COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION
AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES

GEOLOGY OF THE BUCKINGHAM QUADRANGLE VIRGINIA

ERNEST H. ERN

REPORT OF INVESTIGATIONS 15

VIRGINIA DIVISION OF MINERAL RESOURCES

James L. Calver
Commissioner of Mineral Resources and State Geologist

CHARLOTTESVILLE, VIRGINIA
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Commonwealth of Virginia
Department of Purchases and Supply
Richmond
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GEOLOGY OF THE BUCKINGHAM QUADRANGLE, VIRGINIA

By

ERNEST H. ERN[1]

ABSTRACT

The 15-minute Buckingham quadrangle, the most centrally located quadrangle in the State, is situated in the western Piedmont and is underlain mainly by schistose rocks of late Precambrian and/or early Paleozoic age. Eight metamorphosed stratigraphic units are mapped and form sequences of low-rank schists, phyllites, metagraywackes, quartzites, marbles, and greenstones. These eugeosynclinal rocks have been intruded by, and are intimately associated with, metamorphosed sill-like bodies that have an intermediate to ultramafic composition. Sedimentary rocks of Triassic age occur in the Scottsville basin, and all rock types have been intruded by diabase dikes of Late Triassic age.

The thick sequence of pre-Triassic rocks has been deformed into tight, isoclinal folds, many of which have been displaced by high-angle reverse faults. Two generations of cleavage are evident in the more schistose rocks, the older schistosity being transected by a slip cleavage. The most recent normal faults are adjacent to the Triassic sedimentary rocks. The major structure traversing the area consists of a northeastward-trending, narrow, deep trough containing metasedimentary and related rocks that form the James River synclinorium. The Hardware anticline and Arvonia syncline form major structures in the southeast portion of the quadrangle. The Candler Formation is believed to be the oldest in the Evington Group and is successively overlain by the Archer Creek and Mount Athos formations, capped by metamorphosed volcanic rocks. Presumably older rocks lie to the northwest and form the southeast flank of the Blue Ridge-Catoctin Mountain anticlinorium. The rocks in the Evington Group have been faulted over older rocks with minor displacement, and hence the existence of the Martic thrust is precluded.

All pre-Triassic rocks have been subjected to regional metamorphism of mid-Carboniferous age and have formed equilibrium assemblages mainly in the quartz-albite-muscovite-chlorite subfacies of the greenschist facies. The metamorphism was progressive and increased toward the southeast. The area has had an active history of mining manganese and iron oxides, building stone, marble, and crushed stone.

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INTRODUCTION

The area of study is situated mainly in Buckingham County, with the northwest portion in Nelson and Albemarle counties (Figure 1). The total area comprises approximately 233 square miles and is bounded by parallels 37°30′ and 37°45′ north latitude and 78°30′ and 78°45′ west longitude. The geographic center of the State lies in the Buckingham quadrangle at the intersection of 78°37.5′ longitude and 37°30.6′ latitude. This intersection is near the southern margin of the area, approximately 2 miles south of Mount Rush.

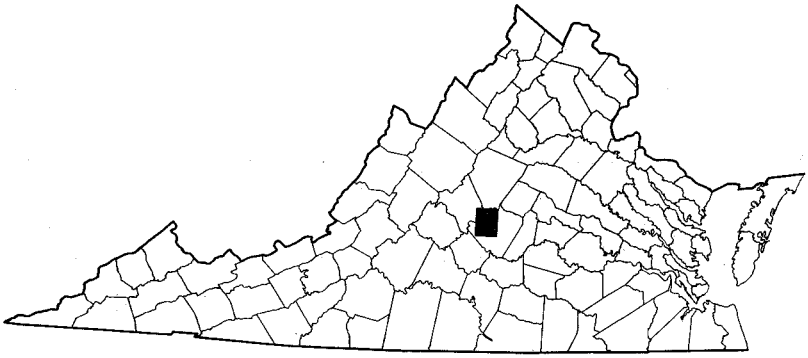

Figure 1. Index map showing location of the Buckingham quadrangle.

A network of primary and secondary highways, fire trails, and logging roads provides ready access to all but a few isolated parts of the quadrangle. Principal routes of travel are along U. S. Highway 60, State Highways 20, 24, and 56, and State Roads 601, 602, and 626. The Chesapeake and Ohio Railway traverses the area on the northwest side of the James River utilizing for the most part the old tow path of the James River and Kanawha Canal as its roadbed. Buckingham Court House, the county seat of Buckingham County, is the largest town and is located in the southeastern portion of the quadrangle. The population is mainly rural, and lumbering and farming are the principal occupations.

The area under consideration was mapped chiefly during the summers of 1963, 1964, and 1965. The author wishes to acknowledge the sincere interest and support of this project by James L. Calver, Commissioner of Mineral Resources and State Geologist. Valuable insight into the complexities of the Virginia Piedmont was gained through discussions and field trips into areas of mutual concern with William R. Brown. The aid and courtesies extended to me by the local residents in the Buckingham area are greatly appreciated.

TOPOGRAPHY AND DRAINAGE

The topography adjacent to the James River and northwestward is one of distinct linear ridges with remarkably uniform elevations. The ridges conform to the strike of the rocks and heights are related to the competencies of the underlying rock units. The local relief in this terrane is approximately 270 feet between the ridges and the adjacent valleys. The ridges are normally underlain by the more siliceous beds in the Candler Formation or the quartzites of the Mount Athos Formation, while carbonate rocks and less resistant schists occur in the stream valleys. The area southeast of the James River is a gently undulating upland surface, 80 to 100 feet lower than the elevations of the linear ridges, which is underlain by rock types of apparently uniform resistance. The dissection of this upland is by a dense network of dendritic streams, resulting in local relief ranging from 80 to 100 feet. This partially dissected area is in distinct contrast to the densely timbered ridges drained by trellis-type streams to the northwest. The greatest relief in the area is in the western and southwestern portions of the quadrangle where linear ridges on the east slope of Spear Mountain attain a maximum elevation of 1240 feet. Most of Spear Mountain, one of the more easterly ridges in the inner Piedmont, is situated in the Shipman quadrangle. The lowest point in the quadrangle is at an elevation of 300 feet and is located in the flood-plain of the James River northeast of Howardsville.

Exposures of fresh rock are scarce on the upland surface, and the thin residual soils are poor for cultivation. The soil is chiefly clay with disseminated sericite flakes and is gray, red, brown, or tan. Fragments of vein quartz, highly siliceous schists, and quartzite, all generally iron oxide-stained, are ubiquitous in the soil. Beneath the soil is a thick zone of saprolite in which the bedrock has been partially to completely decomposed. Although this material is porous and friable, original textures and structures are preserved in detail. Water-well records on file at the Virginia Division of Mineral Resources indicate a general range from 30 to 80 feet in depth to bedrock in the uplands of the Buckingham quadrangle. Espenshade (1954, p. 44) indicates a depth of weathering in excess of 200 feet at the Piedmont mine in Campbell County. Alluvial soils in the flood plains of the larger rivers and streams are fertile and provide the best farmlands in the area, but are of limited extent. Exposures of fresh rock are present in nearly all stream valleys. Patchy deposits of flood-plain gravels occur as high as 200 feet above the river level as remnants of former sheet deposits from an earlier stage in the development of the major drainage system.

Some of the pebbles and cobbles rest on terraces that are parallel to the streams and are separated by 20 to 30 feet in elevation from the next adjacent terrace. At least three terraces are present in the Buckingham quadrangle.

The principal drainage system is that of the James River and its tributaries. It flows across the quadrangle in a northeasterly direction toward Scottsville where it changes course to the southeast. The sinuous northeastward flow of the James River is over the weaker units of the Evington Group and the Triassic sedimentary rocks, and it is contained by the more competent Evington lithologies. The Rockfish River, a major tributary, empties into the James River from the northwest at Howardsville. Most major tributaries have their headwaters in the Blue Ridge and enter the James River from the west or northwest (Espenshade, 1954, p. 45). The rolling upland is drained, for the most part, by numerous short dendritic tributaries that flow into the Slate River which becomes, in turn, a tributary to the James River near New Canton in the Dillwyn quadrangle.

REGIONAL GEOLOGIC SETTING

The Buckingham quadrangle is located in the western Piedmont of Virginia just east of the conspicuous monadnock-dotted terrane of the inner Piedmont (Fenneman, 1938). The center of the area is approximately 35 miles east of the crest of the Blue Ridge Mountains. The bulk of the rocks comprise a thick series of steeply dipping northeastward-trending eugeosynclinal metasedimentary units interspersed with volcanic rocks and injected by plutonic masses. In the north-central portion of the quadrangle, Triassic sedimentary units at the southern termination of the Scottsville basin are in fault contact with the adjacent metamorphic units. All rock types have been intruded by diabase dikes of a presumed Late Triassic age.

The major structure traversing the area consists of a long, narrow trough of metasedimentary and related rocks, which forms the James River synclinorium (Brown, 1941). The units in this synclinorium are the low-rank schists, marbles, quartzites, phyllites, and greenstones of the Evington Group which have been repeated across the regional strike a number of times in association with folds and faults. The varying degree of competency of these thin rock units is exhibited in their intense deformation. The age and stratigraphic order of the units in the Evington Group and its relationship to other similar rock types along strike to the northeast and southwest are a major key to the structural interpretation of the Appalachian Piedmont.

In the northwest portion of the Buckingham quadrangle, older rocks, the Lynchburg and Catoctin formations, form the southeast limb of the Blue Ridge-Catoctin Mountain anticlinorium. The rock units exposed in the southeasternmost portion of the quadrangle are younger than the Evington Group and are situated in the Arvonia syncline. In general, then, the rocks become progressively younger across the area from northwest to southeast.

Masses of hornblende gabbro (amphibolite) have been injected along the southeast limb of the synclinorium as concordant sill-like bodies which have subsequently been folded. Similar extensive masses, but of a more basic character, are associated with the Lynchburg Formation; some of these bodies constitute commercial deposits of soapstone and related rock.

STRATIGRAPHY

Eight distinct upper Precambrian or lower Paleozoic metasedimentary and metavolcanic units have been delineated within the quadrangle. These have been intruded by and are intimately associated with plutonic rocks that were metamorphosed and range from intermediate to ultramafic in composition. Phyllites and mica schists predominate and are interbedded with metagraywackes, micaceous quartzites, marbles, greenstones, amphibolites, and serpentinites. The Triassic sedimentary rocks consist of red shales, arkosic sandstones, and fanglomerates. Quaternary alluvium composes the flood plains along the larger rivers and streams. Representative samples of the various rock types that are exposed in the Buckingham quadrangle have been collected. These samples (R-3179 through R-3203) are on file in the rock and mineral repository of the Virginia Division of Mineral Resources at Charlottesville where they are available for examination.

LYNCHBURG FORMATION

The name Lynchburg gneiss was first used by Jonas (1927, p. 845) for exposures of fine-grained biotite quartz gneiss and schist, in part garnetiferous, in Lynchburg at Madison Heights along the James River. This unit was later raised to formational status (Brown, 1958) because of the abundance and variety of other lithologic types, in addition to the gneissic rocks. The formation forms the bulk of the eastern flank of the Blue Ridge-Catoctin Mountain anticlinorium and extends from southern Culpeper County to Carroll County at the Virginia-North Carolina boundary. In the Buckingham quadrangle the upper part of the formation is exposed in the northwest corner where it is associated

with concordant mafic igneous injections and the overlying Catoctin Formation.

The typical Lynchburg lithology exposed in the area consists of quartz-feldspar-mica schists, in part gneissic or conglomeratic, graphitic schists, metasiltstones, calc-silicate beds, and phyllites. The dominant rock type is medium- to fine-grained, gray schist that is well bedded and composed of oriented blebs of quartz, microcline, or albite, which have a relict clastic texture, enclosed in a phyllosilicate matrix. Graded bedding is fairly common (Figure 2). The graphitic schists were too poorly exposed to be utilized as marker beds within the sequence. The phyllitic rocks are difficult to distinguish megascopically or microscopically from the Candler phyllites of the Evington Group. Throughout much of its exposure, the Lynchburg Formation is overlain by the Catoctin Formation. Along strike to the southwest, however, it is intertongued with the Catoctin or is in direct contact with the Candler Formation of the Evington Group (Virginia Division of Mineral Resources, 1963).

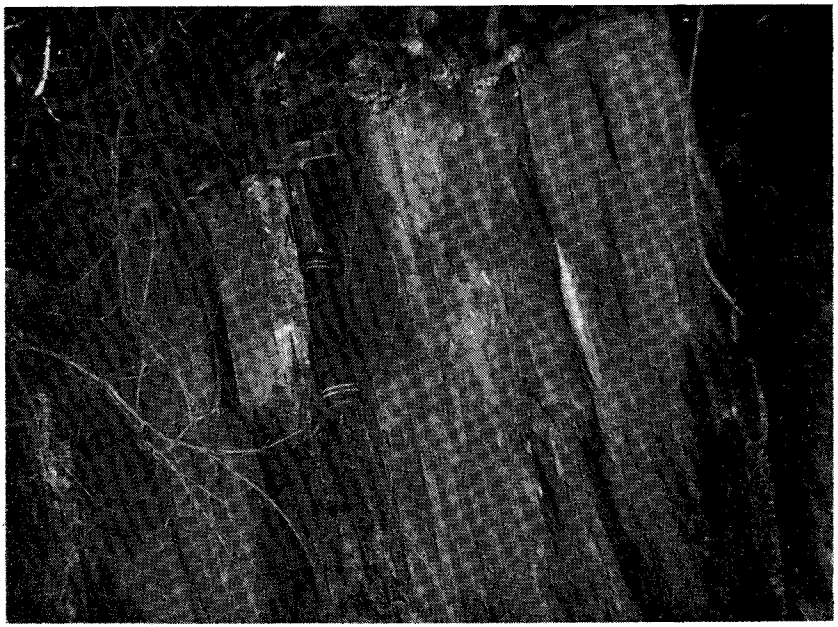

Figure 2. Graded bedding (to right of hammer) in the Lynchburg Formation along State Road 645, 0.3 mile northwest of Ariel Church. Beds have steep southeasterly dips and are right side up.

