Department of Natural Resources
MARYLAND GEOLOGICAL SURVEY
Emery T. Cleaves, Director

REPORT OF INVESTIGATIONS NO. 67

SURFICIAL GEOLOGY OF THE DELTA QUADRANGLE, HARFORD COUNTY, MARYLAND AND YORK COUNTY, PENNSYLVANIA

by

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Governor of Maryland

John R. Griffin
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SURFICIAL GEOLOGY OF THE DELTA QUADRANGLE, HARFORD COUNTY, MARYLAND AND YORK COUNTY, PENNSYLVANIA

by
Frank J. Pazzaglia[1] and Emery T. Cleaves

ABSTRACT

Detailed surficial mapping of the Delta quadrangle has established the stratigraphy, sedimentology, soil stratigraphy and morphology, and major surficial processes for an area of central Appalachian Piedmont of Pennsylvania and Maryland. The fundamental, coarsest-scale mapping unit is a surficial terrane defined by the integration of a characteristic landform, a dominant or characteristic surficial deposit, and a characteristic distribution of deposits across previously defined landscape units (Cleaves and Reger, 1991). The identification of seven surficial terranes illustrates the influence of lithology and the relationship attained between the distribution of surficial deposits and topography. In contrast to more conventional views that hold that the Piedmont is an old landscape dominated by saprolite and residuum, mapping has demonstrated that colluvial diamictons, are the primary surficial unit. Other surficial deposits include structured saprolite, residual soil, alluvium, and minor upland gravels. Deposits are defined primarily on a textural basis which also generally mirrors their relative age. A soil chronosequence estimates deposit age by distinguishing late Wisconsinan (late Pleistocene), Illinoian (late middle Pleistocene), and pre-Illinoian (middle Pleistocene) pedons. Piedmont surficial deposits are superimposed on a landscape that reflects the interaction between long-term, post-middle Miocene base level fall and climatic fluctuations. Piedmont physiography within the quadrangle is generally characterized by valleys with a lower, steep, fluvially incised V-shaped component that opens both upslope and upstream to an upper concavo-convex hillslope component separated by relatively flat, broad interfluves. Accelerated fluvial incision, initiated in the late Tertiary and continuing through the Quaternary in response to base-level lowering, increased relief of the late Tertiary piedmont landscape. Various geomorphic processes responding to Quaternary climatic fluctuations have worked to reduce that relief through several erosional episodes that have removed large quantities of former saprolite and weathered rock from the uplands and incorporated this material into multiple deposits of colluvium.

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INTRODUCTION

The surficial geology of the Delta, Md.-Pa. U.S.G.S. 7½-minute quadrangle has been mapped as part of a COGEOMAP project (Grants 14-08-0001-A0689 and 14-08-0001-A0794) administered by the Maryland Geological Survey and the U.S. Geological Survey. The purposes of this mapping effort were to: (1) identify and describe the stratigraphy and sedimentology of surficial deposits; (2) investigate the relationship between landforms and distribution of surficial deposits; (3) interpret Piedmont landscape evolution; and (4) describe past and present surficial processes.

The Delta quadrangle straddles the Maryland-Pennsylvania border in the eastern Appalachian Piedmont immediately west of the Susquehanna River (Figure 1). The primary drainage is Broad Creek, which nearly bisects the quadrangle as it flows eastward into the Susquehanna River. The southern portion of the quadrangle is drained by Deer Creek, which flows along the boundary with the Bel Air quadrangle, whereas the northwest portion is drained by north-flowing streams that are part of the Muddy Creek drainage basin. Valleys in close proximity to the Susquehanna River in the northern and eastern portions of the Delta quadrangle exhibit a local relief of approximately 60 m and tend to be more deeply incised than those in the south and west. In contrast, streams in the southern and western parts of the quadrangle, part of the Deer Creek drainage or upper reaches of Broad Creek, generally exhibit less than 30 m of local relief.

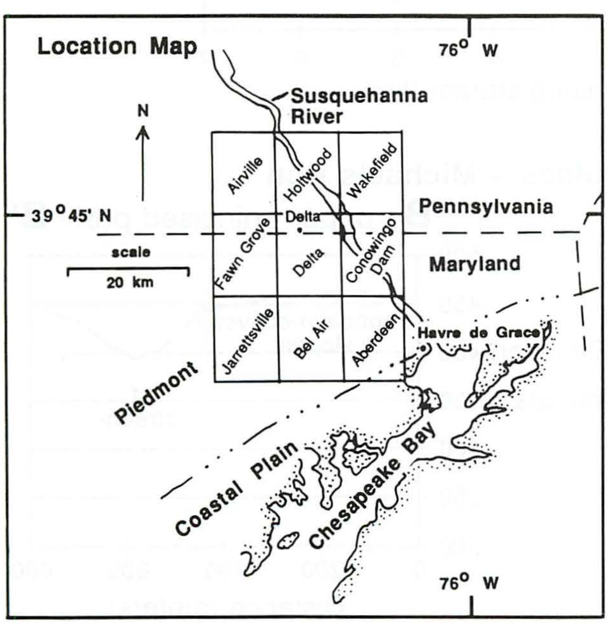

Figure 1.— Location of the the Delta quadrangle and surrounding 7½-minute quadrangles.

Three major components characterize the landscape: (1) an upland surface of low relief that truncates rocks of varying lithology; (2) steep-walled valleys and gorges incised into the upland surface; and (3) the Slate Ridge Monadnock (Cleaves, 1989). Stream valleys are polymorphic, composed of a lower, steep-sided, V-shaped component that opens both up-valley and upslope to an upper concavo-convex hillslope segment separated by relatively flat, broad interfluves (Figure 2). The highest elevation is 245 m above mean sea level (amsl) on Slate Ridge 1 km east of Whiteford, and the lowest elevation is 33 m amsl along the border with the Susquehanna River. The upland surface ranges from 90 - 150 m amsl in elevation. Valley relief does not exceed 76 m in the incised portions of drainages and, generally, is on the order of 24 - 30 m.

The Delta quadrangle is underlain by felsic, ambibolite-grade, quartzo-feldspathic metamorphic rocks of the lower Paleozoic(?) Glen Arm Series, lower Paleozoic(?) ultramafic and granitic intrusive rocks, and Proterozoic (Grenville) gabbroic rocks of the Baltimore Gneiss Complex (Plate 1, Inset Map 1; Muller, 1990; Southwick and others, 1969). The Glen Arm Series rocks underlie approximately 80 percent of the quadrangle with the intrusive lithologies restricted to the southeast and southwest corners. The felsic metasediments strike to the northeast and dip steeply either to the northwest or southeast (Plate 1b). Beginning in the northwest corner of the quadrangle and proceeding southeast, the Glen Arm Series is represented by: (1) Prettyboy Schist, a fine- to medium-grained plagioclase-quartz-mica schist; (2) Pleasant Grove Phyllite; (3) Peach Bottom Formation characterized by a Slate Member surrounded by the Cardiff Metaconglomerate; (4) Peters Creek Quartzite, an interbedded fine-grained quartzite and phyllitic mica schist; (5) Piney Run garnet-mica schist; and (6) Deer Creek Complex, an interbedded quartz metagraywacke, fine- to medium-grained mica schist, quartz pebbly metadiamictite, and massive to foliated talc-chlorite-actinolite ultramafic rocks and serpentinite. The southwest corner of the quadrangle is underlain by medium-grained, massive to foliated, dark metagabbro of the Bel Air Complex. A medium-grained, muscovite-bearing, well-foliated to nearly massive granitic leucogneiss occurs on the south-central edge of the quadrangle.

The bedrock records several deformational events as foliations, folds, cleavages, joints and numerous faults and shear zones (Valentino, 1990; Valentino et al., 1994). The dominant foliation is characterized by a northeast strike and a steep southeast dip. The average foliation strike in the Delta quadrangle is N55°E and the dominant joint orientation is NNW (Figure 3).

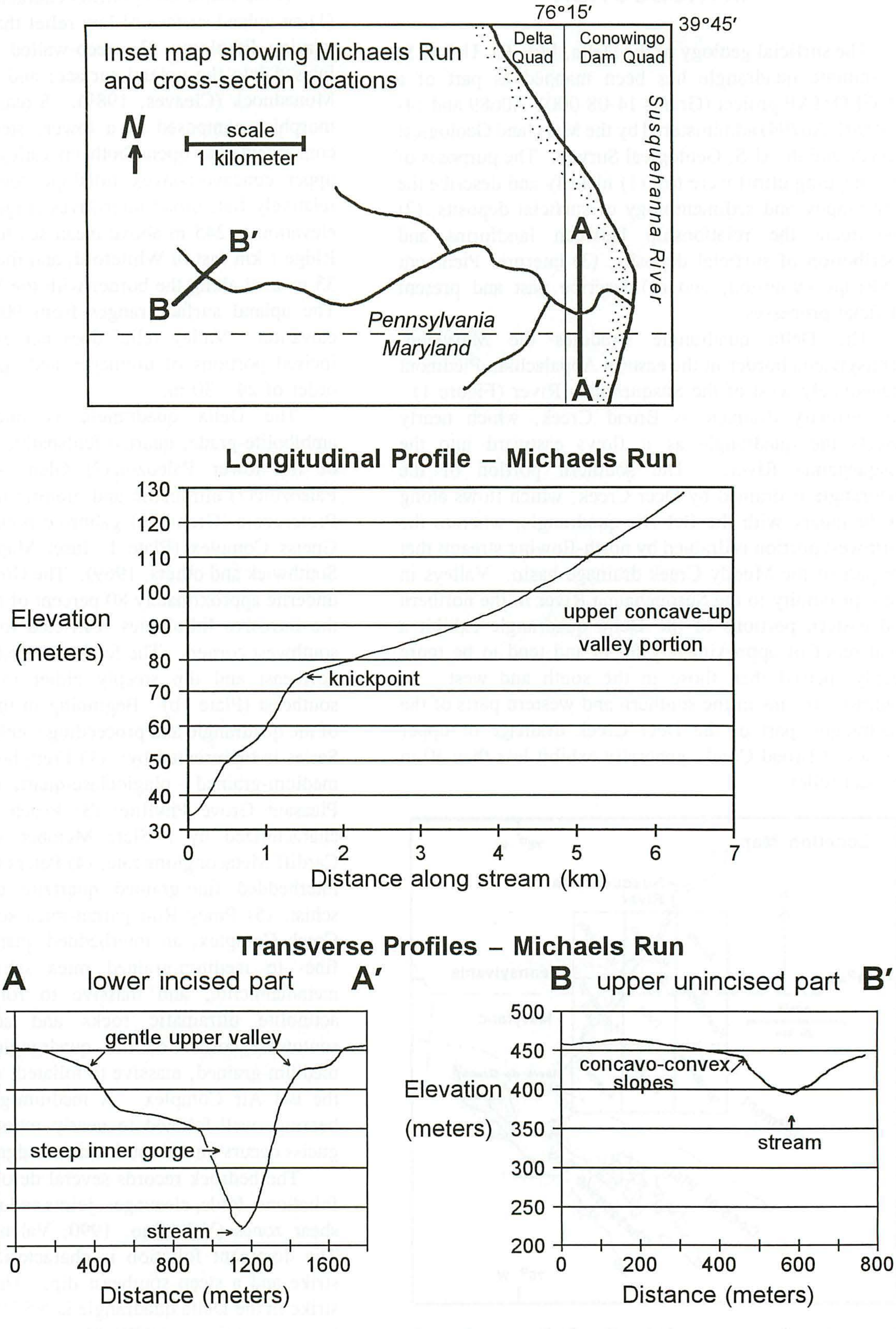

Figure 2.– Stream and topographic profiles for Michaels Run, York County, Pennsylvania.

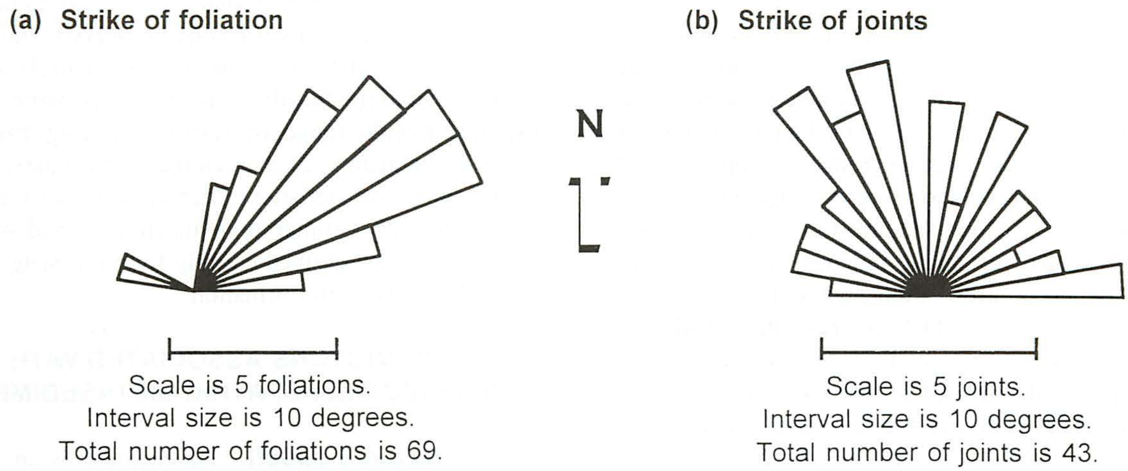

Figure 3.— Rose plots showing (a) strike of foliation and (b) strike of joints for bedrock in the Delta quadrangle.

METHODOLOGY

The surficial geology was established by: (1) surficial field mapping at a 1:24,000 scale; (2) detailed stratigraphic interpretations of pits, trenches, and outcrops; and (3) development of a field stratigraphic and morphology-based soil chronosequence. The Delta quadrangle soil chronosequence uses field soil characteristics such as color, argillic horizon structure, thickness of clay films, and solum thickness to define several diagnostic pedons. In the absence of stratigraphic relationships, these pedons help establish relative age for Piedmont surficial deposits. A Piedmont chronosequence was compared to chronosequences constructed for other parts of the Appalachian Mountains which, in part, are stratigraphically constrained by glacial deposits of known age. Comparison of the Piedmont chronosequences to Appalachian Mountain ones, provides estimates for the absolute age of Delta quadrangle surficial deposits.

SURFICIAL DEPOSITS

MAP UNITS

Surficial deposits in the Delta quadrangle include various diamictons, structured saprolite, residual soil, various alluviums, and upland gravels. The units are defined primarily on textural, secondarily on compositional, and lastly on soil stratigraphic criteria. Bedrock geology and relative relief impart the strongest influences on the composition, genesis and distribution of map units. These influences are reflected and supported by mapping data which have shown how surficial deposits restricted to gentle slopes and interfluves on one bedrock formation may be found only on very steep slopes on an adjacent formation. Because local relief is influenced so strongly by bedrock composition, it is possible to have fairly abrupt contacts between texturally similar, but compositionally distinct deposits, as well as between compositionally similar, but texturally distinct units.

Delta quadrangle surficial map units are morphologically distinct, have a specific minimum thickness (in this case 1 m), and are mappable at the 1:24,000 scale. Exceptions to this convention are upland gravels and a buried diamicton. Upland gravels occur in the landscape only as scattered pebbles and cobbles incorporated within younger deposits, such as diamictons, and are represented as a stipple pattern (Plate 1a) superimposed on another surficial unit. Diamicton 1 is a buried, discontinuous, locally thick (> 3 m) surficial deposit unmappable at the 1:24,000 scale. Locations of diamicton 1 are indicated on the map with a triangle symbol.

Map unit symbols employ four characters to denote deposit age, texture, composition and relative stratigraphic age as determined by relative degree of soil development and stratigraphic relationships (Table 1). The first character of the code is a capital Q and/or T which denotes a Quaternary and/or Tertiary age for the deposit. The second character indicates a textural definition represented by a lower case **d**, **a**, **r**, **g**, **p**, **f**, or **t**, which denote respectively a **d**iamicton, floodplain **a**lluvium, **r**esidual soil, upland **g**ravel, **p**ediment gravel, **f**an alluvium, or **t**errace alluvium. The third character is a numeral from 1 to 6 signifying *relative* stratigraphic age with 1 as the oldest and 6 as the youngest. The numbers are also used to denote the clast to matrix ratio in diamicton deposits (see below). The final character reflects composition of the underlying bedrock, and is represented by a lower case **f, m, u, s,** or **g**, which denote a **f**elsic metasediment, **m**afic meta-igneous, **u**ltramafic igneous, **s**erpentinite, or **g**ranitic leucogneiss source. Four map units deviate from the above-described code (**Qtls, Qadu, dl,** and **ul**) and represent **t**a**l**u**s**, **a**lluvium and **d**iamicton **u**ndivided, and anthropogenically **d**isturbed **l**and and **u**rban **l**and.

Colluvial diamictons are the dominant surficial map unit. They are defined as generally matrix-supported, poorly sorted and poorly stratified hillslope deposits with varying amounts of clast and matrix material derived from weathered bedrock, residual material and, rarely, alluvial material. Diamictons commonly exhibit a crude stratification consistent with transport across the land surface. Diamicton map units are differentiated primarily on textural characteristics, specifically the relative amount of fresh clasts to finer grained matrix. In general, the relative percent of clasts decreases with increasing diamicton age; hence, diamicton 6 contains the most clasts, typically exhibiting a clast-supported texture, whereas diamicton 2 contains few, if any, fresh clasts in an otherwise fine-grained matrix. Thus, for diamictons 2 through 6, the numeric digit in the map code not only denotes relative stratigraphic age of the deposit, it also reflects textural characteristics.

Two important exceptions to the general age-texture trend are demonstrated by diamicton 1 and diamicton 5. Diamicton 1 represents a locally preserved, buried unit with a very specific soil stratigraphy and morphology (see below). Stratigraphically, it is the oldest diamicton, but exhibits a wide range of textures ranging from fine-grained diamicton 2 characteristics to coarse-grained diamicton 4 characteristics. Diamicton 5 is texturally and stratigraphically similar to diamictons 3 and 4, but is composed of and derived entirely from the Slate Member of the Peach Bottom Formation.

DIAMICTONS ASSOCIATED WITH QUARTZO-FELDSPATHIC METASEDIMENTS

Diamicton 6 (Qd6f). Diamicton 6 is an approximately 1 m thick, brown, clast-supported diamicton with little or no matrix material. It is poorly to moderately well stratified, contains only fresh, angular clasts exceeding 1 m in diameter, and overlies weathered and unweathered bedrock. Diamicton 6 soils are poorly developed exhibiting a 0.1-m A horizon and a thin (< 0.5 m), brown, cambic B horizon (Figure 4).

Talus (Qtls). Talus is characterized by poorly to moderately well sorted, generally coarsening-up angular and subangular clasts 0.2 to 2 m in diameter with virtually no interstitial matrix material. Deposits are typically less than 2 m thick and occur as small blockfields underlain by the Rocks Park Metaconglomerate and Cardiff Metaconglomerate.

Table 1.— Map symbol nomenclature code.

