COMMONWEALTH OF VIRGINIA

DEPARTMENT OF CONSERVATION
AND ECONOMIC DEVELOPMENT

DIVISION OF MINERAL RESOURCES

GEOLOGY OF THE VESUVIUS QUADRANGLE VIRGINIA

H. J. WERNER

REPORT OF INVESTIGATIONS 7

VIRGINIA DIVISION OF MINERAL RESOURCES

James L. Calver
Commissioner of Mineral Resources and State Geologist

CHARLOTTESVILLE, VIRGINIA
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GEOLOGY OF THE VESUVIUS QUADRANGLE, VIRGINIA

By

H. J. WERNER[1]

ABSTRACT

In the Vesuvius quadrangle of central Virginia the Precambrian Virginia Blue Ridge Complex composed of granitic and gneissic rocks is unconformably overlain by a succession of Cambrian and Ordovician volcanic and sedimentary rocks that are exposed in the northwest limb of the Blue Ridge-Catoctin Mountain anticlinorium. The Lower Cambrian formations consist of coarse graywackes, arkoses, subgraywackes, altered basalt flows commonly referred to as greenstones, and quartzose sandstones which are conformably overlain by Upper Cambrian and Lower Ordovician shales, limestones, and dolomites. Field relationships indicate that the Lower Cambrian formations were deposited on an eroded and weathered Precambrian surface that had an original easterly gradient. These relationships and the continuity of the stratigraphic succession indicate essentially uninterrupted deposition from the beginning of Cambrian time and extending well into Ordovician time. None of the numerous faults in the quadrangle is interpreted to be sufficiently large to cast doubt on the nature of the stratigraphic succession. Thus, the stratigraphic succession in the Vesuvius quadrangle in the northwest limb of the Blue Ridge-Catoctin Mountain anticlinorium can be related to the formations that occur in the southeast limb of the anticlinorium. These relationships provide a record of the change from a eugeosynclinal to a miogeosynclinal depositional environment from Early Cambrian to Early Ordovician time.

The time of the structural deformation of the Cambrian and Ordovician rocks is uncertain. There is no lithologic evidence to indicate tectonism within the central Virginia region before Middle Ordovician time.

Although the mineral resources of the Vesuvius quadrangle are not of great economic potential, iron, manganese, and tin ores have been mined at various times; and crushed stone, sand, and gravel are presently being produced.

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INTRODUCTION

The Vesuvius quadrangle, located in central Virginia in parts of Nelson, Amherst, Rockbridge, and Augusta counties (Figure 1), is bounded by parallels 37° 45′ and 38° 00′ and meridans 79° 00′ and 79° 15′, and named for the small community of Vesuvius located at the foot of the Blue Ridge. Other small communities within the quadrangle area include Steeles Tavern, Raphine, Spottswood, Montebello, and Massies Mill. It is a sparsely populated area, largely within the George Washington National Forest. The principal routes of access are the Norfolk and Western Railway and U. S. Highway 11, State Highway 56, and the Blue Ridge Parkway. A few secondary roads are suitable for vehicular transportation.

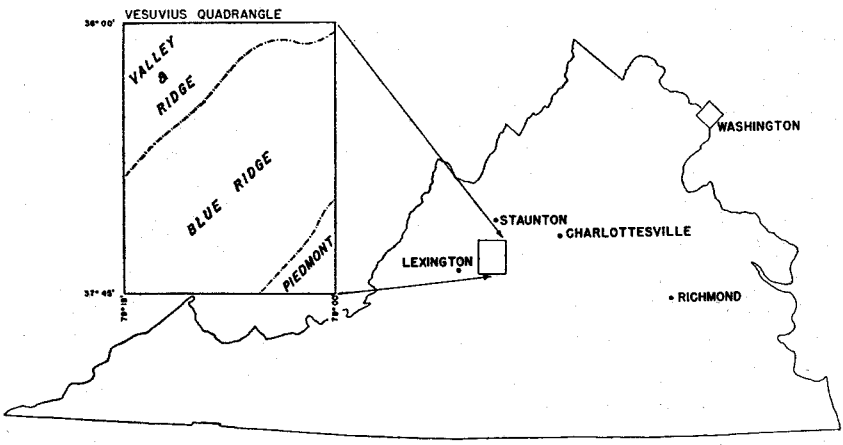


FIGURE 1. Index map showing location of Vesuvius quadrangle.