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CATOCTIN FORMATION

This unit was first named the Catoctin schist (Keith, 1894) for exposures at Catoctin Mountain, Maryland, and has subsequently been termed Catoctin greenstone (Virginia Geological Survey, 1928), metabasalt (Jonas and Stose, 1939), and the Catoctin Formation (Bloomer and Werner, 1955). Workers have had varied opinions concerning the stratigraphic range of the different lithologies included in this formation. In northern Virginia, Reed (1955) incorporated the underlying Swift Run and overlying Loudoun formations with the volcanic rocks. Allen (1963) mapped the Swift Run and Loudoun formations separately. In central Virginia, Bloomer (1950) included sedimentary layers as members of the formation, whereas to the southeast, Brown (1958) chose to limit the name Catoctin to the volcanic rocks and map the metasedimentary rocks separately. In working the James River synclinorium from Altavista to Howardsville, Espenshade (1954) became involved with the question of the stratigraphic order of the units in the Evington Group and their relationship to older units. He designated those volcanic rocks associated with the Lynchburg Formation as "older greenstone," flows at the top of the Evington sequence as "younger greenstone," and volcanic rocks of uncertain correlation as "greenstone" (Espenshade, 1954, p. 19-20). The transgressive, intertonguing nature of the Catoctin Formation has caused a variance in the amount of metasedimentary rocks associated with the greenstone. Catoctin volcanism continued sporadically into the period of Evington-type sedimentation. These facts, combined with the problem of whether the base of the Evington Group rests upon a single volcanic unit that has been tectonically repeated or whether there are several volcanic units at different stratigraphic levels within the Evington Group, account for the uncertainty of the stratigraphic limits of the Catoctin Formation. In the Buckingham quadrangle the greenstones resting upon the Lynchburg Formation are designated as Catoctin and those believed to lie on top of the Evington Group, as metamorphosed volcanic rocks (greenstone in part).

The Catoctin Formation is exposed in both limbs of the Blue Ridge-Catoctin Mountain anticlinorium. The western one extends from southern Pennsylvania through Virginia along the crest of the Blue Ridge as far south as Amherst County. The eastern exposures extend from Orange County to northern Pittsylvania County, traversing the Buckingham quadrangle diagonally in a narrow 4.5-mile strip in the northwest portion.

The Catoctin Formation is predominantly an altered basalt interspersed with minor amounts of pyroclastic rocks. The greenstones (R-3183) and greenschists form a massive to schistose, dark-green to brownish-green rock composed of albite, epidote, chlorite, and quartz with lesser amounts of actinolite, magnetite, sphene, and calcite. Relict pyroxenes and calcic plagioclase occur locally but are generally saussuritized and chloritized. Veins and patches of epidote and quartz, along with amygdules filled with quartz, epidote, and chlorite, are common (Figure 3). The Catoctin Formation weathers deeply, and its soil is characteristically a uniform, elastic silty clay below the A-horizon. The weathered rock is punky, lightweight, and red-brown, and breaks into blocky fragments.

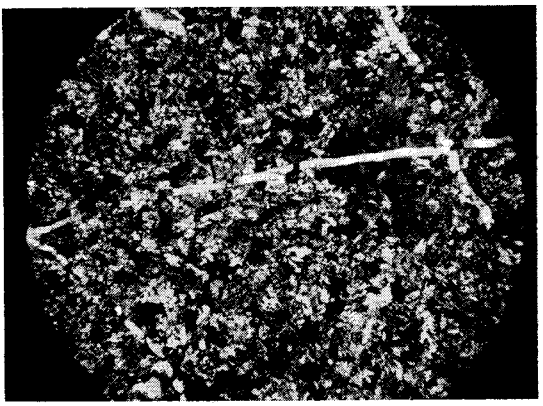

Figure 3. Photomicrograph of Catoctin greenstone from northeast of Ariel Church. Fine-grained matte of saussurite and intergranular oriented biotite transected by quartz veins. Crossed nicols. X 14.

EVINGTON GROUP

The collective name Evington has been applied (Brown, 1951; 1953, p. 91-93; 1958, p. 28-38; Espenshade, 1954, p. 14-20) to a distinctive group of rocks, the stratigraphic order, geologic age, and precise relationship of which to the Lynchburg and Catoctin formations is uncertain. The formations in this group are well exposed near Evington in southern Campbell County. The dominant lithologies of the formations are: Candler Formation—micaceous schist, phyllite, metagraywacke, and minor quartzite; Archer Creek Formation—schistose blue-gray marble and graphitic mica schist; Mount Athos Formation—quartzite, white marble, and minor mica schist; and metamorphosed volcanic rocks (greenstones).

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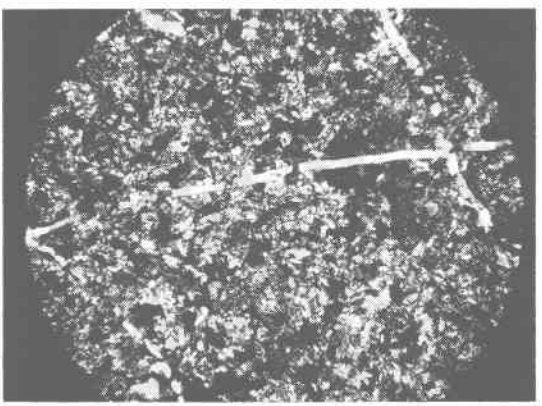

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The stratigraphic names first used for these rock types, however, were those of the Glenarm series of Pennsylvania and Maryland (Jonas, 1927; Virginia Geological Survey, 1928; Furcron, 1935). These correlations were based mainly on lithologic similarities involved in a long-range projection. Brown (1941; 1958, p. 28-31) recognized the possibility of a partial equivalence of the Glenarm series with the group he termed Evington, but the carbonates (Cockeysville) are separable into two distinctly different stratigraphic members, and the chronologic order within the Evington is the reverse of that of the Glenarm series. The order, from oldest to youngest, proposed by Brown (1941, 1953, 1958) with revisions by Espenshade (1954) was: Candler, Archer Creek, Mount Athos, and greenstone volcanic rocks. This chronologic sequence is accepted and utilized in this report (Table 1). As far as is known, there was no interruption by orogenesis or erosion during deposition of the formations in the Evington Group. The preferred stratigraphic order has been based on the following evidence (Brown, 1958, p. 30-31; Espenshade, 1954, p. 14-15, 23-27, 32-37):

1. Drag folds—useful but not entirely conclusive.
2. Thrust faults with resultant formational repetition—alternative stratigraphic sequence accepted normal faults that downdropped "younger" beds on the southeast.
3. Synclinal structure—Candler Formation, in Lynchburg area, dips on both flanks under medial units of carbonate, quartzite, and greenstone and is bordered by the Lynchburg Formation.
4. Mount Athos quartzites become coarser toward the base.
5. Cross laminations in quartzites are indicative of stratigraphic position.
6. Absence of greenstone fragments in Mount Athos quartzite—some fragments of greenstone would probably be present if quartzite were younger.
7. More compatible regional structural picture.

No distinct primary features or fossils were found during the mapping of the Buckingham quadrangle. The acceptance of the sequence of the formations in the Evington Group has been based entirely on known structural relations throughout the James River synclinorium and those seen in the quadrangle. It is difficult to make an accurate estimate of the thickness of the Evington Group in the Buckingham quadrangle because of the presence of tight folds and numerous faults, but it is believed to be in excess of 12,000 feet.

Table 1.—Chart of stratigraphic units.

Furcron (1935)	Brown (1953)	Espenshade (1954)		Redden (1963)	This Report
					Buffards formation
					Arvonia Formation
Wissahickon formation (including greenstone)	Slippery Creek greenstone	Younger greenstone	Evington Group		Metamorphosed volcanic rocks
	Mount Athos formation Pelier schist	Mount Athos formation		Candler Formation	Mount Athos Formation
Cockeysville marble					
	Arch marble Joshua schist	Archer Creek formation		Archer Creek Formation	Archer Creek Formation
Mount Athos formation					
	Candler formation	Candler formation		Mount Athos Formation	Candler Formation
Mount Athos greenstone	Catoctin greenstone	Older greenstone		Greenstone	Catoctin Formation
Lynchburg gneiss	Lynchburg gneiss	Lynchburg gneiss		Lynchburg Formation	Lynchburg Formation

Candler Formation

The Candler Formation, which forms the thickest and most extensive unit in the Evington Group, was named from exposures at Candler Mountain south of Lynchburg (Brown, 1951; 1953, p. 91; Espenshade, 1954, p. 15). The formation has been traced from Patrick County northeastward into Albemarle County. In the Buckingham quadrangle, more than two-thirds of the rocks mapped are Candler Formation. The schists and phyllites are sparsely associated with other formations of the Evington Group except northwest of the James River. In the central and southern portions of the quadrangle, mafic and ultramafic sills intruded, and were folded with, the Candler Formation. Parallel to the James River, the Candler schists and phyllites are in fault contact with Triassic sedimentary rocks.

The Candler Formation is composed chiefly of low-grade phyllites, metagraywackes, and mica schists. Lenses of micaceous quartzite (R-3189) occur locally. The phyllitic rocks weather rapidly to an expansive, resistant, medium-gray to tan clay, interspersed with sericite and greasy to the touch (Figure 4). A punky saprolite underlies the clay. Fresh exposures are uncommon on the uplands, but fresh rocks are abundant in stream valleys. The phyllites (R-3185) are lustrous, fissile, fine grained, and gray to green. Common mineral assemblages are: muscovite-chlorite, muscovite-chlorite-quartz (albite-chloritoid),

Figure 4. Typically weathered Candler schist exposed along State Highway 20, 1.6 miles south of Centenary. Dip of the foliation is 30 degrees to the southeast.

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The Candler Formation, which forms the thickest and most extensive unit in the Evington Group, was named from exposures at Candler Mountain south of Lynchburg (Brown, 1951; 1953, p. 91; Espenshade, 1954, p. 15). The formation has been traced from Patrick County northeastward into Albemarle County. In the Buckingham quadrangle, more than two-thirds of the rocks mapped are Candler Formation. The schists and phyllites are sparsely associated with other formations of the Evington Group except northwest of the James River. In the central and southern portions of the quadrangle, mafic and ultramafic sills intruded, and were folded with, the Candler Formation. Parallel to the James River, the Candler schists and phyllites are in fault contact with Triassic sedimentary rocks.

The Candler Formation is composed chiefly of low-grade phyllites, metagraywackes, and mica schists. Lenses of micaceous quartzite (R-3189) occur locally. The phyllitic rocks weather rapidly to an expansive, resistant, medium-gray to tan clay, interspersed with sericite and greasy to the touch (Figure 4). A punky saprolite underlies the clay. Fresh exposures are uncommon on the uplands, but fresh rocks are abundant in stream valleys. The phyllites (R-3185) are lustrous, fissile, fine grained, and gray to green. Common mineral assemblages are: muscovite-chlorite, muscovite-chlorite-quartz (albite-chloritoid),

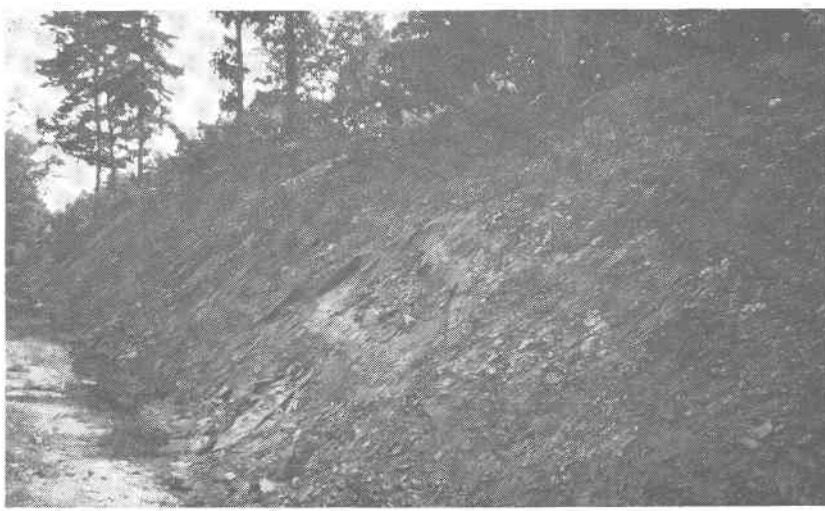

Figure 4. Typically weathered Candler schist exposed along State Highway 20, 1.6 miles south of Centenary. Dip of the foliation is 30 degrees to the southeast.

muscovite-paragonite-quartz (chlorite), and muscovite-quartz-kaolinite (goethite).

In the metagraywacke sequences, quartz is segregated into knots between the platy minerals forming flattened lenses parallel to the schistosity (R-3186); these lenses range from microscopic dimensions to a few inches in length and an inch in width (Figure 5). The metagraywackes are variable in grain size, degree of foliation, and composition. They are all resistant and break with a splintery fracture. Many of the isolated clastic quartz grains have secondary overgrowths and are enclosed in a fine-grained matte of chlorite and muscovite. Abundant albite occurs with the quartz clasts, and the grains are poorly sorted. Limonite pseudomorphs after pyrite are common. The rocks are gray to green, weather yellow to red-brown, and grade into metamorphosed subgraywackes with an increase in quartz and a decrease in feldspar and interstitial detritus.

Figure 5. Photomicrograph of Candler metagraywacke from 2.6 miles north-northwest of Centenary and 0.9 mile west-northwest of Paynes Millpond. Flattened clastic quartz grains are enclosed in a sericite-quartz-chlorite matrix and oriented parallel to the schistosity. Crossed nicols. X 14.