AGE	TEXTURAL DEFINITION	RELATIVE STRATIGRAPHIC AGE and CLAST/MATRIX RATIO[1]	COMPOSITION	OTHERS
Q = Quaternary	d = diamicton	6 = youngest; 0.9	f = felsic metasediments	Qtls = talus
	a = alluvium	5 = intermediate; 0.5-0.9	m = mafic metaigneous	Qadu = alluvium/ diamicton undivided
QT = Quaternary/Tertiary	r = residual soil	4 = young; 0.6-0.9	u = ultramafic igneous	dl = disturbed land
	g = upland gravel	3 = intermediate; 0.5	s = serpentinite	ul = urban land
T = Tertiary	p = pediment gravel	2 = young-old; buried; <2	g = granitic leucogneiss	
	f = fan alluvium	1 = old; buried; <0.2-0.8		
	t = terrace gravel			

[1] Clast/matrix ratio is expressed as the percentage of clasts per unit volume — e.g., 1 (100%) contains all clasts with no matrix, whereas 0.2 (20%) contains 1 part clast and 4 parts matrix by volume.

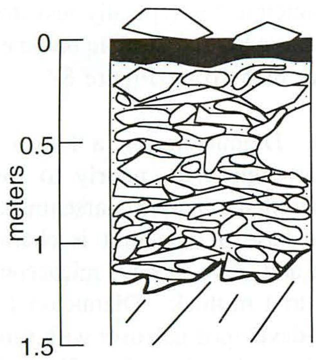

Figure 4.— Felsic diamicton 6 (Qd6f) exposed at outcrop 3-72. (See Plate 1a for location and Appendix 1 for key.)

Diamicton 5 (Qd5f). Diamicton 5 ranges from 1 to 1.5 m in thickness and is a brown, brownish-red, and red matrix-supported, poorly sorted, poorly stratified deposit composed entirely of 1- to 10-cm thick, flat, slate clasts in a uniform, massive, silt matrix. An upper brown unit characterized by a moderately well developed brown and strong brown soil (7.5YR) commonly overlies a lower unit exhibiting a well developed, but truncated reddish brown (5YR) paleosol. Diamicton 5 is associated only with the slate bedrock of the Peach Bottom Formation (Figure 5).

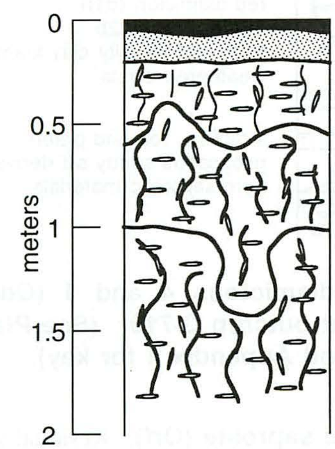

Figure 5.— Felsic diamicton 5 (Qd5f) exposed at outcrop 91-3-710. (See Plate 1a for location and Appendix 1 for key.)

Diamicton 4 (Qd4f). Diamicton 4 is 1 to 2 m thick, orange and brown, poorly stratified, clast-rich, and primarily matrix-supported diamicton. The diamicton exhibits a clast-supported texture in approximately 10 percent of its areal extent. The non-micaceous, silty sand matrix contains mostly fresh, angular clasts 5 to 30 cm in diameter, with a strong slope-parallel fabric except where influenced by cryoturbation features. The deposit exhibits a poorly developed soil characterized by a brown (10YR) cambic B horizon 0.1 to 0.3 m thick followed by a brown (10YR) and strong brown (7.5YR) argillic horizon approximately 0.5 m thick with few thin clay films and poorly developed, subangular blocky structure. Locally, a thin, truncated, buried reddish brown (5YR) argillic horizon occurs beneath the strong brown argillic horizon. Diamicton 4 often exhibits cryoturbation features characterized by roll structures approximately 0.2 to 1 m across and 0.5 m deep, and wedges up to 0.5 m deep and 0.5 m across. This unit overlies weathered and unweathered bedrock, but may also overlie structured saprolite and reworked saprolitic materials (Figure 6).

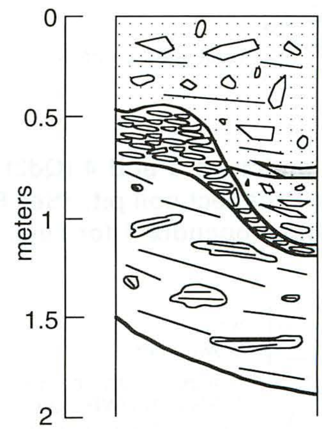

Figure 6.— Felsic diamicton 4 (Qd4f) exposed at outcrop 12-725. (See Plate 1a for location and Appendix 1 for key.)

Diamicton 3 (Qd3f). Diamicton 3 is a 1- to 2-m-thick, orange, brown, yellow, tan and gray, poorly stratified, poorly sorted, and matrix-supported deposit. The matrix is a slightly micaceous silty sand containing fresh and weathered bedrock clasts and "clasts" of structured saprolite. Locally, the clasts exhibit a slope-parallel fabric. The deposit typically exhibits a moderately well developed strong brown (7.5YR) and reddish brown (5YR) soil characterized by a 0.5 m argillic horizon (B2t) with common, thin clay films and moderate, subangular blocky structure that locally buries a thin, red (2.5YR), well developed, truncated, argillic horizon. Approximately 20 percent of the deposit is also characterized by a more poorly developed soil with a morphology consistent with the soil associated with diamicton 4. Diamicton 3 often exhibits cryoturbation features similar to those described for diamicton 4. This unit usually overlies residual materials such as structured saprolite, reworked saprolite, and weathered bedrock, and only rarely overlies fresh bedrock (Figure 7).

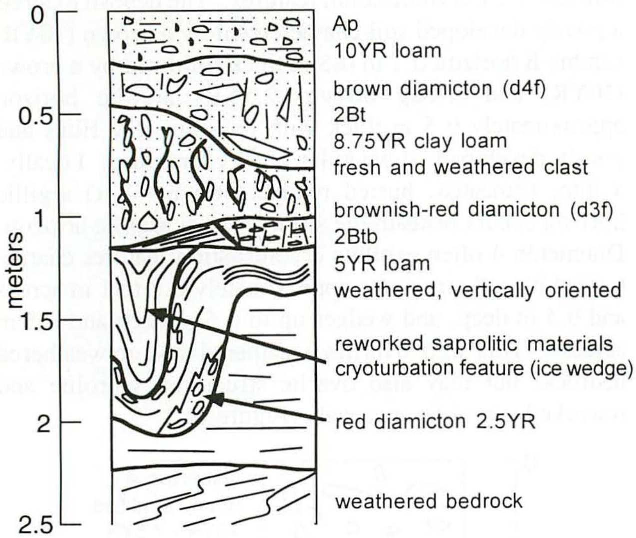

Figure 7.— Felsic diamictons 3 and 4 (Qd3f and Qd4f) exposed in Prospect soil pit. (See Plate 1a for location and Appendix 1 for key).

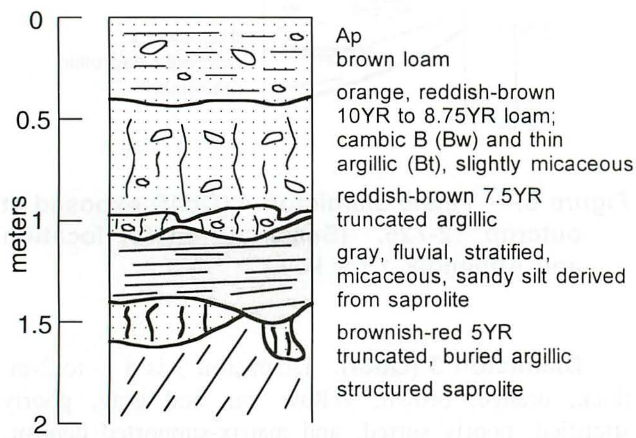

Figure 8.— Felsic diamicton 2 (Qd2f) exposed in Pleasant Grove pit 7. (See Plate 1a for location and Appendix 1 for key).

Diamicton 2 (Qd2f). Diamicton 2 is a brown, brownish-red, gray, green, and olive, often micaceous, very clast-poor deposit that occurs as both a surficial and a buried unit. The deposit is composed of reworked residuum, structured saprolite, weathered bedrock, and is easily distinguished from those materials by its slope-parallel, subhorizontal foliation. Locally, diamicton 2 exhibits shallow trough or tabular cross-stratification, suggesting deposition by hillslope sheet wash processes. Where exposed at the surface, the deposit exhibits a very poorly developed soil characterized by a thin ($\approx$0.3 m), brown (10YR) cambic or argillic B horizon. Where exposed at the surface, diamicton 2 is typically less than 1 m thick; where buried, it has a highly variable thickness ranging from 1 m to greater than 10 m (Figure 8).

Diamicton 1 (Qd1f). Diamicton 1 is a 1 to 5 m thick, red, matrix and clast-supported, poorly to well stratified, buried diamicton with distinctive coarsening-up stratigraphy. Locally, the base of this unit is characterized by a reddish brown and olive, sandy, micaceous, cross-stratified deposit 0.2 to 1 m thick. Diamicton 1 is easily recognized by a well-developed paleosol with some fresh but mostly weathered angular clasts 5 to 30 cm in diameter exhibiting a strong slope-parallel fabric. The fabric is locally disrupted by cryoturbation features. The 2 to 3 m thick argillic horizon exhibits red colors (2.5YR), has well-developed angular blocky structure and many thick, clay films. In poorly drained slope positions, this diamicton acquires an indurated texture and exhibits a bluish-gray color (Figure 9).

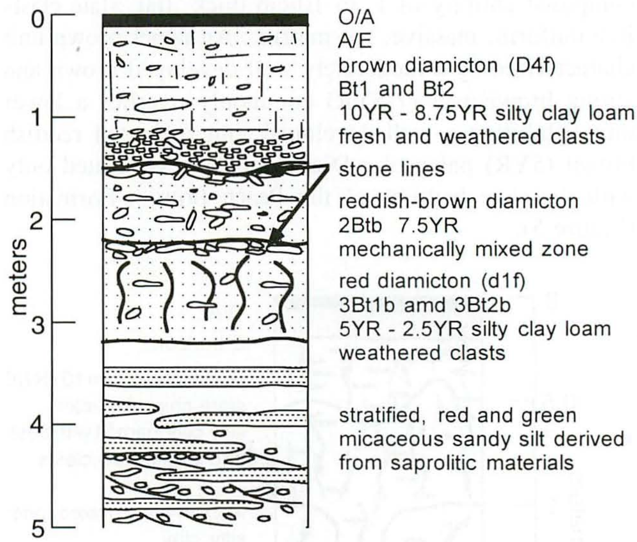

Figure 9.— Felsic diamictons 4 and 1 (Qd4f, Qd1f) exposed at outcrop 3-719. (See Plate 1a for location and Appendix 1 for key).

Residual soil and saprolite (Qrf). Residual soil and saprolite are clast-poor surficial deposits derived from *in situ* chemical weathering and pedogenic processes. Residual soils exhibit distinguishable horizons and an oxidized transitional C-horizon into underlying structured saprolite or weathered bedrock. The micaceous argillic horizon is 0.4 to 8 m thick, exhibits strong brown (7.5YR) to red (2.5YR) colors, moderately well developed subangular blocky structure, and common, thin clay films. Locally, saprolite is very micaceous, especially where derived from phyllite and schist rather than from quartzite and metagraywacke. Saprolite thickness is highly variable, ranging from 1 m to >10 m (Figure 10).

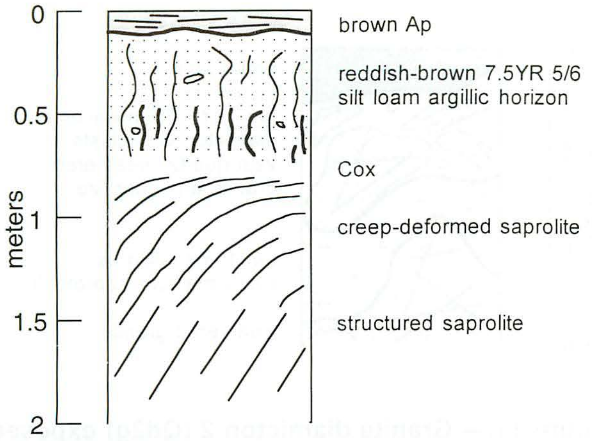

Figure 10.— Felsic residual soil (Qrf) exposed in Pleasant Grove pit. (See Plate 1a for location and Appendix 1 for key.)

DIAMICTONS ASSOCIATED WITH MAFIC AND META-IGNEOUS LITHOLOGIES

Diamicton 6 (Qd6u). Diamicton 6, derived from ultramafic bedrock, is a tan, yellow and brown, clast-supported deposit containing dense, foliated ultramafic rocks and Deer Creek Complex metasediment clasts. The diamicton has little to no matrix material, is poorly to moderately well stratified, and has a strong slope-parallel fabric. This deposit exhibits a very poorly developed, light-colored loamy soil characterized by a thin cambic B horizon. Deposit thickness is typically not more than 1 m.

Diamicton 6 (Qd6s). Diamicton 6, derived from serpentinite bedrock, is a tan, yellow and brown, clast-supported deposit containing dense, foliated, predominantly weathered serpentinite clasts that have thick (≈ 2 cm) goethite weathering rinds. The diamicton is typically less than 0.5 m thick and overlies fresh to slightly weathered serpentinite bedrock. The thin soil supports only a barrens-type vegetation.

Diamicton 4 (Qd4u). Diamicton 4, derived from metagabbro bedrock, is a tan, yellow, and brown, poorly stratified, poorly to moderately well sorted, non-micaceous, matrix-supported deposit with many fresh, angular clasts 5 to 30 cm in diameter. The matrix is a silty sand. The diamicton also has Deer Creek Complex metasediment clasts and dense, foliated, ultramafic clasts with a thick (≈ 2 cm) goethite weathering rind. The deposit exhibits a poorly developed brown (10YR-7.5YR) soil with a cambic or thin argillic horizon characterized by thin clay films and moderate, subangular blocky structure. Locally, a buried soil exhibiting dark, reddish brown and yellowish red (5YR) colors with thick clay films and well-developed structure occurs beneath the brown argillic horizon. Qd4u ranges from 1 to 2 m in thickness and typically overlies a silty saprolite of variable thickness developed in foliated ultramafic bedrock (Figure 11).

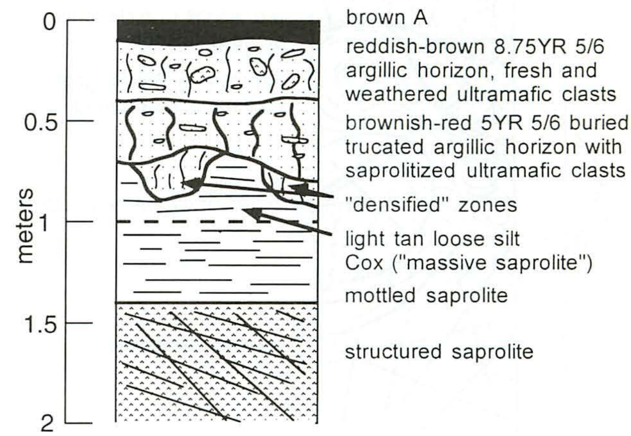

Figure 11.— Ultramafic diamicton (Qd4u) exposed at outcrop 91-627. (See Plate 1a for location and Appendix 1 for key.)

Diamicton 4 (Qd4m). Diamicton 4, derived from metagabbro bedrock, is a dark red, poorly stratified, poorly to moderately well sorted, dominantly sandy silt matrix-supported roundstone diamicton. It contains both fresh and weathered, subangular to well-rounded clasts 0.1 - 2 m in diameter. Dense, massive ultramafic and metagabbro clasts with thick (≈ 2 cm) goethite weathering rinds are concentrated primarily near or at the surface of the deposit forming surficial roundstone lags. The diamicton exhibits a moderate to well-developed red soil characterized by a 0.3- to 1-m thick red (2.5YR - 10R) argillic horizon with many thin to thick clay films and moderate to well-developed structure. The diamicton ranges from 0.5 to 3 m thick and typically overlies a thin (less than 1-2 m) sandy, structured saprolite and/or weathered metagabbro bedrock (Figure 12).

Diamicton 2 (Qd2u). Diamicton 2, derived from ultramafic bedrock is a tan, yellow and brown, very clast-poor, massive sandy silt. The deposit exhibits a very poorly developed soil characterized by a thin cambic B horizon that is gradational downward to underlying residual materials such as saprolite and/or weathered bedrock. This diamicton is easily distinguished from saprolite and residual soil because it displays a textural fabric subparallel to slope as well as a thin (0.5 m), discontinuous, non-foliated, "massive" horizon separating the saprolite from the overlying soil. Qd2u is typically less than 1 m thick, whereas the underlying residual material is highly variable, ranging from 1 m to greater than 10 m in thickness (Figure 13).

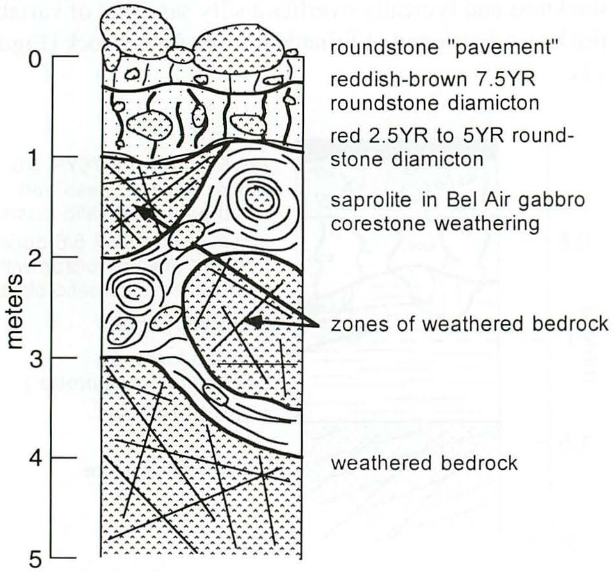

Figure 12.— Mafic diamicton 4 (Qd4m) exposed at outcrop 91-1-412. (See Plate 1a for location and Appendix 1 for key.)

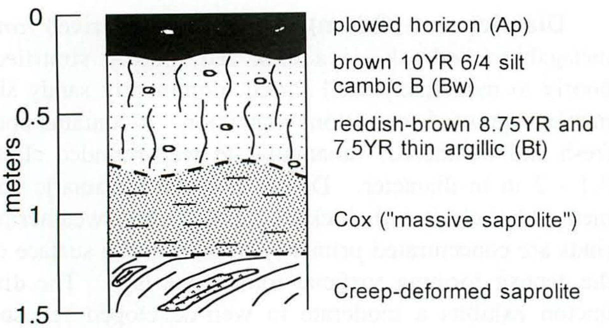

Figure 13.— Ultramafic diamicton 2 (Qd2u) exposed at outcrop 91-5-627. (See Plate 1a for location and Appendix 1 for key.)

Diamicton 2 (Qd2g). Diamicton 2, derived from granitic bedrock, is a tan and white, micaceous, very clast-poor, massive sandy silt. The deposit exhibits a very poorly developed soil characterized by a thin yellow cambic B horizon that grades to underlying residual materials such as saprolite and/or weathered bedrock. This diamicton is easily distinguished from saprolite and residual soil because it displays a textural fabric subparallel to slope, as well a thin ($\approx$0.5 m), discontinuous, non-foliated, "massive" horizon separating the saprolite from the overlying soil. Qd2g is less than 1 m thick, whereas the thickness of saprolite is highly variable, ranging from 1 m to greater than 10 m (Figure 14).