Within the boundaries of the Vesuvius quadrangle are elements of three principal physiographic provinces. Most of the area is located in the mountainous terrain of the Blue Ridge province. This is bounded on the northwest by undulating hills of low topographic relief characteristic of the Valley and Ridge province. A small area in the southeastern part of the quadrangle is located in the Piedmont province. Each province, in addition to its distinctive physiographic aspects, is distinguished by a characteristic type of bedrock.

In the Blue Ridge portion of the quadrangle there are three peaks that are in excess of 4000 feet above sea level. Rocky Mountain, 4067 feet, is the highest point in the quadrangle and is used by the Federal Aviation Agency as a site for a high frequency radio communication

tower. The lowest elevation is in the Piedmont province near Massies Mill at slightly less than 700 feet, thus accounting for a total topographic relief within the quadrangle in excess of 3000 feet.

Within the Vesuvius quadrangle there are three principal drainage systems. The small streams in the northern part of the quadrangle flow northward into the Shenandoah River. South River, the principal stream that drains the Valley and Ridge and the northwest slope of the Blue Ridge, joins the James River near Glasgow, Rockbridge County, several miles southwest of the quadrangle. In the Blue Ridge the principal streams are Tye, Piney, and Pedlar rivers which join the James River in the Piedmont province several miles southeast of the quadrangle.

The principal industry of the Valley and Ridge portion of the quadrangle is farming. Earlier in the century, the timber industry was important in the Blue Ridge where there are still remnants of narrow gauge railway beds. A restoration of a section of narrow gauge railroad can be seen along the Blue Ridge Parkway a few miles southeast of Tye River Gap. Most of the Blue Ridge is now part of the National Forest Preserve System and, as a consequence, very little timber is being cut. The Big Levels Game Refuge located in the northeast part of the quadrangle abounds with a great variety of wildlife. An historical point of interest is Cyrus McCormick's mill located about 0.8 mile northwest of Steeles Tavern. McCormick, the inventor of the grain reaper, was born and spent the early years of his life at this locality.

PREVIOUS AND PRESENT WORK

William Maclure (1809, p. 426), probably the first geologist to visit central Virginia, noted that the Blue Ridge appears to form the boundary between the "primitive rocks" to the east and the "transition rocks" to the west. In 1836, W. B. Rogers studied a section across the Blue Ridge immediately west of the Vesuvius quadrangle in the vicinity of Whites Peak and classified the formations in accordance with his numerical system (Rogers, 1884). Fontaine (1875) made a number of excursions into the Blue Ridge and concluded that the sedimentary rocks thicken southeastward and are represented among rocks in the Piedmont province. This concept, although later abandoned because it was incompatible with the prevailing concepts of the development of the Appalachian geosyncline, (Dana, 1873; Williams, 1897; Walcott, 1892; Willis, 1902, p. 37-40) has been restated in recent years (Bloomer and Bloomer, 1947, p. 103; Kay, 1951, p. 9; Bloomer and Werner, 1955).

J. L. Campbell (1879) emphasized the economic potential of the area. Stose and others (1919) examined the manganese-oxide belt along the northwest foot of the Blue Ridge and published a generalized map. Knechtel (1943) made a study of the manganese deposits between Vesuvius and Sherando. Jonas and Stose (Jonas, 1927, 1932, 1935; Jonas and Stose, 1938, 1939; Stose and Stose, 1946) have reconnoitered the length of the Blue Ridge and have contributed to the understanding of the regional geology.

E. L. Steidtman, Professor of Geology at Virginia Military Institute, began mapping the geology of the Vesuvius quadrangle for the Virginia Geological Survey in 1945, but died soon after the work was begun. Steidtman's field notes, based on pace and compass traverses, and some thin sections of Precambrian rocks were made available to the present writer.