The schists are tan to greenish brown, flaky, and contain abundant muscovite, quartz, and iron oxides. Lesser amounts of chlorite, sodic plagioclase, paragonite, magnetite, and pyrite make up the remainder of the rock. Chloritoid occurs locally as porphyroblasts. The schistose rocks become more competent from east to west across the area, with a notable increase in quartz and chlorite and a change in color to lustrous dark green (R-3188). Magnetite octahedra (R-3187) are common, along with quartz augen, parallel to early foliation planes

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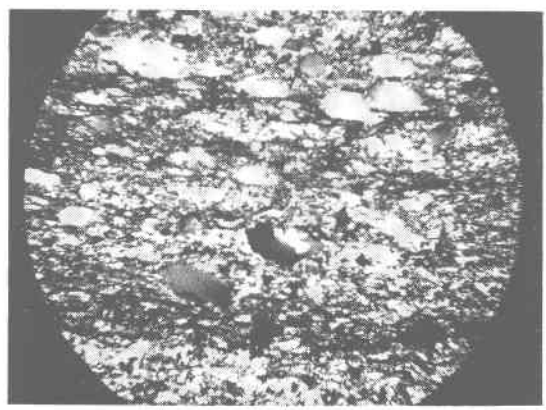

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(Figure 6). Sericite is stained with iron oxide and, along with magnetite, hematite, and sodic plagioclase, makes up the accessory component of the rock. Upon weathering, the schistose rocks have a notable gain in kaolinite, goethite, and mixed-layer clays and a decrease in chlorite and feldspar. The early schistosity is distorted by a later, well-developed slip cleavage that cuts it at an angle of approximately 30 degrees. This is characteristic of all the pelitic rocks in the formation.

Figure 6. Photomicrograph of Candler schist containing magnetite porphyroblast from along U. S. Highway 60, 5.6 miles west of Mount Rush. Quartz and feldspar have migrated to low-pressure zones adjacent to octahedral faces parallel to the schistosity. Crossed nicols. X 14.

Archer Creek Formation

The siliceous graphitic schists and blue marbles, exposed along Archer Creek 1.25 miles above its confluence with the James River east of Lynchburg, have been designated the Archer Creek Formation (Espenshade, 1954, p. 16). This formation includes the Joshua schist and overlying Arch marble of Brown (1953, p. 91; 1958, p. 33-34). The distinctive, fine-grained, blue marble (recrystallized limestone) member is sparsely and sporadically exposed in the Buckingham quadrangle. It has been mapped only east and northeast of Warminster along the James River and along Bishop Creek south of Wingina. The thick, lower graphitic schists that have been mapped elsewhere have not been seen as distinct mappable units. Minor graphitic schist is interbedded with the carbonate at the locations described. In the southwest corner of the area, very thin (nonmappable) siliceous graphitic schists have been observed in tight isoclinal folds with other Evington lithologies. The formation, therefore, is restricted to the

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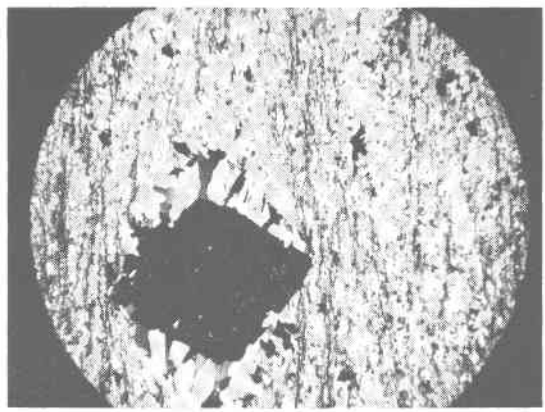

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northwest flank of the James River synclinorium where its exposure is sporadic, and it is generally thin, or removed by tectonic activity and subsequent erosion.

The impure, fine-grained, steel-blue to gray, schistose marbles (R-3190) in the Archer Creek Formation exhibit a low order of recrystallization. For this reason they are often described as impure limestones. Exposures are restricted to stream valleys where micaceous and graphitic laminations clearly outline shear folds in the incompetent marble (Figue 7). Quartz pods and calcite veins are common. The rock is made up of aligned carbonate crystals bounded by sericite flakes, disseminated pyrite, and lesser amounts of quartz, chlorite, and graphite. The rock weathers to a stiff, gray-green, micaceous clay soil that has irregular fragments of vein quartz, many of which contain leached rhombohedral cavities.

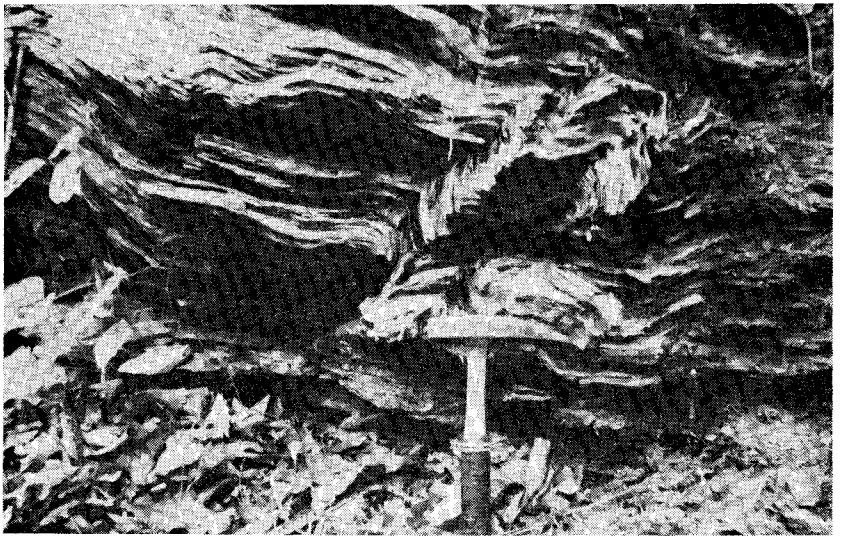

Figure 7. Shear folds in Archer Creek marble along Bishop Creek south of Wingina.

Mount Athos Formation

Furcron (1935, p. 22-23) named the Mount Athos Formation from exposures in Campbell County at Mount Athos, 6 miles east of Lynchburg. He included only quartzite and muscovite schists in this formation; all of the carbonate beds were correlated with what he believed was the overlying Cockeysville marble. It has been demonstrated that the white marbles are associated with the Mount Athos

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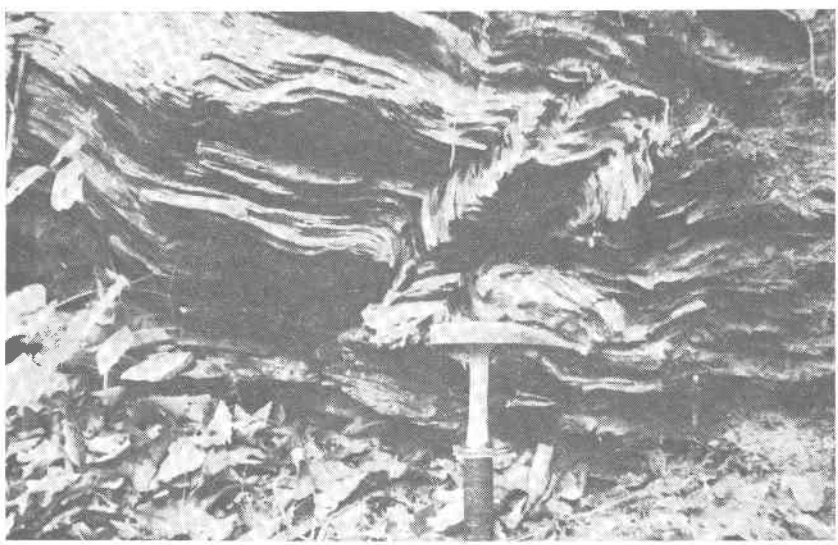

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quartzite and that the blue marbles are stratigraphically separate from this lithologic association (Espenshade, 1954, p. 17-18).

In the Buckingham quadrangle the quartzite forms a distinctive lithologic unit in a stratigraphic sequence where phyllosilicate associations predominate (Figure 8). The Mount Athos Formation is best exposed northwest of the James River where it forms low, narrow, resistant, linear ridges. It is also present south of Wingina where it is tightly folded with Archer Creek marbles, and in the southwestern portion of the quadrangle it occurs with the younger greenstones and siliceous chloritic Candler schists. Two other quartzitic zones have been mapped. One is just north of Katrine and the other at Enonville. Both appear to be arenaceous units in the Candler Formation. Their stratigraphic relationship is uncertain, and the quartzites may be correlative with the Mount Athos Formation.

Figure 8. Resistant Mount Athos quartzite in the bed of the Rockfish River 1.7 miles southwest of Howardsville.

The marbles weather rapidly and are easily overlooked. A number of localized beds have been mapped, and a few have been developed economically. One of the best areas in which to see Mount Athos lithology and its relationship to the overlying metamorphosed volcanic rocks (greenstone) and older Candler schist is 1.7 miles southwest of Howardsville on the left bank of the Rockfish River in Nelson County. A lens of white dolomitic marble borders the quartzite on the east and is overlain by greenstone.

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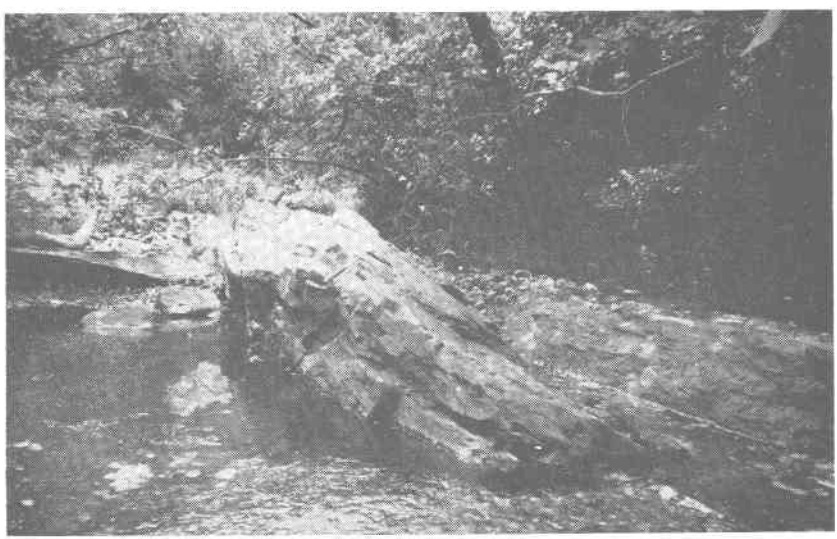

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The Mount Athos is composed of quartzite, conglomeratic quartzite, calcareous quartzite, white marble, and minor interbeds of muscovite schist. Brown (1953, p. 91) mapped the thick siliceous muscovite schist with characteristic porphyroblasts, which forms the base of the formation in the Lynchburg quadrangle, as the Pelier schist. This unit is known to decrease in thickness to the northeast and become more fissile where it was subjected to low-grade metamorphism. It was not recognized as a distinct unit in the Buckingham quadrangle.

The white to gray quartzites (R-3191) of the Mount Athos Formation have a heterogeneous grain size range. They contain stretched grains of quartz and albite enclosed in phyllosilicate sheaves. Clastic-grain boundaries are sutured; muscovite is abundant and well oriented, and lesser quantities of epidote, chlorite, calcite, apatite, tourmaline, and martite make up the groundmass. The coarser layers are gritty and contain large, distinctive, rounded, blue quartz pebbles that are evident where the rock is not too highly deformed. The rocks are distinctly mashed along the southeast contact with the Candler Formation. The quartzites weather to a porous lustrous gray soil stained with black and brown patches of manganese oxide. The appearance of the more calcareous quartzites is characterized by cavities resulting from leaching of minerals. The highly calcareous quartzites grade into discontinuous beds of white marble. Thin interbeds of sericite and muscovite schist are present locally.

The relatively pure marble (R-3192) is coarse to medium grained, and the compact, finer grained carbonates are normally dolomitic. Quartz is common along with muscovite, chlorite, and minor sulfides. The manganese oxides localized in the Mount Athos Formation are believed to have been dissolved from the calcareous beds and concentrated during extensive periods of weathering (Espenshade, 1954, p. 62). After becoming weathered, the marbles lose their crude foliation and form a red-brown loamy soil.

Metamorphosed Volcanic Rocks

The metamorphosed volcanic rocks are distinctively younger than the Catoctin Formation and are associated with the upper part of the Evington Group. Whether they represent a single flow tectonically repeated, a series of multiple extrusions (or intrusions), or whether they are due to sporadic igneous activity during middle to late Evington sedimentation, is not known. Evidence does point, however, to an extrusive origin. Espenshade (1954, p. 19-20) designated these units as "younger greenstone" to distinguish them from the stratigraphically separate "older greenstone" (Catoctin) units associated

with the Lynchburg Formation. The name Slippery Creek greenstone (Brown, 1951; 1953, p. 93) was applied to the youngest rocks in the Evington sequence in the Lynchburg quadrangle. This name has not been adopted in this report due to the uncertainty of the relationship between the younger Evington greenstones on the northwest flank of the James River synclinorium and those exposed in the southeast corner of the Buckingham quadrangle. They are tentatively believed to be equivalent.

In the Buckingham quadrangle metamorphosed mafic volcanic rocks (greenstones) northwest of the James River are associated with, and are flanked to the west by, the Mount Athos Formation. Interlayering of the greenstones with the quartzite at the top of the formation suggests that volcanism was initiated before termination of the quartz sand deposition. An extensive series of flows occurs in the southwest portion of the quadrangle; these are also associated with quartzite beds. In addition to the greenstones, altered intermediate tuffaceous flows have been mapped (Plate 1). The flows have been tightly folded and displaced along high-angle reverse faults. Another concentration of greenstones occurs southeast of Buckingham where they are exposed on the limbs of the Hardware anticline.

Three distinct types of greenstone are common; they range from dark green to tan and from well bedded to massive. The major constituents are chlorite, albite, actinolite, and epidote; quartz, potassic feldspar, magnetite, zircon, and apatite are common accessories. The most common type is a dense, dark-green, flaky, fairly massive, homogeneous metavolcanic rock. Locally, quartz veins several inches wide and concentrations of epidote transect the rock as veinlets. In places amygdaloidal structures filled with epidote or quartz are common. A second type, characterized by an increase in the phyllosilicates, is generally finer grained, more schistose, and more highly deformed. Actinolite needles are common along foliation planes. The third type is a siliceous, well-bedded rock (R-3193) with an abundance of epidote and a scarcity of mica and chlorite. These lithologies are overlain by a distinctive brick-red to red-brown soil. The weathered intermediate to felsic flows can be confused with the saprolite and the micaceous quartzite. They have been altered from an original trachytic or dacitic composition to a highly sericitized, well-foliated, dense rock (R-3194).