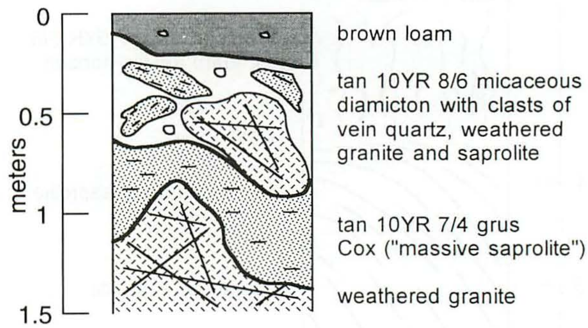

Figure 14.— Granite diamicton 2 (Qd2g) exposed at outcrop 91-4-628. (See Plate 1a for location and Appendix 1 for key.)

Residual soil and saprolite (Qrm). Residual soil, derived from metagabbro bedrock, is a dark red and brownish-yellow, sandy silt with few, fresh and weathered, subangular to well-rounded clasts 0.1 - 2 m in diameter. Massive, dense, ultramafic and metagabbro clasts within this residual soil commonly exhibit a thick ($\approx$2 cm) goethite weathering rind. Soils are characterized by a well developed, red (2.5YR - 10YR) 0.5 to 0.8-m thick argillic horizon with many thick clay films and well developed, angular blocky to prismatic structure. The argillic horizon grades downward to a well developed, reddish-brown, sandy saprolite. The soil commonly has a roundstone lag on the surface and is penetrated by numerous wedge-like "tongues" of yellowish brown (10YR) silt approximately 1 m deep and 0.5 m wide at the top. Qrm is typically 1 to 2 m thick, whereas the underlying sandy, structured saprolite ranges in thickness from 1 m to greater than 10 m (Figure 15).

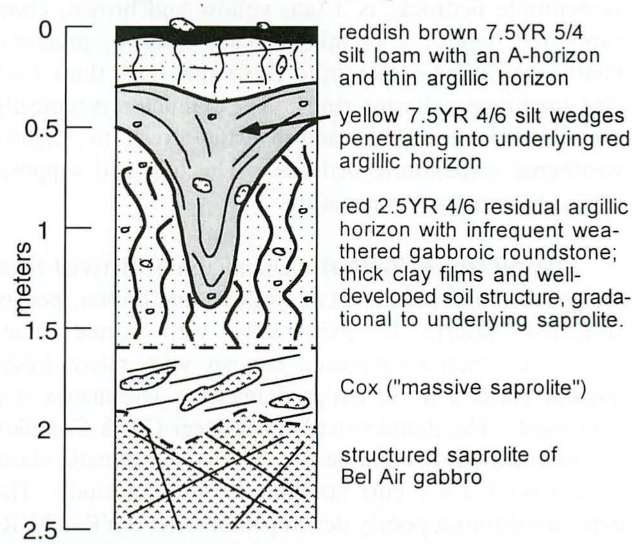

Figure 15.— Mafic residual soil (Qrm) exposed at outcrop 91-5-628. (See Plate 1a for location and Appendix 1 for key.)

Residual soil and saprolite (Qrg). Residual soil, derived from granitic bedrock, is a tan and white, dominantly sandy silt approximately 1 m thick with few, weathered, subangular to well-rounded massive, granitic gneiss clasts 0.1 - 0.5 m in diameter. The soil exhibits a poorly developed, brown and strong brown (10YR-7.5YR) cambic or argillic horizon 0.1 to 0.5 m thick that grades downward to a well developed, sandy, very micaceous white saprolite. Locally, the saprolite has not retained a structured characteristic, occurring rather as a "massive" grus. Saprolite thickness ranges from 1 m to greater than 10 m.

ALLUVIUM

Alluvium (Qt1, Qt2, Qt3). Alluvial deposits typically exhibit a basal, gray, moderately well stratified, subangular to rounded fluvial gravel and sand overlying bedrock and/or saprolite that fines upward to a massive, brown, fine sand and silt loam. The base of an alluvial deposit is composed of one or two sandy gravel units approximately 0.2 - 0.5 m thick that are conformably overlain by a micaceous, cross-bedded, yellow, green, gray, or brown sand approximately 0.5 m thick. The sand and gravel is, in turn, unconformably overlain by a massive brown silty loam cap approximately 0.5 m thick, which locally contains anthropogenic artifacts. The contact between the lower sand and gravel and overlying loam is locally very dark in color and is thought to represent a buried A horizon. Clast composition reflects local Piedmont sources dominated by vein quartz, quartzite, metagraywacke, and schist with minor slate, ultramafic, and felsic-intrusive lithologies. Alluvial deposits are found beneath three distinct, but thin, fill and fill-top terraces (Qt1, Qt2, Qt3) along the major streams such as Broad and Deer Creeks. Qt1 lies approximately 3 to 4 m above stream bed, Qt2 occurs 1 to 2 m above stream bed (main, active floodplain) and Qt3 is represented by active bars in and adjacent to the channel. Terraces Qt2 and Qt3 exhibit poor soil development characterized by a loamy A horizon and a silt loam cambic or argillic horizon less than 0.5 m thick. In constrast, Terrace Qt1 displays a well-developed soil exhibiting a 0.5- to 1-m thick, red (2.5YR) argillic horizon with many thick clay films and well developed, angular blocky structure (Figures 16 and 17).

Alluvial fan (Qf). Alluvial fan deposits are gray, moderately well stratified, subrounded fluvial gravels and sand overlain by a massive to well-stratified fine sandy brown loam. Large subangular boulders 0.5 to 2 m in diameter occur within and on fan surfaces. Soil development is similar to that found on terrace Qt2. Fan deposits are approximately 1 to 5 m thick and found primarily at the foot of large gaps along the southeast flank of Slate Ridge. Smaller alluvial fans are also very common at stream confluences, but are unmappable individually at a 1:24,000 scale. These smaller fans are included as alluvium/diamicton undivided in this landscape position.

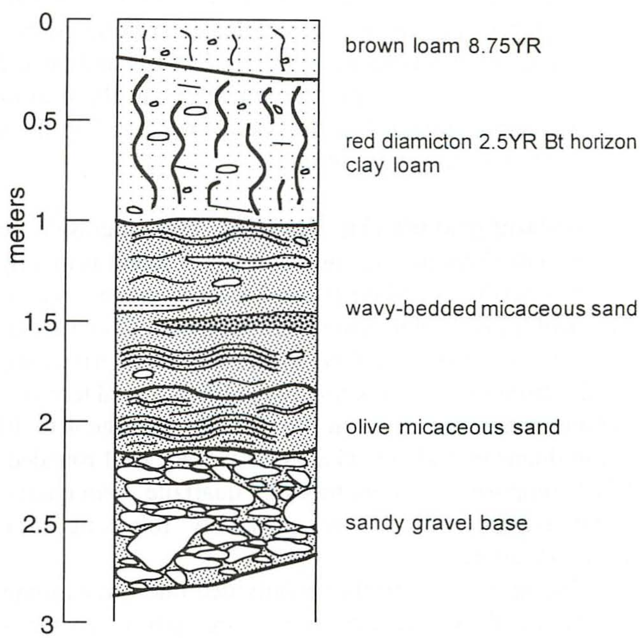

Figure 16.— Alluvium 1 (Qt1) exposed at outcrop 8-88 (See Plate 1a for location and Appendix 1 for key).

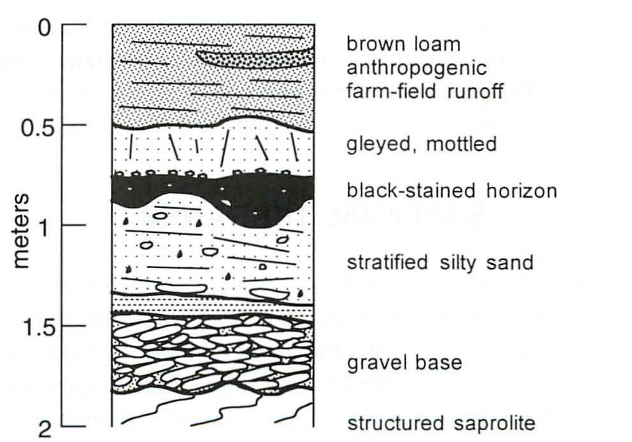

Figure 17.— Alluvium 2 (Qt2) exposed at outcrop 1-627. (See Plate 1a for location and Appendix 1 for key.)

Alluvium and diamicton deposits, undivided (Qadu). Alluvial and diamicton deposits too small to accurately map at the 1:24,000 scale are grouped as alluvium and diamicton undivided. Qadu includes both poorly to moderately well stratified fluvial sand, silt, and gravel and poorly stratified, poorly sorted diamicton in valley bottom locations along most streams and in natural and man-made drainageways on the interfluves. Deposits on the interfluve regions are dominated by fine-grained sands and silts concentrated in drainageways and behind hedgerows. The deposits are typically 1 m thick in or near perennial streams but may be as much as 3 m thick in the upland, interfluve setting.

Upland gravels (Tg, Tp, QTt). Upland gravels are single-clast-thick pebble and cobble lags found primarily on flat interfluves and on flats adjacent to major streams. The pebbles and cobbles are incorporated into the various diamicton deposits described above, but were derived originally from former, now highly modified fluvial terraces. Pebbles range in size from 2 to 20 cm, average 4 to 10 cm in diameter and are subangular to very well rounded. Clast composition is dominated by quartzite, vein quartz, metagraywacke, and schist, generally reflecting local Piedmont sources.

The gravels are further subdivided into three groups distinguished by their elevation, geographical, compositional, and textural characteristics. Tg deposits are very well rounded quartz and quartzite pebbles and cobbles along Broad Creek, Deer Creek, and the Susquehanna River at or above 100 m in elevation. Tp deposits represent a more heterolithic assemblage of subangular to subrounded pebbles and cobbles including metaconglomerate, slate, schist, and quartzite that occur on flats along the southeast flank of Slate Ridge. QTt deposits are subangular to subrounded pebbles and cobbles of diverse lithologic composition dominated by vein quartz, quartzite, and schist. The deposits occur on flats adjacent to Broad Creek and Deer Creek, at elevations less than 100 m.

SURFICIAL TERRANES

The Delta quadrangle is located in the Piedmont Upland Section of the Appalachian Piedmont Province of Fenneman (1938). The Piedmont Upland Section has been subdivided into the Chesapeake Gorges Region and the Harford Plateaus and Gorges Region following the classification system of Godfrey and Cleaves (1991) (Plate 1a, Inset Map 2). Within the Delta quadrangle these regions are further subdivided into three districts and two areas. The Harford Plateaus and Gorges Region contains the Deer Creek Area of the Gunpowder Gorge District and the Slate Ridge Area of the Norrisville Upland District. The Susquehanna Gorge District, which occupies a small portion of the northeast part of the quadrangle, is part of the Chesapeake Gorges Region.

One of the goals of the surficial mapping effort was to investigate the relationship, if any, between the distribution of surficial deposits and geomorphic landforms as defined by Godfrey and Cleaves (1991) and Cleaves and Reger (1991). The Districts and Areas have been subdivided into smaller units called Zones, which are based upon slope gradient, length, concavity and convexity (Cleaves and Reger, 1991). Because slope and relief, along with parent material, strongly influence deposit texture and composition (Pollack, 1992), map units, and the distribution of map units directly related to Zones.

The fundamental, coarsest scale mapping unit defined in this study is the surficial terrane. A surficial terrane integrates a characteristic landform, a dominant or characteristic surficial deposit, and a characteristic distribution of deposits across a previously defined landscape unit (Cleaves and Reger, 1991; also see Plate 1a, Inset Map 2). Surficial terrane boundaries closely follow lithologic and structural contacts and consequently are named for the underlying bedrock formation. The seven surficial terranes are the Bel Air Complex surficial terrane, Granitic Gneiss surficial terrane, Deer Creek Complex surficial terrane, Peters Creek surficial terrane, Ultramafic surficial terrane, Slate Ridge surficial terrane, and the Pleasant Grove surficial terrane (Plate 1a, Inset Map 3).

BEL AIR COMPLEX SURFICIAL TERRANE

The Bel Air Complex surficial terrane is a topographically high (120 to 140 m amsl), broad, flat upland, only locally dissected by headwaters of small streams such as Hopkins Branch. This terrane is almost entirely contained within the Norrisville Upland District, but a small southwestern portion extends into the Deer Creek Area (Plate 1a, Inset Maps 2 and 3). A well-developed western escarpment with up to 60 m of relief separates this terrane from the Granitic Gneiss surficial terrane.

The dominant deposit in the Bel Air Complex surficial terrane is Qrm, a reddish-brown, yellow, and red (2.5YR) residual soil and saprolite derived from dark metagabbro. The residual soil is characterized by a reddish-brown epipedon 20 - 50 cm thick overlying 0.5 to 1.5 m of a thick red, argillic horizon with thick clay films and well developed, angular blocky and prismatic structure. The soil exhibits yellow, vertically oriented "wedges" 0.3 to 1 m in length, with a silty texture that appear to have partially consumed the red argillic horizon. The wedges resemble relict cryoturbation features such as ice-wedges. Qrm also contains weathered and rounded gabbro clasts, 0.1 to 1 m in diameter, which are the remnants of corestone-weathered gabbro. Large corestones, often exceeding 1 m in diameter, occur at the surface. The saprolite ranges in color from gray to brown to reddish-brown, locally contains pods of unweathered bedrock, and ranges in thickness from 1 to 10 m. Residual soil and saprolite occur on broad, flat interfluves associated with Hn8, Hn9, and Hgd9 landforms (Plate 1a, inset maps).

The other deposit mapped in this terrane is diamicton 4 (Qd4m), a red (2.5YR) matrix and clast-supported roundstone diamicton derived from colluviated residual soil and saprolite. Clasts in Qd4m are subangular to rounded, range in diameter from 0.1 to 2 m, and are concentrated primarily as a roundstone lag near or at the surface of the deposit. Qd4m is approximately 1 m thick and overlies bedrock and/or saprolite. This roundstone diamicton with a well-developed surficial lag occurs generally on steeper slopes in incised regions associated with Hn7, Hn4, Hgd3, Hgd4, and Hgd7 landforms (Plate 1a, inset maps).

GRANITIC GNEISS SURFICIAL TERRANE

The Granitic Gneiss surficial terrane is a topographically low (60 to 115 m amsl), dissected region comprised mainly of slopes and narrow interfluves deeply incised by Deer Creek. This terrane is completely contained in the Deer Creek Area and occupies a narrow region trending north-northeast between the Deer Creek Complex surficial terrane to the west and the Bel Air Complex surficial terrane to the east (Plate 1a, inset maps).

The dominant deposit in the Granitic Gneiss surficial terrane is a light brown and tan diamicton derived from a grus-dominated saprolite (Qd2g). Qd2g is generally less than 1 m thick, and exhibits a very poorly developed soil characterized by a thin A, cambic B (both less than 0.5 m) and Cox horizon. Qd2g is dominantly clast-supported, but may be matrix-supported where it occurs at the base of a hillslope. Clasts are deeply weathered, subangular to subrounded and average 20 cm in diameter. Qd2g occurs generally along the steep slopes of incised tributaries to Deer Creek and is associated with Hgd3, Hgd4, and Hgd7 landforms (Plate 1a, inset maps).

The other deposit mapped in this surficial terrane is residual soil and saprolite (Qrg). The residual soil is characterized by a thin (less than 20 cm thick), clast-rich, tan A horizon followed by a brown (10YR) Bw or Bt horizon approximately 1 m thick. Near-surface saprolite tends to be massive, locally resembling a grus, whereas deeper saprolite contains corestones and retains foliation. Qrg occurs on gentle slopes and interfluves associated with Hgd4, and Hgd5 landforms (Plate 1a, inset maps).

ULTRAMAFIC SURFICIAL TERRANE

The Ultramafic surficial terrane is characterized by topographically high uplands (generally 120 m amsl) of both broad, sloping interfluves and steep-sloped, narrow valleys. Dissected regions occur adjacent to Deer Creek and Broad Creek, whereas the undissected areas are located in the upland interfluve between these major drainages. This terrane occupies a narrow band just north of the Bel Air Complex and Granitic Gneiss surficial terranes and occurs as isolated pods across the southern one-third of the quadrangle within the Norrisville District and the Deer Creek Area (Plate 1a, inset maps).

Three major types of deposits are developed on three distinct ultramafic lithofacies. Residual soil and saprolite (Qrm) are derived from a Bel Air Complex-type ultramafic bedrock and are characterized by a 1- to 1.5-m thick, reddish brown (5YR), dense, argillic horizon with thick clay films. The underlying saprolite strongly resembles the saprolite developed in the Bel Air Complex gabbro and ranges in thickness from less than 1 m to greater than 5 m. Qrm underlies most of ultramafic upland areas associated with Hn9, Hn8, and Hgd8 landforms (Plate 1a, inset maps).

Diamicton 2 (Qd2u) is associated with a light-colored, foliated, fine-grained Deer Creek Complex-type ultramafic bedrock. Qd2u is characterized by a tan, yellow to light brownish-red 0.5-m thick cambic or argillic B horizon with thin clay films. The underlying saprolite is generally thin and massive, grading into a dense, heavy, foliated, light-colored, locally talc-rich ultramafic bedrock. This deposit is associated with Hn8, Hn7, Hgd8, and Hgd7 landforms (Plate 1a, inset maps).

Diamicton 6 (Qd6s) is derived from weathered serpentinite bedrock and occurs near Delta, the Broad Creek Scout Camp, and the extreme southwest corner of the quadrangle (Plate 1a). Qd6s contains little matrix material, exhibits a tan, poorly developed soil less than 0.5 m thick, and supports only barrens vegetation.

Other deposits that occur in the Ultramafic surficial terrane include Qd6u, Qd4u and Qd4m. Diamicton Qd4u occurs on moderately-steep slopes associated with Hn3, Hn4, Hdg3, and Hdg4 landforms (Plate 1, inset maps). Diamicton Qd4m underlies non-incised regions adjacent to the Bel Air Complex and a small area south of Dublin Road, and an incised region around Boyd Road associated with Hn3, Hn4, Hn7, Hgd3, Hgd4, and Hgd7 landforms (Plate 1, inset maps). Diamicton 1 (Qd1) (less than 1 to 2 m thick) locally occurs beneath Qd4u and Qd4m.

DEER CREEK COMPLEX SURFICIAL TERRANE

The Deer Creek Complex surficial terrane is an intricately dissected upland of the quartzo-feldspathic component of the Deer Creek Complex occurring between 60 and 120 m amsl. This terrane straddles the boundary between the Norrisville Upland District to the north and the Deer Creek Area to the south (Plate 1a, inset maps). It occupies the southern one-third of the quadrangle bounded on the south by an Ultramafic surficial terrane and on the north by the Peters Creek surficial terrane. Bedrock dips to the northwest, and tributary streams to Broad Creek and Deer Creek follow a well-developed NNW-SSE joint set.

