GEOLOGY OF THE HANOVER ACADEMY AND ASHLAND QUADRANGLES, VIRGINIA

by

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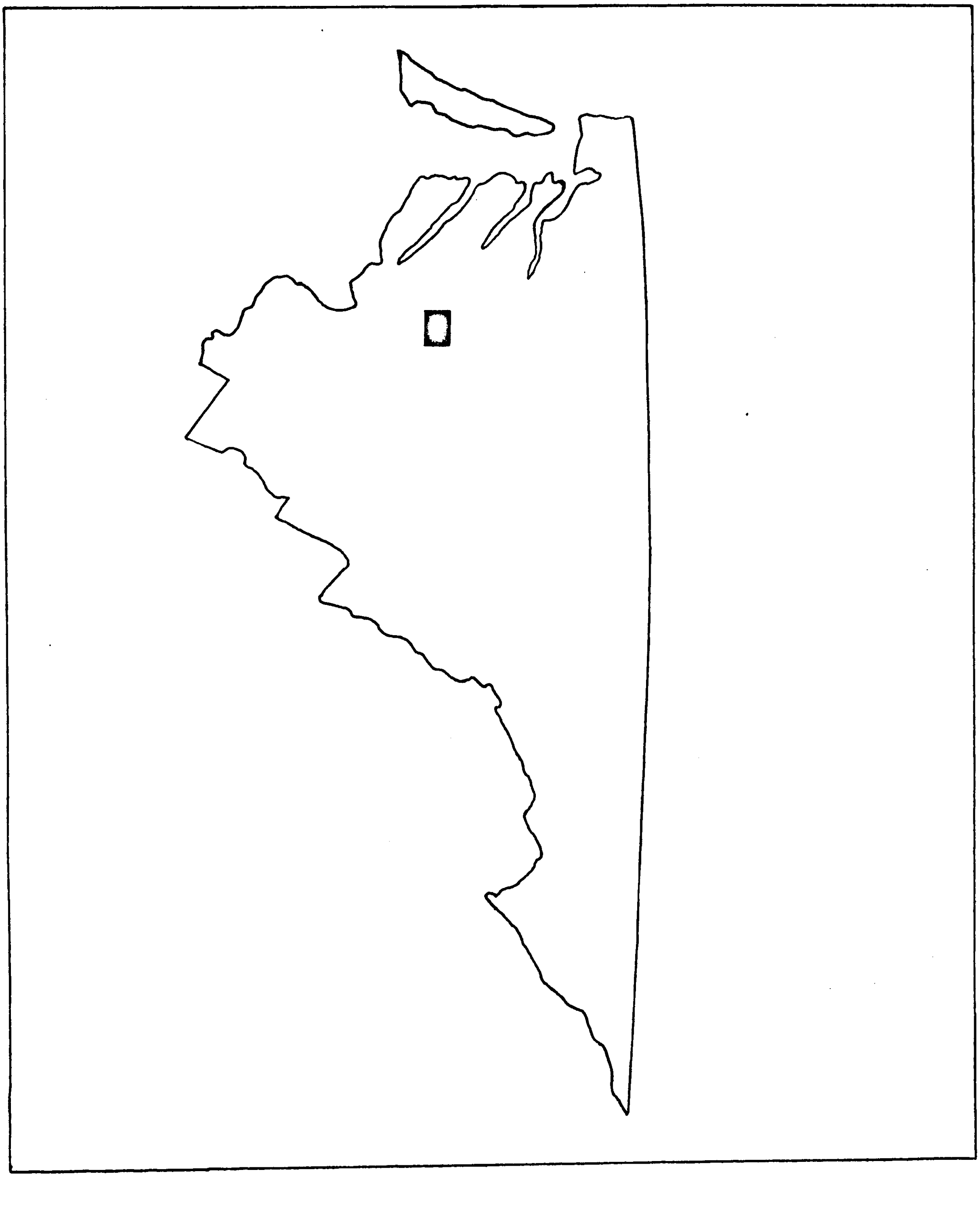
INTRODUCTION

The Ashland and Hanover Academy 7.5-minute quadrangles are in east-central Virginia 15 miles north-northwest of Richmond (Figure 1). They include portions of Hanover and Caroline counties, have a combined area of 118 square miles and are bounded by parallels 37 45' and 37 52'30" north latitude and meridians 77 22'30" and 77 37'30" west longitude. Ashland is the largest and only incorporated town (pop. 2773). Small communities include Doswell, Gum Tree, and Taylorsville.

The area is crossed by State Highway 54, U. S. Highways 1 and 33, and Interstate Highway 95. The Chesapeake and Ohio Railroad crosses the northern and eastern portions of the Ashland quadrangle, and the Richmond, Fredericksburg, and Potomac Railroad crosses the central portion of the Ashland quadrangle in a north-south direction.

All streams, except those in a small area in and just west of Ashland, are part of the Pamunkey River drainage system. The streams near Ashland are are part of the Chickahominy drainage system. The major rivers in the area are the South Anna River, Newfound River, Little River, and North Anna River

Figure 1. Index map showing location of Ashland and Hanover Academy quadrangles



(Plate 1). These converge in the eastern part of the Ashland quadrangle to form the upper reaches of the Pamunkey River. The stream patterns are generally meanders that are entrenched into terraces, but locally the drainage is influenced by the underlying geology. Examples of structural influence include the pronounced northeastward trend of the South Anna River as it enters the Hanover Academy quadrangle and the pronounced southward trend of the North Anna River beginning just north of the Ashland quadrangle and continuing into that quadrangle. The effects of "basement" displacements in late Tertiary time, which extend upward through the Tertiary gravel covering the present surface, may have influenced these trends. Major rapids occur along the South Anna River near Gilman, on the Newfound River just east of the mouth of Beaver Creek, and on the Little River just below the bridge on State Road 685 which spans that river in the extreme northeast corner of the Hanover Academy quadrangle. These and other analogous rapids elsewhere mark the Fall Line, which is usually taken as the boundary between the Coastal Plain and Piedmont physiographic provinces in eastern Virginia. However, in the Hanover Academy and Ashland quadrangles these rapids occur along the western border of the Taylorsville Basin which contains rocks of Triassic age.

The area generally has a low and gently rolling terrain, though locally along the Fall Line steep cliffs 50 to 100 feet high are developed along the banks of the larger creeks and rivers. In the Piedmont, deep weathering has produced thick saprolites on the metamorphic complex along stream divides. The maximum and minimum elevations in each quadrangle are as follows:

Quadrangle	Maximum Elevation, feet	Minimum Elevation, feet	Total Relief, feet
Ashland	244	*ca.* 20	*ca.* 224
Hanover Academy	*ca.* 310	*ca.* 60	*ca.* 250

Although land is used predominantly for agriculture, suburban growth from Richmond is rapidly encroaching upon the area. At present, beef and dairy cattle farms occupy large tracts of cleared land and much of the remaining cleared land is used to grow crops supporting these farms. Immature forests and brush thickets are the most widespread land cover.

Little previous geologic investigation has been done in the quadrangles under study. The Triassic rocks of the Taylorsville Basin have been studied only sporadically, so that none of the previous investigators developed a detailed picture of the stratigraphic and structural relationships. William Barton Rogers (1835, 1840) alluded to the sandstones around Taylorsville in early state geological reports (reissued in 1884) and made a reconnaissance of this basin. Knowlton (1899), in a paper on the petrified wood of the Potomac Group (Cretaceous), commented upon a piece of wood from the "Cretaceous" of the Taylorsville area. The specimen must have come from Triassic strata in the Taylorsville Basin because it was collected near Taylorsville, which lies on the Triassic, and because the same genus (Araucarioxylon) is known from the Triassic rocks in the Richmond Basin (Roberts, 1928) but is unknown elsewhere from the Cretaceous (Knowlton, 1899). Sanford (1913) referred to a well drilled in Ashland which penetrated Triassic strata. The outcrop pattern of Coastal Plain strata has been little changed since the report of Clark and Miller (1912). Watson (1913) described a zirconiferous sandstone from the vicinity of Ashland. He considered the sandstone to be a deposit formed along a beach. Studies of the Petersburg Granite have generally focused on areas south of the Ashland and Hanover Academy quadrangles (Watson, 1906, 1910;

Darton, 1911; Bloomer, 1939; Steidtmann, 1945). Brown (1937) and Goodwin (1970) have mapped some of the metamorphic units along strike to the southwest.

STRATIGRAPHY

Of the seventeen mappable lithologic units within the study area (Figure 2), four are in the pre-Triassic metamorphic-igneous complex of the Piedmont Province, four are in the Taylorsville Basin, and nine are in the Coastal Plain. An amphibolite-grade metamorphic terrain composed of two map units of biotite gneiss separated by a unit of interbedded muscovite-biotite schist, amphibolite, and granite gneiss, underlies most of the northern and western Hanover Academy quadrangle. This terrane is structurally separated from the Petersburg Granite on the southeast by a fault zone, the Hylas Zone. Terrestrial strata of Triassic age occur in the Taylorsville Basin along the east side of the Piedmont Province and include four formations herein named the Falling Creek Formation, the Gum Tree Conglomerate, the Stagg Creek Sandstone, and the Cherrydale Formation in ascending order. A few diabase dikes intrude the Triassic strata and the Piedmont metamorphic complex. The easternmost portion of the mapped area is in the Coastal Plain Province and contains the Patuxent Formation of Cretaceous age, the Aquia Formation of Paleocene age, the Marlboro Clay of Eocene age, the St. Marys and Brandywine formations of Late

Figure 2. Geologic units in the Ashland and Hanover Academy quadrangles

CENOZOIC	Recent	Alluvium	
	Pleistocene	Talbot	
		Wicomico	
	(?)Pliocene	Sunderland	
	Miocene	Brandywine Formation	St. Marys Formation
	Eocene	Marlboro Clay	
	Paleocene	Aquia Formation	
MESOZOIC	Cretaceous	Patuxent Formation	
	Triassic	Diabase Dikes	
		Cherrydale Formation	
		Stagg Creek Sandstone	
		Gum Tree Conglomerate	
		Falling Creek Formation	
PALEOZOIC (?)	biotite gneiss	← uncertain age relationship →	Petersburg Granite
	schist-gneiss complex		
	biotite gneiss		

Miocene age, sediments of the Columbia Group, which are mostly of Pleistocene age, and Recent alluvium.

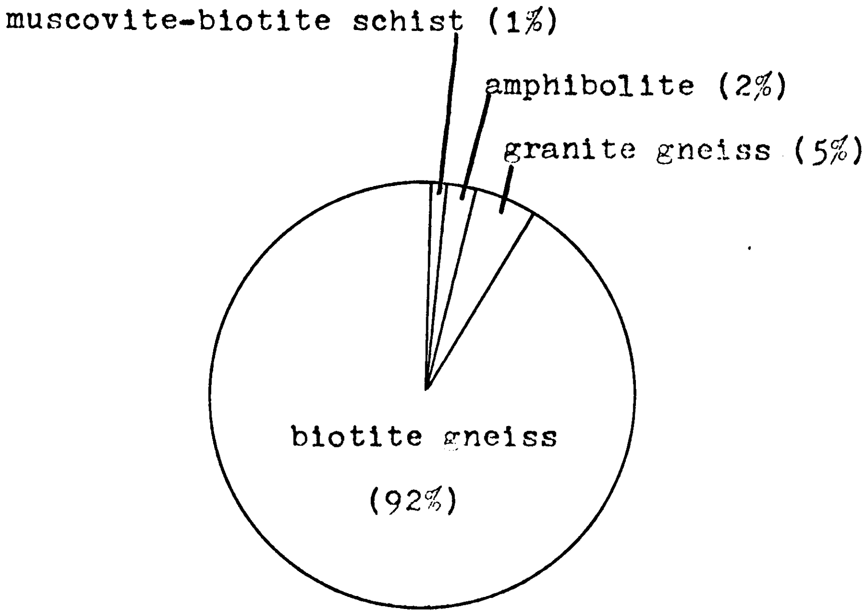
Pre-Triassic Rocks

The geologic age of the pre-Triassic rocks could be Paleozoic and/or Precambrian. Two units of biotite gneiss separated by a unit herein termed a schist-gneiss complex are suggestive of a single structurally deformed terrane in the northeastern portion of the Hanover Academy quadrangle. The biotite gneiss units and the schist-gneiss complex comprise intercalated biotite gneiss, amphibolite, muscovite-biotite schist, and granite gneiss. Biotite gneiss is by far the most common rock type in this terrane (Figure 3), with the other lithologic units occurring mostly in the medial schist-gneiss complex (Plate 1).

Biotite Gneiss

The fresh biotite gneiss is dark gray, fine- to medium-grained, and well foliated. In some places light gray, plagioclase-rich phases are intercalated with the predominantly dark gray phase.

Figure 3. Approximate bulk composition of metamorphic terrane northwest of the Hylas Zone



Approximate mineral compositions are given in Appendix I, Table 1 for three samples (R-5277, R-5278, R-5279) of the typical biotite gneiss. Quartz, potassium feldspar, plagioclase, and biotite occur in all three specimens and are the predominant minerals. The potassium feldspar, plagioclase, and quartz are anhedral, with the quartz prominently strained. Garnet and metallic opaques (magnetite?) are the most common accessory minerals. Most of the garnets are anhedral, highly fractured, and apparently were rotated during growth. The average mineralogy of the upper and lower biotite gneiss units appear identical. Two samples (R-5280, R-5281, Appendix I, Table 1) contain abundant kyanite. Assuming no change in bulk composition, the weight ratios of SiO_2 to Al_2O_3 and of Na_2O plus CaO to K_2O in these samples suggest that they were originally graywackes (Garrels and Mackenzie, 1971, p. 227). Thus at least some of the metamorphic rocks in the biotite gneiss belt may be of a sedimentary origin. Except in some of the more deeply entrenched stream valleys, the biotite gneiss is weathered to red saprolite which is prominently banded.

Schist-Gneiss Complex

Between the two belts of biotite gneiss is a sequence of complexly interbedded muscovite-biotite schists, amphibolites, and granite gneisses. Sample R-5282 (Appendix I, Table 3), from one of several beds of amphibolite, is preponderantly hornblende with considerable plagioclase. Minor amounts of quartz and epidote are present. The amphibolites could represent impure magnesian carbonates, basalt flows, sills, or beds of mafic pyroclastic debris because they invariably occur as concordant bodies within the schist-gneiss complex. The mineralogy of the muscovite-biotite schist (R-5283, Appendix I, Table 3) would seem most suggestive of a metasedimentary unit flanking the antiformal dome in the northcentral Hanover Academy quadrangle (Plate 1).