ARVONIA FORMATION

The Arvonia Formation was named for exposures in northern Buckingham County along the James and Slate rivers and in the quarries at Arvonia by Watson and Powell (1911, p. 36-43). The

formation extends southward from Fluvanna County, where it occupies the centers of three synclines, into the Buckingham quadrangle east of Enonville. At this point a slaty to phyllitic facies has been buckled into a trough that is possibly an extension of the Long Island syncline (Smith, Milici, and Greenberg, 1964, Plate 1). To the southeast a porphyroblastic biotite-garnet schist facies forms the northwest limb of the Arvonia syncline (Plate 1).

The northwest belt of the Arvonia Formation in the quadrangle is subparallel to the almandine isograd (Plate 1). The lithology ranges from a slaty phyllite (R-3203) to a garnetiferous phyllite. The rocks are composed of a fine-grained matrix of sericite, quartz, and biotite with varying quantities of graphite, pyrite, chlorite, magnetite, hematite, garnet, and tourmaline. The rock is dark gray to black and has lustrous cleavage surfaces. In many places quartz occurs in lenticular masses along with local carbonate blebs. To the northeast, interbedded quartzites, pebble conglomerates, and tuffaceous layers are common. The schist facies (R-3202) of the Arvonia Formation contains porphyroblasts of almandine and biotite, 1.5 mm in diameter, in a matte of quartz, albite, chlorite, and fine-grained biotite. The rock locally contains abundant chloritoid. The soil profiles over the Arvonia lithologies are notably shallow and uniform to a depth of 3 to 4 feet where particles of soft, weathered slate and phyllite occur. The B-horizon forms a very plastic, resistant soil.

BUFFARDS FORMATION

The Buffards formation, named from typical exposures at Buffards (pronounced Bū′ fards) Mountain 3.5 miles northeast of Dillwyn in Buckingham County (Brown, manuscript in preparation), has been traced from 0.4 mile south of the confluence of the Slate and James rivers to the southeast corner of the Buckingham quadrangle where a belt less than 0.4 mile long is exposed. The characteristic lithology is a schistose conglomerate. Pebbles of quartz are stretched and enclosed in a granular matrix of quartz and minor albite, with muscovite, chloritoid, and lesser amounts of biotite oriented along the foliation planes. Typical mineral assemblages are muscovite-quartz-biotite-albite-almandine and muscovite-chloritoid-quartz-almandine (epidote-albite). The formation is bounded by porphyroblastic biotite and biotite-garnet schists of the Arvonia Formation. It is younger in age than the conglomerate at the base of the Arvonia Formation (Brown, manuscript in preparation).

METAMORPHOSED IGNEOUS ROCKS

Metamorphosed mafic and ultramafic rocks northwest of the James River are approximately 12 miles apart from the mafic rocks southeast of the river. These rocks form part of an extensive series of related rocks that have been traced from Alabama to Newfoundland (Hess, 1955). The northwestern exposures have received, by far, the greatest attention because they are in the principal area of soapstone production in the State. These tabular bodies, injected into the Lynchburg Formation as concordant mafic and ultramafic sills, have been altered to slightly foliated metapyroxenites, serpentinites, soapstones, metagabbros, and amphibole-chlorite schists. They have steep southeasterly dips.

The fine- to medium-grained soapstone and serpentinite have irregular thicknesses. Composed primarily of talc with varying quantities of chlorite, amphibole, and calcite, the soapstone is an extensively hydrothermally altered rock that has undergone negligible change in volume. Its origin has been discussed by Burfoot (1930), Hess (1933a, 1933b), and Brown (1958, p. 38-47). The soapstone is dark green to blue-gray and has characteristic thin veins of carbonate, talc, or quartz; it grades compositionally into metapyroxenite and serpentinite. Some

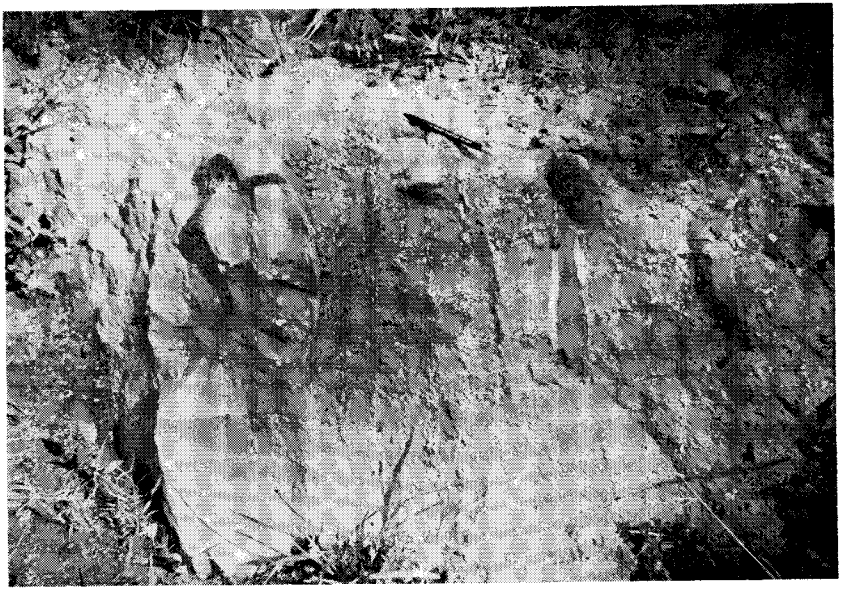

Figure 9. Oriented fragments of metagraywacke and schist incorporated in a metagabbro sill near the contact with country rock, 1.7 miles southeast of Mount Rush.

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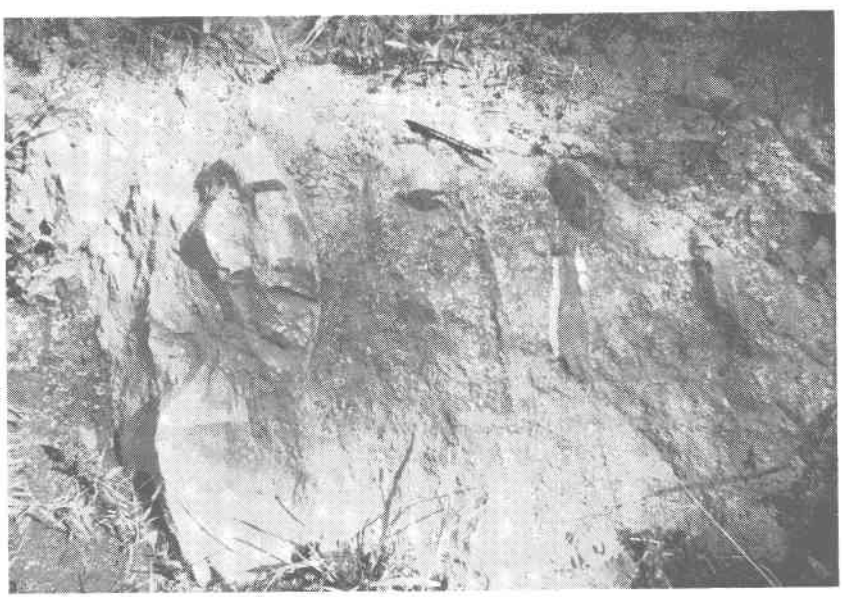

Figure 9. Oriented fragments of metagraywacke and schist incorporated in a metagabbro sill near the contact with country rock, 1.7 miles southeast of Mount Rush.

serpentinites are rimmed by a talc-carbonate rock that is mantled by steatite. A granoblastic hornblende-plagioclase rock is interlaminated with the ultramafic bodies and has a wide variation in grain size. A conspicuously coarse-textured metagabbro (R-3182) with sprays of hornblende crystals averaging 0.25 inch in diameter has been mapped along the southeast border of the metagabbro unit located about 0.7 mile northwest of Ariel Church parallel to State Road 722. The hornblende is green to black and encloses andesitic plagioclase along with minor amounts of quartz, magnetite, brown biotite, chlorite, and sphene. Locally the metagabbro has been discordantly injected by quartz monzonite dikes.

Southeast of the James River, tabular concordant intrusions have been injected into the phyllites and metagraywackes of the Candler Formation. These bodies consist of well-differentiated, intensely deformed sills interlayered with metasedimentary rocks (Figures 9, 10). The lower differentiates are fine-grained metapyroxenites; these are overlain by coarser grained metapyroxenites that grade upward into metagabbro. Late-stage intermediate differentiates are parallel to, and also transect, the lower units as injections along joints and shear zones

Figure 10. Sheared, fine-grained metagabbro and metapyroxenite with boudinage structure, 1.6 miles east of Camm along Stadon Creek.

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in the sills (Figure 11). Thus the rocks that compose these bodies are gradational in chemical composition as well as highly variable in grain size. Alteration is intense, and the country rock has been mylonitized, sheared, and strained along with the injections.

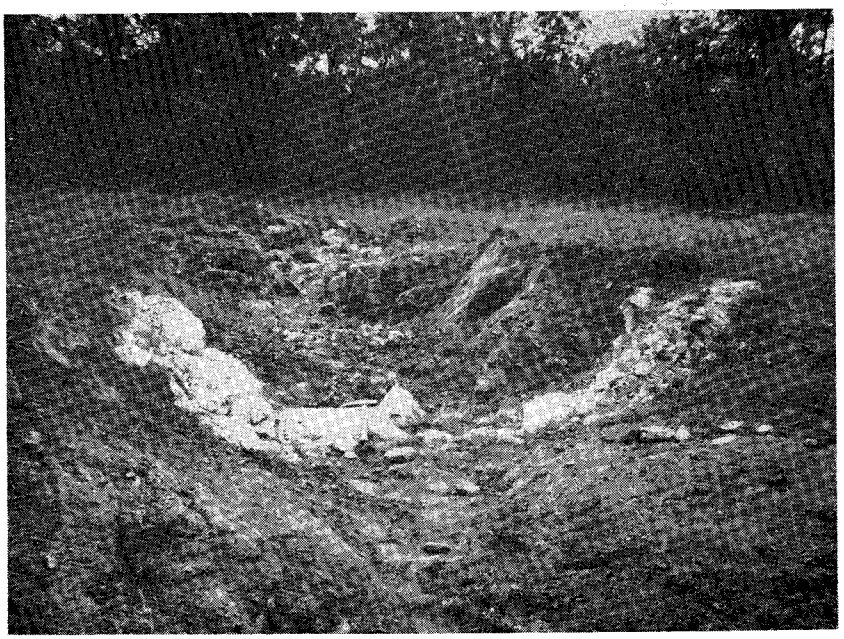
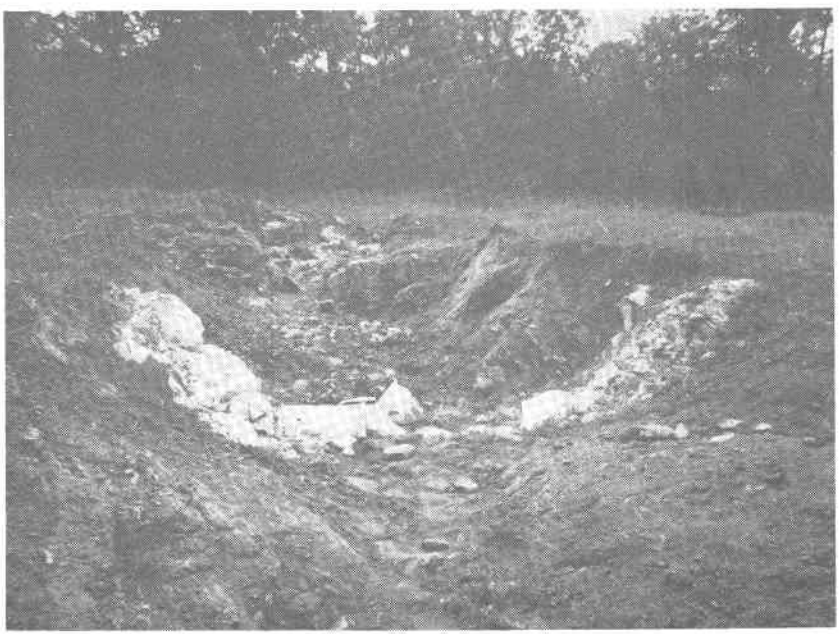


Figure 11. Dike of quartz monzonite, a late-stage differentiate, injected into coarse-grained metagabbro east of Old Mount Vinco.

The metapyroxenite (R-3197) is a dark-green to black rock that has a concentration of mafic minerals and veins of secondary calcite and epidote. Subhedral uralitized pyroxene constitutes the bulk of the rock, which has a hypidiomorpic-granular texture. Alteration (chloritization) is complete except for a few grains of original hypersthene and aegirine-augite (Figure 12). Serpentinized pseudomorphs after euhedral crystals of olivine are common; antigorite and chrysotile form the pseudomorphs. Talc and magnetite are also present as alteration products of olivine. Small residual magnetite crystals outline some of the relict crystals. Some of the orthopyroxenes have been serpentinized and have a bastite structure. A minor amount of plagioclase occurs in some metapyroxenites, and it has been saussuritized to a fine-grained aggregate of zoisite, albite, epidote, calcite, and sericite; accessories include ilmenite, magnetite, sphene, and apatite.

A dark-green and white appearance characterizes the horn-

in the sills (Figure 11). Thus the rocks that compose these bodies are gradational in chemical composition as well as highly variable in grain size. Alteration is intense, and the country rock has been mylonitized, sheared, and strained along with the injections.