The primary deposit in the Deer Creek Complex surficial terrane is diamicton 3 (Qd3f), a tan, brown and reddish-brown, matrix-supported, mica-poor, silt-loam colluvium. Qd3f is derived from weathered bedrock and structured saprolite and is deposited in wedges 1 to 2 m thick. Clasts are flat, angular, slightly to heavily weathered and 0.1 to 0.5 m in diameter. The soil developed in this deposit is characterized by a 0.5-m thick argillic horizon with 10YR to 8.75YR colors and thin clay films. Qd3f commonly overlies a red, dense paleosol of diamicton 1, fine-grained deposits derived from saprolitic material (diamicton 2) and massive and structured saprolite that is slightly micaceous, very silty and green to tan in color. Qd3f dominates the western two-thirds of the Deer Creek Complex surficial terrane west of Whiteford Road, where it occurs on Hn4, Hn7, Hgd4, and Hgd7 landforms (Plate 1, inset maps).

Other deposits in the Deer Creek Complex surficial terrane include Qd2f, Qd1f, and Qd6f. Qd2f occurs throughout the Deer Creek Complex surficial terrane associated with Hn8, Hn5, Hgd8, and Hgd5 landforms. Qd1f is most prevalent in the eastern, incised part of the Deer Creek Complex surficial terrane east of Whiteford Road, where it occurs on landforms Hn2 and Hn3. Qd6f occurs on very steep slopes (landforms Hn2 and Hgd2) (Plate 1, inset maps).

PETERS CREEK SURFICIAL TERRANE

The Peters Creek surficial terrane is a topographically high (90 to 150 m amsl), intricately dissected upland with narrow, rounded interfluves and an overall slope to the southeast, away from Slate Ridge. Incised streams follow a well-developed northeast-southwest foliation and a NNW joint set. Northeast-oriented valleys are asymmetric with steep south-facing slopes and gentle north-facing slopes. The asymmetric slopes reflect the steep southeast dip of interbedded quartzites and phyllitic schist. The steep slope occurs along the quartzite bed dip-slope, while the gentle slope lies on the opposing phyllitic schist. This terrane is located almost entirely within the Norrisville Upland District except for the extreme northeastern part, which is located in the Susquehanna Gorge District (Plate 1a, inset maps). Several dissected pediments are present at the junction of the Slate Ridge and Peters Creek surficial terranes. The Peters Creek surficial terrane includes both the area underlain by the Peters Creek Formation as well as small areas underlain by the Piney Run Schist and Prettyboy Schist.

The primary deposit in the Peter Creek surficial terrane is diamicton 4 (Qd4f), a poorly sorted, mica-poor, generally matrix-supported, clast-rich sandy silt-loam colluvium approximately 1 - 2 m thick. Qd4f exhibits a poorly developed soil characterized by a brown and strong brown (10YR to 7.5YR), argillic horizon that is 0.5 m thick, has thin clay films and poor to moderate structure. Qd4f overlies bedrock, multi-colored micaceous saprolite, and Qd2f. This unit also frequently overlies Qd1f, which results in brown over red soil stratigraphy. Qd4f occurs on most slopes and sloping interfluves for the area east of Whiteford Road and Deep Creek. The deposit occurs on landforms Hn3, Hn4, Hn7, Hn8, Cs3, Cs4, and Cs8 (Plate 1, inset maps).

Other deposits associated with the Peters Creek surficial terrane include Qd6f, Qd3f, Qd2f, and a very deeply weathered, red Qd1f. Qdf2 is derived primarily from saprolite that has undergone downslope creep mass movement; however, some buried Qdf2 deposits are very well stratified and sorted and exhibit cross-stratification. Qd3f occurs on landforms Hn3, Hn2, Cs2, and Cs3. Qdf2 occurs both at the surface and at the base of diamictons 1, 3, and 4 on the broad interfluves west of Whiteford Road and intermediate flats throughout the terrane primarily on landforms Hn8, and Hn5 (Plate 1, inset maps).

SLATE RIDGE SURFICIAL TERRANE

Slate Ridge is a steep-sided, elongate ridge with a relatively flat crest. It marks the topographically highest part of the quadrangle. Elevations range from 150 to 210 m amsl. The ridge, which is breached by a water gap at Pylesville, is recognized as an Area within the Norrisville Upland District (Plate 1a, inset maps). Ridge sides are underlain by the Cardiff Conglomerate Member of the Peach Bottom Formation, whereas the core is underlain by the Slate Member of the Peach Bottom Formation. The width of the Peach Bottom Formation outcrop narrows as it approaches the Susquehanna River, and the ridge loses its prominence to the northeast. The Slate Ridge terrane also includes a small region near Burkins Road that is underlain by the Rocks Park Metaconglomerate in the southwestern part of the quadrangle (Plate 1a).

The primary deposits on the Slate Ridge surficial terrane are diamictons 4 and 5 (Qd4f, Qd5f). Qd4f is a stratified to poorly stratified steep hillslope colluvium composed of matrix-supported conglomerate and slate clasts found on Hns3 and Hns4 landforms (Plate, inset maps). This deposit has a poorly developed brown soil similar to the soil on Qd4f of the Peters Creek surficial terrane. Qd5f is a brown and red, silty, matrix-supported, clast-rich slate colluvium, typically less than 1 m thick, but locally occurring up to 1.5 m thick. The soil in Qd5f is characterized by a brown and strong brown (10YR-7.5YR) moderately well developed argillic horizon about 40 cm thick that overlies and partially reworks a buried, truncated, well-developed reddish brown (5YR) paleosol with thick clay films and well-developed soil structure. Qd5f occurs on Hns6, Hns7, Hn8, Hn7, Cs4, Cs7, and Cs8 landforms (Plate 1, inset maps).

Other deposits occurring on the Slate Ridge surficial terrane include Qf, Qd1f, Qd6f, and Qtls. Qd6f and Qtls are typically associated with very steep slopes on Cardiff Conglomerate and Rocks Park Formations and include Hns2, Hns3, and Hn3 landforms (Plate 1, inset map). Alluvial fan (Qf) deposits occur as thin aprons less than 5 m thick at the foot of southeast-facing gaps in Slate Ridge and are associated with Hn7, and Hn8 landforms (Plate 1, inset maps).

PLEASANT GROVE SURFICIAL TERRANE

The Pleasant Grove surficial terrane is a topographically high (90 to 180 m amsl), dissected upland with relatively broad, flat interfluves and a pervasive NNW foliation. This terrane lies within the Norrisville Upland District and is underlain by steeply dipping, light-colored, micaceous phyllite, phyllitic schist and quartzite. Some valleys are underlain by rather homogeneous phyllite and tend to be flat-bottomed, resembling a valley underlain by carbonate.

The primary deposit in the Pleasant Grove surficial terrane is diamicton 3 (Qd3f), a colluvium 1 m thick and derived from weathered bedrock, residuum and saprolite with few fresh clasts. The deposit is light tan, brown and yellowish in color and exhibits a poorly to moderately well developed reddish-brown soil similar to that developed on the Qd3f of the Deer Creek surficial terrane. The diamicton typically overlies weathered bedrock, saprolite, or Qd2f 1 to 5 m thick. Less frequently it overlies and truncates the buried soil of Qd1f. Qd3f occurs on moderate slopes away from deeply incised drainages associated with Hn4 landforms (Plate 1, insets).

Other deposits that occur on the Pleasant Grove surficial terrane include Qd2f, Qd4f, Qd6f, and Qrs. Qd2f underlies most uplands, thin discontinuous interfluves, intermediate flats and very gentle slopes associated with Hn5, Hn7, and Hn8 landforms. Qd4f underlies both steep slopes in the vicinity of major drainages, such as Scott Run, and more schistose bedrock associated with Hn3 and Hn4 landforms. Qd6f occurs on very steep slopes associated with Hn2 landforms, and underlies the broad interfluve areas associated with Hn8 landforms (Plate 1, inset maps).

AGE AND CORRELATION OF SURFICIAL DEPOSITS

The age of Delta quadrangle surficial deposits are established from field stratigraphic relations and relative soil development, combined with the regional geologic setting. Except for units Qt3 and Qadu, all age assignments are relative rather than absolute. Units Qt3 and Qadu contain human agricultural artifacts, which demonstrate that they are recent, anthropogenic deposits 300 years old or less. Small amounts of charcoal have been found in alluvial unit Qt2 and, to a much lesser extent, in diamicton unit Qd4f but have not been submitted for analysis because of small sample size and likely contamination from young material such as rootlets.

ALLUVIUMS

Alluvium underlies three distinct inset terraces along Broad Creek and Deer Creek. Qt2 and Qt3 are also inset into diamictons where the two deposits are in direct contact (Figure 18), whereas Qt1 is typically overlain unconformably by a younger diamicton such as Qd4f. Previous investigations of several Piedmont streams including Deer Creek determined that the coarse-grained portion of Qt2 was deposited prior to 1730, or pre-agricultural development of the uplands, while Qt3 and the loamy cap of Qt2 were deposited by aggradational events related to agriculture (Jacobson and Coleman, 1986). The relative ages of alluviums Qt1 and Qt2 are derived from soil morphologic criteria and discussed below in conjunction with diamicton soil stratigraphy.

DIAMICTONS

Field stratigraphic relations clearly demonstrate that most of the diamictons are composed of multiple depositional units, strongly influenced by cryoturbation and bioturbation processes, and separated by erosional unconformities (Figures 6 and 19; Pollack, 1992). Diamictons are genetically interpreted as colluvium based on various textural characteristics including clasts oriented subparallel to the local slope, poor to moderate stratification, sharp erosional bases, and general lobate form. These characteristics are consistent with well known colluvial deposits of the Valley and Ridge (Ciolkosz and others, 1990; Graham and others, 1990; Gardner and others, 1991).

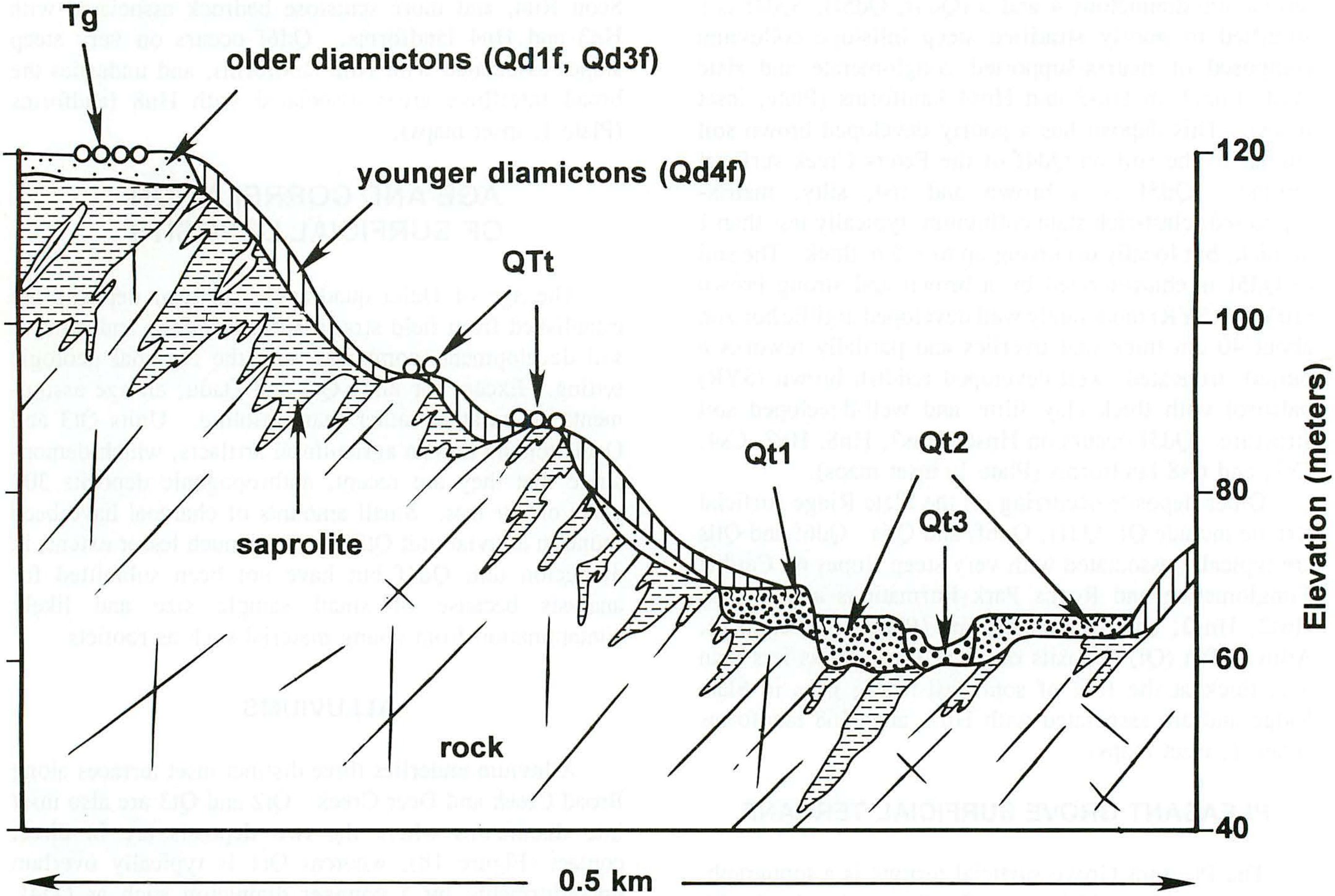

Figure 18.— Schematic cross section showing upland gravels and alluvial terrace stratigraphic relations.

Field soil morphologic properties chosen to characterize colluvial diamicton soil-stratigraphic units are soil color, texture, structure, clay film development, and thickness of argillic horizon (Birkeland, 1984). Soil development is a function of climate, organisms, parent material, relief and time (Jenny, 1941). Soils also reflect the relative stability of a landscape. We assume that field morphologic properties primarily represent cumulative, unidirectional development and that over long periods the soil profile strongly reflects the effects of climate and age.

The field soil morphologic criteria define three characteristic profiles or pedons for the diamictons: (1) a brownish yellow and brown (10YR - 8.75YR) loam and silt loam with a cambic B and/or weakly developed argillic horizon with thin clay films and poor soil structure (Table 2); (2) a strong brown and reddish brown (7.5YR - 5YR) silt loam that exhibits an argillic horizon about 0.5 m thick and has thin clay films and moderately well developed soil structure (Table 3); and (3) a red (2.5YR - 10YR) clay loam and silt loam that exhibit an argillic horizon approximately 0.5 to 2 m thick, with thick clay films and well-developed soil structure (Table 4).

The pedons described for Piedmont surficial materials in the Delta quadrangle are morphologically similar to soils developed in colluvial diamictons of the Valley and Ridge Physiographic Province and to some of the soils developed in tills along the glacial border 200 km north of the Piedmont. There remains disagreement on the precise correlation and age of tills along the glacial border. Attempts to match till stratigraphy with the marine oxygen isotope record (Shackleton and others, 1984; Braun, 1989; Ridge and others, 1992; Gardner and others, 1993; 1994) suggest that the three most extensive tills along the glacial boundary in Pennsylvania and New Jersey correlate to the late Wisconsinan (Woodfordian) glaciation (isotope stage 2; 35 - 18 ka), Illinoian glaciation (isotope stage 6; 135 - 155 ka), and a pre-Illinoian glaciation(s) (isotope stages 12, 16, or 22; greater than 200 ka). The soil developed in tills, especially the stratigraphically older tills, are both cumulic and polygenetic, thus demonstrating the effects of variable climates and time on soil genesis.

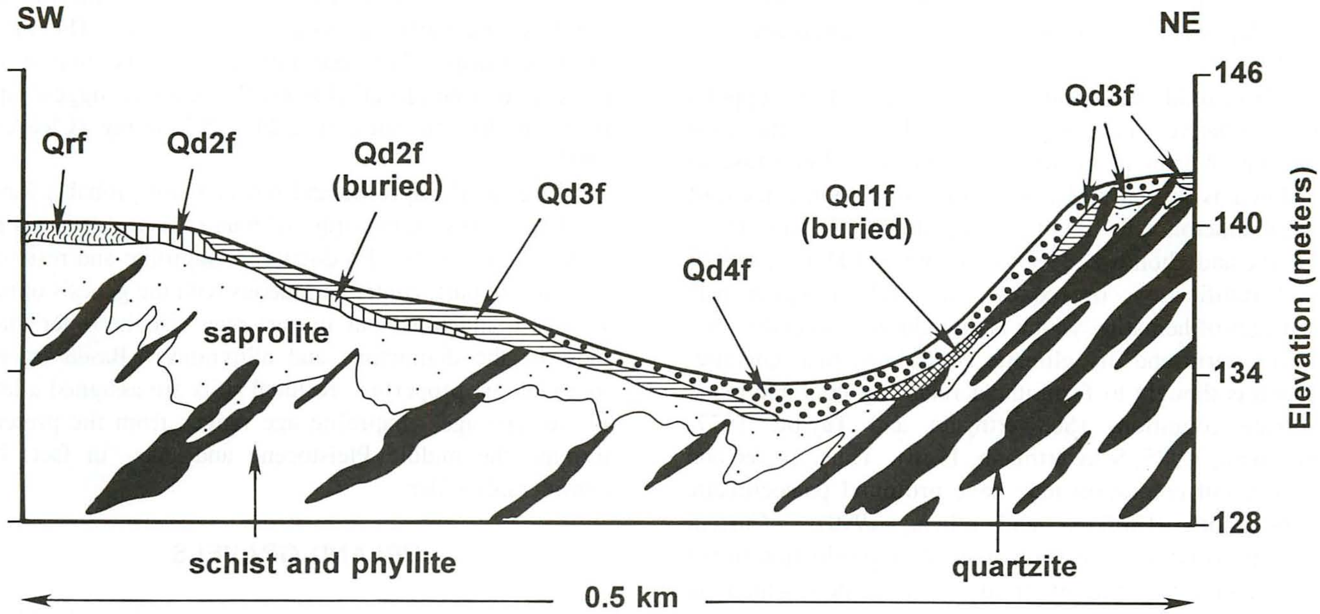

Figure 19.—Schematic diagram showing stratigraphic relationships of diamictons, residual soil, saprolite, and bedrock for the Peters Creek surficial terrane.

Soils developed in Woodfordian tills are brown (10YR-7.5YR) loams and silt loams with cambic B horizons about 0.5 m thick (Levine and Ciolkosz, 1983; Marchand and others, 1978; Marchand and Crowl, 1991). The stratigraphically youngest Valley and Ridge colluviums (Hoover and Ciolkosz, 1988; Ciolkosz and others, 1990; Marchand and Crowl, 1991; Gardner and others, 1991) as well as soils developed in diamictons of the Virginia Piedmont (Graham and others, 1990) exhibit soil development characteristics similar to Woodfordian tills. The age of brown-colored diamictons in West Virginia has been radiometrically dated at 21 - 28 ka (Jordan and others, 1987). In addition, thermoluminesence dates of 12 to 18 ka have been obtained from loess directly overlying brown colluvium in New York (Snyder, 1988; Snyder and Bryant, 1992). The relative amount of soil development in the brown colluvium and tills is correlated to Delta pedon 1 (Table 2).