Petersburg Granite

The Petersburg Granite in the study area occurs only southeast of the previously discussed units and is separated from them by the Hylas Zone. The granite was not observed in contact with the previously discussed units anywhere in the Hanover Academy quadrangle. Sample R-5284 (Appendix I, Table 4) from the Ashland quadrangle where the Chesapeake and Ohio Railroad crosses the South Anna River has a composition of about 32 percent quartz, 43 percent potassium feldspar, 21 percent plagioclase feldspar, and 4 percent muscovite. Two specimens (Samples R-5285 and R-5286) from the Hanover Academy quadrangle on Stagg Creek and on the South Anna River near the mouth of Beech Creek have an average composition of 27 percent quartz, 30 percent potassium feldspar, 37 percent plagioclase feldspar, and 6 percent biotite, muscovite, and/or metallic opaques in varying proportions. Near the apparently younger Hylas Zone the granite is highly fractured and changes from a light gray to a rusty red color. The color change is gradational from west to east and is interpreted as a secondary characteristic possibly related to the extent of fracturing of the rock near the Hylas Zone. This secondary coloration largely obscures any possible field observation of protoliths or facies within the granite that might be present.

Over most of the study area the Petersburg Granite has been disturbed in various degrees by later faulting. Sample R-5284 from an outcrop in the Ashland quadrangle shows the least disturbed texture found in the granite. In thin section the granite lacks a perthitic texture and is roughly equigranular with crystals 2-4 millimeters across. A few small garnets are present which show no evidence of having been rotated during growth. Either the Petersburg Granite is a subsolvus granite, solidifying at temperatures and pressures so low that potassium feldspar and plagioclase solidified as separate crystals, or else the Petersburg Granite has been through at least one metamorphism which has destroyed any perthitic texture originally present.

Rocks of the Hylas Zone

The Hylas Zone, as here defined, is a narrow belt with very fine to very coarse grained rocks running northeastward through the Hylas and Midlothian quadrangles (Goodwin, 1970), and the Hanover Academy, Hewlett, and Ruther Glen quadrangles. The belt, whose width ranges from 0.5-2 miles, separates the biotite gneiss and schist-gneiss complex on the northwest from the Petersburg Granite on the southeast. To the southwest this belt disappears at the James River. It may continue under the western edge of the Triassic rocks in the Richmond Basin. To the northeast the belt continues past the North Anna River and disappears under the sediments of the Coastal Plain. Rocks of the Hylas Zone include the "aporhyolite" of Brown (1937) and the "metavolcanics" of Goodwin (1970).

The Hylas Zone contains rocks of varied lithologies best characterized by the frequent occurrence of fine- to very fine-grained phases. These can be best seen in the Royal Stone Quarry and Luck Quarry just south of Hylas in the Hylas quadrangle. Analyses of rocks from the Hylas Zone are given by Goodwin (1970) and in Appendix I, Table 6 (sample R-5290). In the vicinity of Hylas and especially to the northeast in Hanover Academy quadrangle, augen gneiss with a fine-grained groundmass is abundant. Although both textures have been considered primary (Brown, 1937; Goodwin, 1970), it is likely that these textures are secondary (Lynn Glover, oral communication, 1972). By the criteria emphasized by Higgins (1971), the observed fine-grained textures of these rocks appear to have been induced by cataclasis. Larger crystals are subrounded to well rounded and their size relates to physical hardness rather than ease of crystallization; quartz is invariably fine-grained and feldspars form the augen. Crush trains can be seen frequently, and augen and garnets are commonly severely sheared and crushed internally. All stages of cataclasis can be seen. The "metavolcanic" fine-grained textures are mylonitic (Higgins, 1971), whereas extremely fine-grained lenses are ultramylonites, such as seen at Rocketts Mill where State Road 685 crosses the Newfound River in the Hanover Academy quadrangle. Just west of where the Little River leaves the Piedmont and enters the Taylorsville Basin is a granite-like rock which is a potassium feldspar-poor protomylonite (sample R-5288).

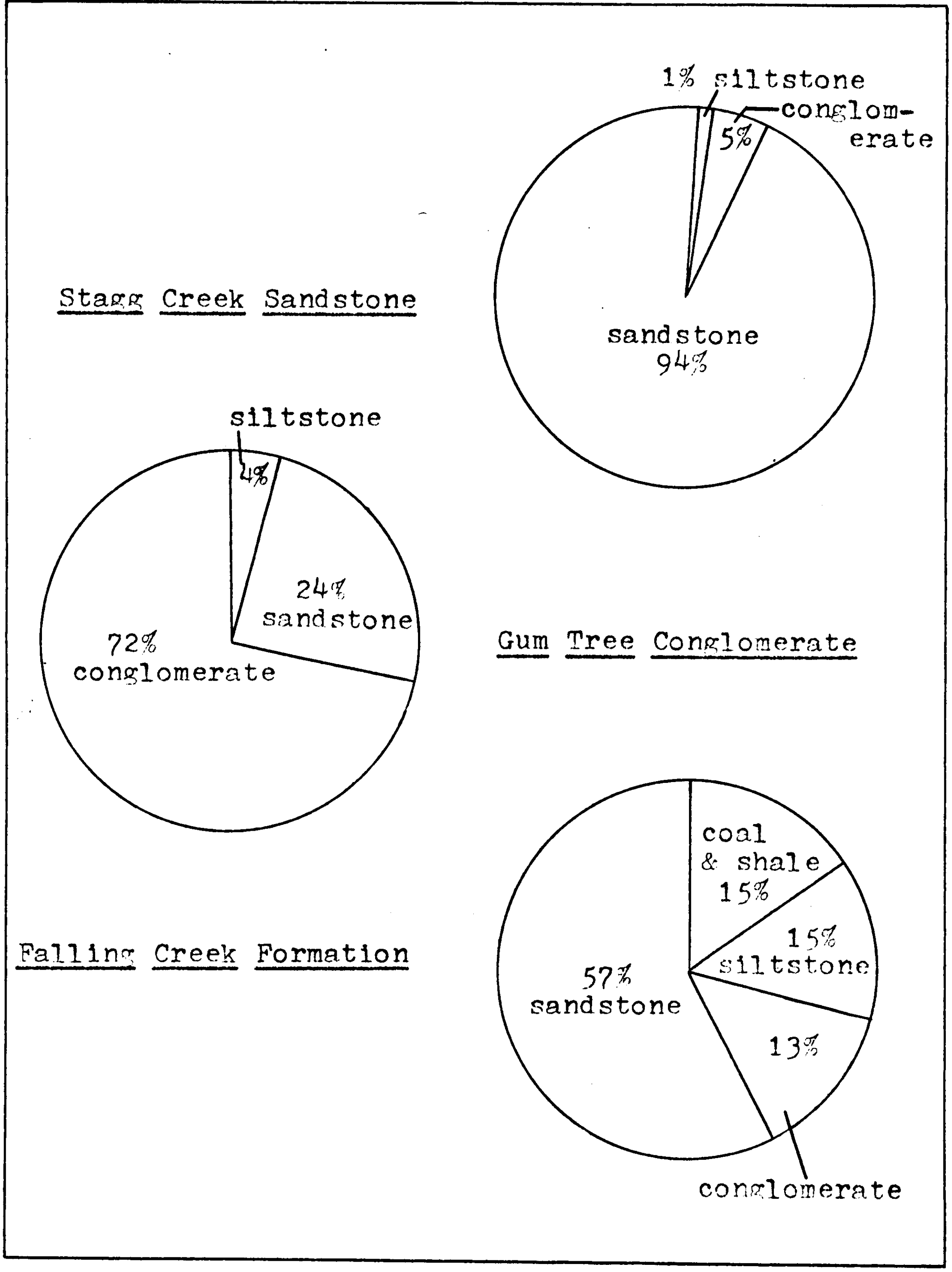
In addition to the cataclastic rocks, there are a number of rock types in the Hylas Zone that are of more obscure origin. Some, such as the gneisses at Rocketts Mill and the Verdon Crushed Stone Quarry on the north border of the Hanover Academy quadrangle, are well banded and coarse grained. Except for being more intensely strained, they are very similar to rocks in the biotite gneiss terrane. Such textures could represent either strained blocks of gneiss isolated within the Hylas Zone but uncrushed or mylonite gneiss in which the quartz has been recrystallized around the feldspar augen. Although the large body of biotite gneiss at Ground Squirrel Bridge on U. S. Highway 33 is probably largely isolated within the Hylas Zone, it escaped cataclasis. The geometry of the large amphibolite body in the Hylas Zone in central Hanover Academy quadrangle suggests that it is a basic dike injected into the zone and later disrupted and metamorphosed (Plate 1).

Triassic System

Falling Creek Formation

The oldest Triassic unit in the Taylorsville Basin is the Falling Creek Formation. Vertebrate remains of a fish (Dictyopyge macrura, W. C. Redfield), a phytosaur (Rutiodon (?)carolinensis, E. Emmons), and a small dinosaur (cf. Spinosuchus caseanus, F. von Huene) have been recovered by the author. These fossils indicate a partially or wholly late Triassic (late Karnian or early Norian stage) age (Gregory, 1955). In addition palynomorphs from this formation are suggestive of a Karnian or Norian age (M. J. Fisher, written communication, 1972). The composition of this and other Triassic formations is shown in Figure 4. Siltstone, shales, and fine- to medium-grained sandstones predominate. The less resistant siltstones and shales are not well exposed in most places, although the small creeks leading into Falling Creek do contain numerous small outcrops of the fine-grained rocks (Appendix II, Section II). It is from such exposures along and near Falling Creek that this formation is named. The only place where this formation can be seen on the surface from its approximate and presumably

Figure 4. Approximate bulk composition of the Triassic formations in the Taylorsville Basin



unfaulted nonconformable contact with the underlying Petersburg Granite to its intertonguing conformable contact with the overlying Gum Tree Conglomerate is along Stagg Creek (Appendix II). Along this creek, however, most of the fine-grained units in the Falling Creek Formation are covered. For example, from an old coal shaft on the bluff above Stagg Creek, a traverse was made along strike toward the creek. The strata containing this coal bed crossed the creek at a swampy locality without outcrops (Interval 59, Section I, Appendix II). Probably most such covered intervals represent easily eroded shaly strata. Near the middle of the formation is an interval of coals and shales which is thick enough and persistent enough to serve as a marker horizon within the formation (Plate 1).

Conglomerates, though uncommon, occur at several horizons in this formation (Intervals 12, 14, 87, 96, and 98, Section I, Appendix II). Most clasts are well rounded and appear to be mainly mylonite from the Hylas Zone, with lesser quantities of granite, vein quartz, and biotite gneiss. Near the eastern edge of the basin at the lowest stratigraphic horizons most clasts are composed of Petersburg Granite. Thus early in the development of the basin, local sources from all directions contributed sediment to the basin. By the end of Falling Creek time, however, most clasts throughout the basin were derived from west of the Fork Church fault (Plate 1), indicating that by late Falling Creek time the basin was filling in most rapidly from the west. This indicates that by late Falling Creek time most structural activity and consequent erosion was localized along the west border fault.

As conglomerates are few in the Falling Creek Formation and as fanglomerates are very sparsely developed along the borders of the basin, there is no compelling evidence for a significant scarp at the fault-bounded edge of the Taylorsville Basin in Falling Creek time. If there had been a scarp with an abrupt change in relief, angular conglomerates should be abundant within the basin near its borders. The dip directions of foreset beds preserved in the Falling Creek Formation, uncorrected for structural effects, generally suggest a northeastward transport direction in the exposed portion of the basin. Whether this reflects the dominant transport direction within the basin or only represents the transport direction along a small portion of a large alluvial fan (e.g., Willard, 1951, 1952) centered at the present southern edge of the basin is not clear.

The shales, siltstones, and fine-grained sandstones, together with a few coals, are indicative of low relief in the basin. Most of the siltstones and shales are gray to black. The laterally continuous bedding in many of the shales and the occurrence of fossil fish (Interval 29, Section II, Appendix II) indicate that most of these siltstones and shales represent lacustrine environments. The mottled appearance of many of the siltstones (Interval 9, Section I, Appendix II) and the lack of stratification in many others (Intervals 47, 65, and 115, Section I, Appendix II) suggest that they have been bioturbated. Since no marine fossils have been found in the Taylorsville Basin, these siltstones are assumed to represent paludal environments or possibly well aerated lake bottoms.

On the whole the Falling Creek Formation seems to represent a time of abundant precipitation and poorly developed drainage within the basin. However, the presence of feldspar grains in some sandstones, as well as rounded cobbles, shows that erosion of the surrounding terrain must have proceeded rapidly. Otherwise, the feldspar would have been weathered to clay and the cobbles broken down to their component grains. The drainage of the terrain around the basin probably was much better developed than within the basin proper.

Gum Tree Conglomerate

The Gum Tree Conglomerate is named for the excellent outcrops near Gum Tree, especially just downstream along the South Anna River from the Ashland Roller Mill on either side of Falling Creek where it enters the South Anna. The section exposed along Stagg Creek (Appendix II, Section I) is a convenient reference section. Other excellent exposures are on the South Anna just above Blunts Bridge, on Stagg Creek just south of State Highway 54, and on the Richmond, Fredericksburg and Potomac Railroad between the South Anna and Little rivers. The Gum Tree Conglomerate conformably overlies fine-grained sandstones of the Falling Creek Formation and is overlain conformably by fine-grained sandstones of the Stagg Creek Sandstone. The intertonguing relationships of the Gum Tree Conglomerate and the Falling Creek Formation can be seen in the south bank of the South Anna on either side of U. S. Route 1 and near the mouth of Falling Creek. The intertonguing of the Gum Tree Conglomerate and the

Stagg Creek Sandstone can be seen in the Richmond, Fredericksburg, and Potomac Railroad cut between the South Anna and Little rivers.

Coarse sandstones and conglomerates predominate, and fine-grained sediments are rare or absent in the outcropping portions of the Gum Tree Conglomerate. Unlike most conglomerates below and above this unit, most clasts are composed of vein quartz, with gneissic and mylonitic clasts occurring in subordinate quantities. Clasts of the conglomerates and most of the sandstones are well rounded to subrounded. Besides the coarse texture, planar crossbedding is a prominent characteristic of this unit. The virtual absence of organic matter and fossils suggest rapid deposition in a well aerated environment. The Gum Tree Conglomerate is interpreted to represent coalescing alluvial fans which spread over at least the southern end of the basin. Similarly developed fanglomerates are found in other Triassic basins (Krynine, 1950 and Reinemund, 1955). Since most clasts from the upper Falling Creek Formation and the Stagg Creek Sandstone were derived from west of the Fork Church fault, presumably most sediment of the Gum Tree Conglomerate also was derived from the west.