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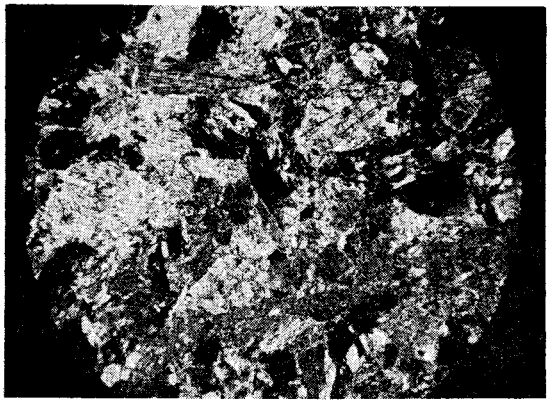


Figure 12. Photomicrograph of fine-grained metapyroxenite from 2.4 miles east of Camm. Section contains euhedral uralitized aegirine-augite, olivine, magnetite, and minor altered plagioclase. Crossed nicols. X 14.

blende-plagioclase rocks. These metagabbros (amphibolites) (R-3181, R-3196) have hypidiomorphic-granular texture with pigeonite or clinohypersthene poikilitically enclosing the plagioclase (An_{30}). The original twinned plagioclase has been replaced by epidote-zoisite, albite, sericite, and minor calcite; most of the pyroxene has altered to green pleochroic hornblende and chlorite (Figure 13). The large number of accessory minerals includes sphene, zircon, apatite, magnetite, and picotite. The grain size ranges from fine to very coarse (0.5 inch diameter hornblende crystals), and gneissic banding is fairly common.

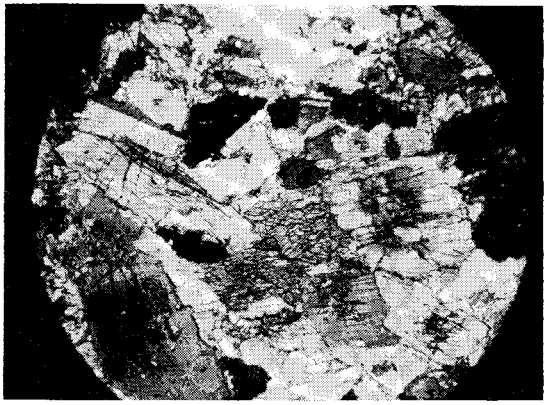
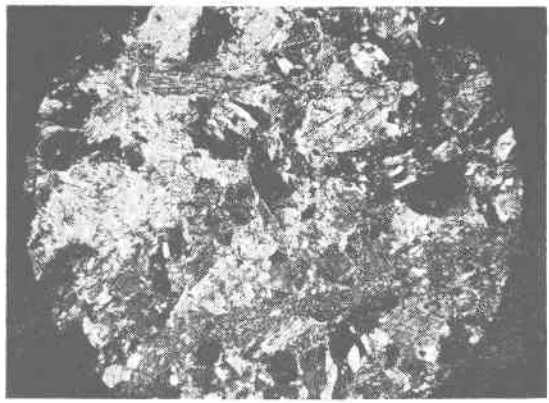


Figure 13. Photomicrograph of coarse-grained metagabbro from 1.5 miles south of Katrine. Laths of altered plagioclase are enclosed by clinohypersthene and hornblende. Plain light. X 14.



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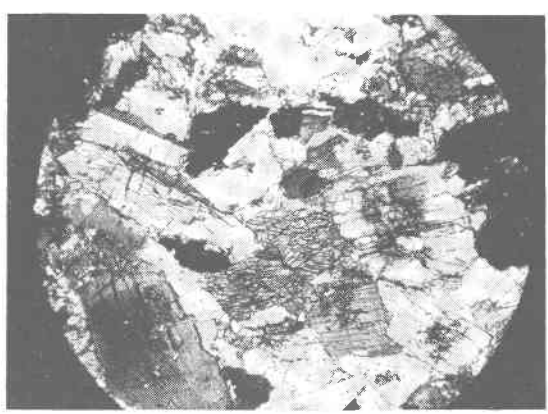

Figure 13. Photomicrograph of coarse-grained metagabbro from 1.5 miles south of Katrine. Laths of altered plagioclase are enclosed by clinohypersthene and hornblende. Plain light. X 14.

The last differentiate of the series to form is more felsic and ranges from a quartz monzonite (R-3198) to a felsic diorite. The rock is medium to fine grained and composed mainly of plagioclase, potassic feldspar, primary hornblende, and quartz. Biotite, apatite, sphene, and magnetite are common accessories.

The area underlain by this complex has a distinctive topography, a smooth, undulatory upland drained by broad, shallow streams. The overall soil tone is dark brown to red. The B-horizon is nearly impervious, and a marked change in volume occurs when the clay pan dries out and develops large shrinkage cracks. The soil is not well suited for agricultural purposes, but is well adapted to dairy farming; hence, open, cleared pasturelands are typical.

TRIASSIC ROCKS

Poorly sorted, heterogeneous, arkosic sandstones, siltstones, shales, and conglomerates of Triassic age occur in the northern and northwestern portions of the area. The deposits are lenticular and gradational, and lack continuous bedding. These rocks are a southwestern extension of the Scottsville basin that trends to the northeast beyond Keene in Albemarle County. This was one of seven basins studied by Roberts (1928) in his investigations concerning the Triassic System in the State. The Scottsville basin was studied in considerable detail by Kingery (1954), and it was found to have coalescing alluvial fans that had accumulated in an active fault trough.

Three distinct facies of sedimentary rocks are readily identifiable. The easternmost facies is composed of a gradational sequence of red, tan, and green siltstones and shales; fine- to medium-grained arkosic sandstones; and coarse-grained sandstones containing fragments derived from rocks in the Evington Group. The terrane of the fanglomerate facies northwest of the James River in the vicinity and southwest of Howardsville is generally thickly timbered and has a distinct topographic contrast to the lower, more subdued, gently undulatory surface underlain by the finer grained sedimentary rocks. The fanglomerate is massive and consists mainly of moderately rounded boulders of Catoctin greenstone (R-3200), with lesser amounts of pre-Triassic schist, granite gneiss, and vein quartz. Minor amounts of brick-red sandstone and gray siltstone are interbedded with the fanglomerate (Figure 14). The western facies is composed of green to gray shales and siltstones associated with pebble conglomerates and poorly sorted sandstones containing quartz, epidote, and mica. The source area for these materials was undoubtedly to the west, and deposition was rapid and somewhat chaotic. Soils developed on the

Triassic sedimentary rocks are distinctively chocolate-red to brown, moderately fertile, and provide the best upland soils for cultivation in the area.

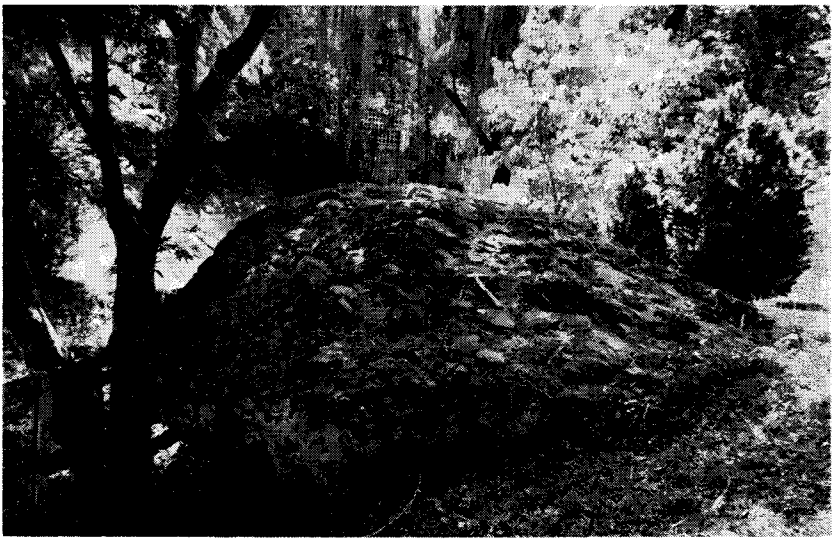

Figure 14. Boulder of Triassic fanglomerate at Howardsville. Detrital fragments consist of Catoctin greenstone and pre-Triassic schist.

Numerous tabular, discordant, steeply dipping masses of diabase intrude the pre-Triassic metamorphic rocks, as well as the Triassic sedimentary rocks in the area. The dikes range from a few feet to several hundred feet in thickness and generally occur in parallel swarms that trend to the north or northwest, although irregular or branching patterns have been mapped. Many dikes are too small to depict at the scale of the geologic map (Plate 1). Most dikes are continuously exposed for 1 to 2 miles, and a few, up to 8 miles. Characteristic outcrops of the diabase consist of rounded boulders enclosed in concentric shells of the decayed rock. This feature is caused by chemical and mechanical weathering of the rock along joint planes. The finely crystalline texture (R-3201) of some diabases coarsens to that of a fine-grained gabbro. Laths of plagioclase (An_{50-65}), along with augite, some olivine, phyllosilicates, and numerous accessories, are subophitically arranged in a highly altered matte (Figure 15). Wall rocks adjacent to the diabase are altered within a few inches of their contacts. The dikes are believed to be Late Triassic in age.

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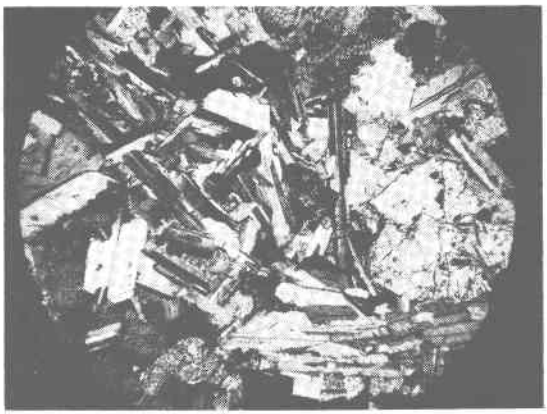
Figure 15. Photomicrograph of diabase from a dike on the south side of Muddy Creek Watershed Dam No. 1, about 3.3 miles southeast of Glenmore. Laths of calcic andesine are subophitically enclosed by augite and olivine. X 14.

STRUCTURAL GEOLOGY

The structural setting of the Buckingham quadrangle is one of intense isoclinal folds and high-angle reverse faults in northeastward-trending pre-Triassic rocks that dip primarily to the southeast and have

Figure 16. Isoclinally folded Candler schist displaced by a high-angle reverse fault east of Walton Lake.



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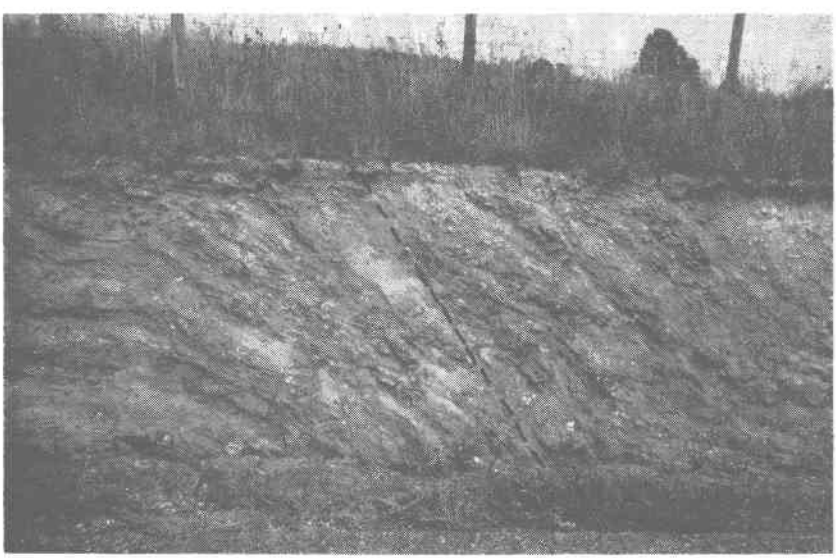

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undergone low-grade regional metamorphism (Figure 16). Minor structures are prevalent, and two generations of cleavage occur in the more schistose rocks, the older schistosity being transected by a slip cleavage. The most recent faults are normal and involve Triassic sedimentary units.

The structural relations in the Buckingham quadrangle reflect a deep homoclinal or synclinal Evington sequence resting upon a westward-thinning wedge of Lynchburg metasedimentary rocks that unconformably overlie the Virginia Blue Ridge Complex to the west. The transgressive Catoctin greenstones interfinger with the Lynchburg-Evington sequence. Major fold axes in rocks of the Evington Group have been delineated by minor stuctures imposed on tight isoclinal folds, the western limbs of which have been sheared by high-angle reverse faults. The major structures, from northwest to southeast across the area, are the Blue Ridge-Catoctin Mountain anticlinorium, James River synclinorium, Hardware anticline, and Arvonia syncline.

MINOR STRUCTURAL FEATURES

Foliation

As used in this report, foliation refers to any megascopic planar structure originating through mineral orientation, and to banding resulting from changes in composition or grain size, whether of primary or secondary origin. Bedding is any primary compositional banding in the rocks. Banding due to metamorphic processes commonly simulates bedding but is not included. Differences in composition and texture are the most reliable criteria for distinguishing bedding. Bedding is imperfectly preserved in the area, but is discernible in the interbedded metagraywackes and phyllites of the Candler Formation, as well as the siliceous marbles and quartzites of the Evington Group. In thick phyllites or low-grade schists, it is most difficult to recognize bedding. Recrystallization of platy minerals parallel or subparallel to the bedding produces bedding schistosity, which is by far the most common foliate structure in the quadrangle.

Cleavage is the planar property of a rock that breaks along closely spaced parallel surfaces. Unlike schistosity planes, cleavage surfaces do not necessarily involve mineralogic alignment. Mimetic recrystallization, however, may occur along cleavage planes, closely simulating schistosity. Three types of cleavage are present in the area: a prominent flow cleavage, slip cleavage, and less well developed fracture cleavage.