Soils developed in tills initially described as Altonian (early Wisconsinan) (Levine and Ciolkosz, 1983) but now interpreted to be Illinoian (Ridge and others, 1990) are strong brown, reddish brown and, and yellowish red (7.5YR-5YR) silt loams with cambic B horizons and 0.5-m thick argillic horizons (Marchand and others, 1978). Paleosols in buried colluviums in the Valley and Ridge and Allegheny Plateau typically exhibit this level of soil development (Waltman, 1985; Ciolkosz and others, 1990; Gardner and others, 1991; Graham and others, 1990). Similar reddish-brown colluviums have been found to bury peats in South Carolina (Eargle, 1977). The peat is radiocarbon dead (greater than 55 ka; Whitehead and Barghoon, 1962) but has yielded pollen with a distinct Pleistocene cold-climate flora (Cain, 1940). The relative degree of soil development in the reddish-brown colluviums is correlated to Delta pedon 2 Table 3).

Soils developed in pre-Illinoian tills are red (2.5YR) silt loams and silty clay loams and have thick, well-developed argillic horizons approximately 1 to 1.5 m thick (Cunningham and Ciolkosz, 1984; Levine and Ciolkosz, 1983; Marchand and others, 1978). The stratigraphically oldest buried colluviums in the Valley and Ridge typically exhibit this level of soil development (Ciolkosz and others, 1990). The relative amount of soil development in the red tills and colluviums correlates to Delta pedon 3 (Table 4).

Comparison of Delta pedons 1, 2 and 3 to the existing glacial and colluvial chronosequences helps provide relative age constraints for the numerous diamictons. Pedon 3, a soil-stratigraphic unit always associated with metagabbro diamicton Qd4m, felsic diamicton Qd1f, and alluvium Qt1, exhibits a degree of soil development consistent with deposits of pre-Illinoian, middle Pleistocene age (greater than 200 ka). Pedon 2, typically associated with felsic diamictons Qd3f, Qd4f and Qd5f, exhibits evidence of cryoturbation and a degree of soil development consistent with deposits of late Pleistocene (Illinoian) age (18 - 135 ka). Pedon 1, typically associated with felsic diamictons Qd2f, Qd4f, and Qd6f, mafic diamictons Qd6u, Qd6s, Qd4u, Qd2u, and Qd2g and alluvium Qt2, exhibits a degree of soil development consistent with deposits of late Pleistocene (Wisconsinan) age (35 - 18 ka).

Iron oxide mineralogy in the soil profiles supports these relative age assignments. Typically, the total amount of iron in brown diamicton soils like those of pedon 1 is virtually identical to the total iron content of red diamicton soils like those of pedon 3 (Hoover, 1983; Levine and Ciolkosz, 1983; Ciolkosz and Dobos, 1990). Soil rubification, or redness, may reflect higher percentages of hematite, which is thought to form under relatively warm and dry climatic conditions, than goethite, which is thought to form under relatively cool and moist climate conditions (Schwertmann and Taylor, 1977; Waltman, 1985; Schwertmann, 1988). Thus, the red and brown soil coloration may have profound paleoclimatic implications (Ciolkosz and others, 1990). Current climatic conditions may favor goethite production in the Piedmont weathering environment, consistent with field evidence that illustrates that all of the stratigraphically youngest diamictons are brown, yellow, and orange in color. Bright red colors are associated only with the buried diamictons which stratigraphically are pre-Woodfordian and presumably were exposed to the most recent interglacial (Sangamon) and older interglacial climates thought to be warmer than the present (Webb, 1988; Groot, 1991).

RESIDUAL MATERIALS

The age of residual materials, specifically residual soil and structured saprolite, is more poorly constrained than the age of diamictons and alluvium. Geochemical mass-balance data obtained from a continuous core of quartzo-feldspathic and mafic lithologies in the Virginia Piedmont suggests that the rate of weathering bedrock into saprolite is roughly the same as the rate of converting saprolite into residual soil (Pavich, 1986; Pavich and others, 1989). The residual soils however are not excessively thick (usually about 1 m thick) and exhibit moderately well developed profiles similar to Pedon 2, which suggests that they have not had a very long residence time at the surface and are constantly undergoing loss of mass due to erosion. Cosmogenic ^{10}Be inventories within the residual soil and saprolite suggest a soil-saprolite residence time of about 0.8 - 1.6 my and a surficial erosion rate of 4 - 5 m/my (Pavich, 1989).

Steady-state saprolite production and erosion have limited validity because they do not account for changes in processes and rates of weathering. Saprolitization rates inferred from a monitored Piedmont watershed in Maryland range from 4.18 (Cleaves and others, 1970) to 48 m/my (Cleaves, 1989). These rates are highly dependent on climatically linked variables such as temperature, moisture and partial pressure of soil CO_2. The most recent estimates that take into account the impact of periglacial - interglacial climatic fluctuations suggest saprolite production rates of 2.24 - 5.3 m/my (Cleaves, 1993).

In general, saprolite and residual soil probably have residence times on the order of hundreds of thousands to a few million years. Production of saprolite and residual soils are, in part, contemporaneous with the genesis of the various diamictons, but in part may also be older than most of the diamictons and alluviums. Based on its morphologic properties, residual soils are assigned a late Pleistocene age. Saprolite age ranges from the present through the middle Pleistocene and may, in fact, be considerably older.

UPLAND GRAVELS

Upland gravels occur as scattered pebbles and cobbles within diamictons on relatively broad, flat interfluves. Clast roundness, composition and position in the landscape distinguish between an upland gravel (Tg), terrace gravel (QTt) or pediment gravel (Tp). In the Delta quadrangle, upland gravels and terrace gravels tend to be well rounded and occur on interfluves near streams. In contrast, pediment gravels are subangular and subrounded, reflect local lithologies, and occupy wide interfluves along the southeast flank of Slate Ridge. Deposition of various fluvial upland gravel deposits along the Fall Zone south of the Delta quadrangle was strongly influenced by base level changes attributed to both isostatic and eustatic mechanisms (Pazzaglia and Gardner, 1992; Pazzaglia and Gardner, 1994). Ages assigned to the upland gravels on the Fall Zone, inferred from petrographic correlations to dated basinward Coastal Plain deposits, range from late Miocene for deposits 120 m amsl (Tg) to Pliocene for deposits 35 m amsl (QTt) and early Pleistocene for deposits 20 m amsl (QTt) (Pazzaglia, 1993). The ages established for Fall Zone fluvial deposits can be projected into the Piedmont along fluvial terraces of the Susquehanna River and its tributaries. The upland gravels in the Delta quadrangle above 120 m amsl in elevation are thought to have originated from fluvial terraces deposited in the middle to late Miocene (Tg) during Bryn Mawr and Brandywine Formation deposition on the Fall Zone. Similarly, deposits 45 - 90 m amsl (QTt) are thought to have originated from terraces deposited in the Pliocene and early Pleistocene. Upland gravel deposits less than 20 m (QTt) above Broad Creek are locally stratified and may be as young as middle Pleistocene.

Table 2.— Pedon, brown soil developed in Qd4f colluvium on the Peters Creek Quartzite.

Horizon/ Boundaries	Depth (cm)	Color Moist/Wet	Texture >2%	Structure	Clay Films
Ap	0-21	10YR4/3	loam	1,2msbk to 1fpl	—
a s					
Bw/B1t	21-68	7.5YR5/6 7.5YR4/6	silt loam	2mabk	1npo,pf
c w					
B2t	68-95	9YR5/4 10YR5/4	silt loam 10-20%	1,2msbk	v1npf
c w					
Bw	95-110	8.75YR5/8 8.75YR5/8	loam 10%	sg to 1fsbk	—
g w					
B2t	110-130	9YR5/4 10YR5/4	silt loam 10-20%	1,2msbk	v1npf
a w					
2Cox1	130-250	variegated 10YR-7.5 YR	loam 30%	1mpl	—
c w					
2Cpx2	250+	variegated 10YR-7.5YR	loam sand <5%	sg	—

Symbols (Soil Survey Staff, 1975)

1) A = mineral horizon, B = illuvial horizon, C = weathered parent material, R = rock; w = weak, t = illuvial clay accumulation, b = buried, ox = oxidized, x = fragipan.
2) Boundaries: a = abrupt, c = clear, g = gradual, d = diffuse, s = smooth, w = wavy, i = irregular, b = broken.
3) Structure: 1 = weak structure, 2 = moderate structure, 3= strong structure; vf = very, f = fine, m = medium, c = coarse, vc = very coarse, sg = single grain, sbk = subangular blocky, abk = angular blocky, pl = platy, pr = prismatic, m = massive.
4) Clay Films: v1 = few, 1 = few, 2 = common discontinuous, 3 = many, continuous; n = thin, mk = moderately thick, k = thick, po = in pores, pf = on ped faces, br = bridges.

Table 3a.— Pedon 2, brownish-red soil developed in residual material on the Pleasant Grove Phyllite.

Horizon/ Boundaries	Depth (cm)	Color Moist/Wet	Texture >2%	Structure	Clay Films
Ap	0-28	10YR4/4	silt	2mpr	—
a s					
B1t	28-40	7.5YR5/6 7.5YR5/6	silt loam <2%	2msbk	2npf
c w					
B2t	40-70	5YR5/8 7.5YR6/8	silt loam <2%	2msbk	2mkpf
c w					
Cox	70+	variegated 10YR-5YR	sandy loam <2%	sg	—

Symbols (Soil Survey Staff, 1975); see Table 2 or 4 for key to symbols.

Table 3b.— Pedon 1 overlying Pedon 2. Brown over brownish-red soil developed in colluvium on the Peters Creek Quartzite.

Horizon/ Boundaries	Depth (cm)	Color Moist/Wet	Texture >2%	Structure	Clay Films
Ap	0-24	10YR4/3	loam	1,2msbk to 1fpl	—
a s					
B1t	24-56	5YR5/8 7.5YR5/6	clay loam	2m,csbk	2n,mkpo,pf
c s					
B2tb	56-62	5YR4/6 5YR4/6	silt loam 5%	1fsbk	v1npf
c s					
2Btb	62-95	7.5YR6/6 7.5YR5/6	loam 20-30%	1m,csbk	—
c w					
2Cox	95+	variegated 10YR-5YR	loamy sand <5%	sg	—

Symbols (Soil Survey Staff, 1975); see Table 2 or 4 for key to symbols.

Table 4.— Pedon 3, red soil developed in colluvium on the Peters Creek Quartzite.

Horizon/ Boundaries	Depth (cm)	Color Moist/Wet	Texture >2%	Structure	Clay Films
Pedon 1	0-123				
2Btb	123-150	7.5YR5/6 8.75YR5/6	clay loam 30%	2msbk	2n,mkpf
a w					
3B1tb	150-239	5YR5/8 7.5YR5/6	silt loam loam 30%	2msbk	2mkpf
g s					
3B2tb	239-310	2.5YR4/8 2.50YR4/8	clay loam loam 30%	2msbk to 1fpl	2mkpf
c s					
4B1tb	310-400	2.5YR5 to 5YR	sandy clay loam 20%	1mpl	1npf
g s					
4B2tb	400+	7.5YR to 2.5YR	sandy loam loam 20%	2cpl	3npf

Symbols (Soil Survey Staff, 1975)

1) A = mineral horizon, B = illuvial horizon, C = weathered parent material, R = rock; w = weak, t = illuvial clay accumulation, b = buried, ox = oxidized, x = fragipan.
2) Boundaries: a = abrupt, c = clear, g = gradual, d = diffuse, s = smooth, w = wavy, i = irregular, b = broken.
3) Structure: 1 = weak structure, 2 = moderate structure, 3= strong structure; vf = very, f = fine, m = medium, c = coarse, vc = very coarse, sg = single grain, sbk = subangular blocky, abk = angular blocky, pl = platy, pr = prismatic, m = massive.
4) Clay Films: v1 = few, 1 = few, 2 = common discontinuous, 3 = many, continuous; n = thin, mk = moderately thick, k = thick, po = in pores, pf = on ped faces, br = bridges.

LANDSCAPE EVOLUTION

Delta quadrangle physiography and surficial stratigraphy are generally representative of the Maryland and Pennsylvania Piedmont and hold many of the keys to understanding the late Cenozoic geologic history of this region. Prior to this research, the Piedmont was traditionally viewed as an old landscape, composed of fluvially beveled geomorphic surfaces (peneplains) (Davis, 1889; Campbell, 1933; Knopf, 1924) and mantled by a thick sequence of residual materials. Others refuted the genetic implications of peneplains and described the Piedmont landscape in terms of a dynamic equilibrium established between surficial processes and lithology (Hack, 1960; 1975). The results presented herein support some of the traditional views but also suggest alternative interpretations regarding the effects of base level and climate as well as the influence of bedrock lithology and structure on the geomorphic evolution of the Piedmont.

SURFICIAL PROCESSES

Five critical observations help reconstruct the surficial processes that have shaped the Piedmont landscape: (1) streams are incised into bedrock; (2) the landscape is characterized by polymorphic valley forms (Figure 2); (3) the dominant surficial deposit is a thin, but pervasive colluvial diamicton; (4) there have been major climatic fluctuations over the past 2 my related to the glacial - interglacial cycle; and (5) there have been major base level changes throughout the late Tertiary and Quaternary attributed to eustatic fluctuations and isostatic uplift (Pazzaglia and Gardner, 1992; Pazzaglia and Gardner, 1994). Distinctive polymorphic valley profiles (Figure 2) clearly reflect the effects of long-term, post-Miocene regional base level fall (Haq and others, 1987). Superimposed on this incised landscape are numerous colluvial diamictons indicative of extensive mass-wasting, believed to have been active under a different climatic regime than now present. The interaction between base level lowering and climatic changes has combined to produce the modern Piedmont landscape.

Anthropogenic Processes. Anthropogenic processes that impact the current landscape include upland stream incision as well as siltation behind debris dams and man-made dams. Of particular interest is the stream incision in the upland setting. The headwaters of many first-order tributaries as well as the tributaries themselves are incised about 1 to 2 m into their own alluvium or residual material. Historical accounts and reconnaissance air photo interpretation reveal that this incision occurred very recently, probably within the last 25 years. The incision does not appear to be related to an internal intrinsic threshold mechanism like that known to exist with arroyos in a semi-arid environment (Schumm, 1977) because streams across the entire quadrangle apparently started incising at about the same time. Discounting the effects of a small, recent climatic change, incision may coincide with increased runoff and increased peak runoff during storms. These new runoff conditions are caused, in part, by the paving of roads and driveways associated with housing developments beginning approximately 25 years ago. Additionally, conversion of agricultural fields from corn cultivation into grazing, removes a roughness element, generating more Hortonian overland flow during precipitation events and stream incision.

In contrast, anthropogenic effects attributed to agriculture are recorded by local aggradation of eroded soil in the uplands. Despite recent efforts to minimize soil loss, recent alluvial deposits (Qt3), the overbank, loamy portion of Qt2, debris dam deposits (Qadu) and thick (3+ m) accumulation of fine-grained material behind hedgerows (Qadu), all illustrate increased hillslope denudation and transport of relatively fine-grained sediment by fluvial processes.

Hillslope Processes. Colluvium genesis and downslope transport are favored by mechanical weathering and mass movement processes. These processes often are associated with cold, periglacial climates characteristic of glacial stages in the Pleistocene (Gardner and others, 1991; Ridge and others, 1992) or significant climatic changes from cool and moist to warm and dry conditions (Reneau and others, 1991) has also been demonstrated for landscapes underlain by folded metamorphic lithologies in tropical regions (Wells and others, 1990). Features typically associated with permafrost conditions have been identified in the Piedmont colluviums as well as in residual soils developed in the metagabbro. These periglacial features include vertically oriented frost wedges, sediment pots developed in fine-grained silty material, and large-scale roll structures. The periglacial features are always found immediately below the present ground surface or buried immediately below the sharp erosional base of an overlying unit (Figure 7). Recognition of buried periglacial features strongly suggests multiple periods of permafrost conditions and genesis of colluvial lobes.

Soil stratigraphic relations are also consistent with multiple episodes of colluviation and downslope transport. At least three episodes of colluviation, each followed by relative surface stability and soil development, are illustrated by three distinct pedons in the Delta quadrangle. However, it remains possible that more than three periods of colluviation have occurred but cannot be distinguished with the available sedimentologic and soil stratigraphic data. Correlation of the Piedmont colluvial soil stratigraphy to soil chronosequences developed in similar deposits throughout the central Appalachians (Ciolkosz and others, 1990; Graham and others, 1990; Gardner and others, 1991; Ridge and others, 1992) suggests one or more colluviation episodes in the middle Pleistocene, a colluviation event associated with the periglacial climate accompanying the Illinoian glaciation (late middle Pleistocene), and a colluviation event associated with the periglacial climate accompanying the late Wisconsinan (Woodfordian) glaciation (late Pleistocene).

Bedrock lithology strongly influences colluvial diamicton composition and texture. For example, on the Peters Creek surficial terrane, diamictons near elongated septa of bedrock that are at or very near the surface tend to be the most clast-rich and clast-supported. Colluvial diamictons in the Pleasant Grove, Granitic Gneiss and Bel Air Complex surficial terranes tend to be clast-poor, reflecting the abundance of residual material in these areas. Colluviums exhibit sedimentological, compositional and textural characteristics consistent with short, local transport. Colluvial stratigraphy reconstructed from pits dug at various locations on a typical concavo-convex hillslope in an upland setting suggest no more than a few meters to a few tens of meters of transport.

The thin, but ubiquitous colluvial mantle on the Piedmont landscape attests to past periods of hillslope instability and downslope transport processes (Ridge and others, 1992). Current, active mass movement is much more difficult to recognize in the modern landscape. In stands of natural forest cover, trees typically grow with straight trunks even on steep hillslopes, and streams remain below capacity. Nevertheless, poor soil, particularly exhibited by pedon 1 in Qd3 and Qd4, suggests some amount of recent mass movement processes.

Tree throw has been recognized as a mechanism for mass movement on forested hillslopes in humid-temperate regions. Bormann and Likens (1979) suggest significant vertical soil turnover over a period of hundreds of years by tree throw mechanisms. The longevity of tree throw mounds created by this process is affected by several factors, including soil texture, forest litter, vegetative cover, abundance of large armoring clasts, and climate (Schaetzl and Follmer, 1990). Piedmont colluvial diamictons contain large armoring clasts that increase the longevity of tree-throw mounds and vertical soil turnover to the order of thousands of years. The rate of tree throw does not appear great enough to cause widespread colluvial development and transport. Rather, tree throw appears to be an effective process of homogenizing the top meter of a soil profile, resulting in the observed relatively poor soil structure and ill-defined soil horizons.

Composite upland hillslope colluvial stratigraphy for a landscape underlain by felsic metasediments illustrates the type and amount of material moved across Piedmont surfaces by colluvial processes during past periods (Figure 19). Typically, saprolite-derived material (Qd2f) with a slope-parallel fabric attributed to creep unconformably overlies undeformed saprolite and/or weathered bedrock. Locally, Qd2f contains a fine-grained, laminated, sometimes cross-stratified facies attributed to fluvial and or sheet-wash deposition of materials derived from residuum. Unit Qd2f is then unconformably overlain by the various younger colluvial diamictons such as Qd3f and Qd4f. The composite stratigraphy exhibits a general coarsening-up profile interpreted as reflecting an unroofing of the interfluves. Initially, the landscape may have been dominated by residual materials, now represented in part by Qd2f and fined-grained portion of Qd1f. As more saprolitic material was stripped, weathered and fresh bedrock pinnacles and septa became exposed at the surface, and fresh and weathered rock clasts were incorporated into the younger, coarse-grained colluvial deposits.