Stagg Creek Sandstone

This formation is named for exposures in the bed of Stagg Creek immediately northeast of State Highway 54. The reference section is given in Appendix II (Section I). Other excellent outcrops occur between Horseshoe Bridge and Blunts Bridge on the South Anna River in the Hanover Academy quadrangle and along Little River south and west of Taylorsville in the Ashland quadrangle. As previously noted, this formation intertongues with the underlying Gum Tree Conglomerate and is overlain conformably by the interbedded sandstones, silty sands, and conglomerates of the Cherrydale Formation. Medium- to fine-grained sandstones are the predominant lithology, with minor amounts of gray siltstone and conglomerate developed locally (Appendix II, Section I). As most clasts consist of biotite gneiss and mylonite, the sediment presumably was derived from west of the Fork Church fault. Although the sediments of the Stagg Creek Sandstone are finer than those of the Gum Tree Conglomerate, the scarcity of siltstones and shales suggests deposition was still rapid. Locally, evidence of mass slumping to the northeast resulting from steep initial dips can be seen. The Stagg Creek Sandstone is generally unfossiliferous except for occasional large tree trunk casts (Araucarioxylon). As identical tree trunk casts have been reported from the Otterdale Sandstone in the Richmond Basin (Roberts, 1928), the depositional environment was probably similar for both sandstones. Limbs and branches have not been found, so the trees presumably grew on the terrain surrounding the valley and were washed into the valley only after being uprooted.

Cherrydale Formation

The Cherrydale Formation is a thick sequence of interbedded compact silty sands, sandstones, and poorly consolidated subangular to angular conglomerates conformably overlying the Stagg Creek Sandstone. The Formation is best seen in the ravines on the north side of the Newfound River between State Roads 688 and 667 near Cherrydale Farm, and in the ravines leading into Little River northwest of State Road 688. The base of this formation is marked by the first compact silty sand layer above the monotonous sequence of Stagg Creek sandstones. Where very fresh, this basal silty sand may be gray to blue, but in most exposures it exhibits a maroon red or maroon brown color. The Cherrydale Formation, which contains more red beds than any other formation in the Taylorsville Basin, is poorly consolidated to unconsolidated. Bedding is poorly developed. The variable lithology, color, and degree of consolidation offer a marked contrast with the well-cemented, massive, tan to gray monotonous Stagg Creek sandstones. The Cherrydale Formation, only sparsely conglomeratic in its lowest portions, becomes more conglomeratic high in the section. These conglomeratic phases are best developed along Little River northwest of State Road 688, where the extremely angular clasts indicate derivation from a prominent scarp along the west edge of the basin. No fossils have been reported from the Cherrydale Formation.

Diabase Dikes

Five nearly vertical diabase dikes (Plate 1) intrude Triassic and older rocks. These bodies strike N 10 W, N 30 W, and N 10 E. As no dikes are known to cut Cretaceous or younger rocks, and no such relationship has been reported elsewhere (King, 1961), these dikes must be of latest Triassic or Jurassic age.

Cretaceous System

Patuxent Formation

In Virginia the oldest exposed Coastal Plain sedimentary rocks belong to the Cretaceous Potomac Group, which lies unconformably upon Triassic and older rocks. The post-Triassic and pre-Paleocene Coastal Plain unit in the study area has been assigned to the Patuxent Formation (Clark and Miller, 1912) on the basis of its lithology. No megafossils have been found or reported in the Ashland quadrangle. Here the Patuxent consists of gray to yellow, fine- to coarse-grained sands and blue to gray clays. No conglomerate was observed. Bright yellow, muscovite-bearing sands of this formation unconformably overlie Triassic rocks along the North Anna and South Anna rivers (Plate 1). The top of this unit is marked by a persistnet 1- to 2-foot thick layer of glauconite-stained cobbles and other clasts. This contact is exposed in several outcrops along the Pamunkey River, where the Patuxent is overlain by a boulder bed which, in turn, is overlain by shell Aquia greensands. The Patuxent is poorly exposed, but on the basis of the Patuxent section penetrated by a well at Hanover half a mile east of the Ashland quadrangle (Virginia Division of Mineral

Resources W-1613), the Patuxent on the east border of the Ashland quadrangle must be at least 120 feet thick. A dip to the east of at least 70 feet per mile is indicated. Only one thin indurated sandstone layer was observed; the remaining beds are unconsolidated. In the study area the Patuxent is pervasively weathered, and no feldspars were observed in the sands. Where fresh, the Patuxent has been reported to be arkosic (Clark and Miller, 1912; Teifke, 1973). A general lack of organic matter in the Patuxent suggests that drainage was not often occluded during deposition and consequently most organic matter was oxidized and recycled. Erosion of most sedimentary rocks in the Taylorsville Basin was interrupted in Early Cretaceous time with the deposition of Patuxent sediments. Only the southwest corner of the basin has been eroded intermittently since then.

Tertiary System

Aquia Formation

The Aquia Formation of the Pamunkey Group rests unconformably upon the Patuxent Formation. The base of the formation is marked by a persistent 1- to

2-foot thick layer of pebbles, cobbles, and boulders composed mostly of vein quartz and feldspathic quartzite. Excellent outcrops occur sporadically along the Pamunkey River. The Aquia originally was considered to be Eocene (Clark and Martin, 1901) but is now considered to be Paleocene (Loeblich and Tappan, 1957). In the study area it consists principally of dark green or greenish gray, glauconitic, silty, quartz sands and glauconitic shell beds. The abundance of glauconite and shells in the Aquia suggests that detrital material accumulated slowly in early Tertiary time. The well at Hanover (Virginia Division of Mineral Resources W-1613) suggests the base of the Aquia dips eastward at a rate of 32 feet per mile. On the south bank of the Pamunkey River 600 feet east of the Ashland quadrangle, the Aquia is overlain apparently conformably by light gray Marlboro Clay. However, at all points within the Ashland quadrangle where the upper contact of the Aquia could be seen, as on the south bank of the Pamunkey 1200 feet west of the border of the Ashland quadrangle, the Aquia is unconformably overlain by the St. Marys Formation. The contact is marked by an irregular burrowed surface. The previously cited well data and surface outcrops at the east border of the Ashland quadrangle suggest the Aquia is about 70 feet thick.

The boulder bed at the base of the Aquia has been reported from Richmond (Darton, 1911) and perhaps occurs everywhere at the base of the Aquia from the Pamunkey River southward to the James River. To the north, the base of the Aquia does not crop out on the Mattaponi River, and a basal boulder bed has not been reported in the Rappahannock or Potomac River valleys. Many of the clasts are quite large; some are more than a foot in diameter (greater than 300 mm.). All clasts are either vein quartz, feldspathic quartzites, or siliceous tuffs. The presence of such clasts in a sequence otherwise suggestive of slow deposition presumably supplied by very sluggish streams is anomalous.

Dr. John Funkhouser (oral communication, 1972) called the writer's attention to an excellent exposure of the Patuxent Formation at Drewry's Bluff on the James River approximately 25 miles south of the mapped area where an approximately 40-foot bluff of unconsolidated, non-glauconitic coarse sand contains numerous clasts of Piedmont rocks up to a foot (300 mm.) in diameter. Most are granite and mylonite, with a subordinate amount of feldspathic quartzites, vein quartz, and siliceous tuffs. The granite and mylonite is in an advanced state of decay and can be easily crumbled. The vein quartz, feldspathic quartzites, and siliceous tuffs are virtually unaltered and in size and shape resemble the boulders of the basal Aquia. The Aquia boulder bed probably consists of boulders reworked from the Patuxent Formation. The only difference between the Patuxent and Aquia boulders is that the former have smooth surfaces whereas those of the latter are pitted, possibly from being transported from nearby Patuxent outcrops to the edge of the Aquia sea. The nearest ultimate source of such silicic cobbles is the belt of schists and quartzites 30 miles to the west of the study area in the vicinity of Mineral in Louisa County, Virginia.

Marlboro Clay, Nanjemoy Formation, Calvert Formation

The Marlboro Clay, Nanjemoy Formation, and Calvert Formation have not been recognized in outcrop in the Ashland quadrangle. Yet because the next youngest St. Marys Formation rests upon an irregular surface of unconformity, undetected outliers of these units may occur in the Ashland quadrangle. The Marlboro Clay and Nanjemoy Formation can be seen 600 feet east of the Ashland quadrangle on the south bank of the Pamunkey River. There, three feet of light gray massive Marlboro Clay rests conformably on the Aquia. It is overlain by five feet of light brown sands referred to the Nanjemoy. The Marlboro-Nanjemoy contact is unconformable, with burrows in the Marlboro filled with Nanjemoy sand. The Calvert has been observed three miles east of the Ashland quadrangle at Gravett's Mill Pond in the Hanover quadrangle in King William County; no outcrop closer to the Ashland quadrangle has been found. The Marlboro Clay is inferred to extend barely into the Ashland quadrangle, but the Nanjemoy and Calvert are inferred to be absent.

St. Marys Formation

The St. Marys Formation is present in most of the Ashland quadrangle (Plate 1). In the eastern part of the quadrangle it may be as much as 100 feet thick. West of the North Anna River it thins rapidly at a rate of about 38 feet per mile and pinches out before reaching the Hanover Academy quadrangle. To the east in the Hanover quadrangle, the base of the St. Marys rises, but only at a rate of about 5 feet per mile. Most of the sediments of the St. Marys are silty clays, silts, and very fine sands of a medium gray to medium greenish-gray color. Upon prolonged weathering these sediments acquire a light gray color. At elevations above 140 to 170 feet, the St. Marys grades upward into fine- to medium-grained, brightly colored, red, orange, or yellow sands. The sands are well sorted, frequently contain concentrations of magnetite, and have conglomeratic lenses (Section III, Appendix II). This is interpreted to represent deposition in shallow marine to tidal environments during the regressive phase of the St. Marys. The abundance of the gastropod *Turritella plebeia* in the lower portions of this unit is suggestive of brackish conditions (Gernant, 1972), and in conjunction with the geometry of the base of the formation suggests the St. Marys in this area was deposited in an estuary or embayment with restricted circulation. Remains of organisms indicative of more nearly normal marine environments (*Chlamys santamaria*, *Anadara idonea*, mysticete whale bones, *etc*.) occur only in a few thin lenses at elevations of 100 to 120 feet.

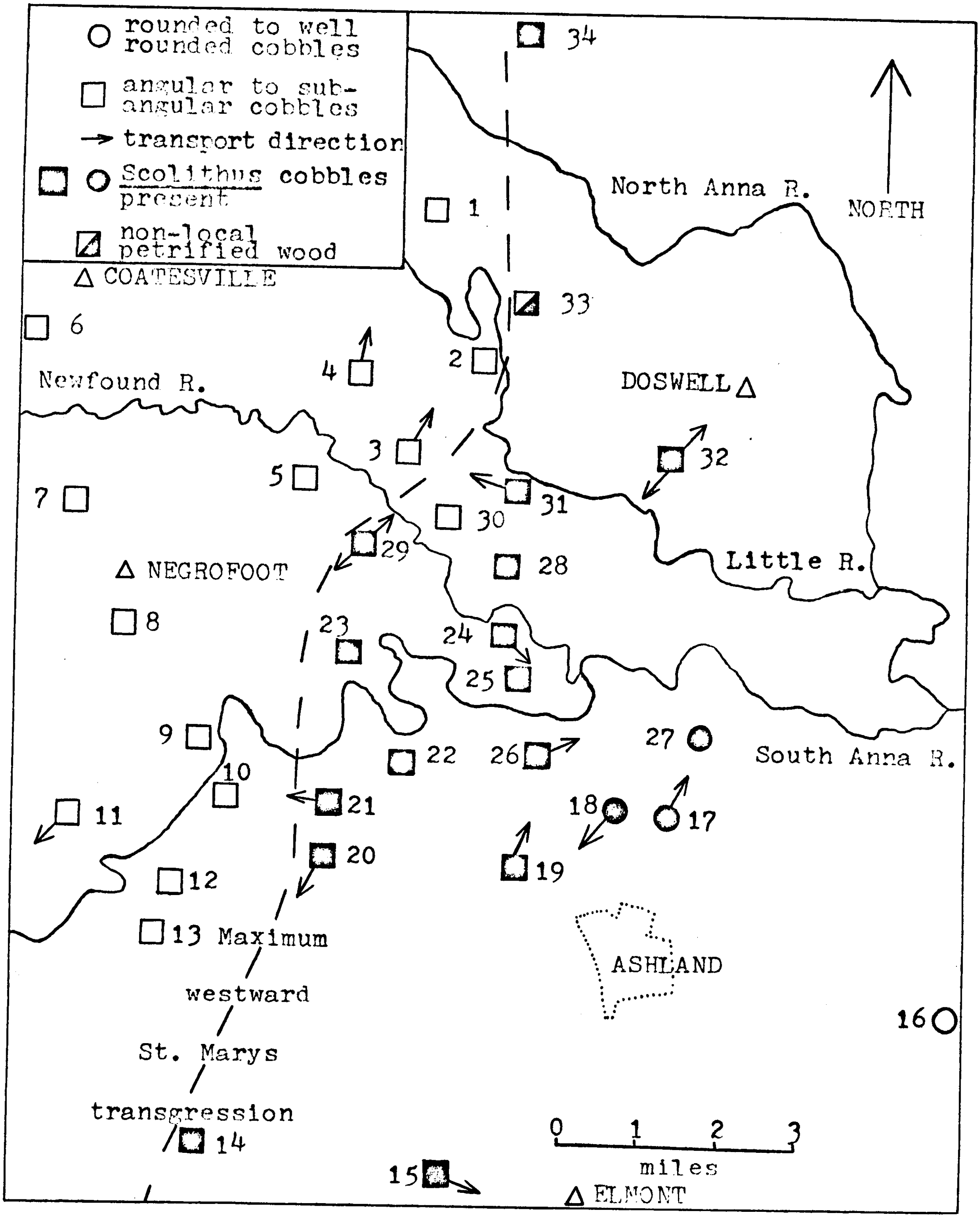
The St. Marys rests unconformably upon older units. The contact with older units, as seen 600 feet east of the Ashland quadrangle on the south bank of the Pamunkey River, is undulatory, marked by prominent burrows filled with St. Marys sediments, and marked by sparse gravels and rare, well-worn bones and teeth. The gravels are concentrated occasionally in the bottoms of burrows. The upper contact of the St. Marys in the mapped area appears to be conformable with the overlying Brandywine Formation. For this reason, the Brandywine might reasonably by considered to be a facies of the St. Marys or at least be older than the Pliocene age usually assigned it. The contact is defined as the base of the beach gravel with flat, disc-shaped, smooth cobbles present between the fossiliferous, well rounded sediments of the marine St. Marys and the angular sediments of the fluvial Brandywine. Where intertonguing occurs, the contact is drawn where the grain morphology changes from dominantly well rounded to dominantly angular. Locally, channeling has removed the regressive sequence of the upper St. Marys so that Brandywine fluvial gravels rest directly on shallow marine St. Marys sediments.

