as glacial-age deposits. Based upon the soil-development arguments stated earlier, most of the slope deposits are Pleistocene in age. Unfortunately, clear and direct indications of solifluction or periglacialization, such as ice-wedge casts or convolute structures, were absent in the Piedmont pipeline exposures. Future research may reveal other paleoenvironmental indicators useful in establishing the timing of colluviation at the study sites.
SUMMARY

The surficial sediments which mantle the northern Virginia Piedmont landscape are relatively thin except along active or relict toeslopes. Colluvium buries alluvium and well-developed paleosols at many of those sites. Alluvium is often present beneath hillslope benches lying at several levels above the valley bottom but it also exists as patches which have no geomorphic expression.

Differential soil development between deposits at various elevations and on materials at the same level reflects episodic downcutting and subsequent deposition by fluvial and slope processes. The older deposits may be at least early Pleistocene in age based upon both the presence of shallow bedrock only in valley bottoms and the rates of saprolite formation reported by others. Although evidence is mounting from many neighboring areas that cold Pleistocene climates induced relatively rapid mass wasting in the Virginia Piedmont, the causes of the episodic colluviation in the study area are not clearly understood.

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