Colluvial stratigraphy in the upland argues for a dynamic surface undergoing modification by mass movement processes. Over time, the colluvial deposits in the upland have partly filled in pre-existing topographic lows. It is hypothesized that prior to widespread colluviation, the upland was dominated by residual materials, but exhibited more local relief than present. Pleistocene colluviation has worked to fill in that local relief thereby creating a smoother upland surface.

Fluvial Processes. The lack of thick, extensive alluvial deposits reflect long-term incision of the Piedmont landscape. Alluvial deposits occur primarily in the upper portions of a drainage basin, above the prominent profile knickpoint (Figure 2). Currently, modern alluvial deposits (Qt3) are inset into all older alluviums and hillslope diamictons, illustrating that streams are under capacity in terms of sediment load. The thin, fill terraces Qt1 and Qt2 suggest that periodically in the past, streams aggraded in response to higher sediment loads. Soil stratigraphic and morphologic similarities between the alluvial and hillslope diamictons suggest aggradation during periods of active colluviation. It is unclear whether the thin (≈ 1 - 3 m) terraces reflect minor aggradation attributed to small increases in sediment supply and similar discharge with respect to the present, or to large increases in both sediment supply and discharge with respect to the present. In either case, field evidence suggests that the Piedmont did not experience a protracted period of fluvial aggradation from the late Tertiary to present. Older alluvial deposits such as Tg, Tp, and Qtg suggest that strath-terrace development and rapid incision predominated in the late Tertiary.

By the late middle Pleistocene, the approximate age of terrace Qt1, most of the present incision had been accomplished. Synchronous hillslope colluviation and thin fluvial aggradation are hypothesized as reflecting regional climatic modulation of an otherwise base level sensitive landscape.

The distribution of the upland gravels on the Delta landscape, combined with relative ages and distribution of colluvium, suggest that the late Tertiary landscape was shaped predominantly by fluvial processes, rather than the combination of hillslope and fluvial processes dominant in the Quaternary. Tertiary upland gravel deposits (Tg and Tp) occur south of Slate Ridge and on upland interfluves immediately adjacent to Broad Creek and Deer Creek. The distribution of pediment gravels suggests that Slate Ridge was a positive relief feature (monadnock ?) in late(?) Tertiary time, and that at least a part of a late Tertiary upland surface remains preserved on the modern upland landscape. For example, gravel deposits (Tg) project through the water gap incised by Broad Creek into the southwestern nose of Slate Ridge. Modern relief between the ridge crest and adjacent upland gravel deposits approaches 60 meters, and may have been greater in the late Tertiary. Just as Slate Ridge is currently a topographic high, it probably was also a high ridge in the late Tertiary prior to significant late Tertiary-Quaternary base level fall. The distribution of upland gravels indicates that both Broad Creek and Deer Creek have remained essentially in the same place throughout the Pliocene and Quaternary. Subsequent upland gravel deposits (QTt) and thin fill terraces (Qt1, Qt2 and Qt3) are inset into the valleys of both creeks, and are evidence of incision of the streams into the landscape (Figure 18, Plate 1a, 1b).

In contrast, the occurrence and distribution of the various diamictons, particularly their stratigraphic relationships on both the gentle and steep parts of the valley landscapes (Figures 18 and 19), suggest that: (1) most stream incision (dissection) was probably accomplished by middle Pleistocene time; and (2) upland gathering areas (hollows) and first- and second-order stream valleys are, at present, only partly filled with colluvium (Plate 1a and 1b, Figures 18 and 19). If Quaternary hillslope processes completely dominated fluvial processes, the hollows first, and possibly second-order valleys, should be completely filled with colluvium. To the extent that colluvium from the upland areas reaches the slopes and moves into the stream valleys, an efficient fluvial transport mechanism exists to move material through the fluvial system and deposit it elsewhere outside the quadrangle.

GEOMORPHIC HISTORY

We hypothesize that the late Cretaceous to late Tertiary Piedmont was a landscape of moderate relief, somewhat less than present (Cleaves and Costa, 1979). Most of the Tertiary relief occurred in and near stream valleys. Streams were incised into bedrock in response to progressive base level fall attributed to slow, steady isostatic uplift (Pazzaglia and Gardner, 1992; 1993). Climatic conditions, as indicated by palynofloras (Groot, 1991; Heusser and King, 1988; Webb, 1988), were favorable for the formation of deep weathering profiles (residual soils) and saprolite on the interfluves. Hillslopes may have supported thin colluvial deposits derived from saprolite and other residual materials. Landscape lowering proceeded at a relatively slow pace modulated by the chemical-dominated weathering environment.

Accelerated base level fall was initiated in the late Tertiary in response to both continued eustatic fall (Haq and others, 1987) and isostatic uplift of the Piedmont (Pazzaglia and Gardner, 1992; 1994). Fluvial systems responded by accelerated incision of master streams into bedrock creating a lower V-shaped valley component downstream from generally open concavo-convex drainage basins (Figure 2). Fluvial incision added potential energy to the hillslope system in the form of steeper slopes, but because hillslope processes respond more slowly than fluvial processes, the hillslopes lagged temporally behind the streams in adjusting to the new base level conditions.

Continued climatic degradation in the late Tertiary culminated with northern hemisphere glaciation in the late Pliocene and the introduction of colder, periglacial climatic conditions and surficial processes to the Piedmont. Under these new climatic conditions, which may have resulted in a landscape with a very limited vegetative cover (Delcourt and Delcourt, 1981), denudational processes were accelerated as saprolite and weathered bedrock were partially stripped from the rolling uplands and deposited in colluvial wedges (diamictons 1 and 2). Residual materials were completely removed from some areas, exposing the bedrock. The exposed bedrock supplied clasts for coarse-grained colluvial wedges now locally preserved as diamicton 1. Subsequent climatic fluctuations between warm interglacial and cold periglacial resulted in more mass-movement, which produced coarse-grained colluvial lobes, reworked older colluvial deposits, and generated the deposits now recognized as diamictons 3, 4, 5, and 6.

This hypothesis of landform evolution suggests that base level fall triggered incision of the major rivers and streams, resulting in steep hillslopes and exposed bedrock, the source of much of the coarse-grained colluvium. However, climatic fluctuations caused the conditions that mobilized the material and moved it across the landscape, thereby generating widespread colluvial deposits. Just as the stream valleys exhibit a polygenetic history, the uplands also exhibit a polygenetic character with an earlier Tertiary history of chemical weathering and fluvial processes dominated by strath genesis, and a late Tertiary-Quaternary history dominated by accelerated fluvial incision and periodic, periglacially induced colluviation.

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APPENDIX

Appendix 1.— Explanation of Symbols Used in Figures 4 to 17

Appendix 2.— Soil Profile Descriptions (descriptions by Frank J. Pazzaglia)

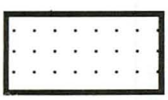
Appendix 1.— Explanation of Symbols Used in Figures 4 to 17.
(Symbols are often superimposed to show more than one morphologic feature.)

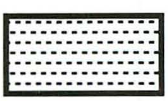

bedrock and weathered bedrock clasts


gravelly sand and sandy gravel


sand and silty sand

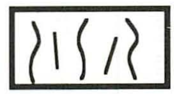

silty, clayey loam

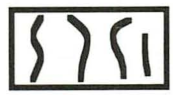

loam

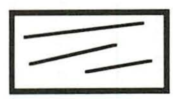

silty clay


dark, organic-rich sand, silt, or clay

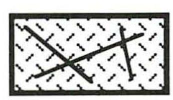

organic material and humus

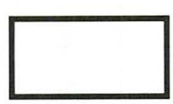

poorly to moderately well-developed soil structure


well-developed soil structure


foliation, schistosity or linearity


mafic and ultramafic lithologies


granitic lithologies


felsic lithologies

Appendix 2.— Soil Profile Descriptions

(Descriptions by Frank J. Pazzaglia)

Explanation of Symbols

Horizons	**A** = mineral horizon; **B** = illuvial horizon; **C** = weathered parent material; **R** = rock **w** = weak; **t** = illuvial clay accumulation (argillic); **b** = buried; **ox** = oxidized; **'** = continuation of interrupted upper horizon
Boundaries	**a** = abrupt; **c** = clear; **g** = gradual; **d** = diffuse; **s** = smooth; **w** = wavy; **i** = irregular; **b** = broken
Structure	**1** = weak structure; **2** = moderate structure; **3** = strong structure **vf** = very; **f** = fine; **m** = medium; **c** = coarse; **vc** = very coarse **sg** = single grain; **sbk** = subangular blocky; **abk** = angular blocky; **pl** = platy; **pr** = prismatic; **m** = massive
Consistency	*Wet Soil*: **so** = nonsticky; **ss** = slightly sticky; **s** = sticky; **po** = nonplastic; **ps** = slightly plastic; **p** = plastic *Moist Soil*: **lo** = loose; **vfr** = very friable; **fr** = friable; **fi** = firm; **vfi** = very firm *Dry Soil*: **lo** = loose; **s** = soft; **sh** = slightly hard; **h** = hard; **vh** = very hard
Clay Films	**v1** = very few; **1** = few; **2** = common; discontinuous; **3** = many; continuous **n** = thin; **mk** = moderately thick; **k** = thick **po** = in pores; **pf** = on ped faces; **br** = bridges
Roots	**1** = few; **2** = common; **3** = many **vf** = very fine (<1mm); **f** = fine (1-2mm); **m** = medium (2-5mm); **co** = coarse (>5mm)
Pores	**1** = few; **2** = common; **3** = many; **vf** = very fine (0.1-0.5mm); **f** = fine (0.5-2mm); **m** = medium (2-3mm); **co** = coarse (>5mm); **dis** = discontinuous; **cons** = constricted; **cont** = continuous; **ver** = vertical; **hor** = horizontal; **ran** = random; **obl** = oblique; **v** = vesicular; **i** = irregular; **t** = tubular

SOIL DESCRIPTION SHEET

Location: Quarry Road STOP 91-4-710
Date: July 10, 1991
Name/Pedon: Pedon 1 / Pedon 2 / Pedon 3

Topographic Surface: 5-8% slope
Geomorphic Surface: Broad, NW aspect slope; Qd5f
Vegetation: Oak - Hickory - Pine forest cover

Horizons/ Boundaries	Depth cm	Color Moist/Wet	Texture %<2mm	Structure	Consistency Moist/Wet	$CaCO_3$	Clay Films	Roots/ Pores	Comments
O/A	0-5	10YR5/2 10YR4/2	silt <2%	1fsbk	fr ss ps	—	—	2f / m	brown Qd5f slate diamicton
a w									
E	5-15	10YR5/4 10YR5/4	silt <2%	sg to 1fsbk	vfr ss ps	—	—	2f / m	
c w									
Bw/Bt	15-21	10YR6/6 10YR5/4	silt <2%	1msbk	fi ss ps	—	—	1f / m —	
c w									
Bt	21-45	10YR7/6 7.5YR6/5	clayey silt ≈5%	2msbk	fi s ps	—	2npf	 1fdis ran	
c i									
2Btb	45-100	7.5YR5/6 7.5YR4/6	silty clay 2%	2msbk	fi s p	—	2mkpf	—	mixed brown and brownish red
c i									
3Btb	100+	2.5YR4/6 5YR4/6	silty clay 5%	2abk	fi s p	—	3mkpf	— 2fdis ran	buried red paleosol "Qd1f"

Note: Excellent example of brown over red soils that are characteristic of deposits derived from the Peach Bottom Slate. Slate is generally weathered, much more so in the buried paleosol.

SOIL DESCRIPTION SHEET

Location: Trench Road, west of Flintville Road at Mason-Dixon Line
Date: June 28, 1990
Name/Pedon: Soil 1-628 / Pedon 2

Topographic Surface: Gently rolling hill 0-3% slope
Geomorphic Surface: Upland interfluve Qd3f
Vegetation: Cultivate: corn

Horizons/ Boundaries	Depth cm	Color Moist/Wet	Texture % < 2mm	Structure	Consistency Moist/Wet	$CaCO_3$	Clay Films	Roots/ Pores	Comments
Ap	0-27	9YR4/4 10YR4/4	loamy silt 2%	2f,m abk	frm ss po	—	—	1f 1m c t v	common, small charcoal flecks, some mixing with Bt
a s									
Bt1	27-42	7.5YR5/6 7.5YR4/6	silt loamy silt 5%	2f,c abk	frm ss ps	—	1npf po	2f d t r	krotovina
c w									
Bt2	42-80	7.5YR5/8 8.75YR5/8	clay silt loam 5%	2mabk	frm s ps	—	2,3mk pf,po	2f d t r	slightly micaceous with small fresh and weathered clasts
c w									↓
Cox1	80-104	7.5YR5/6 7.5YR4/6	silty loamy sand < 2%	mass 1fsbk	fr so po	—	—	— —	
g w									
Cox2	104+	7.5YR6/8 7.5YR6/8	loamy sand < 2%	mass 1mpl	vfrfi so po	—	—	— —	structured saprolite

Note: Good example of Qd3f in an interfluve area.

SOIL DESCRIPTION SHEET

Location: Broad Creek Scout Camp
Camp Saffran, water pump intake road
Date: July 27, 1990
Name/Pedon: Soil 1-727 / Pedon 1 / Pedon 2 / Pedon 3

Topographic Surface: Upland reach of drainage; concave hillslope; 8% slope
Geomorphic Surface: "Filled" upland swale; Qd4f/Qd1f
Vegetation: Deciduous forest cover

Horizons/ Boundaries	Depth cm	Color Moist/Wet	Texture % < 2mm	Structure	Consistency Moist/Wet	$CaCO_3$	Clay Films	Roots/ Pores	Comments
OA a s	0-10	10YR3/2 10YR3/2	silt loam <2%	1fgr	— ss ps	—	—	2fvf —	
AE c s	10-23	10YR5/4 10YR5/4	sandy silt loam <2%	1fgr	lo ss ps	—	—	2vf —	Qd4f
Bt1 g s	23-91	7.5YR4/6 8.75YR5/6	silt loam 20%	2fsbk	fr s ps	—	1npf	2fvf 1f d r i	
Bt2 c w	91-123	8.75YR4/6 8.75YR5/6	silt loam 20%	fsbk	fr ss ps	—	2mkpf po	— 1vf d r i	
2Btb a w	123-150	7.5YR5/6 8.75YR5/6	silt loam 30%	2msbk	frm ss ps	—	2n,mk pf	— 2vf d r v	mechanically mixed, base of Qd4f - - - - - - - - - - - - - - -
3Bt1b g s	150-239	5YR5/8 7.5YR5/6	sand silt loam 30%	1fsbk	fr ss po	—	1npo	— 2f d r v	Qd1f more micaceous
3Bt2b cs	239-310	2.5YR4/8 2.5YR4/8	silty clay loam 30%	2msbk to 1fpl	fr s p	—	2mkpf	— 2fm d r v	Qd1f
4Bt1b gs	310-400	2.5YR4/8 7.5YR4/6 5YR4/6 7.5YR5/4	sand silt loam silt loam 50%	1mpl	vfr, fr ss ps ss ps	—	1npf —	1vf 1f d r v	texturally different banding red - - - - - - - - - - - - - - -
4Bt2b	400+	2.5YR4/8 7.5YR4/8 5YR4/6 7.5YR5/4	sand silt loam silt loam 50%	2cpl	vf, fr ss po ss ps	—	3npf —	1vf 1f d r v	brown

Note: Good exposure of diamicton 4 over diamicton 1 with a mixed zone in between.

SOIL DESCRIPTION SHEET

Location: Peach Bottom Road (Atom Road), SE bank, 1 km NE of Flintville Road
Date: August 7, 1990
Name/Pedon: Soil 1-87 / Pedon 1

Topographic Surface: 2-4 m of relief, 3-8% slope
Geomorphic Surface: Hillslope, NW aspect: Qd5f/Qd2f
Vegetation: Deciduous cover with underbrush

Horizons/ Boundaries	Depth cm	Color Moist/Wet	Texture % < 2mm	Structure	Consistency Moist/Wet	$CaCO_3$	Clay Films	Roots/ Pores	Comments
A	0-30	7.5YR5/4 10YR4/4	silt loam 5%	2.3 m,csbk	sh ss ps	—	—	3vf-m 2vf-f d r	All slate
a w								Qd5f	
Bw	30-50	7.5YR3/4 10YR4/4	silt 50%	1vf,f sbk	fr ss ps	—	—	— —	
a w									
Bt	50-60	5YR4/6 5YR4/6	silt 20%	1vf,f sbk	fr ss ps	—	v1npf	— —	
a w									
Bw	60-102	7.5YR3/4 10YR4/4	silt loam 50%	1vf,f sbk	fr ss ps	—	—	— —	
a s									
2Bw1b	102-114	5YR5/8 5YR4/6	sandy silt 10%	1msbk to m	fr so po	—	—	— —	stratified micaceous
a s									buried Qd2f
2Bw2b	114-130	7.5YR5/8 7.5YR5/8	sandy silt 50%	1msbk	fr so po	—	—	— —	stratified with large clasts 5-15 cm
a s									
3Coxb	130+	various reds, yellows, oranges	sand loam 5%	sg	vf, lo ss ps	—	—	— —	saprolite

Notes: Diamicton 5 composed of slate chips overlying a thin diamicton 2 which overlies "creep" saprolite. The break between diamicton 5 and underlying saprolite is well developed. Creep in the upper 20 cm of saprolite however is apparent.

SOIL DESCRIPTION SHEET

Appendix 2E

Location:	Whiteford spray trenches; Whiteford and Dooley Roads	Topographic Surface:	0-3% slope
Date:	July 11, 1991	Geomorphic Surface:	Hilltop crest flat; Qrf
Name/Pedon:	Phyllite Residual / Pedon 2	Vegetation:	Grass meadow after farming

Horizons/ Boundaries	Depth cm	Color Moist/Wet	Texture % < 2mm	Structure	Consistency Moist/Wet	$CaCO_3$	Clay Films	Roots/ Pores	Comments
Ap	0-28	10YR4/4 7.5YR4/4	silt <2%	2mpr	fi ss po	—	—	—	plowed horizon
a w									
Bt1	28-40	7.5YR5/6 7.5YR5/6	silt loam <2%	2msbk	fi ss ps	—	2npf	—	clay films are a bit more red (≈5YR)
a w									
Bt2	40-70	5YR5/8 7.5YR6/8	silt loam <2%	2msbk	fi s ps	—	2mkpf	—	clay films are a bit darker (≈5YR4/6)
c w									
Cox	70+	variegated	silty sand <2%	sg	lo so po	—	—	—	saprolite

Note: Phyllitic bedrock; good example of a "true" residual profile on quartzo-feldspathic bedrock in a relatively flat upland setting.