Brandywine Formation

The Brandywine Formation was proposed by Clarke (1915) to replace the names Appomatox and Lafayette for gravels and loams which are widespread in the western Coastal Plain of Maryland and Virginia at elevations of about 180 to 300 feet. This unit, the most widespread unit in the study area, ranges in thickness from 0 to 70 feet and underlies the highest terrace in the area (200 to 300 feet elevation). Traditionally, it has been considered Pliocene in age, although Hack (1955) suggested it may be of Miocene age. In Maryland its fluvial origin seems well established (Schlee, 1957). In the Ashland and Hanover Academy quadrangles, however, the Brandywine is interpreted as a shoreline to fluvial equivalent of the St. Marys. The reasons for considering the Brandywine as a facies equivalent of the St. Marys are:

(1) In the Ashland quadrangle (Figure 5) the basal Brandywine is a beach gravel. Well rounded, unpitted, flat, disc-shaped cobbles, characteristic of a strandline environment (Dobkins and Folk, 1970), are common. Higher in the sequence and to the west, gravels are more angular, and flat disc-shaped cobbles are not seen. Therefore, though in general mostly of fluvial origin, the basal Brandywine in the Ashland area was apparently deposited in the surf zone. However, no eastern marine equivalent is known from outcrops of comparable elevation. Yorktown and younger marine deposits occur at much lower elevations; any assumed equivalence would require the presumption of over 100 feet of tectonic warping in Plio-Pleistocene time cleanly separating onshore and offshore sediments.

Figure 5. Transport directions of gravels of the Brandywine Formation



(2) An unconformity cannot be demonstrated between the Brandywine and the nearshore upper St. Marys unit. The rapid change in grain size between the upper St. Marys sands and the gravels of the basal Brandywine can be attributed to the higher energy present in the surf zone and not necessarily to an unconformity.

(3) The Columbia Group terrace sediments of questionable Pleistocene age are red and contain large boulders of locally derived gneiss. The sands and gravels of the Brandywine, however, are most often yellow and contain little or no gneissic materials. Because the Brandywine is lithologically distinct it should not be included in the Columbia Group.

(4) No fluvial landward equivalent of the marine St. Marys, expected in any normal offlap sequence, has been recognized previously.

To account for the previous observations, the writer proposes the Brandywine be considered a strandline and fluvial facies equivalent of the St. Marys. This implies the Brandywine is of Late Miocene age.

The lower gravelly portion of the Brandywine is composed of clasts which are highly siliceous; unstable minerals are unrepresented. Quartzites and sandstones are common, and cherts scarce. Some quartzites and cherts contain fossils which offer clues to their provenance. Fossils are most numerous in cobbles and boulders derived from the Lower Cambrian Antietam (Erwin) Quartzite, which contain tubes of Scolithus. Rarely are fossiliferous cherts seen. One chert pebble contains bryozoans. According to Dr. Richard Boardman of the National Museum of Natural History (written communication, 1972) "...the pebble is most likely Silurian in age. The cystoporate bryozoans are too well shaped to be Ordovician." A second pebble was formed entirely from a silicified colony of coral. This was studied by Dr. William Oliver of the National Museum of Natural History who stated (written communication, 1972) "...the second pebble is of a Favosites. This is of Silurian or Devonian age but is most likely to be from the Helderberg group. This would be the uppermost Silurian and Devonian interval. It can hardly be younger than Oriskany and probably no younger than Helderberg. It could be from the Mckenzie or Wills Creek but Favosites are not common in these pre-Keyser units." These chert pebbles constitute the earliest known occurrence of Valley and Ridge derived clasts in the Coastal Plain of Virginia. Their occurrence in the Brandywine has been noted before (Clark and Miller, 1912) but taxonomic assignment of their fossils was not attempted. Perhaps such materials were also being shed into the Coastal Plain at an even earlier time because Scolithus pebbles have been found in the high level and probably pre-St. Marys gravels described by Goodwin (1970) near Midlothian.

In the Hanover Academy and Ashland quadrangles, two types of Brandywine gravels can be distinguished on the basis of (1) presence or (2) absence of Paleozoic fossils. A fabric analysis of a number of outcrops was made (Figures 5 and 6). This analysis suggests that the fossiliferous gravels had a preponderantly northeast and/or southwest transport direction. Thus the extent of the fossiliferous, frequently disc-shaped gravels probably marks the edge of the St. Marys sea, and these gravels apparently were introduced by longshore currents or distributary channels. The more angular unfossiliferous gravels likely were derived from a local source.

Quaternary System

Columbia Group

Since the late Miocene, the North and South Anna rivers have been eroding the Brandywine. During this downcutting, three mappable terraces underlain by

Figure 6. Rose diagrams of fabric of gravels at selected outcrops shown in Figure 5. Outcrop numbers from Figure 5 are unbracketed; number of cobbles analyzed per outcrop are in parentheses.

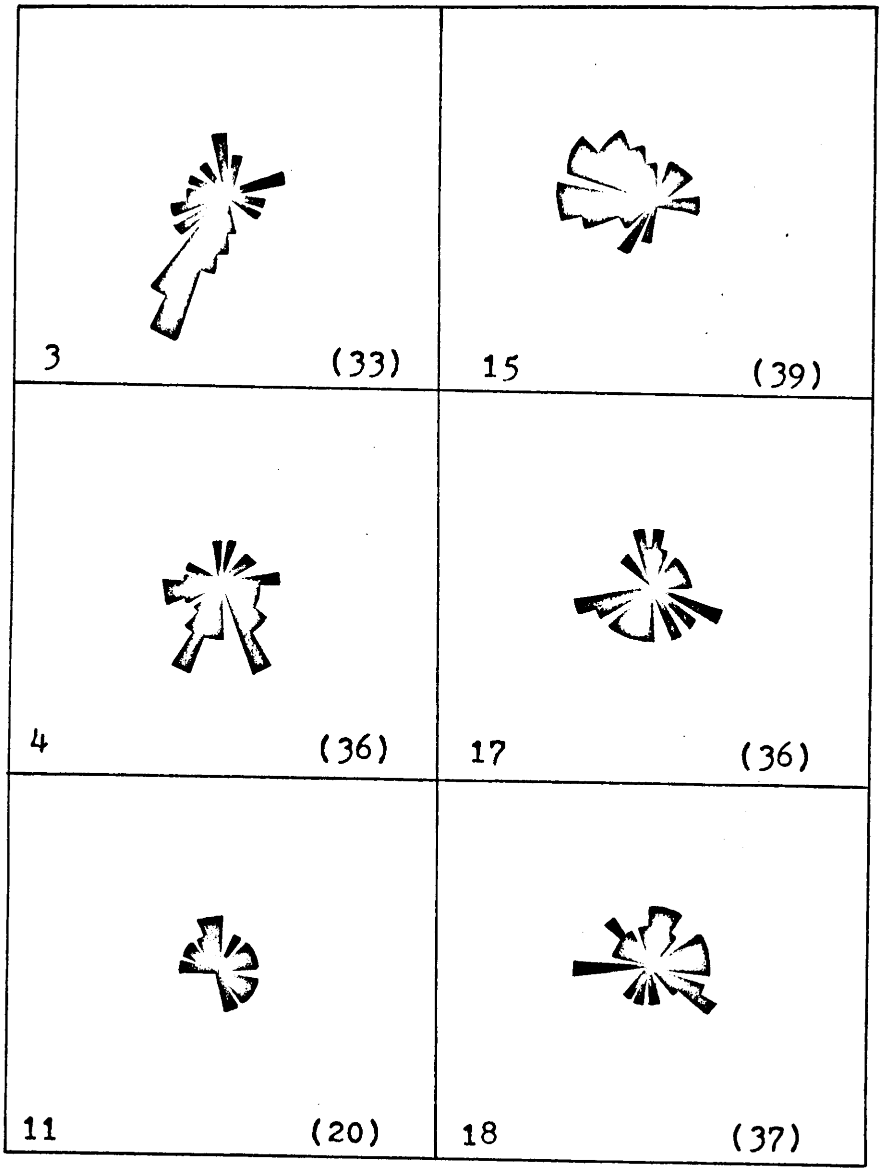


Figure 6, (continued)

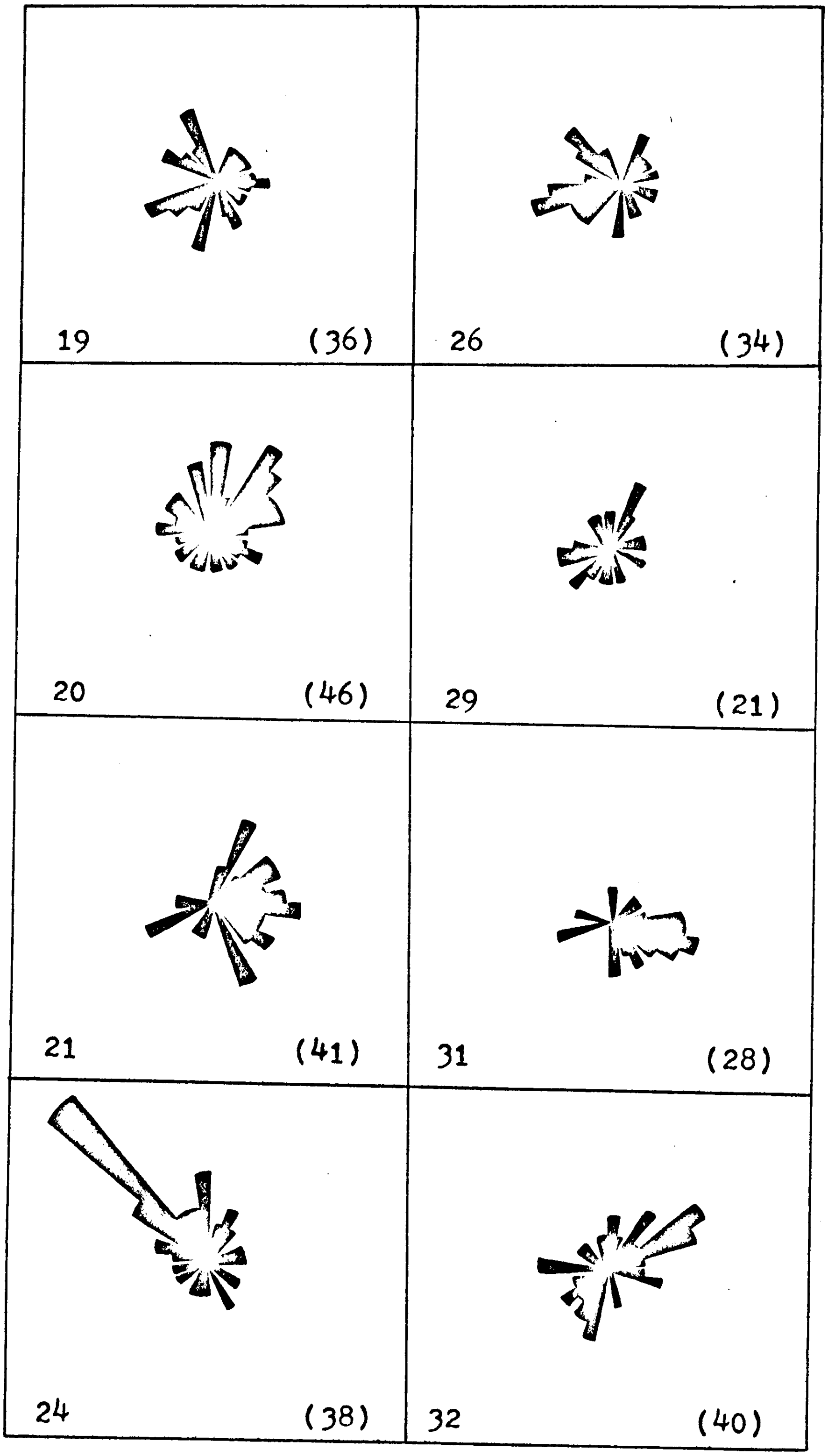
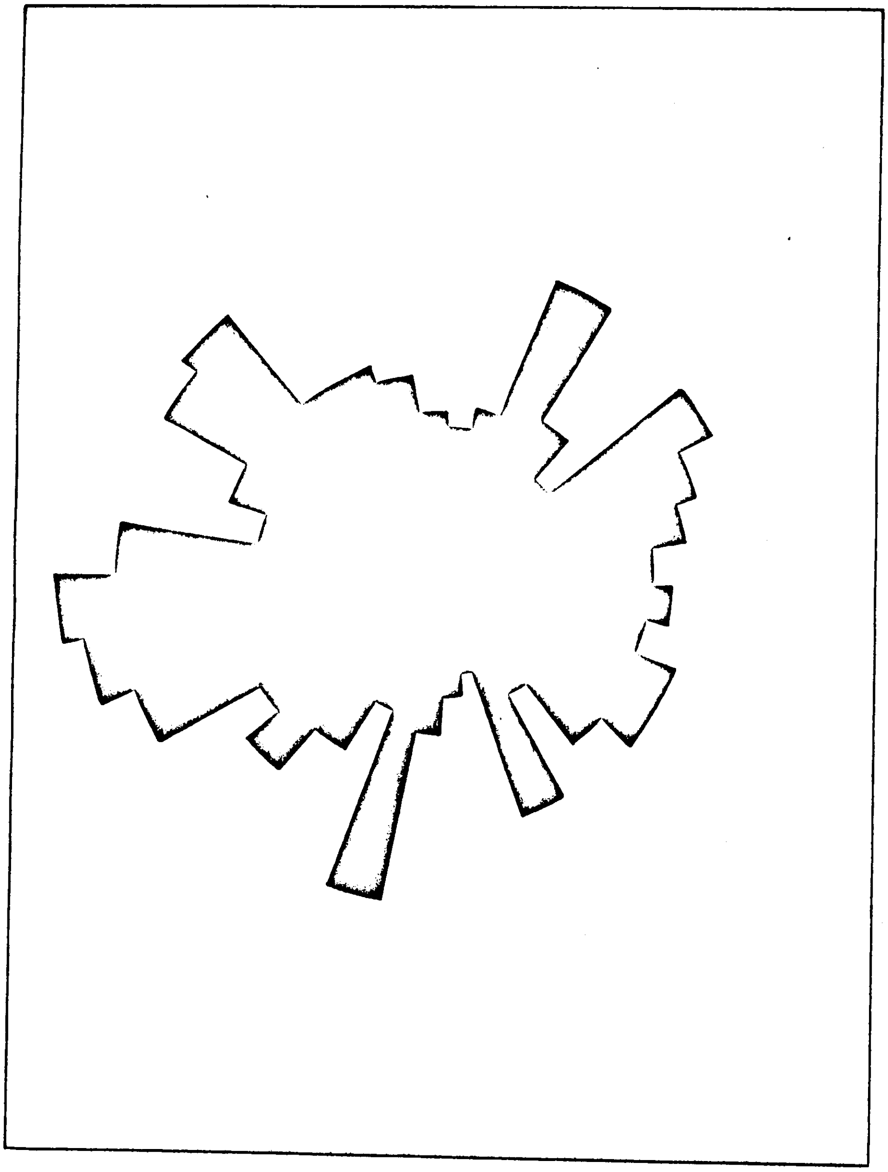