The schistosity is a flow or axial-plane cleavage due to the orientation

or parallelism of minerals, and is best developed in the finer grained rocks. The schistosity is approximately parallel to the bedding in most of the area, but locally transects the bedding at a slight angle. The second prominent cleavage is a slip cleavage that is due more to flowage than fracture. Displacement along the cleavage plane need not take place, but in order for slip cleavage to develop it is necessary that the platy minerals have subparallel arrangement along potential shear planes (Figures 17, 18). Slip cleavage is most readily seen in the incompetent rocks where it is superimposed on an earlier foliation. In more competent or massive rocks only a single cleavage is present. Unlike the multiple cleavages in the northern Appalachians (White, 1949), the slip cleavage in the Virginia Piedmont is related to a single orogenic period. Fracture cleavage is better developed in the more siliceous rocks where shearing has occurred along closely spaced fractures. Mineral parallelism, diagnostic in part of slip cleavage, is totally absent.

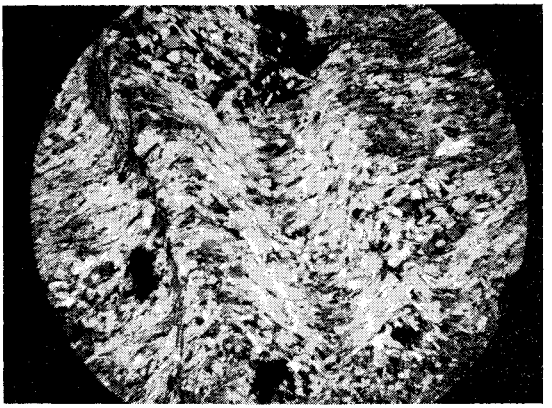

Figure 17. Photomicrograph of Candler schist with slip cleavage from an exposure near the intersection of State Road 604 and U. S. Highway 60. Note mineral parallelism along cleavage planes and concentration of magnetite and quartz in adjacent low-pressure areas. Crossed nicols. X 14.

Lineation

Linear features in the rocks are the result of crinkles, mineral streaks, foliation intersections, rodding, or axes of minor folds. Streaks, caused by the shearing out primarily of chlorite and muscovite, are oriented down dip in the foliation plane but not normal to the axes of minor folds or crinkles. Intersections of bedding and flow cleavage are not

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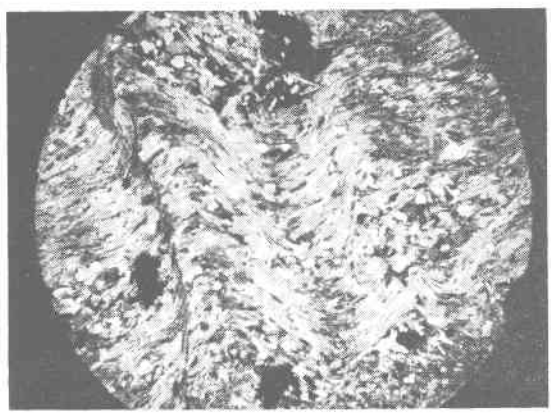

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well developed because the schistosity is parallel or subparallel to the foliation planes. Intersections of cleavages, however, are abundant and best developed in tight isoclinally folded phyllites. These intersections plunge at moderate to low angles parallel to the regional trend or tectonic "b" axis. Many of the minor folds form a chaotic pattern, particularly those in marble and phyllite, and plunge steeply. In many places, quartzites have well-developed rodding.

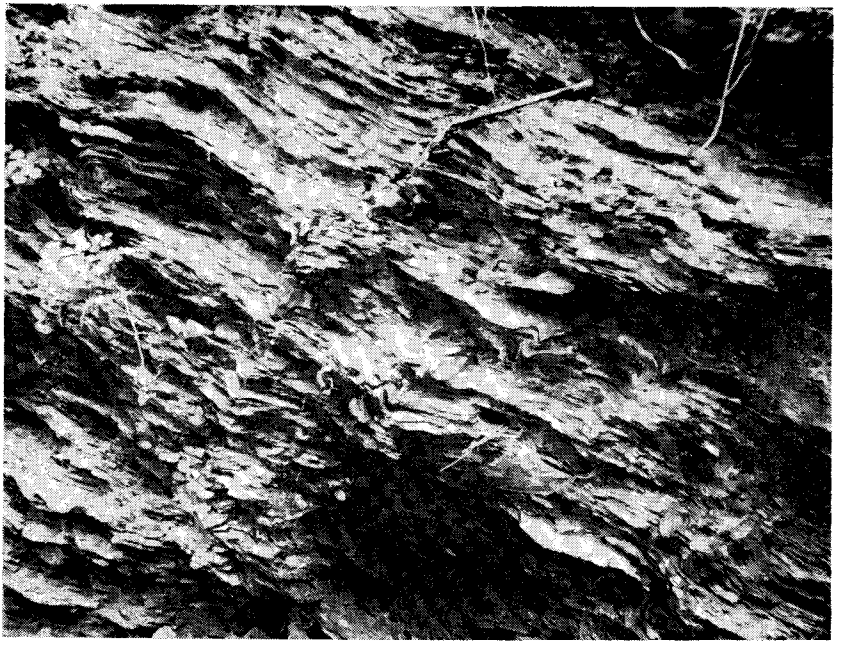

Figure 18. Slip cleavage in Candler phyllite along Sheldries Creek west of Maple Grove Church.

Minor Folds

Minor folds range in amplitude from microscopic dimensions to those tens of feet across, depending upon the thickness and competency of the rocks. They are best exposed in stream valleys and recent roadcuts (Figure 19). Axial planes of most folds are inclined steeply to the southeast, and the fold pattern is asymmetric. Associated with the tight folds is a contemporaneously formed schistosity that is subparallel to bedding on the limbs of the folds, but transects bedding at the crests (Figure 20). Shear folds that have developed in some of the more massive, less competent rocks are later than the schistosity,

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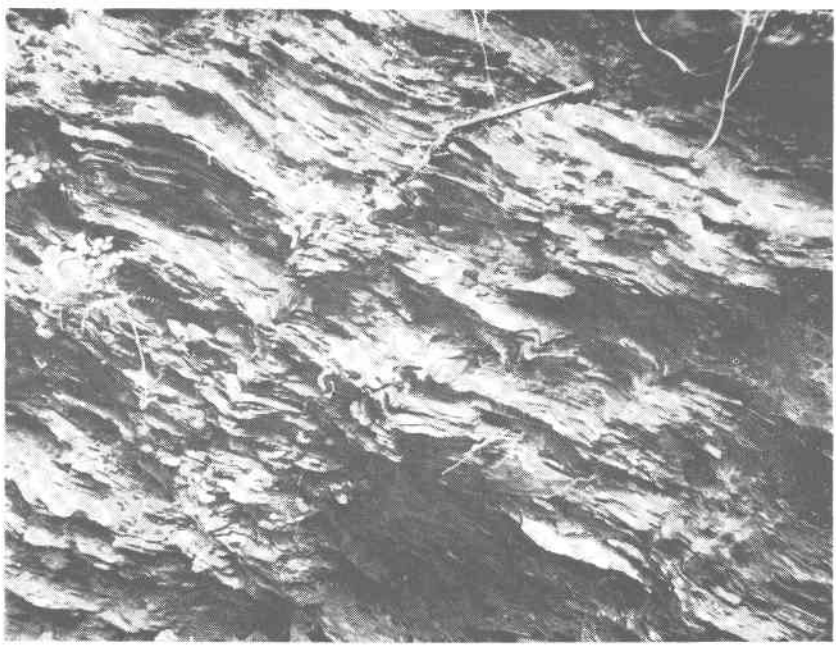

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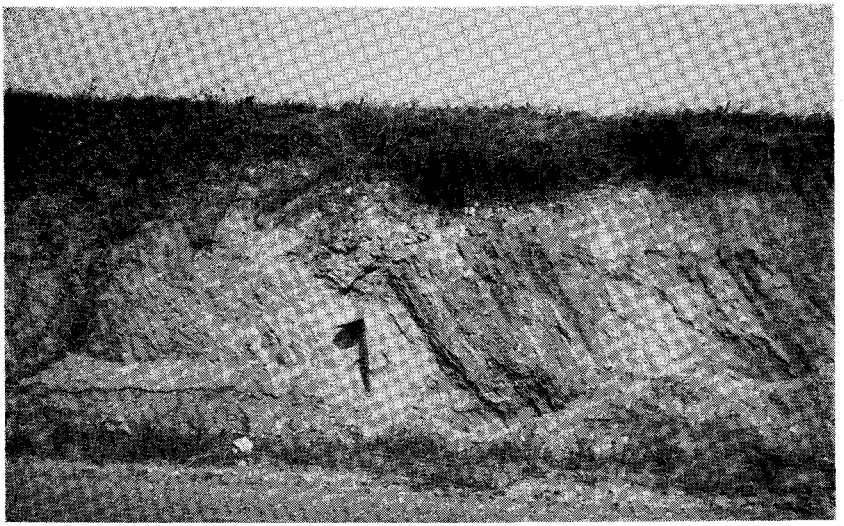

Figure 19. Sinistral folds in Candler Formation along State Road 649, 1 mile east of Slate River Mills.

Joints

Two distinctive sets of joints have been mapped in the rocks in the area. Joints are best developed in the more massive phyllitic and quartzitic beds, although they are recognizable in schistose beds. Strike joints, parallel or subparallel to the minor folds, dip steeply or are vertical; they strike to the northeast, and many are filled with vein quartz. Transecting the strike joints, are cross joints that strike to the northwest and have steep dips.

MAJOR STRUCTURAL FEATURES

Blue Ridge-Catoctin Mountain Anticlinorium

The northeastward-trending Blue Ridge-Catoctin Mountain anticlinorium extends eastward more than 25 miles from the northwest flank of the Blue Ridge to the Piedmont (Jonas and Stose, 1939). The southeast limb of the anticlinorium contains the Lynchburg and Cat-

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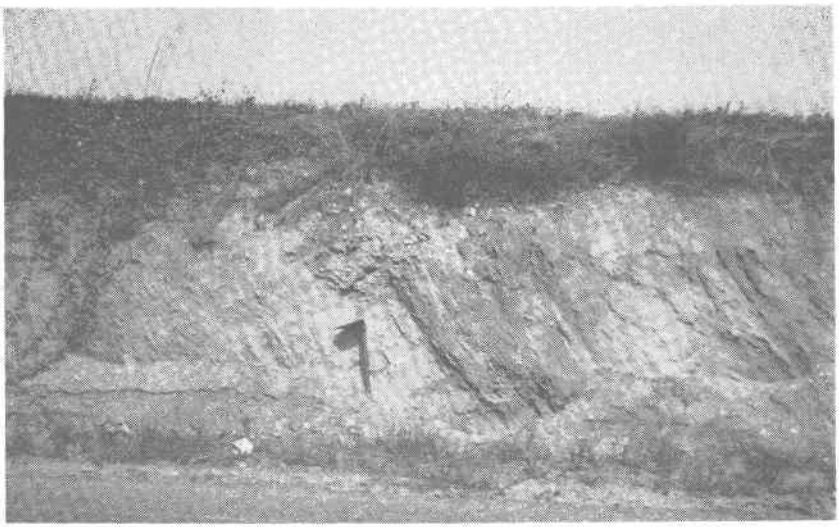

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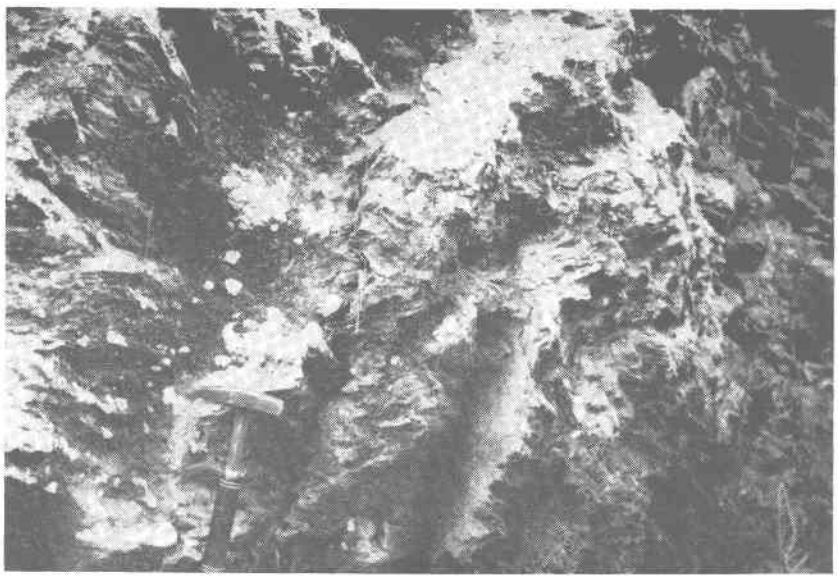
Figure 20. Tight flowage folds in Candler Formation 1.9 miles southwest of Howardsville. The folds have a plunge of 18 degrees in a direction of S. 20° W.

octin formations that are exposed in the northwestern portion of the area. The Lynchburg Formation has southeasterly dips and is characterized by a series of intricate folds and probable faults that are difficult to define without marker beds. The unit has been intruded by younger ultramafic and mafic sills and dikes that were metamorphosed along with the Lynchburg lithologies. The overlying transgressive Catoctin Formation is tightly folded in repetition with the Lynchburg Formation (Espenshade, 1954, Plate 1).

James River Synclinorium

Located parallel to and southeast of the Blue Ridge-Catoctin Mountain anticlinorium, the James River synclinorium extends from Orange County southward to Patrick County on the Virginia-North Carolina boundary (Brown, 1953, 1958). The Evington Group of rocks is within this long, tight, deep structure that trends diagonally across most of the quadrangle. These units dip essentially to the southeast and have been isoclinally folded and repeated a number of times in their association with high-angle reverse faults.

Axial-surface deformation is difficult to assess without distinct marker beds; however, the folds within the synclinorium are believed



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Axial-surface deformation is difficult to assess without distinct marker beds; however, the folds within the synclinorium are believed

to have horizontal fold axes as evidenced by their linear outcrop belts. Axial-plane schistosity is dominant, but is transected by slip cleavage, particularly in the Candler Formation. The S_1 and S_2 surfaces have an almost constant angular relationship to one another, with the flatter slip cleavage transecting the schistosity at an angle of approximately 30 degrees. An unnamed anticlinal-synclinal structure has been mapped in the center of the quadrangle. Although exposures are poor, open folds in the stream beds, particularly to the northeast; bedding cleavage; and drag folds are indicative of a series of intricate, isoclinal, recumbent folds depressed in tight troughs. These are difficult to locate because of the nonvariation in lithology.