SOIL DESCRIPTION SHEET

Appendix 2F

Location: Delta Prospect Road Pit #6
Date: November 9, 1990
Name/Pedon: Delta Pit #6 / Pedon 1

Topographic Surface: Gentle slope, midslope-toeslope position
Geomorphic Surface: Slightly dissected upland; Qd3f/Qd2f
Vegetation: Agricultural — corn

Horizons/ Boundaries	Depth cm	Color Moist/Wet	Texture % < 2mm	Structure	Consistency Moist/Wet	$CaCO_3$	Clay Films	Roots/ Pores	Comments
Ap a s	0-21	10YR4/3 10YR4/3	loam 20%	1,2 msbk, 1fpl	fr ss po	—	—	— —	plowed horizon
Bw/Bt1 c w	21-68	7.5YR5/6 7.5YR4/6	silt loam 10%	2msbk	fr,fi ss ps	—	1npo, pf	— —	Qd3f clasts deeply weathered
Bt2 g w	68-95	9YR5/4 10YR5/4	loamy silt 10-20%	1,2 msbk	fr ss ps	—	v1npf	— —	Qd3f very micaceous clasts deeply weathered
Bw g w	95-110	8.75YR5/8 8.75YR5/8	sandy silt 10%	sg to 1fsbk	vfr so po	—	—	— —	Qd3f very micaceous clasts deeply weathered
Bt2 a w	110-130	9YR5/4 10YR5/4	loamy silt 10-20%	1,2 msbk	fr ss ps	—	v1npf	— —	Qd3f
2Cox1b c w	130-250	banded 10YR5/6 7.5YR5/6 --------- 8.75YR5/4	loamy silt 30%	1mpl	fr so po	—	—	— —	buried Qd2f micaceous
2Cox2b	250+		loamy sand < 5%	sg	fr so po	—	—	— —	rolled saprolite

Note: Excellent example of fine-grained, stratified hillslope deposits. Schist chips in a greenish-gray silty sand matrix. Texturally, the base of this deposit is diamicton 2, but in this case it is buried by a younger diamicton 3 unit.

SOIL DESCRIPTION SHEET

Location: Delta Propect Road Pit #5
Date: November 9, 1990
Name/Pedon: Delta Pit #5 / Pedon 1 / Pedon 2

Topographic Surface: Gentle slope 0-3% upper shoulder
Geomorphic Surface: Slightly dissected upland; Qd3f
Vegetation: Agricultural — corn

Horizons/ Boundaries	Depth cm	Color Moist/Wet	Texture % < 2mm	Structure	Consistency Moist/Wet	$CaCO_3$	Clay Films	Roots/ Pores	Comments
Ap	0-24	10YR4/3 10YR4/3	loam 5%	1-2 msbk 1fpl	fr ss po	—	—	— —	plowed horizon
a s									
Bt1	24-56	5YR5/8 7.5YR5/6	clay loam 5%	2m,c sbk	fi-fr s p	—	2n,mk po,pf	2vf dis v	Qd3f; slightly micaceous; deeply weathered clasts
c s									
Bt2b	56-72	5YR4/6 5YR4/6	silt loam 5%	1fsbk	fr ss po	—	v1npf	— —	micaceous; deeply weathered clasts; truncated
c s									
2Btb	72-95	7.5YR6/6 7.5YR5/6	sand loam 20-30%	1m,c sbk	vfr ss po	—	2n,mk pf	— —	buried Qd2f; very micaceous colluviated saprolite
c w									
2Coxb	95+	variegated red, tan, yellow, orange	loamy sand <5%	sg	vfr so po	—	—	— —	rolled structured saprolite; pot structures

Note: A brown over brownish-red diamicton underlain by rolled structured saprolite. Brownish-red diamicton may be an older, buried soil as evidenced by the truncation by overlying brown diamicton. Brown-red contact is also transitional. Roll structures have the morphology of sediment pots observed in Coastal Plain upland gravels. They are 20 cm across and 15 cm deep.

SOIL DESCRIPTION SHEET

Appendix 2H

Location:	Delta Prospect Road Pit #3	Topographic Surface:	Straight, steep lower shoulder
Date:	November 8, 1990	Geomorphic Surface:	Slightly dissected upland; Qadu
Name/Pedon:	Delta Pit #3 / Pedon 1	Vegetation:	Agricultural — corn

Horizons/ Boundaries	Depth cm	Color Moist/Wet	Texture % < 2mm	Structure	Consistency Moist/Wet	$CaCO_3$	Clay Films	Roots/ Pores	Comments
Ap	0-20	10YR4/3 10YR4/3	loam 5%	1-2 msbk 1fpl	fr ss po	—	—	— —	plowed horizon
a s									
Bt1	20-85	7.0YR4/6 7.5YR5/6	clay loam < 5-10%	2csbk	fo-fr s p	—	1,2n po,pf	2f,vf dis t	non-micaceous cumulic eroded A
c w									
Bt2	85-120	10YR5/6 10YR5/4	silt loam < 5%	1csbk	fi ss po	—	1npo, pf	— 2vf dis v	slightly micaceous
a s									
2Bt	120-163	8.75YR5/4 10YR5/4	silt loam < 2%	2cpr	fi ss po	—	1npf	— 2vf dis t	buried A? saprolite "rip-up"
a w									
3Coxb	163 +	10YR7/8 10YR7/8	loamy sand < 2%	sg	vfr so po	—	—	—	structured saprolite

Note: Profile described on 2-3 meter bench upslope of man-made hedgerow. Entire soil is most likely cumulic and fill eroded from agricultural land upslope.

SOIL DESCRIPTION SHEET

Location: Delta Prospect Road Pit #2
Date: November 8, 1990
Name/Pedon: Delta Pit #2 / Pedon 2

Topographic Surface: Straight, steep shoulder
Geomorphic Surface: Slightly dissected upland; Qd3f
Vegetation: Agricultural, corn

Horizons/ Boundaries	Depth cm	Color Moist/Wet	Texture % < 2mm	Structure	Consistency Moist/Wet	$CaCO_3$	Clay Films	Roots/ Pores	Comments
Ap	0-23	10YR4/3 10YR4/3	loam 5%	1-2 msbk	fr ss po	—	—	— —	plowed horizon
a s									
Bt1	23-42	5YR5/6 7.5YR5/6	silty clay loam 5%	2msbk	fi ss ps	—	2npf, po	1f dis t	Qd3f; many small schist chips
c w									
Bt2	42-80	3.75YR4/6 5YR4/6	loam 5-10%	2mabk	fi ss po	—	3npf	— —	slightly micaceous
a w									---------
2Cox1b	80-119	variegated	loamy sand < 2%	1csbk to sg	fr so po	—	—	—	buried Qd2f; very micaceous
a s									* * * stone line * * *
2Cox2b	119+	variegated	loamy sand < 2%	sg	fr so po	—	—	—	rolled saprolite

Note: At least two soils may be represented by the two argillic horizons. However, it is not clear that the lower profile is buried, rather than just reworked.

SOIL DESCRIPTION SHEET

Location: Bel Air quadrangle, 0.5 km north of Kalmia on Forge Road
Date: June 28, 1991
Name/Pedon: Soil 1-628 / Residual Soil

Topographic Surface: Flat, level upland 0-3% slope
Geomorphic Surface: Undissected upland underlain by metagabbro
Vegetation: Open grass field after original deciduous cover

Horizons/ Boundaries	Depth cm	Color Moist/Wet	Texture % < 2mm	Structure	Consistency Moist/Wet	$CaCO_3$	Clay Films	Roots/ Pores	Comments
A	0-20	10YR4/3 10YR4/3	loam 5%	1msbk	s so po	—	—	2f 1fdisrani	
a s									
Bt1	20-42	7.5YR4/4 7.5YR3/4	clayey silt 5%	2cpr to 1mabk	h ss ps	—	2npo, pf	1f,m 2fconvert	roundstones present
a w									
Bt2	42-135	10YR6/6 10YR5/6	silt clay 2%	2mabk	h s p	—	2n,mk po,pf	— 2fdisrani	yellow, vertical wedges; reduction of lower horizon
a i									
Bt3	135-180	2.5YR3/6 2.5YR3/4	sandy clay 2%	3mabk	sh s p	—	3mkpf	— —	well-developed red, residual argillic horizon
c s									
Cox	180+	5YR 5YR	coarse sandy loam	sg	lo so po	—	—	— —	structured saprolite

Note: Good example of dark red residual soil overlying structured saprolite after Bel Air Complex metagabbro. The brown roundstone horizon at the top of the profile could be classified as a roundstone diamicton, but this entire profile, as well as the surrounding landscape, is dominated by residual, rather than colluvial materials.

SOIL DESCRIPTION SHEET

Location: Delta Prospect Road Pit #1
Date: November 8, 1990
Name/Pedon: Delta Pit #1 / Pedon 1 / Pedon 2

Topographic Surface: Flat upland, 0-3% slope
Geomorphic Surface: Slightly dissected upland; Qd4f/Qd3f
Vegetation: Agricultural, corn

Horizons/ Boundaries	Thickness cm	Color Moist/Wet	Texture % < 2mm	Structure	Consistency Moist/Wet	$CaCO_3$	Clay Films	Roots/ Pores	Comments
Ap	0-19	10YR4/3 10YR4/3	loam 5%	1-2 msbk, 1fpl	fr ss po	—	—	— —	plowed horizon
a s									
2Bt	19-60	7.5YR4/6 8.75YR4/6	clay loam 10%	2mabk	fi s p	—	1npf	—	reddish brown and brown Qd4f; fresh clasts
c i									
2Btb	60-105	5YR5/6 5YR5/6	loam 10%	1-2 fsbk	fi-fr s ps	—	2-3mk pf	—	brownish red Qd3f; weathered clasts
c w									
3Btb	105-120	10YR6/6 10YR6/6	sand loam < 2%	sg, 1fsbk	vfr so po	—	v1nbr	— —	buried Qd2f and rolled saprolite
c b									
3Cox1b	120-194	10YR6/8 10YR6/8	loamy sand < 2%	sg, 1fsbk	vfr so po	—	—	—	very sandy; possible fossil ice wedge
a b									
3Cox2b	194-210	2.5YR4/6 2.5YR4/6	loamy sand 10%	sg	vfr so po	—	—	— —	Qd1f and red diamicton with rolled saprolite
d w									
4Coxb	210+	variegated red, tan, yellow, orange	sand 50%	sg	vfr so po	—	—	— —	rolled saprolite and rubblized bedrock

Note: Good example of reddish-brown diamicton 4 over brownish-red diamicton 3 in an upland setting. Extensive cryoturbation of an earlier soil/diamicton. Possibly a diamicton 1 exists below diamicton 3.

STATE OF MARYLAND
DEPARTMENT OF NATURAL RESOURCES
MARYLAND GEOLOGICAL SURVEY
Emery T. Cleaves, Director

SURFICIAL GEOLOGIC MAP OF THE DELTA QUADRANGLE, MARYLAND-PENNSYLVANIA

by Frank J. Pazzaglia

1998

LEGEND

Anthropogenic

dl — **DISTURBED LAND:** Land disturbed by mining activity.

ul — **URBAN LAND:** Land disturbed by urban areas, including houses, streets, and parking lots.

Alluvium

Qadu — **ALLUVIUM/DIAMICTON UNDIVIDED:** Includes both poorly to moderately well-stratified fluvial sand, silt, and gravel and poorly stratified, poorly sorted diamicton in the valley bottom toeslope positions along most streams and in natural and man-made drainageways on the interfluves. Deposits in the interfluve regions are dominated by fine-grained sands and silts concentrated in the drainageways and behind hedgerows. The deposits are typically 1 meter thick in or near perennial streams but may be as much as 3 meters thick in the upland interfluve setting.

Qf — **ALLUVIAL FAN:** Gray, moderately well-stratified and rounded fluvial gravel and sand, overlain by a massive to well-stratified, fine sandy brown loam. Large subangular boulders 0.5 - 2 meters in diameter within and on deposit surface are common. Soil development is poor and similar to that found on terrace Qt2. The deposit is approximately 1 to 5 meters thick and found primarily at the foot of large gaps along the southeast base of Slate Ridge. Alluvial fans are also very common at the confluence of streams, but are unmappable at a 1:24,000 scale. They are mapped as alluvium/diamicton undivided in this landscape position.

Qt3 — **ALLUVIUM:** Gray, moderately well-stratified, subangular to rounded fluvial gravel and sand found as bars and constructional features on the modern floodplain. Composition of clasts reflects local Piedmont sources dominated by vein quartz, quartzite, metagreywacke, and schist with minor slate, ultramafic, and felsic-intrusive lithologies. Deposit thickness is approximately 1 meter.

Qt2 — **ALLUVIUM:** Gray, moderately well-stratified, subangular to rounded fluvial gravel and sand, fining upward to a massive to well-stratified, brown fine sand and silt loam. The base of the alluvial deposit is composed of one or two sandy gravel units approximately 0.2 to 0.5 meter thick that is conformably overlain by a micaceous, cross-bedded, yellow, green, gray, or brown sand approximately 0.5 meter thick, which is in turn unconformably overlain by a massive brown silty loam 0.5 meter thick. The contact between the basal gravels and overlying sand is commonly stained black and is thought to represent the mean annual ground-water table. Total deposit thickness is typically 1 to 2 meters. Composition of clasts reflects local Piedmont sources dominated by vein quartz, quartzite, metagreywacke, and schist with minor slate, ultramafic, and felsic-intrusive lithologies. Terrace Qt2 is found beneath a terrace surface 1 to 2 meters above the modern stream and exhibits poor soil development characterized by a loamy A horizon and silt loam Bw/Bt horizon <0.5 meter thick. This deposit appears to be strongly influenced by recent anthropogenic aggradational and incisional events.

Qt1 — **ALLUVIUM:** Gray, moderately well-stratified, subangular to rounded fluvial gravel and sand, fining upward to a massive to well-stratified, brown, fine sand and silt loam. The base of the alluvial deposit is composed of one or two sandy gravel units approximately 0.5 to 1.5 meters thick, which is conformably overlain by a micaceous, cross-bedded, yellow, green, gray, or brown sand approximately 0.5 meter thick, which is in turn unconformably overlain by a massive red silty loam 0.5 to 1 meter thick. Total deposit thickness is typically 2 to 4 meters. Composition of clasts reflects local Piedmont sources dominated by vein quartz, quartzite, metagreywacke, and schist with minor slate, ultramafic, and felsic-intrusive lithologies. This deposit is found beneath a distinct terrace surface about 3 to 4 meters above the modern streambed and displays a well-developed soil with a 0.5- to 1-meter thick red (2.5YR) argillic horizon exhibiting many thick clay films and well-developed angular blocky structure.

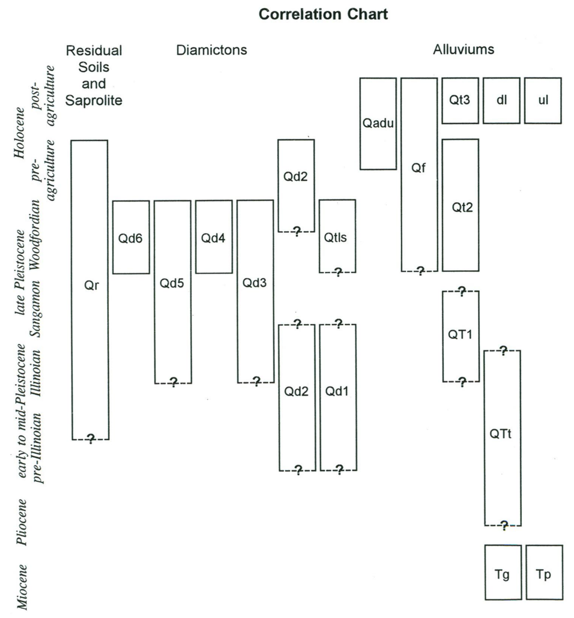
UPLAND GRAVELS: Thin (<1 meter thick) gravel lags to widely scattered lag pebbles typically found on flat interfluves and on flats adjacent to major streams. Pebbles range in size from 2 to 20 cm, average 4 to 10 cm in diameter and are subangular to very well-rounded. Clast composition generally reflects local Piedmont sources and is dominated by quartzite, vein quartz, metagreywacke, and schist. The gravels are further subdivided into the following three groups distinguished by their elevation, geographical, compositional, and textural characteristics:

QTt — Subangular to subrounded gravels of diverse lithologic composition dominated by vein quartz, quartzite, and schist on flats adjacent to larger streams at elevations less than 400 feet.

Tp — Subangular to subrounded gravels of diverse lithologic composition dominated by meta-conglomerate, slate, schist, and quartzite on flats interpreted to be dissected and colluviated pediments along the southeast flank of Slate Ridge.

Tg — Very well-rounded quartz pebble upland gravels along Broad Creek, Deer Creek, and the Susquehanna River at or above 400 feet in elevation.

Correlation Chart



Diamictons derived from mafic and meta-igneous rocks

Qd6u — **DIAMICTON 6:** Tan, yellow, and brown, clast-supported diamicton of dense, foliated ultramafic rocks and of Deer Creek Complex metasediment clasts. The diamicton has little to no matrix material, is poorly to moderately well-stratified and has a strong slope-parallel fabric. This deposit exhibits a very poorly developed light-colored loamy soil characterized only by a cambic B horizon. Diamicton thickness is typically no more than 1 meter.

Qd6s — **DIAMICTON 6:** Tan, yellow, and brown, clast-supported diamicton composed of dense, foliated, fresh and weathered serpentinite clasts that may have a thick (≈2 cm) goethite weathering rind. The diamicton is typically less than 0.5 meter thick and overlies fresh to slightly weathered serpentinite bedrock. The lack of any appreciable soil results in the support of only a barrens-type vegetation.

Qd4u — **DIAMICTON 4:** Tan, yellow, and brown, poorly stratified, poorly to moderately well-sorted, generally non-micaceous, matrix-supported deposit with many fresh angular clasts 5 to 30 cm in diameter. The silty sand matrix supports dense clasts of foliated ultramafic rock with a thick (≈2 cm) goethite weathering rind and clasts of Deer Creek Complex metasediment. The deposit exhibits a poorly developed light-colored (10YR-7.5YR) soil with a Bw/Bt horizon characterized by thin clay films and moderate subangular blocky structure. A buried soil exhibiting dark, brownish-red (5YR) colors with thick clay films and well-developed structure occurs in some areas. The diamicton ranges from 1 to 2 meters in thickness and typically overlies a silty saprolite of variable thickness developed in foliated ultramafic bedrock.