Figure 6, (continued). Cumulative rose diagram of all preceding rose diagrams for outcrops containing <u>Scolithus</u>



fluvial sands and gravels were formed. As downcutting proceeded the North Anna tended to migrate eastward down the eastward dip of the base of the unconsolidated St. Marys Formation (Plate 2). These three terraces, at 120 feet, 70 feet, and 45 feet elevation, are widespread. Though flat near the major streams, each is inclined upward where it adjoins higher (and older) terrain.

Because each terrace deposit has incorporated material from all older exposed units, the rock types represented in each terrace are very diverse. Generally, however, the abundance of gneissic clasts in the terrace deposits distinguish them from the Brandywine Formation. Deposits of the 120-foot terrace most frequently are coarse sands; deposits of the 70-foot terrace most frequently are gravelly; and deposits of the 45-foot terrace most frequently are fine and loamy. Even so, any single rock type can be found in more than one terrace. Because no terrace has a truly distinctive lithology, correlations with the post-Miocene formations named by Oaks and Coch (1973) have not been attempted. The terraces are principally distinguished locally by their elevation of occurrence, and are simply named by the traditional names of Sunderland, Wicomico, and Talbot, from oldest to youngest. Though listed as

Pleistocene in age, one or more could be Pliocene or even uppermost Miocene (Yorktown) in age. The sediments beneath the terraces may be up to 20 feet thick. Each terrace merges westward into the alluvium presently accumulating along the major streams.

STRUCTURAL GEOLOGY

Pre-Triassic Tectonics

Because the schist-gneiss complex and the biotite gneiss are intercalated, they are presumably of approximately equivalent age and have shared a common tectonic history. The dome in the north-central part of the Hanover Academy quadrangle (Plate 1; Plate 2, Section C-C') indicates that the biotite gneiss enclosed by the dome is the structurally lowest unit in the area. Presumably the regional terrane is not overturned. Rotation of garnet crystals during growth (R-5277, R-5279) indicates that folding had commenced in these units before the thermal maximum for metamorphism was reached. Folding or refolding also must have occurred after the thermal maximum, for extensive crushing of the feldspars has taken place in some dikes intersecting the schist-gneiss complex. Such folding may represent a separate later event, and the rather variable directions of foliation dip around the dome in north-central Hanover Academy quadrangle also suggest this. These variably oriented foliations contrast sharply with the more uniformly southeastward foliation dips associated with isoclinal folds in the southern part of that quadrangle and to the southwest in the Hylas quadrangle (Goodwin, 1970). Probably this dome was formed in a milder structural deformation following the event producing nearly isoclinal folds. Metamorphism, possibly concurrent with the earlier folding event, apparently peaked within the lower amphibolite grade. Hornblende and kyanite are common, the plagioclase has a relatively high anorthite content (24 to 32 percent), and typical greenschist facies minerals are present only where secondary shearing and crushing effects are evident.

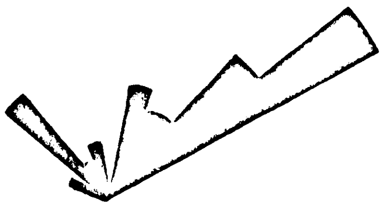
The Petersburg Granite is too poorly exposed to show much structure in the study area, and because of the intervening Hylas Zone its age relations to the biotite gneiss and schist-gneiss sequence is unclear. It has a persistent foliation trending northeasterly to northwesterly. This foliation and the lack of perthitic texture (see page 14) suggest that the Petersburg Granite may have been through at least one metamorphism. This event may or may not be related to either of the two deformational events in the biotite gneiss and schist-gneiss complex.

The Hylas Zone seems to be a wide zone of cataclastic rocks one-half to two miles in width. Along its borders small scale folds are developed (Plate 1; Plate 2, Section E-E') which may be related to small scale drag folding along the margins of the fault zone. There is no unit in the study area which can be correlated across it; therefore motion could have been predominantly vertical, lateral, or oblique. Internally the zone shows all stages of cataclastic disruption. Motion along the fault has apparently been recurrent, for some of the cataclastic textures have been partly recrystallized (augen gneiss) while others have not (mylonite and protomylonite). This fault zone postdates the metamorphic units and the granite in the study area, but its age is only known to be pre-Triassic. Possibly some or all of the mylonite and protomylonite were formed as part of the structural event producing the Triassic border faults, which are discussed later. Probably the northeast-trending joint set (Figure 7) is associated with motion along this fault zone; this joint set is most intensely developed within the fault zone, parallels the fault zone, and becomes progressively more weakly developed away from it.

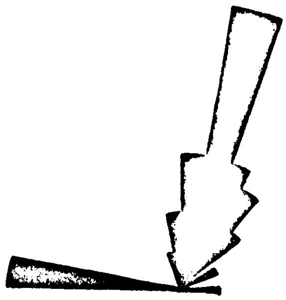
Triassic Tectonics

The Taylorsville Basin is bounded by a major normal fault on the west, herein named the Fork Church fault. The Fork Church fault is buried in

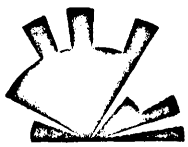
Figure 7. Rose diagrams of joint trends at selected localities in the Hylas Zone and the Taylorsville Basin



Newfound River at Rocketts Mill
(Hylas Zone)



South Anna River at Gilman Bridge
(Hylas Zone)



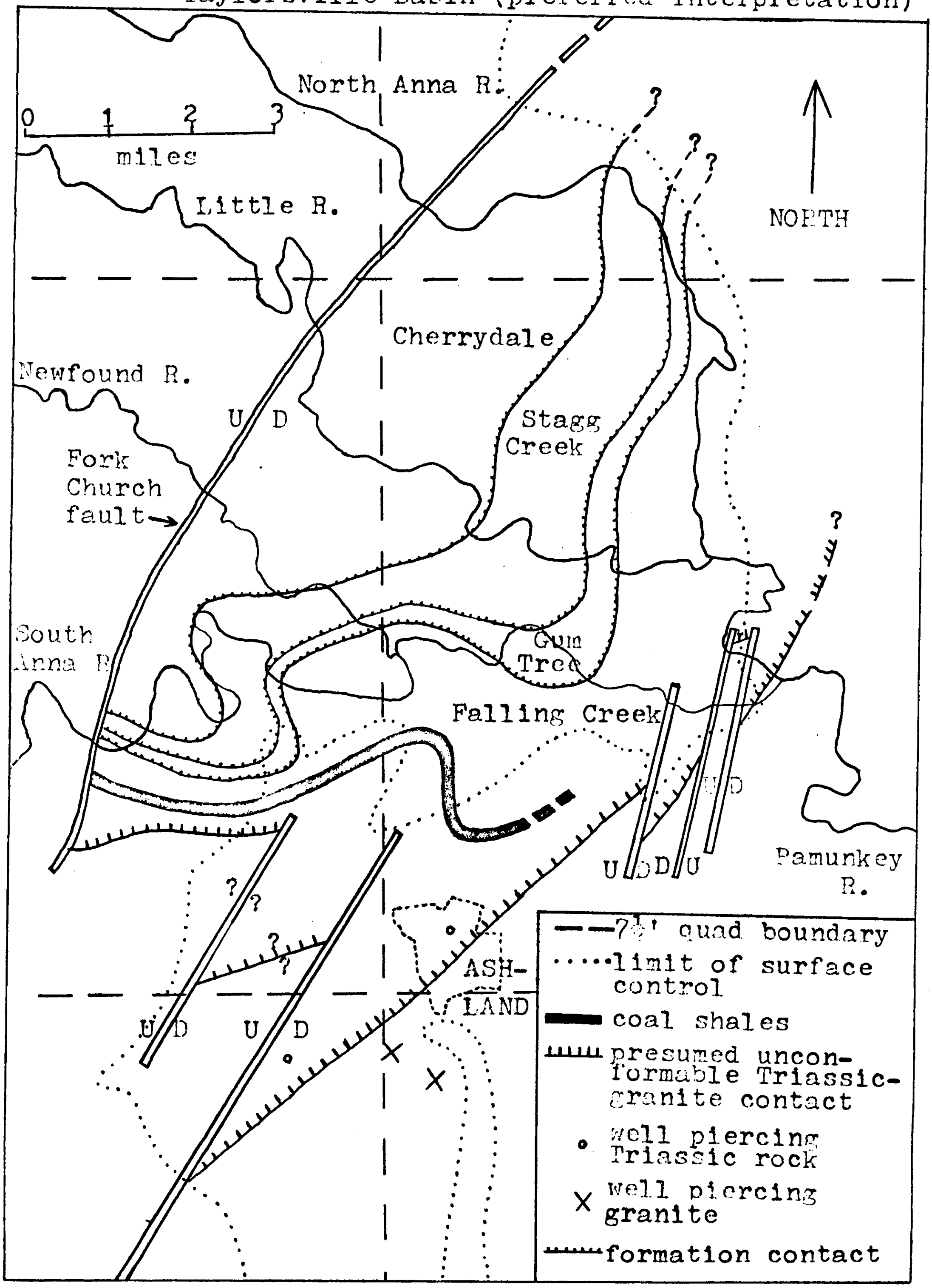
Little River at U. S. Route 1
(Taylorsville Basin)

most stream valleys, but it is well exposed on a small tributary of Beech Creek. Here black carbonaceous shales rest on a slickensided granite face which strikes N 6 E. Slickensides indicate movement was entirely dip-slip. Both to the north and south the strike of the fault becomes more northeasterly.

The sediments in the basin are broadly folded, apparently due to differential subsidence of the floor of the basin and also to draping of sediments over the basement blocks of granite. In the Ashland quadrangle, where the Chesapeake and Ohio Railroad crosses the South Anna River, an inlier of the Petersburg Granite, which seems to have resulted from motion along two faults (Plate 2, Section B-B'), also roughly corresponds to the northwesterly trending axis of one of the depositionally shallower regions of the basin. Thus the folds present in the strata of the basin could be the result of subsidence along an entirely hidden northwesterly trending fault set or due to differential subsidence along the demonstrable northeasterly trending fault set. Coastal Plain cover precludes clarification of this problem. Besides the small faults developed along the eastern margin of the basin along the North Anna and South Anna rivers, evidence of basement faulting within the basin is also indicated in the subsurface by two wells drilled in Ashland (Sanford, 1913, p. 185) and two miles southwest of Ashland in the Glen Allen quadrangle (W-2340, samples in the repository of the Virginia Division of Mineral Resources). Both wells pierced Triassic (Falling Creek) strata (Figure 8). Certainly the presence of Triassic strata in these two wells is difficult to explain without the presence of faulting in the "basement". Nowhere is surface or subsurface data complete enough to allow a determination of the direction and degree of dip along these presumed faults.

The sequence of sediments in the Taylorsville Basin suggests periodic pulses of tectonic activity rather than continuous subsidence. The lowest Falling Creek sediments in the basin suggest moderate tectonic activity followed by quiescence (coal-bearing shales), followed by increasing tectonic activity. Activity peaked in Gum Tree time, resulting in a major influx of gravel, then fell off through Stagg Creek and lower Cherrydale time, as progressively finer grained sediments were introduced. Late in Cherrydale time tectonic activity increased and coarse gravels flooded the basin a second time. Since the Cherrydale silts are not as fine as the Falling Creek shales, and the Cherrydale conglomerates are more angular than

Figure 8. Approximate structure and configuration of the Taylorsville Basin (preferred interpretation)



the Gum Tree Conglomerate, tectonism probably did not subside in early Cherrydale time as much as it did in middle Falling Creek time, and the late Cherrydale pulse of tectonism was probably more intense than that in Gum Tree time. Therefore, episodes of increasingly intense tectonic activity along the Fork Church fault, coinciding with increasingly coarser sediment influx from the northwest, would seem to best explain the origin and development of the Taylorsville Basin. Presumably tilting of the Triassic column occurred concurrently with deposition, for the oldest sediments in the basin dip most steeply (up to 60 degrees) whereas the youngest sediments dip less steeply (6-8 degrees). The development of local subbasins within the Taylorsville Basin (Figure 8; Plate 2, section F-F') indicates that subsidence was not uniform across the entire basin floor.