Delineation of faults is based entirely on general outcrop pattern and position of the Evington Group stratigraphic sequence. One of the most critical contacts is between the Evington Group and the older units to the northwest in the vicinity of Ariel Church. This is related to the problem of the existence of the Martic overthrust in Virginia, a problem that also has not been resolved in the Maryland and Pennsylvania Piedmont where it is so critical to the age of the Glenarm series (Hopson, 1964, p. 204). The rocks (Wissahickon) in the area of the James River synclinorium (Brown, 1953) were correlated on the Geologic Map of Virginia (Virginia Geological Survey, 1928) with the Glenarm series of Maryland. Jonas (1929, p. 507-508; 1932, p. 32-34) believed that the rocks were thust westward over the Lynchburg as a nappe for a distance of 15 to 20 miles; she (Jonas, 1932, p. 11), therefore, considered the Wissahickon (Candler) to be a retrograde phyllonite of a former higher grade rock. To explain the relatively straight contact between the Wissahickon and the older rocks in the area, Jonas (1929, p. 508) suggested the Martic block was "separated" from the Precambrian rocks of the Blue Ridge-Catoctin Mountain anticlinorium by a normal fault. Structural and petrographic evidence in the Buckingham quadrangle is indicative that the uniform Candler sequence is a progressive, low-grade metamorphic assemblage. The incompetent, fissile Candler is more intensely deformed near the Lynchburg Formation, and this contact is interpreted as a minor high-angle reverse fault. It cannot be overemphasized that the determination of the correct stratigraphic order for the Evington Group is imperative to the solution of this as well as other regional problems in the Appalachian Piedmont.

The fault between the Mount Athos quartzite and the Candler schists on the southeast is readily mappable. The Candler lithologies become progressively more chaotic and intensely deformed toward the fault (Figure 21). An intensely deformed area occurs in the

southwestern portion of the quadrangle. Lithologic units have been thinned to nonmappable thicknesses, and probable high-angle faults have disconnected the mappable subparallel minor folds.

Figure 21. Intensely deformed Candler schist near faulted contact with the Mount Athos Formation along State Road 602, 0.8 mile northwest of Howardsville.

Hardware Anticline

From Palmyra in Fluvanna County southeastward into Buckingham County, the Hardware anticline can be traced as a distinctive structure along the northwestern and west-central portions of the Dillwyn quadrangle into the southeastern part of the Buckingham quadrangle. This structure was first reported by Brown (1962), and excellent exposures occur along the banks of the James River east of Scottsville. The northwest limb, which has steep dips and is in places overturned, is defined by the upper muscovite-chlorite unit (Smith, Milici, and Greenberg, 1964). In the Buckingham quadrangle the Candler phyllite parallels the axial trace, and structurally repeated metamorphosed volcanic rocks are present on the limbs; the fold is overturned to the northwest.

Arvonia Syncline

The Arvonia syncline has been mapped for a distance of approximately 30 miles from east of Enonville (this report) northeastward to

southwestern portion of the quadrangle. Lithologic units have been thinned to nonmappable thicknesses, and probable high-angle faults have disconnected the mappable subparallel minor folds.

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Arvonia Syncline

The Arvonia syncline has been mapped for a distance of approximately 30 miles from east of Enonville (this report) northeastward to

Carysbrook Station in Fluvanna County (Smith, Milici, and Greenberg, 1964). The syncline is overturned to the southeast with the Buffards formation lying along its axial trace. This formation is flanked to the northwest by the Arvonia Formation.

Scottsville Basin

Paralleling the regional trend, Triassic rocks of the narrow Scottsville basin extend about 10 miles northeast of the quadrangle and cover a total area of approximately 50 square miles. These heterogeneous, poorly sorted, immature sedimentary rocks, that have a close relation to parent rocks to the west, are believed to have accumulated as a series of overlapping alluvial fans in an environment of contemporaneous sedimentation and gravity faulting (Kingery, 1954). Bounded on the west, and along most of the eastern border as well, by normal faults, the Triassic rocks dip to the northwest at an average of 20 to 30 degrees. Evidence for displacement of a considerable magnitude on the west is abundant (Figure 22). Local variations in strike direction are common, along with reversals in dip, brecciation, drag folds, slickensides, and boudinage in quartz veins. Espenshade (1954, p. 35), in discussing the western border fault where Ivy Creek joins the Rockfish River, states: "Green Triassic shales and phyllite of the Candler formation are mashed and deformed within 25 feet of the fault, and gash veins, 1 foot thick, of quartz with carbonate masses, occur in the Triassic rocks." On the east side of the basin there is little displacement along the normal fault and notable lack of coarse clastic rocks. South of the main mass of Triassic rocks, a number of isolated fault slices occur whose northeastward extension from the mass is masked by alluvium along the James River. A graben is present in the western facies of sedimentary rock northwest of Midway Mills. About 1.5 miles south of Howardsville, a passive body of Evington rock persists as a horst, thus bifurcating the main Triassic mass.

METAMORPHISM

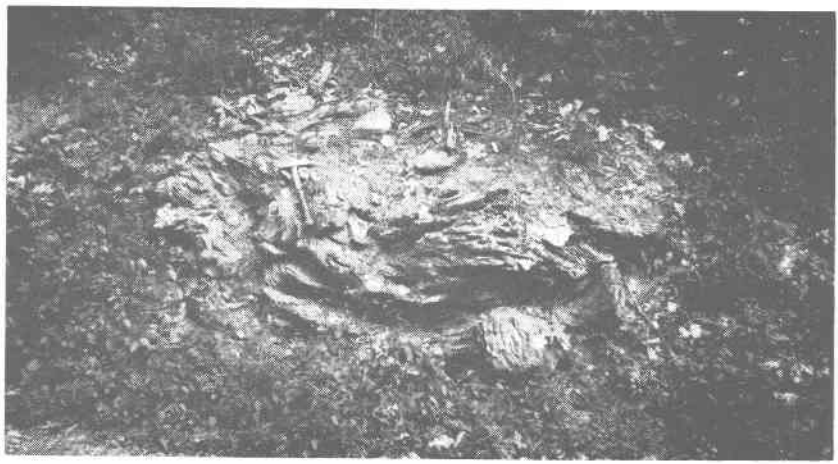
The rocks in the Buckingham quadrangle, except for the diabase dikes and sedimentary rocks of Triassic age, have undergone regional metamorphism. Mineral assemblages indicate most of the area is in the quartz-albite-muscovite-chlorite subfacies (chlorite zone) of the greenschist facies (Fyfe, Turner, and Verhoogen, 1958, p. 219-223). A garnet isograd, subparallel to the regional structure, has been delineated in the extreme southeastern part of the area. Garnet has been identified in the pelitic rocks south of the James River along the western margin

Figure 22. Deformed Candler Formation near the normal fault along the east side of the Scottsville basin, along State Road 724 north of the Rockfish River.

of the area and in the mafic and ultramafic intrusives in the Evington Group. A distinct biotite isograd could not be delineated; but if one were to be drawn, it would be almost superimposed on the garnet isograd.

Most of the pelitic rock assemblages are characterized by a large number of minerals which are caused by an inherent extreme sensitivity to chemical and physical fluctuations. Multicomponent greenschists are abundant and contain various combinations of chlorite, chloritoid, muscovite, paragonite, green biotite, epidote, albite, actinolite, microcline, and quartz. Typically, the pelitic rocks have a fine-grained matrix of chlorite, muscovite, and quartz along with different amounts of albite (An_{2-5}) and epidote. Chloritoid occurs locally, frequently as porphyroblasts, along with fine-grained stilpnomelane and magnetite octahedra. Accessory minerals include tourmaline, zircon, apatite, leucoxene, and rutile. Graphitic schists have a similar mineralogy, but additionally contain fine-grained disseminated graphite and pyrite. Although there are textural changes in the quartzitic and calcareous rocks, there is little change in mineralogy. Greenstones are essentially actinolite-albite-chlorite-epidote assemblages with a small amount of quartz.

A mineralogic variation and coarsening in texture mark the transition to the garnet zone in the southeastern portion of the quadrangle. Biotite occurs as distinct flakes and as porphyroblasts, some of which transect the schistosity (cross biotite). There is a notable decrease in



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the amount of chlorite, and it is not as green and contains more magnesium. In the quartz-albite-epidote-almandine subfacies the chief assemblage is muscovite-biotite-almandine-quartz with minor albite and epidote. Much of the biotite is partially altered to chlorite. Mineral assemblages are ascribed to a progressive increase in metamorphism to the southeast in the James River area. In Fluvanna County, delicate sedimentary features that are preserved west of the garnet isograd have been obliterated to the east, and high-temperature pseudomorphs are absent in the lower grade rocks (Smith, Milici, and Greenberg, 1964, p. 30). Bedding is moderately well preserved in low-grade rocks in the Buckingham quadrangle and is reported absent in higher grade rocks elsewhere (Espenshade, 1954, p. 42).

ECONOMIC GEOLOGY

BUILDING STONE

Medium- to fine-grained sandstones of Triassic age were a popular building stone at the time of the Civil War. Hotchkiss (1880) noted the opening of a "brownstone" quarry at Midway Mills. A considerable amount of stone has been removed, but the quarry (Plate 1, No. 22) has been abandoned for about 70 years. The Federal court building at Abingdon (Roberts, 1928, p. 119) and the mill at Midway Mills are among structures built of this stone. A few small prospects occur along the right bank of the James River across from Howardsville.

Four quarries for soapstone were developed by the Alberene Stone Division of the Georgia Marble Company due north of Ariel Church (Plate 1, Nos. 1-4). The most recently operated quarry, the Climax (Plate 1, No. 3), was abandoned in 1964 (Figure 23). The openings average 100 feet in width and length and are from 60 to 150 feet deep. There has been production in the Alberene-Schuyler soapstone belt since the early 1880's, and at present the company is the only producer of dimension soapstone in the United States. The quarried and dressed soapstone is cut into specific shapes and sizes for use primarily as chemically resistant furnishings and for architectural applications.

CRUSHED STONE

Quartz veins are abundant in all the metamorphosed rocks and range in size from short, limited exposures to those several hundred feet long and as much as 25 feet wide. Most are parallel to the regional strike, although a few are discordant. Only one quartz vein (Plate 1, No. 21)

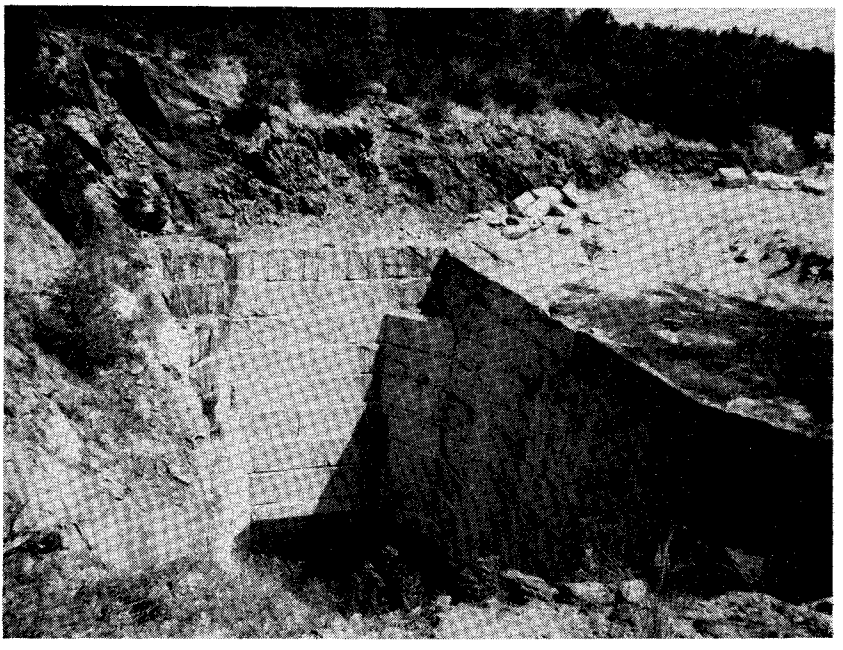
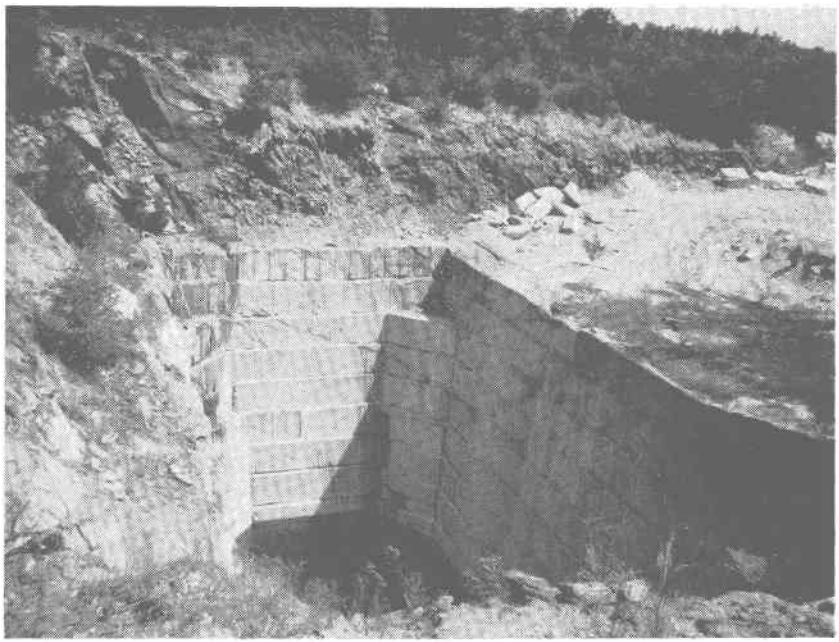


Figure 23. Abandoned Climax soapstone quarry of the Alberene Stone Division of the Georgia Marble Company northeast of Glade Creek.

has been prospected in the area, and that subsequently has been abandoned. The excavation, 20 feet long, 12 feet wide, and 10 feet deep, is exposed adjacent to State Road 648, 1.7 miles south of Katrine. This milky-quartz vein strikes N. 20° W. and is relatively barren of other minerals, as are all veins in the area. The locations of other quartz veins of significant size have been indicated on Plate 1, although none appeared suitable for development. Within recent years crushed "bull" quartz has gained popularity as a decorative aggregate in concrete, hence its active development in Fluvanna County (Smith, Milici, and Greenberg, 1964, p. 35-37).