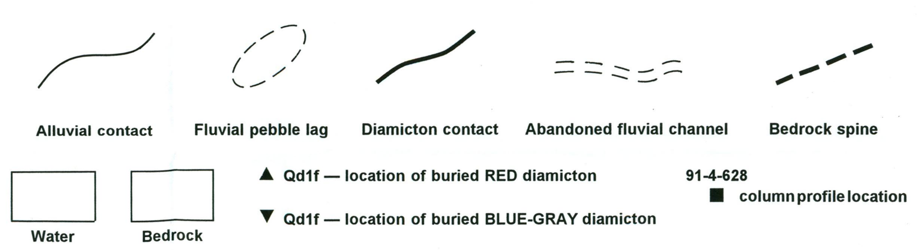
Qd4m — **DIAMICTON 4:** Dark red, poorly stratified, poorly to moderately well-sorted, dominantly matrix-supported roundstone diamicton with both fresh and weathered subangular to well-rounded clasts 0.1 - 2 meters in diameter. Matrix is sandy silt. Clasts consist of dense, massive ultramafic rocks and metagabbro with a thick (≈2 cm) goethite weathering rind that are commonly concentrated near or at the surface of the deposit forming surficial roundstone lags. The diamicton exhibits a moderately to well-developed red soil characterized by a 0.3- to 1-meter thick red (2.5YR-10R) argillic horizon with many thin to thick clay films and moderate to well-developed structure. The unit is 0.5 to 3 meters thick and typically overlies a thin (<1 to 2 meters) sandy, structured saprolite, and/or weathered bedrock.

Qd2u — **DIAMICTON 2:** Tan, yellow, and brown, very clast-poor, massive sandy silt deposit that is the near-surface expression of reworked residuum derived from foliated ultramafic rocks. The deposit exhibits a very poorly developed soil characterized by a thin cambic B horizon that is gradational to underlying residual materials such as saprolite and/or weathered bedrock. This diamicton is easily distinguished from true saprolite and residual soil, because it displays a textural fabric sub-parallel to slope, as well as a thin (0.5 m) discontinuous, non-foliated "massive" residual material separating remobilized saprolite from the overlying soil. The deposit is typically about a meter thick, whereas the underlying residual material is highly variable, ranging from 1 to >10 meters.

Qd2g — **DIAMICTON 2:** Tan and white, very clast-poor, massive sandy silt deposit that is the near-surface expression of reworked residuum derived from structured saprolite of granitic gneiss. The deposit exhibits a very poorly developed soil characterized by a thin yellow cambic B horizon that is gradational to underlying residual materials, such as saprolite and/or weathered bedrock. This diamicton is easily distinguished from true saprolite and residual soil because it displays a textural fabric sub-parallel to slope as well as a thin, discontinuous, non-foliated (≈0.5 m) "massive" saprolite zone separating the remobilized saprolite from the overlying soil. Deposit thickness is less than 1 meter while the thickness of saprolite is highly variable, ranging from 1 to >10 meters.

Qrm — **RESIDUAL SOIL and SAPROLITE:** Dark red and brownish-yellow, sandy silt residual soil with few fresh and weathered subangular to well-rounded clasts 0.1 to 2 meters in diameter, composed of massive, dense, ultramafic rocks and metagabbro with a thick (≈2 cm) goethite weathering rind. The deposit exhibits a well-developed red soil (2.5YR - 10R) characterized by a 0.5- to 0.8-meter thick argillic horizon with many thick clay films and well-developed angular blocky to prismatic structure that grades downward to a well-developed reddish-brown sandy saprolite. The soil commonly has a roundstone lag on the surface and is penetrated by numerous wedge-like "tongues" of brownish-yellow (10YR) silt, approximately 1 meter deep and 0.5 meter wide at the top. The residual soil is generally 1 to 2 meters thick, while the underlying sandy structured saprolite ranges in thickness from 1 to >10 meters.

Qrg — **RESIDUAL SOIL and SAPROLITE:** Tan and white dominantly sandy silt residual soil approximately 1 meter thick with few weathered subangular to well-rounded clasts 0.1 to 0.5 meter in diameter, composed of massive, light-colored granitic gneiss. The soil is poorly developed and characterized by a reddish-brown (10YR - 7.5YR) Bw/Bt 0.1 to 0.5 meter thick, transitional downward to a well-developed, sandy, very micaceous white saprolite. The saprolite has locally lost its structured characteristic and appears as a massive saprolite. Saprolite thickness ranges from 1 to >10 meters.



Diamictons derived from felsic and metasedimentary rocks

Qd6f — **DIAMICTON 6:** Brown, clast-supported diamicton with little or no matrix material. It is poorly to moderately well-stratified and contains only fresh, angular clasts 0.1 to 0.5 meter, rarely >1 meter in diameter. This unit exhibits a very poorly developed soil characterized by <0.5-meter thick A and Bw horizons. The deposit is typically about 1 meter thick and overlies weathered and unweathered bedrock.

Qtls — **TALUS:** Poorly to moderately well-sorted, generally coarsening-up blockfields composed of angular and subangular clasts 0.2 to 2 meters in diameter with virtually no interstitial matrix material. The deposits are typically less than 2 meters thick and compose the surficial cover of only small areas underlain by the Rocks Park and Cardiff metaconglomerates.

Qd5f — **DIAMICTON 5:** Brown, brownish-red, and red poorly sorted and stratified slate-clast deposit with 1- to 10-cm flat slate clasts imbedded in a uniform, massive silt matrix. This deposit is actually at least two separate diamictons consisting of an upper brown unit characterized by a moderately well-developed brownish-red soil (7.5YR) that overlies a diamicton with a well-developed, but truncated, red (5YR) paleosol. Total thickness of slate diamicton is 1 to 1.5 meters. This unit is associated only with slate bedrock of the Peach Bottom Formation.

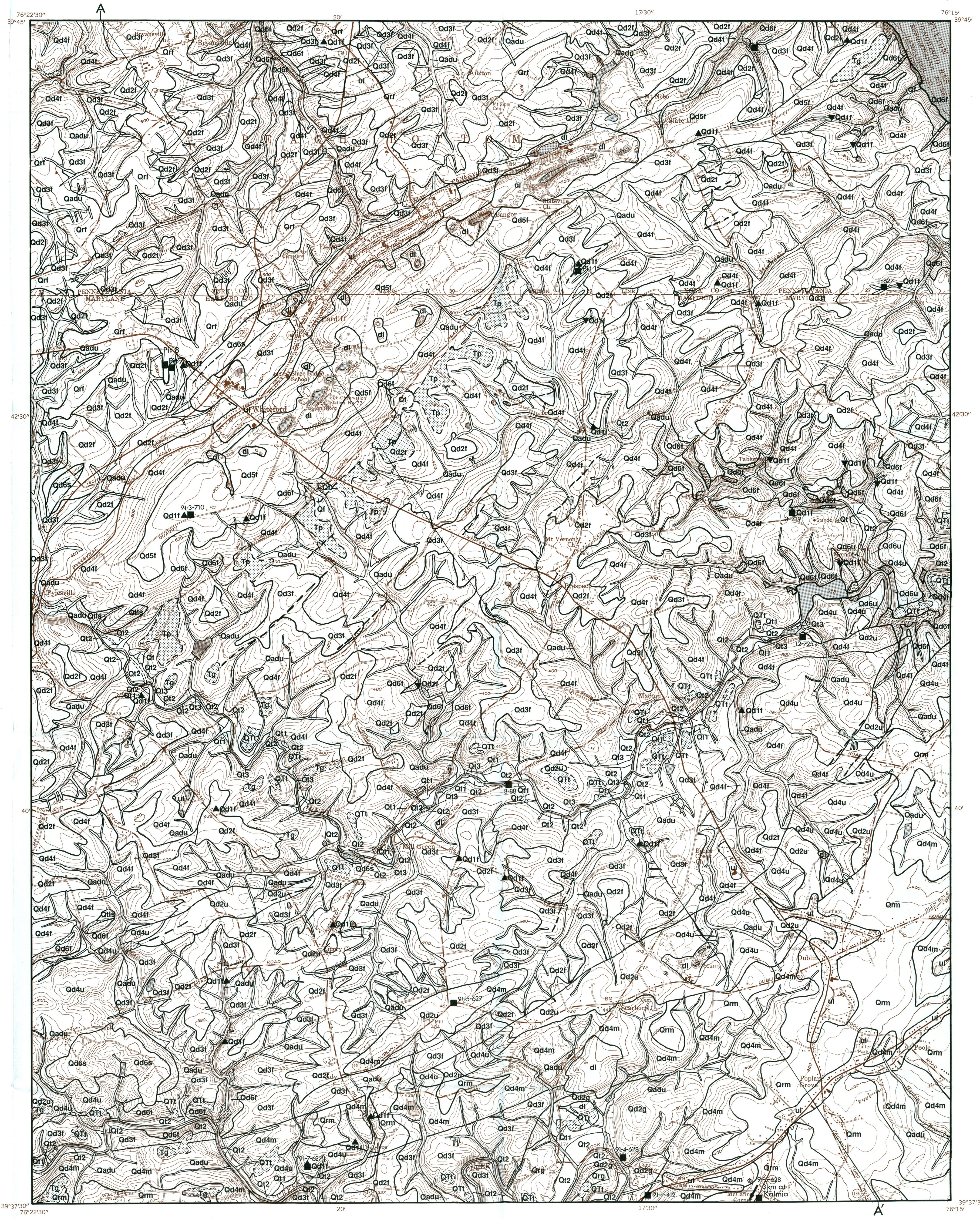
Qd4f — **DIAMICTON 4:** Orange and brown, poorly stratified, clast-rich diamicton that is dominantly matrix-supported but which also exhibits a clast-supported texture in approximately 10 percent of its areal extent. The non-micaceous silty-sand matrix supports mostly fresh, angular clasts 5 to 30 cm in diameter with a strong slope-parallel fabric except where disturbed by cryoturbation features. The deposit exhibits a poorly developed soil characterized by a brown (10YR) cambic B horizon 0.1 to 0.3 meter thick followed by a brown (10YR) and reddish-brown (7.5YR) argillic horizon approximately 0.5 meter thick with few thin clay films and poorly developed subangular blocky structure. This upper argillic horizon may be followed by a thin, truncated, buried brownish-red (5YR) argillic horizon. Diamicton 4 often exhibits cryoturbation features characterized by roll structures 0.2 to 1 meter across and 0.5 meter deep and wedges 0.5 meter across and 0.5 meter deep. The unit is typically 1 to 2 meters thick and usually overlies weathered and unweathered bedrock, but may also overlie structured saprolite and reworked saprolitic materials.

Qd3f — **DIAMICTON 3:** Orange, brown, yellow, tan, and gray, poorly stratified and sorted, always matrix-supported diamicton. The matrix is a slightly micaceous silty sand that supports fresh and weathered bedrock clasts and "clasts" of structured saprolite. The clast to matrix ratio is 50:50 or less, and clasts generally exhibit a slope-parallel fabric. The deposit typically exhibits a moderately well-developed reddish-brown (7.5YR) and brownish-red (5YR) soil characterized by a 0.5-meter argillic horizon with common thin clay films and moderate subangular blocky structure often followed by a thin, truncated, buried, red (2.5YR), well-developed argillic horizon. Approximately 20 percent of the deposit is also characterized by a more poorly developed soil with a morphology consistent with the soil found with diamicton 4. Diamicton 3 often exhibits cryoturbation features characterized by roll structures 0.2 to 1 meter across and 0.5 meter deep and wedges 0.5 meter across and 0.5 meter deep. This 1- to 2-meters thick unit usually overlies residual materials such as structured saprolite, reworked saprolite, and weathered bedrock. This diamicton rarely overlies fresh bedrock.

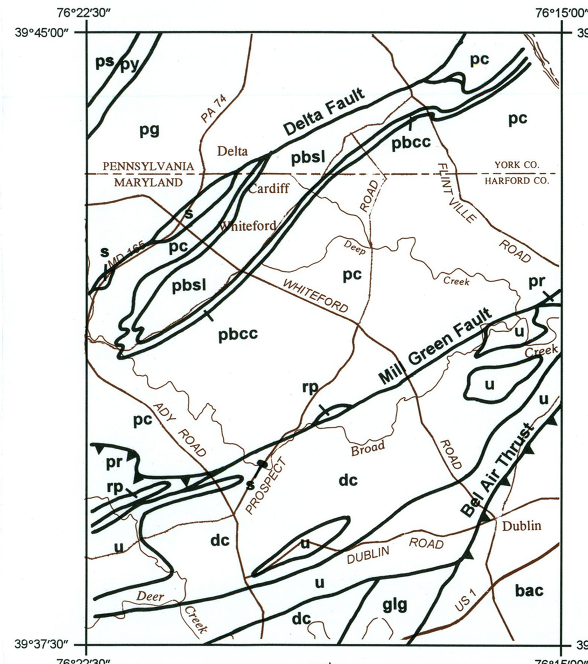
Qd2f — **DIAMICTON 2:** Brown, brownish-red, gray, green, and olive, often micaceous, very clast-poor diamicton that is either a near-surface or buried deposit of reworked residuum derived from structured saprolite and weathered bedrock. This diamicton is easily distinguished from underlying saprolite because it typically exhibits a slope-parallel, sub-horizontal foliation which differs markedly from the nearly vertical foliation of non-deformed structured saprolite and bedrock. Where exposed at the surface, the deposit exhibits a very poorly developed soil characterized by a brown (10YR) Bw/Bt horizon approximately 0.3 meter thick. Diamicton 2 is typically less than 1 meter thick, while thickness of the underlying residual material from which it is derived is highly variable, having been observed to range from 1 to >10 meters.

Qd1f — **DIAMICTON 1:** Red, matrix- and clast-supported, poorly to well-stratified, buried diamicton that distinctly coarsens upward. The base of this unit is often characterized by a red, brown, olive, or green sandy, micaceous, often cross-stratified deposit 0.2 to 1 meter thick. It is interpreted to be fluvially reworked material derived from saprolite (diamicton 2). Diamicton 1 is easily recognized by a well-developed paleosol with mostly weathered, but some fresh, angular clasts 5 to 30 cm in diameter that exhibit a strong slope-parallel fabric except where disturbed by cryoturbation features. The argillic horizon exhibits deep red colors (2.5YR), has well-developed angular blocky structure, many thick clay films, and may be 2 to 3 meters thick in some of the thicker deposits. This diamicton is indurated in poorly drained positions where it has been observed to exhibit a bluish-gray color. Thickness ranges from <1 to 5 meters.

Qrf — **RESIDUAL SOIL and SAPROLITE:** Clast-poor surficial deposit derived entirely from *in situ* chemical weathering and pedogenic processes. The slightly micaceous soil has easily distinguishable horizons and a clearly visible transitional Cox-horizon into underlying structured saprolite or weathered bedrock. The argillic horizon is approximately 0.4 to 0.8 meter thick, reddish-brown (7.5YR) to red (2.5YR) with moderately well-developed subangular blocky structure and common thin clay films. The residual soil is 1 to 1.5 meters thick, whereas underlying saprolite ranges from 1 to 10 meters. Micaceous content of the saprolite differs with bedrock type. Generally saprolite derived from phyllite and schist contains more mica than that derived from quartzite and metagreywacke.

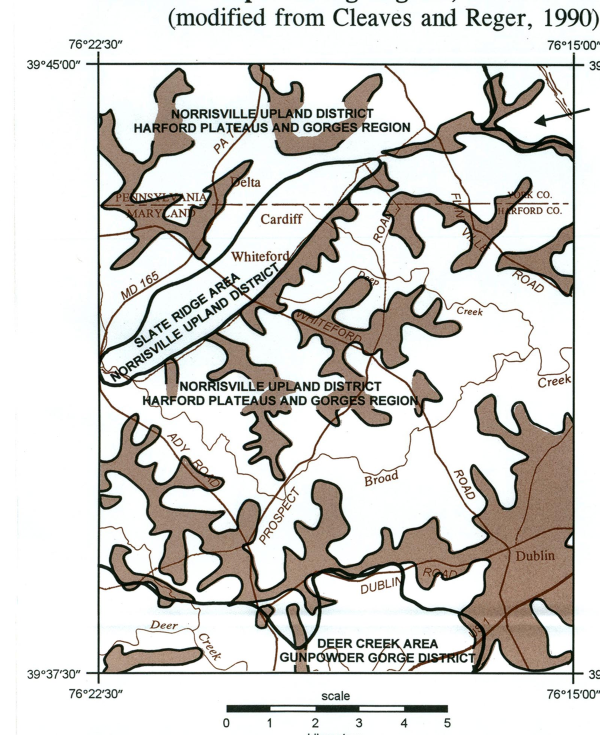


Bedrock Geology of Delta Quadrangle (adapted from Muller, 1990)



pbsl	Peach Bottom Slate
pbcc	Peach Bottom Cardiff Metaconglomerate
ps	Prettyboy Schist
py	unnamed phyllite
pg	Pleasant Grove phyllite phyllitic schist
pc	Peters Creek quartzite and phyllitic schist
dc	Deer Creek Complex: schist metagraywacke and intrusives
pr	Piney Run schist
rp	Rocks Park metaconglomerate
glg	Granitic geucogneiss
bac	Bel Air Complex metagabbro
u / s	Ultramafic intrusive bodies locally serpentinized

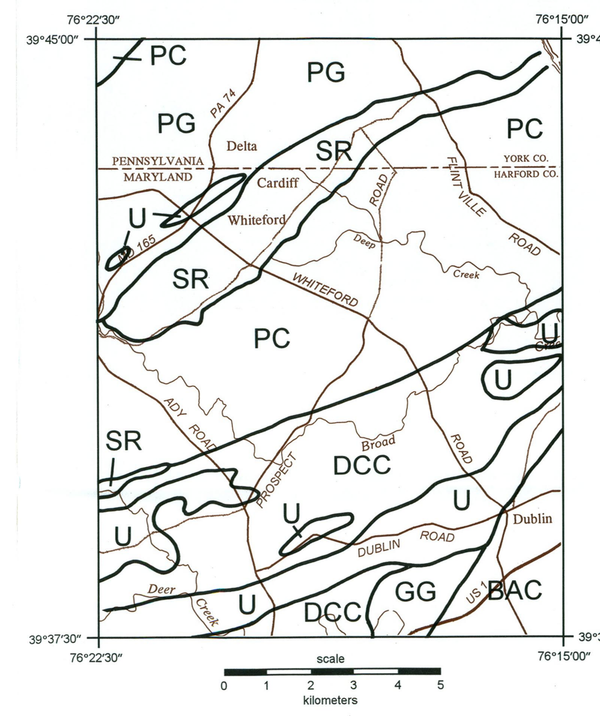
Landform Map Showing Regions, Districts and Areas (modified from Cleaves and Reger, 1990)



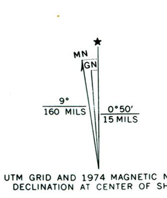
Undissected upland interfluves

Landform boundary

Surficial Terranes in the Delta Quadrangle



BAC	Bel Air Complex Surficial Terrane
GG	Granitic Gneiss Surficial Terrane
DCC	Deer Creek Complex Surficial Terrane
PC	Peters Creek Surficial Terrane
U	Ultramafic Surficial Terrane
SR	Slate Ridge Surficial Terrane
PG	Pleasant Grove Surficial Terrane



SCALE 1:24 000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETRE

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

ROAD CLASSIFICATION

Heavy-duty — Light-duty
Medium-duty — Unimproved dirt
U. S. Route — State Route

DELTA, MD.—PA.

N3937.5—W7615/7.5

1956
PHOTOREVISED 1974
AMS 5763 III NE—SERIES V833

Cross Section A-A′ (northwest to southeast)

Plate 1b

Colluvium by Frank J. Pazzaglia
Saprolite and rock weathering interpretation by Emery T. Cleaves

Horizontal Scale 1:24,000
Vertical Scale 1:1,200
VE = 20×