Diabase dikes cut across all preserved formations of the Triassic and show a strong preference for the N 10 -30 W joint set. This preferred joint set is better developed within the basin than in the surrounding terrane (Figure 7). This may partly explain why most dikes are within the basin and do not cut across the Fork Church fault into the metamorphic terrane. The two dikes which could be traced within the basin near Taylorsville and Hanover Academy (Plate 1) appear to be quite straight. This indicates the dikes were emplaced after differential subsidence of the basin had ceased. Only one small dike was found to follow the northeast joint set. Although all exposed basement faults involved in the formation of the basin have a northeast trend, as does the basin itself, features associable with late basin or post-basin development show a northwest trend instead. These features include the northwest trending dikes, joints, and subbasin fold axes (Plate 1). In addition northwest trending strike-slip faults cutting across Newark and older strata have been reported in the Danville Basin (Meyertons, 1963) and in the New Jersey Basin (Sanders, 1962). Goodwin (1970) reported northwest trending faults classically considered to be dip-slip faults but apparently of unproven motion. Northwesterly trending slickensides, developed at the Rocketts Mill exposure on a subhorizontal joint plane, also may be referrable to small scale northwest motion in the mapped area at the same time as the period of strike-slip faulting. Whether these features reflect a discrete late and/or post-Newark structural event or simply reflect the culmination of a continuous change in the strain field throughout

Newark time is unclear. Although the early Newark northeast trends clearly reflect a classic northeast "Applachian" trend, the later northwest trends are more reminiscent of the northwest-southeast structural axes present in the subsequently developed Coastal Plain (Gernant, Gibson, and Whitmore, 1971, p. 6).

Post-Triassic Tectonics

After deposition and folding of the Cherrydale Formation a major interval of erosion ensued throughout the Jurassic. The volume of material removed during this interval cannot be estimated, but the occurrence of semi-consolidated sediment in the upper Cherrydale Formation and the lack of any great thicknesses of Jurassic sediments encountered to the east beneath the Coastal Plain suggest that little material may have been removed.

Classically, sedimentation in the Coastal Plain has been pictured as occurring without deformation except for regional seaward tilting. In recent years this simple picture has been increasingly questioned (for example, Minard and Owens, 1966; Brown, 1972). Spangler and Peterson (1950) were the first to note an area in northeastern Virginia and southern Maryland, just west of the Potomac River Bridge on U. S. Highway

301, where subsurface structure seems to influence the sediment thicknesses. This same area lies nearly along the axis of a Paleocene (Aquia) depositional basin postulated by Schifflett (1948). The region in question extends from just east of Washington, D. C., to the vicinity of Taylorsville. This strip probably represents a portion of the Taylorsville Basin buried beneath the Coastal Plain. Possibly continued subsidence along a northeastward extension of the Hylas Zone-Taylorsville Basin complex produced both the local depositional basin present in Aquia time, and the unusual thicknesses of sediments noted by Spangler and Peterson. In view of this evidence for early Tertiary fault-controlled motion along the Hylas Zone-Taylorsville Basin complex, the abnormal thickness of the St. Marys and the unusually steep dip of the base of the St. Marys in the Ashland quadrngle west of the North Anna River (38 feet per mile) may have resulted from Miocene tectonic activity as well (Plate 2, Sections A-A' and C-C').

The present geomorphology has been influenced by older structures and faults. In the Hanover Academy quadrangle, the South Anna River is deflected northeast along the strike of the Hylas Zone. The nearly north-south joints and faults in the Taylorsville

Basin, and its underlying basement, probably influenced the northward trend of Stagg and Beech creeks, as well as the northward deflection of the South Anna River just west of the Hanover Country Club. Smaller deflections of rivers and streams parallel to local trends of foliation or bedding occur widely, but joints and faults seem to have had the greater effect on the present geomorphology. In the Ashland quadrangle the most prominent geomorphic effect is the progressive eastward deflection of the North Anna River. Rather than entrench into consolidated Triassic rocks, the river has cut obliquely eastward along the bottom of the Coastal Plain (St. Marys) strata. The result has been cannibalization of terraces on the east side of the river. Thus the valley of the North Anna is steeper on its east side than on the west (Plate 2, Section A-A').

ECONOMIC GEOLOGY

A number of mining and quarrying enterprises have been attempted in the past in the Hanover Academy and Ashland quadrangles. Most were started for purely local markets and were soon displaced by other, more economic enterprises elsewhere. Iron, mica, coal, shell marl, gravel, and crushed stone have all been exploited. Only crushed stone has endured.

Iron

No deposits of high iron content are present, but probably the iron-enriched saprolites above the metamorphic rocks were a source of this metal for early settlers. Scotchtown, in the Hanover Academy quadrangle, had an early foundry, and the remnants of an old iron furnace, probably identical with the Scothchtown enterprise, were unearthed at Rocketts Mill just west of where State Road 685 crosses the Newfound River (Mrs. I. C. Blickenstaff, oral communication, 1972). Probably this foundry operated from local iron sources only.

Mica

Mica was successfully mined at several localities in Hanover Academy quadrangle (Plate 1). Details of these mines are given by Brown (1962). The quality of the muscovite is excellent, but the pegmatites in which it occurs are very variable in width and generally pinch out rapidly at depth and along strike. Even the best prospects remained productive for only a few months before production began to decline. The market for muscovite has been dwindling in recent years, and now it is used only for some types of electronic circuitry. However, even for these purposes it is no longer the most preferred material.

Coal

Coal was mined at least as early as the 1830's in the Hanover Academy and Ashland quadrangles (Rogers, 1884). Probably this coal is no longer worth developing comercially. Presumably it was never mined for more than local consumption. Rogers mentioned two operations, one on Stagg Creek and one on "Beach Creek". The Stagg Creek operation was on the "Poor House" property and surely corresponds to the mine site shown southwest of Patrick Henry High

School in the Hanover Academy quadrangle. The "Beach Creek" mine presumably corresponds to the old workings shown on Plate 1 south of the South Anna River in the Ashland quadrangle. This operation was abandoned before anyone's memory and no stories about its operation persist (Fairfax Davis, oral communication, 1973). Since no trace of any mine was found on Beech Creek in the Hanover Academy quadrangle, it is likely that the "Beach Creek" that Rogers mentioned is not Beech Creek shown on current maps and that only two operations were attempted.

Shell Marl

Shell marl was mined in the 19th century to increase fertility of agricultural land, and even today, fragments of shark's teeth in the fields of the Ashland quadrangle attest to its use. The glauconitic Aquia was the best source of these marls. Marl pits were once operated just northeast of the present Chesapeake and Ohio tracks between Wickam Crossing and Blanton Crossing in the Ashland quadrangle (R. R. Taylor, oral communication, 1973) but have since been all but obliterated by filling and slumping.

Gravel

The Brandywine Formation and the Wicomico terrace have been the chief sources of gravel up to the present time. The Sunderland and Talbot terraces have been partially exploited, but these generally have a large clay and silt content which renders them useless. Because it is easy to quarry and is close at hand, local gravel is a prime source of fill dirt for road construction in the area.

Crushed Stone and Dimension Stone

By far the most important mineral resource of the area are the rocks comprising the highly jointed Hylas Zone. These are currently being recovered in the Hanover Academy quadrangle for crushed stone only at Verdon on the border with the Hewlett quadrangle to the north. Near Ground Squirrel Bridge (Plate 1) Col. T. E. McCracken (ret.) has started several quarries near the Hylas Zone to produce dimension stone. The supply for both purposes appears to be nearly inexhaustible, at least for the foreseeable future.

Zircon

Although zircon was reported in the Hanover Academy quadrangle early in this century (Watson, 1913), no attempt has been made to develop this resource. Watson thought the zircon was concentrated in beach sands of the Calvert Formation, but in fact the occurrence is in the St. Marys Formation. The zircon is in an 18-inch thick layer of heavy mineral sand (Watson, 1913), apparently deposited along a St. Marys' beach or bar (Plate 1).

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Appendix I. Location, modal and constructive chemical analyses of samples.

Biotite Gneiss

R-5277 Bed of unnamed creek 1.5 miles south of Negrofoot, 800 feet southeast of State Road 671, Hanover Academy quadrangle.

R-5278 On south side of Beaver Creek, 2 miles ENE. of Negrofoot, Hanover Academy quadrangle.

R-5279 East side of Stone Horse Creek 0.5 mile SSW. of Ground Squirrel Bridge on U. S. Highway 33, Hanover Academy quadrangle.

R-5280 100 feet SSE. of State Road 671 in bed of Cedar Creek, Hanover Academy quadrangle.

R-5281 Bed of unnamed creek 1.25 miles WSW. of Negrofoot, Hanover Academy quadrangle.

Schist-Gneiss Complex

R-5282 North side of Newfound River 1.5 miles WSW. of Oliver, Hanover Academy quadrangle.

R-5283 South side of Newfound River 1.4 miles SW. of Oliver, Hanover Academy quadrangle.

Petersburg Granite

R-5284 100 feet west of Chesapeake and Ohio Railroad trestle over South Anna River on north side of river, Ashland quadrangle.

R-5285 Stagg Creek north of State Road 696 just south of contact of Falling Creek Formation and Petersburg granite, Hanover Academy quadrangle.

R-5286 100 yards west of Fork Church border fault on south bank of South Anna River, Hanover Academy quadrangle.

Hylas Zone

R-5287 Bed of Newfound River 50 feet west of State Road 685, Hanover Academy quadrangle.

R-5288 100 yards southwest of State Road 685 in bed of Little River, Hanover Academy quadrangle.

R-5289 Verdon quarry on border of Hanover Academy and Hewlett quadrangles, just west of State Road 685.

R-5290 Luck quarry, 2 miles south of Hylas just east of State Road 623, Hylas quadrangle, 4 miles southwest of mapped area.

Table 1. Modal Analysis (in percent) of Samples from Biotite Gneiss Units

	R-5277	R-5278	R-5279	R-5280	R-5281
Quartz	36.5	26.0	37.1	47.6	54.0
Plagioclase	42.0	17.7	14.0	17.4	----
Potassium feldspar	----	23.7	9.2	25.4	----
Biotite	19.5	27.9	12.4	----	----
Muscovite	----	----	----	2.0	2.0
Kyanite	----	----	----	7.6	16.5
Garnet	0.5	----	7.9	----	----
Hornblende	----	----	5.3	----	----
Epidote	----	4.7	14.1	----	----
Chlorite	----	----	----	----	15.5
Myrmekite	----	----	----	----	10.5
Opaques	1.5	----	----	----	1.5
	100.0%	100.0%	100.0%	100.0%	100.0%

Table 2. Approximate Chemical Analysis (in percent) Computed from Modal Analysis.

	R-5277[a]	R-5278[b]	R-5280[c]	R-5281[c]
SiO_2	67.4	62.1	76.0	69.6
Al_2O_3	14.0	14.5	16.1	14.6
(Mg,Fe)O	7.9	10.9	----	12.1
FeO,Fe_2O_3	1.5	----	----	1.5
CaO	2.8	2.2	1.1	0.3
K_2O	2.1	7.8	5.1	0.3
Na_2O	3.7	1.7	1.6	0.5
H_2O	0.6	0.8	0.1	1.1
	100.0%	100.0%	100.0%	100.0%

a--(An_{32})

b--(An_{24})

c--(An_{31})

Table 3. Modal Analysis (in percent) of Samples of the Schist-Gneiss Complex

	R-5282	R-5283
Quartz	3.5	37.4
Plagioclase	20.5	13.6
Potassium feldspar	----	3.4
Muscovite	----	25.9
Hornblende	71.0	----
Biotite	----	19.4
Epidote	5.0	----
Opaques	----	0.3
	100.0%	100.0%

Table 4. Modal Analysis (in percent) of Samples of the Petersburg Granite

	R-5284	R-5285	R-5286
Quartz	32.2	26.7	29.4
Plagioclase	20.7	35.5	38.8
Microcline	31.0	7.0	19.0
Potassium feldspar (undifferentiated)	11.7	24.8	9.5
Muscovite	3.9	0.5	0.9
Biotite	----	4.6	2.4
Garnet	0.5	----	----
Opaques	----	0.9	----
	100.0%	100.0%	100.0%

Table 5. Approximate Chemical Analysis (in percent) Computed from Modal Analysis

	R-5284 (An_{26})
SiO_2	71.7
Al_2O_3	16.2
(Mg,Fe)O	0.3
CaO	1.1
K_2O	8.6
Na_2O	1.9
H_2O	0.3
	100.0%

Table 6. Modal Analysis (in percent) of Samples from the Hylas Zone

	R-5287	R-5288	R-5289	R-5290
Quartz	51.2	30.1	19.2	46.3
Plagioclase	41.9	64.1	64.5	32.0
Potassium feldspar	----	----	1.0	21.2
Biotite	4.4	4.3	11.3	----
Garnet	1.0	----	----	----
Hornblende	----	----	1.5	----
Chlorite	----	1.5	1.0	----
Epidote	----	----	1.5	----
Laumontite	----	----	----	0.5
Opaques	1.5	----	----	----
	100.0%	100.0%	100.0%	100.0%

Table 7. Approximate Chemical Analysis (in percent) computed from modal analysis

	R-5289 (An_{31})
SiO_2	61.8
Al_2O_3	20.3
(Mg, Fe)O	5.6
CaO	4.6
K_2O	1.4
Na_2O	5.9
H_2O	0.4
	100.0%

Appendix II: Stratigraphic Sections

Section I. Section of Cherrydale Formation, Stagg Creek Sandstone, Gum Tree Conglomerate, and Falling Creek Formation along Stagg Creek in the Hanover Academy quadrangle from the Hanover Country Club south to the Petersburg Granite. Total thickness is 3603 feet.