MARBLE

Marbles occur at two stratigraphic positions in the area. One marble is steel gray to blue with numerous micaceous and graphitic laminations; veins of white calcite, irregular calcite augen, and pyrite concentrations are common. These pitted blue-gray marbles have been correlated with the Archer Creek Formation. The other marble is medium to coarse grained and ranges from white to gray. It invariably occurs as nonpersistent lenses in the quartzite of the Mount Athos



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Formation. Phyllosilicates are common, and the more dolomitic portions are finer grained.

Excellent exposures of approximately 100 feet of intensely shear-folded Archer Creek marble in repetition with Mount Athos quartzite and chloritic Candler schists occur in the prominent bluff west of the James River bridge south of Wingina. The beds dip at a low angle to the east and extend 1.3 miles upstream along Bishop Creek. An exploratory pit and some trenching are evident along the right bank of the creek (Plate 1, No. 20).

A number of abandoned quarries are present east and northeast of Warminster (Plate 1, Nos. 17, 18, 19). Along the tracks of the Chesapeake and Ohio Railway west of Dog Island, approximately 90 feet of white to pink marble is exposed in a bluff on the left bank of the James River (Plate 1, No. 17). Jefferson (1787, p. 6) noted "marble of very good quality occurs in great abundance overlying a navigable part of the James River at the confluence with the Rockfish River in the form of a very large precipice." Although this exposure is more than 1.5 miles below the confluence of the Rockfish and James rivers, it appears to be the only logical exposure he could have made reference to.

On the right bank of the James River due east of Warminster and at the termination of State Road 693, both varieties of marble occur in repetition with the Candler Formation (Plate 1, No. 19). The largest exposure consists of approximately 150 feet of white Mount Athos marble that is both massive and schistose. Three blocks of this stone were shown at the St. Louis Exposition (Furcron, 1935, p. 75). Northwest of this outcrop a 15-foot-thick bed of Archer Creek "limestone" is exposed. Rogers (1884, p. 314) described both types and commented: "Several varieties occur here, white, reddish and blue, and varying in texture from close granular to slaty and micaceous. It is quarried extensively for the locks and other works on the James river canal." The blue marble with graphitic and schistose layers was burned for lime for agricultural purposes and had a calcium carbonate content ranging from 81.4 to 88.4 percent (Rogers, 1884, p. 82). An 80-foot-wide pink to white dolomitic marble with talcose seams is exposed in an abandoned quarry (Plate 1, No. 18) in Nelson County. Watson (1907, p. 314) reported the following analysis: calcium carbonate, 54.8 percent; magnesium carbonate, 33.5 percent; aluminum and iron oxide, 3.6 percent; silica, 5.5 percent; phosphoric oxide, 0.2 percent; water, 1.2 percent; and organic matter, 0.8 percent.

An excellent historical account of the economic development of marble along the James River north of Roanoke is given by Furcron

(1935, p. 60-77). The stone is of fair quality and has been used for masonry construction, burned for agricultural lime, and used as a fluxstone in local blast furnaces.

MANGANESE ORE

A comprehensive study of the geology and manganese deposits from Howardsville, 60 miles southwest to Altavista was made by Espenshade (1954). All previously investigated and currently known deposits in the area were treated in great detail in that report; therefore, only a few pertinent comments need be considered here.

Former manganese oxide operations (Plate 1, Nos. 6-16) in the quadrangle are evident by caved shafts, tunnels, open cuts, and prospect pits that were originally part of four mines: Piedmont, Cabell, Bugley, and Simpson. The mines, located northwest of Warminster, are in the Mount Athos Formation, and the ore is associated with weathered and sheared fissile quartzites. The ore was localized as heavy, nodular, irregular clusters of psilomelane-type minerals and commonly occurs imbedded in clay seams that are conformable to the enclosing rocks and as residual concentrates in the soil. Noncommercial, soft, lightweight "wad" also occurs mixed with the clay and weathered rock (Espenshade, 1954, p. 55-56). A total of 8000 to 9000 tons of washed ore was reported to have been shipped from the 4 mines between 1868 and 1885 (Furcron, 1935, p. 108). All deposits in the district are thin and localized and represent an estimated total reserve of less than 10,000 long tons of washed ore. Espenshade (1954, p. 147) concluded his evaluation by stating: ". . . it is unlikely that the district could produce more than several thousand tons of washed ore annually for more than a few years."

IRON ORE

A poorly exposed prospect (Plate 1, No. 5) of specular hematite is located in the same belt of Mount Athos quartzite as the manganese oxide deposits. The pit is situated south of Ivy Creek, 1.1 miles southwest of its confluence with the Rockfish River. The iron oxide is reported to occur in steeply dipping beds and lenses parallel to the regional schistosity. Minor amounts of magnetite, partly altered to martite, are associated with the hematite.

CLAY AND SHALE

Analyses were made of clay and shale by the Virginia Division of Mineral Resources in cooperation with the U. S. Bureau of Mines to

evaluate their potential for ceramic and other uses (Calver and others, 1964). Two samples of Triassic shale and one of a Recent (?) clay were collected in and adjacent to the Buckingham quadrangle. The samples of Triassic shale, one (R-2) from Albemarle County northwest of Warren and the other (R-1671) from along State Road 602, 0.5 mile east of the James River bridge at Howardsville, may represent potential sources for use in the manufacture of brick, tile, and quarry tile. The Recent (?) clay (R-1785), from Nelson County west of Wingina, had no potential use unless mixed with a lower maturing clay.

GROUND WATER

Domestic water supplies are obtained from springs, dug wells, and drilled wells in the area. Most springs and dug wells are located in or near the James River valley or other large valleys where the water table is at or near the surface. Most dug wells have been replaced by drilled wells, and only a few springs are now being used for water supply. Subsurface water is obtained from the pore spaces in the weathered saprolite zone, 30 to 60 feet below the surface, and in rock below the saprolite, water is obtained mainly from interconnecting fractures. Rock fractures decrease in size and number with depth, particularly below 150 feet.

Information on more than 30 drilled water wells in the Buckingham quadrangle is on file at the Virginia Division of Mineral Resources. A compilation of this data indicates the following ranges: depth to bedrock, 10 to 115 feet (probably fairly coherent saprolite); depth to water table, 10 to 105 feet; total depth of well, 42 to 177 feet; and yield, up to 35 gallons per minute. The yield of water from individual wells, even in the same type of rock and in the same area, is highly variable. The chemical quality of the water is generally good, although in some instances the iron content is high enough to be objectionable.

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COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES
James L. Calver
Commissioner of Mineral Resources and State Geologist

Base from U.S. Geological Survey, 1959
Buckingham Quadrangle, 15-minute Series

GEOLOGIC MAP OF THE BUCKINGHAM QUADRANGLE, VIRGINIA

Geology by Ernest H. Ern

Williams & Heintz Map Corporation
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Commonwealth of Virginia

APPROXIMATE MEAN DECLINATION, 1961

SCALE 1:62 500

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

1968

QUADRANGLE LOCATION

EXPLANATION

CENOZOIC — QUATERNARY

Qal — Alluvium

MESOZOIC — TRIASSIC

Td — Diabase

Ŧn, Ŧnf — Newark Group
Ŧn, *arkosic sandstone, red shale, graywacke, conglomerate;* Ŧnf, *fanglomerate.*

PALEOZOIC — ORDOVICIAN

Pzb — Buffards formation
Conglomeratic quartz-muscovite schist

Oa, Oap — Arvonia Formation
Oa, *slate and slaty phyllite;* Oap, *porphyroblastic biotite-garnet schist.*

hg, hgc — Metagabbro
hg, *hornblende metagabbro and diorite, amphibolite, gneiss and some granodiorite;* hgc, *coarse-grained metagabbro.*

um — Ultramafic rocks
Metapyroxenite, soapstone, serpentinite, and amphibole-chlorite schist.

v, vs — Metamorphosed volcanic rocks
v, *metamorphosed mafic igneous rocks (greenstone);* vs, *metamorphosed felsic to intermediate volcanic rocks.*

EVINGTON GROUP

Pzma, m — Mount Athos Formation
Pzma, *quartzite, quartzitic conglomerate, and micaceous schist;* m, *white marble.*

Pzac — Archer Creek Formation
Blue-gray schistose marble and limestone; minor graphitic schist and quartz-mica schist.

Pzc, m, q — Candler Formation
Pzc, *muscovite-chlorite-quartz-paragonite phyllite and schist, metagraywacke;* q, *micaceous quartzite member (may equal* Pzma*);* m, *white marble unit (may equal white marble in Mount Athos Formation).*

PRECAMBRIAN

ЄpЄc — Catoctin Formation
Metamorphosed mafic lava flows, chlorite-albite-epidote-amphibole-quartz schist, amygdaloidal in part.

pЄly — Lynchburg Formation
Micaceous schist and gneiss, micaceous quartzite, and metaconglomerate.

CONTACTS

exposed — approximate — covered

FOLDS with trace of axial plane

Anticline — Overturned anticline
Syncline — Overturned syncline

FAULTS

exposed — approximate — covered
U - upthrown side; D - downthrown side

ATTITUDE OF ROCKS

67 Strike and dip of beds
50 Strike and dip of overturned beds
Strike of vertical beds
Horizontal beds

FOLIATION AND CLEAVAGE

Strike and dip of foliation
Strike of vertical foliation

BEARING AND PLUNGE OF LINEATIONS

12 Bedding - foliation intersections
8 Axes of crinkles or minor folds
15 b, biotite streak

JOINTS

85 Strike and dip of joints
Strike of vertical joints

ISOGRAD

Almandine present on hachured side of isograd

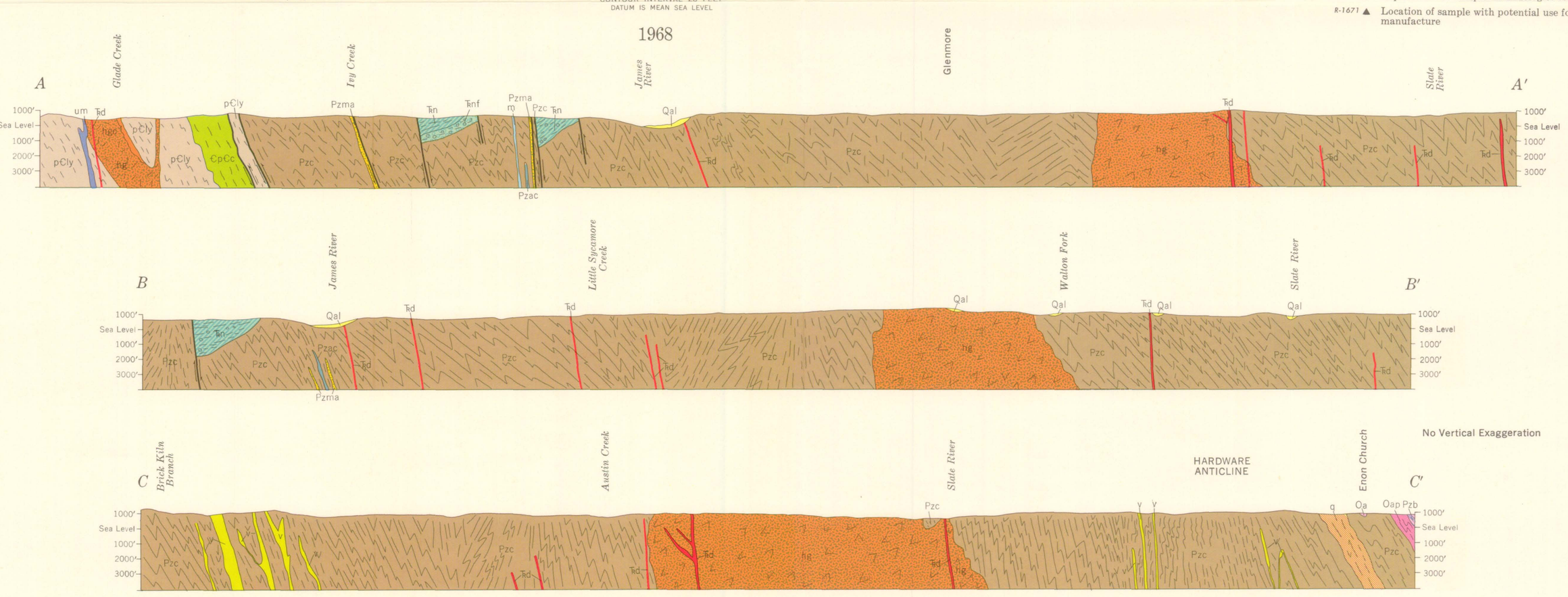
MINES, QUARRIES, AND PROSPECTS

1 ABANDONED QUARRY OR MINE
1, 2, 3, 4. Alberene Stone Division of the Georgia Marble Company - Climax quarries: soapstone
6, 7, 8, 9. Piedmont mines: manganese oxide
10. Cabell mine: manganese oxide
11, 12. Bugley mines: manganese oxide
13, 14, 15, 16. Simpson mines: manganese oxide
17. Marble
18. Marble
19. Marble
22. Sandstone

5 PROSPECT
5. Specular hematite
20. Marble
21. Vein quartz

QUARTZ VEINS

SAMPLE LOCALITIES

R-3200 △ Representative samples of lithologies studied

R-1671 ▲ Location of sample with potential use for brick manufacture