Interval	Lithology	Thickness (feet)
Cherrydale Formation (567 feet, alluvium above section)		
181	Sandstone, light brown, coarse-grained, well cemented	20
180	(covered)	5
179	Siltstone, dark blue, laminated	7
178	(covered)	9
177	Sandstone, light gray, fine-grained, slightly micaceous	13
176	Sandstone, medium red, coarse-grained	1
175	(covered)	12
174	Sandstone, light tan, coarse grained, poorly sorted, slightly micaceous	8
173	Sandstone, light brown, fine-grained, slightly micaceous	28

Interval	Lithology	Thickness (feet)
172	(covered)................................	5
171	Sandstone, light gray, fine-grained........	4
170	(covered)................................	20
169	Sandstone, light gray, fine-grained........	3
168	(covered)................................	19
167	Sandstone, light tan layers interlayered with dark blue layers, fine-grained, slightly silty.........	11
166	Sandstone, light tan, fine-grained, slightly silty..................	11
165	(covered)................................	7
164	Sandstone, light tan, fine-grained, broadly crossbedded, slightly micaceous......................	16
163	(covered)................................	12
161	Siltstone, dark gray, laminated, slightly sandy...........................	10
160	Sandstone, light tan, medium-grained.......	2
159	(covered)................................	46
158	Sandstone, medium gray, fine-grained, soft; very silty interbeds............	14
157	(covered)................................	12
156	Sandstone, medium red, very coarse-grained, contains a few cobbles of mylonite and vein quartz........	4

Interval	Lithology	Thickness (feet)
154	Sandstone, medium gray, fine-grained, micaceous, slightly silty.......	5
153	(covered)......................................	16
152	Sandstone, medium gray, medium- to coarse-grained..................	19
151	(covered)......................................	15
150	Sandstone, light tan, fine- to medium-grained.........................	15
149	(covered)......................................	15
148	Sandstone, light tan, medium-grained, slightly micaceous..............	15
147	(covered)......................................	91
146	Sandstone, medium red, coarse-grained......	17
145	(covered, laterally equivalent to basal Cherrydale siltstone bed exposed in gully to east)......................................	74

Stagg Creek Sandstone (500 feet)

Interval	Lithology	Thickness (feet)
144	Sandstone, medium gray, fine-grained.......	11
143	Sandstone, light tan, very coarse-grained; contains a few cobbles of mylonite and vein quartz........	17
142	(covered)......................................	14
141	Sandstone, light tan, coarse-grained.......	20
140	(covered)......................................	26

Interval	Lithology	Thickness (feet)
139	Sandstone, light tan, coarse-grained.......	1
138	(covered)..................................	8
137	Sandstone, light tan, coarse-grained.......	1
136	(covered)..................................	13
135	Sandstone, light tan, coarse-grained.......	12
134	Sandstone, light tan, medium-grained, soft.	24
133	(covered)..................................	24
132	Sandstone, light tan, coarse-grained.......	1
131	Sandstone, light tan, medium-grained, soft.	14
130	Sandstone, light tan, coarse-grained, crossbedded.....................	60
129	(covered)..................................	32
128	Siltstone, medium gray, laminated, slightly silty..................	1
127	Sandstone, light tan, coarse-grained; fine sandstone interbeds.............	63
126	Sandstone, light tan, fine- to medium-grained, slightly micaceous.....	23
125	Sandstone, light tan, coarse-grained, slightly micaceous..............	13
124	(covered)..................................	36
123	Sandstone, light tan, coarse-grained.......	13
122	(covered)..................................	34

Interval	Lithology	Thickness (feet)
121	Sandstone, brown, coarse-grained, slightly micaceous..............	12
120	Sandstone, brown, medium-grained, soft.....	7
119	(covered)....................................	10

Gum Tree Conglomerate (496 feet)

118	Sandstone, light tan, coarse-grained, crossbedded; numerous pebbles less than one inch in diameter of vein quartz and mylonite; some fine-grained sandstone lenses..........................	53
117	(covered)....................................	60
116	Sandstone, light tan, coarse-grained, crossbedded, numerous pebbles and cobbles of vein quartz and mylonite.........................	98
115	Siltstone, light gray, massive, slightly sandy...........................	13
114	(covered)....................................	25
113	Sandstone, light tan, coarse-grained, notably crossbedded; some fine sandstone lenses; numerous pebbles and cobbles of vein quartz and mylonite.............	50

Interval	Lithology	Thickness (feet)
112	Sandstone, light tan, medium-grained, soft, slightly silty............	25
111	(covered)..................................	37
110	Conglomerate, light tan, rounded cobbles of mylonite....................	2
109	Sandstone, light tan, fine-grained.........	10
108	(covered)..................................	37
107	Sandstone, light tan, coarse-grained.......	1
106	(covered)..................................	10
105	Sandstone, light tan, coarse-grained.......	3
104	(covered)..................................	36
103	Sandstone, light tan, coarse-grained, crossbedded throughout..........	36

Falling Creek Formation (2040 feet)

102	Sandstone, light tan, fine-grained.........	5
101	(covered)..................................	24
100	Sandstone, light tan, fine-grained.........	39
99	Siltstone, medium gray.....................	6
98	Conglomerate, light tan; much coarse-grained sandstone; cobbles of mylonite.......................	10
97	(covered)..................................	23
96	Conglomerate, light tan; little sandstone; cobbles of mylonite.............	10
95	Clay, light gray (shale residue?)..........	9

Interval	Lithology	Thickness (feet)
94	(covered)	31
93	Clay, medium gray, laminated	3
92	(covered)	6
91	Sandstone, medium blue, coarse-grained, slightly micaceous	3
90	(covered)	145
89	Sandstone, light tan, fine-grained, poorly laminated	14
88	(covered)	42
87	Conglomerate, light tan; cobbles up to 4 inches in diameter of vein quartz and mylonite	4
86	(covered)	21
85	Siltstone, light gray	4
84	(covered)	11
83	Clay, light gray, (shale residue?)	14
82	(covered)	13
81	Sandstone, light tan, fine-grained	2
80	Clay, light gray, (shale residue?)	14
79	Sandstone, light tan, fine-grained, poorly laminated	29
78	Sandstone, light tan, fine-grained, well laminated	2
77	(covered)	21

Interval	Lithology	Thickness (feet)
76	Clay, light gray (shale residue?)..........	15
75	Sandstone, light tan, fine-grained, well laminated..................	18
74	(covered).................................	2
73	Sandstone, light tan, fine-grained, well laminated..................	20
72	Siltstone, medium gray, with interbedded gray clay...........	18
71	Sandstone, light tan, fine-grained, well laminated..................	19
70	Siltstone, medium gray.....................	7
69	Sandstone, light gray, fine-grained, well laminated..................	9
68	Sandstone, light tan, coarse-grained.......	3
67	Sandstone, light tan, fine-grained, well laminated..................	34
66	Clay, light gray (shale residue?)..........	4
65	Siltstone, medium gray, mostly massive.....	8
64	Sandstone, light tan, fine-grained, well laminated..................	3
63	Siltstone, medium gray, laminated..........	9
62	Sandstone, light tan, fine-grained, laminated........................	18
61	Siltstone, medium gray.....................	4

Interval	Lithology	Thickness (feet)
60	Sandstone, light tan, fine-grained, well laminated	8
59	(largely covered interval, but gray clays and dank stagnant deep pools, plus the fact that this stretch is along strike from an abandoned coal pit, indicate this stretch contains carbonaceous shales and thin coal seams)	226
58	Sandstone, light red, fine-grained, well laminated	9
57	(covered)	9
56	Sandstone, light tan, fine-grained, well laminated	9
55	(covered)	6
54	Sandstone, light tan, fine-grained, poorly laminated	17
53	(covered)	8
52	Sandstone, light tan, fine-grained, well laminated	12
51	(covered)	12
50	Sandstone, light tan, fine-grained	5
49	Siltstone, mostly dark red but contains frequent black interbeds	11
48	Sandstone, light tan, fine-grained	2
47	Siltstone, medium gray, massive	2

Interval	Lithology	Thickness (feet)
46	Sandstone, light tan, fine-grained, well laminated..................	5
45	Siltstone, medium red and medium gray interbedded in bands............	3
44	(covered)....................................	27
43	Sandstone, light tan, fine-grained, well laminated..................	4
42	Siltstone, medium gray......................	2
41	(covered)....................................	33
40	Sandstone, light tan, fine- to medium-grained, slightly micaceous.....	42
39	Shale, black; contains a few thin sandstone interbeds............	6
38	Sandstone, light tan, fine-grained.........	2
37	(covered)....................................	65
36	Sandstone, light tan, fine-grained, well laminated..................	7
35	Siltstone, medium gray, well laminated.....	3
34	Sandstone, light tan, fine-grained, well laminated..................	10
33	(covered)....................................	36
32	Sandstone, light tan, coarse-grained.......	3
31	(covered)....................................	74

Interval	Lithology	Thickness (feet)
30	Sandstone, light tan, coarse-grained in lower part but grading continuously upward through medium-grained to fine-grained..	74
29	Sandstone, light tan, coarse-grained.......	4
28	(covered)...................................	18
27	Sandstone, light tan, coarse-grained; scattered cobbles of mylonite...	1
26	(covered)...................................	14
25	Sandstone, light tan, coarse-grained with scattered cobbles of mylonite...	35
24	(covered)...................................	64
23	Clay, light pink (shale residue?)..........	10
22	Sandstone, light tan, coarse-grained to medium-grained with pebbles (mostly quartz) smaller than 1 inch in diameter..............	117
21	Sandstone, light tan, coarse-grained with interbedded cobble conglomerates; cobbles up to 3 inches in diameter.....................	129
20	Sandstone, light tan, fine-grained, well laminated.......................	2
19	Sandstone, light tan, coarse-grained.......	20

Interval	Lithology	Thickness (feet)
18	Sandstone, light tan, coarse-grained with interbedded cobble conglomerates	20
17	(covered)	5
16	Sandstone, light tan, coarse-grained with small quartz pebbles	24
15	(covered)	3
14	Conglomerate, light tan; cobbles of mylonite	8
13	(covered)	9
12	Conglomerate, light tan; cobbles of mylonite becoming larger (up to 3 inches in diameter) upward.	21
11	Sandstone, medium gray and dark red blotched, medium-grained, interbedded with dark gray siltstones	3
10	Sandstone, medium red, medium-grained, contains cobbles of Petersburg Granite and more rarely cobbles of vein quartz, micaceous gneiss, and mylonite; cobbles well rounded to sub-angular and up to 5 inches in diameter	6

Interval	Lithology	Thickness (feet)
9	Siltstone, dark red with medium gray blotches........................	8
8	Sandstone, medium red, medium-grained......	3
7	Sandstone, medium red, medium-grained, scattered small quartz pebbles..	3
6	Siltstone, dark red.........................	10
5	(covered)..................................	23
4	Siltstone, dark blue........................	7
3	(covered)..................................	16
2	Clay, dark red..............................	1
1	(covered)..................................	28

(Section rests with presumed nonconformity upon the Petersburg Granite; faulted relationship is possible but deemed improbable)

Section II. Section of Falling Creek Formation on tributary of Falling Creek beside State Road 667, Hanover Academy quadrangle. Section near middle of formation.

Interval	Lithology	Thickness (feet)
Falling Creek Formation (311 feet; top of section covered by alluvium)		
35	Sandstone, medium gray, fine-grained, sparsely micaceous; trails and current scour marks on bedding planes	7
34	(covered)	14
33	Sandstone, light tan, fine-grained, well laminated, slightly silty	4
32	Sandstone, light tan, fine-grained, slightly micaceous	13
31	Siltstone, dark red, massive, soft	23
30	Siltstone, dark red, well laminated, with shaly partings	21
29	Shale, black; contains compressed fish	5
28	Shale, dark red, well laminated	3
27	Sandstone, medium red, fine-grained, well laminated	9

Interval	Lithology	Thickness (feet)
26	Sandstone, medium red, coarse-grained, poorly laminated	8
25	Sandstone, medium red, fine-grained, well laminated	12
24	Sandstone, medium red, fine-grained, well laminated with a few interbedded black shales	16
23	Siltstone, medium gray, micaceous	3
22	Shale, black, fissile	7
21	(covered)	19
20	Sandstone, black, fine-grained, micaceous	2
19	(covered)	4
18	Sandstone, medium gray, fine-grained, micaceous, slightly silty	11
17	Sandstone, medium gray, coarse-grained, well laminated	13
16	Sandstone, medium gray, slightly conglomeratic, well laminated	11
15	Sandstone, light red, fine-grained, slightly crossbedded; a few quartz pebbles	3
14	(covered)	5
13	Sandstone, dark gray, fine-grained, well laminated, interbedded with thin coarse-grained sandstone lenses.	6

Interval	Lithology	Thickness (feet)
12	Shale, black, fissile, slightly silty; contains thin calcite lenses....	7
11	Sandstone and shale interbedded, light tan and medium gray respectively; sandstone, fine-grained with carbonized wood fragments scattered on some bedding planes	6
10	(covered)...................................	4
9	Sandstone, dark gray, fine-grained, well laminated, micaceous, slightly silty...........................	10
8	(covered)...................................	26
7	Sandstone, dark gray, fine-grained, soft...	4
6	Sandstone, light brown, coarse-grained.....	1
5	(covered)...................................	6
4	Sandstone, reddish brown, fine-grained, soft, well laminated, slightly micaceous, scattered quartz pebbles.........................	9
3	(covered)...................................	15
2	Sandstone, dark brown to dark red, fine-grained, well laminated, slightly silty.................	2

Interval	Lithology	Thickness (feet)
1	Clay, black to dark gray, poorly developed partings........................	2

(covered to base by Brandywine gravels and loams)

Section III. Section of St. Marys Formation 3000 feet south of crossing of Richmond, Fredericksburg, and Potomac Railroad and U. S. Highway 1 on east side of railroad, Ashland quadrangle.

Lithology	Thickness (feet)
Brandywine Formation (6 feet)	
Gravel, yellow and white quartz cobbles up to 5 inches in diameter; well rounded, many discoids..............................	6
St. Marys Formation (34 feet)	
Sand, brown, fine-grained; gray clay interbeds.......	9
Gravel, white quartz pebbles, well rounded and polished..................................	1
Sand, buff, fine- to medium-grained; detrital magnetite lumps scattered throughout......	1
Sand, buff, fine- to medium-grained; pebble band at base consisting of scattered quartz pebbles..................................	11

Lithology	Thickness (feet)
Silty clay and silt, light gray; gravel band at base with mostly quartz pebbles and cobbles; some sandstone clasts; clay and silt contain *Discinisca lugubris*......	12
Falling Creek Formation (8 feet to base of gully)	
Siltstones and shale interbedded, gray to blue, fissile but poorly laminated..............	8
Total...................	48

Appendix III: Location of outcrops of Brandywine gravels used in plotting Figure 6 (distances on map are linear, not along trace of roads):

1. 3900 feet SSE. of Mt. Carmel Church, Hewlett quadrangle.
2. 2600 feet SSW. of bridge across Little River along Va. Route 685 on west side of road, Hanover Academy quadrangle.
3. 2100 feet SSW. of Fork Church along State Road 685 on west side of road, Hanover Academy quadrangle.
4. 4700 feet NW. of the Church of Truth along State Road 738 on south side of road, Hanover Academy quadrangle.
5. Under intersection of N-S power line and State Road 685 on north side of road, Hanover Academy quadrangle.
6. 3800 feet WNW. of bridge on State Road 671 over Newfound River, Hanover Academy quadrangle.
7. 400 feet NW. of Mt. Olivet Church along State Road 671 on east side of road, Hanover Academy quadrangle.
8. Under "282" elevation notation 3200 feet south of Negrofoot along east side of State Road 671, Hanover Academy quadrangle.

9. 3500 feet NW. of eastern junction of State Road 697 and State Road 657, Hanover Academy quadrangle.

10. 300 feet NW. of Gilman along abandoned road, Hanover Academy quadrangle.

11. 1400 feet south of Cedar Creek along State Road 671, Hanover Academy quadrangle.

12. 7400 feet SSW. of Gilman along State Road 670 on east side of road, Hanover Academy quadrangle.

13. 1500 feet SSW. of Taylors Creek along State Road 611 on west side of road, Montpelier quadrangle.

14. 1900 feet SSE. of Farrington along U.S. Route 33 on north side of road, Glen Allen quadrangle.

15. 600 feet west of Stony Run Creek on south side of State Road 660, Yellow Tavern quadrangle.

16. 700 feet SW. of Va. Route 54 along State Road 798 on east side of road, border of Ashland quadrangle and Yellow Tavern quadrangle.

17. 5600 feet NNE. of Richmond, Fredericksburg, and Potomac Railroad crossing NW. of Gandy High School along access road beside Richmond, Fredericksburg, and Potomac Railroad, Ashland quadrangle.

18. 1900 feet SSE. of Falling Creek along State Road 667 on west side of road, Ashland quadrangle.

19. 300 feet SE. of Falling Creek along both sides of State Road 669, Hanover Academy quadrangle.

20. 1100 feet WSW. of Stagg Creek along north side of State Road 696, Hanover Academy quadrangle.

21. 1000 feet SE. of Gaging Station on South Anna River at State Highway 54 crossing, along road to south into a new housing development not shown on map, Hanover Academy quadrangle.

22. 2200 feet SSW. of Horseshoe Bridge on east side of State Road 686 along inside of 90 degree curve, Hanover Academy quadrangle.

23. 5000 feet NW. of Horseshoe Bridge on north side of State Road 686, Hanover Academy quadrangle.

24. 2000 feet south of bridge over Newfound River on east side of State Road 667, Hanover Academy quadrangle.

25. 2200 feet NW. of Blunts Bridge on east side of State Road 667, Hanover Academy quadrangle.

26. 50 feet north of junction of State Road 669 and 667, Hanover Academy quadrangle.

27. 100 feet NNE. of underpass at Elletts Crossing along east side of Richmond, Fredericksburg, and Potomac Railroad tracks, Ashland quadrangle.

28. 900 feet north of bridge over Newfound River on east side of State Road 667, Hanover Academy quadrangle.

29. 1800 feet south of Campbells Pond on east side of State Road 686, Hanover Academy quadrangle.

30. 300 feet SW. of bridge over Little River along east side of State Road 688, Hanover Academy quadrangle.

31. 5400 feet east of Campbells Pond, Hanover Academy quadrangle.

32. 3500 feet west of Jerusalem Church in gravel pit, Ashland quadrangle.

33. Walls of crushed stone quarry at Verdon, border of Hanover Academy quadrangle and Hewlett quadrangle.

34. Gravel quarry 1200 feet SSW. of junction of State Roads 658 and 689, Hewlett quadrangle.

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GEOLOGY OF THE HANOVER ACADEMY AND

ASHLAND QUADRANGLES, VIRGINIA

by

Robert E. Weems

(ABSTRACT)

The Ashland and Hanover Academy quadrangles in east-central Virginia lie astride the Fall Line. Metamorphic and granitic rocks of the Piedmont Province to the west of the Fall Line are pre-Triassic in age. Biotite gneiss, granite gneiss, muscovite-biotite schist, amphibolite, and Petersburg Granite are represented. Along the eastern margin of the Piedmont a northeast trending half-graben, the Taylorsville Basin, bordered on the northwest by the Fork Church fault, contains rocks of Triassic age. These rocks are divided in this report into four successive conformable formations. Unconsolidated Coastal Plain sediments east of the Fall Line are Cretaceous, Tertiary, and Quaternary in age. This province includes the Patuxent Formation (Cretaceous), the Aquia Formation (Paleocene), the Marlboro Clay

(Eocene), the St. Marys Formation (Miocene), the Brandywine Formation (Miocene), and the Sunderland, Wicomico, and Talbot terraces (?Pliocene-Pleistocene), as well as Recent alluvium.

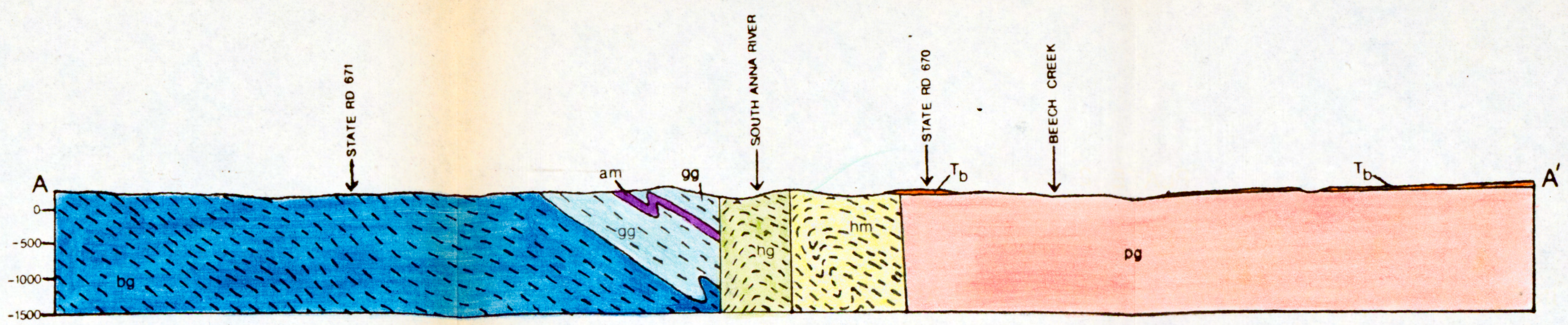
The Hylas Zone, a linear zone of cataclastic rocks which trends northeast-southwest across the Piedmont portion of the mapped area, is interpreted as a fault zone that has disrupted the Piedmont rocks. The zone also served as a locus for faulting in Triassic time and has affected at least indirectly the thicknesses and attitudes of Coastal Plain strata at least as young as Paleocene.

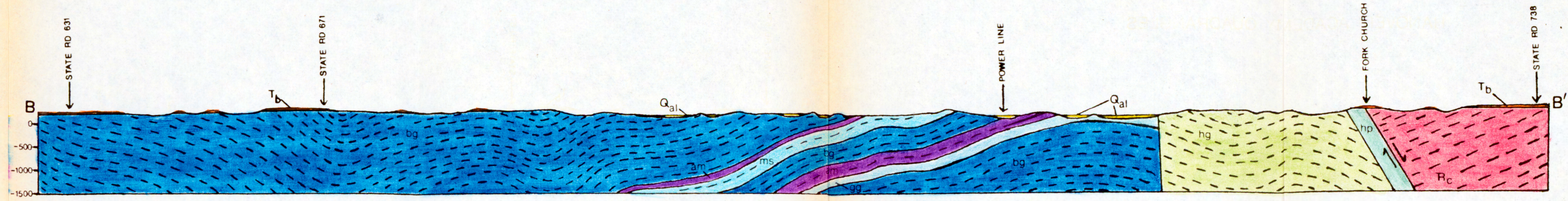
PLATE 1   GEOLOGIC MAP OF THE ASHLAND AND HANOVER ACADEMY QUADRANGLES, VIRGINIA

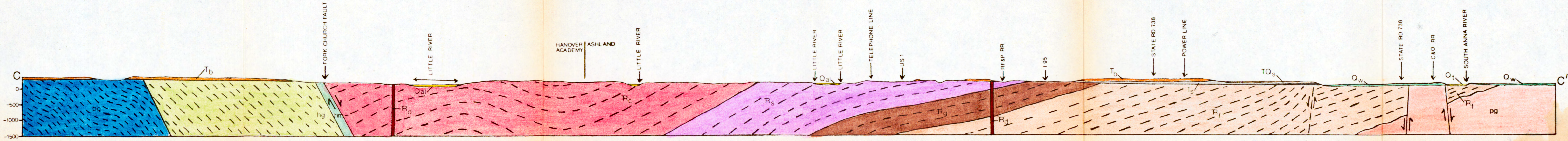
PLATE 2

INTERPRETIVE CROSS SECTIONS ACROSS THE ASHLAND AND

HANOVER ACADEMY QUADRANGLES

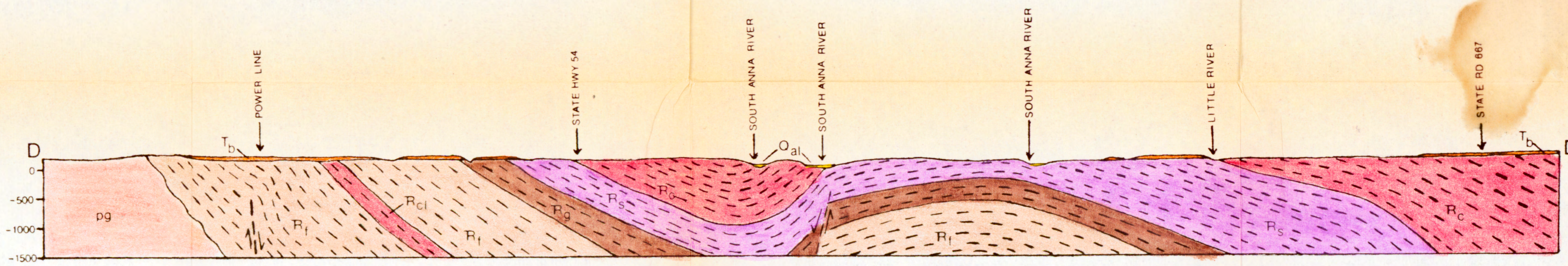


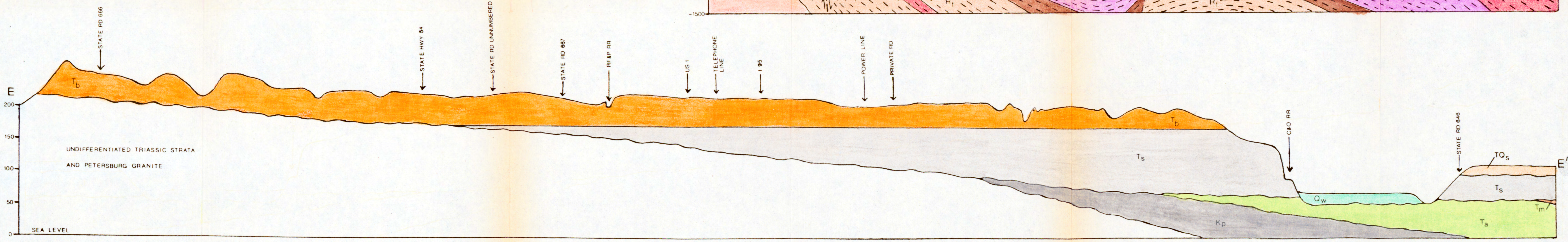




VERTICAL SCALE EQUALS HORIZONTAL SCALE IN A THROUGH D,

X20 VERTICAL SCALE IN E AND F.





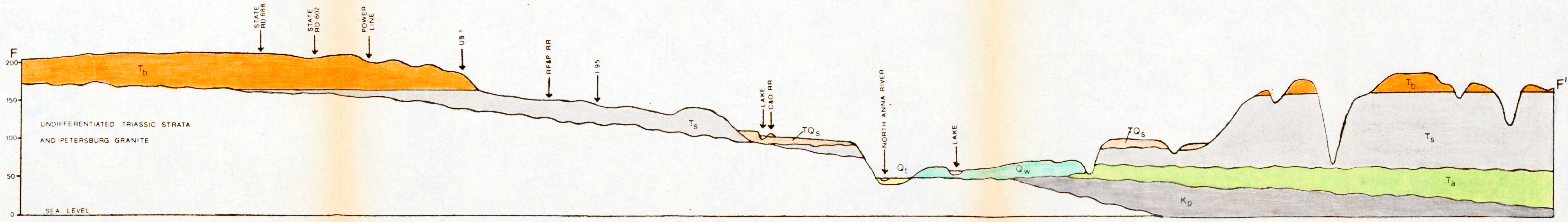


PLATE 3 - EXPLANATION OF COLORS AND SYMBOLS USED ON PLATES 1 AND 2

Qal	Recent Alluvium		QUATERNARY	CENOZOIC
Qt	Talbot Terrace Deposits	PLEISTOCENE	QUATERNARY	CENOZOIC
Qw	Wicomico Terrace Deposits	PLEISTOCENE	QUATERNARY	CENOZOIC
TQs	Sunderland Terrace Deposits	PLIOCENE?	TERTIARY	CENOZOIC
Tb	Brandywine Formation	MIOCENE	TERTIARY	CENOZOIC
Ts	St Marys Formation	MIOCENE	TERTIARY	CENOZOIC
Tm	Marlboro Clay	EOCENE	TERTIARY	CENOZOIC
Ta	Aquia Formation	PALEOCENE	TERTIARY	CENOZOIC
Kp	Patuxent Formation		CRETACEOUS	MESOZOIC
Rd	Diabase Dikes		TRIASSIC	MESOZOIC
Rc	Cherrydale Formation		TRIASSIC	MESOZOIC
Rs	Stagg Creek Sandstone		TRIASSIC	MESOZOIC
Rg	Gum Tree Conglomerate		TRIASSIC	MESOZOIC
Rf	Falling Creek Formation (Rcl coal shale)		TRIASSIC	MESOZOIC

PRECAMBRIAN? AND PALEOZOIC

- pg — Petersburg Granite
- Hylas Zone:
  - hp — Protomylonite
  - hm — Mylonite
  - hg — Mylonite Gneiss and Strained Relict Gneiss
- bg — Biotite Gneiss
- Schist-Gneiss Complex:
  - am — Amphibolite
  - ms — Muscovite-Biotite Schist
  - gg — Granite Gneiss

Observed Contact

Approximate Contact

Inferred Contact

X R5280 Sample Locality

Observed Fault Trace

Approximate Fault Trace

Buried Fault Trace

U Upthrown side of fault

D Downthrown side of fault

Strike-Dip Symbol

Gneissic Terrane Foliation

Hylas Zone Foliation

Petersburg Granite Foliation

Synclinal Axis

Anticlinal Axis

Plunging Overturned Synform

Plunging Overturned Antiform