The writer began mapping the area in 1949 as part of a cooperative effort with R. O. Bloomer on the geology of the Blue Ridge of central Virginia; this work was sponsored, in part, by the Virginia Geological Survey and was published in 1955. The present report incorporates some of the data of the earlier publication. During the summer of 1964 the writer completed the mapping of the Valley and Ridge portion of the quadrangle and checked some previous mapping in the Blue Ridge.

METHODS

Deciphering the geology of the Vesuvius quadrangle has been complicated by the lack of detailed knowledge of the regional stratigraphic relationships of the various rock units and by the complex structure in the area. In order to resolve these problems, outcrops were mapped at a large scale and a detailed inventory was made of all structural features. Throughout the course of the field work several thousand structural observations were made and plotted. These data were then reduced to the scale of the present map (Plate 1; 1:62, 500), but many structural observations could not be shown on the final map. Structural symbols plotted on Plate 1 represent an average attitude (strike and dip) at a particular locality.

ACKNOWLEDGEMENTS

During the course of mapping in the Vesuvius quadrangle the writer discussed the geological features of the area with P. B. King, John Rodgers, J. B. Hadley, R. B. Newman, B. W. Wilson, Ernst Cloos,

R. S. Edmundson, W. C. Overstreet, Kali Neuvoven, and Chris Oftedahl whose criticisms and suggestions are very much appreciated. L. H. Warwick, H. C. Sunderman, and the late William M. McGill at various times provided assistance that is gratefully acknowledged. James L. Calver, State Geologist, encouraged the writer to complete the present manuscript and kindly provided editorial comments. A special expression of gratitude is extended to the author's teacher, colleague of many years, and field companion, Robert Oliver Bloomer, who guided much of the early work that is now being reported.

STRATIGRAPHY

The Vesuvius quadrangle is underlain by a great diversity of rock types (Table 1) that owe their origin to a wide variety of sedimentary, igneous, and metamorphic processes. The Blue Ridge and the adjacent Piedmont foothills are underlain by the Virginia Blue Ridge Complex of Precambrian age (Brown, 1958). In the Vesuvius area, the complex is represented by the Pedlar, Marshall, and Lovingston formations. Resting on the Virginia Blue Ridge Complex, in a greatly distorted anticlinal arch called the Blue Ridge-Catoctin Mountain anticlinorium, is a sequence of volcanic and sedimentary rocks. At the base of the sequence is the Swift Run Formation, which is characterized by coarse-grained graywackes and arkoses, and at the top, several thousand feet above the Swift Run are shales and carbonate rocks that are typical of the Appalachian Valley (Butts, 1940). This entire stratigraphic succession from the Swift Run at the base up to Middle Ordovician limestone at the top appears to be a conformable sequence of sedimentary units. This sequence shows a change in lithology from graywackes and pyroclastic rocks at the base, through quartzites and shales, to limestones and dolomites at the top, and a change from a eugeosynclinal to a miogeosynclinal environment.

TABLE 1.—Formations in the Vesuvius quadrangle.

System	Formation	Remarks
Quaternary		Alluvium: upland gravels, talus, and flood-plain deposits
Triassic		Diabase dikes
Ordovician	Edinburg	Argillaceous limestone and black shale
	New Market-Lincolnshire	Medium- and coarse-grained limestone
	Beekmantown	Massive beds of dolomite; contains chert
	Chepultepec	Blue limestone with few fossils
Cambrian	Conococheague	Limestone and dolomite with interbedded quartzose sandstone
	Elbrook	Dolomite, limestone, and siltstone
	Rome	Dolomite, limestone, and maroon shale
	Shady	Deeply weathered clayey residuum; no unweathered exposures in Vesuvius area
	Antietam (Erwin)	Quartzite; considered upper formation of Chilhowee Group
	Hampton (Harpers)	Alternating siltstones and quartzites; the Snowden Member, consisting of quartzite, occurs near the middle of the formation
	Unicoi	Quartzite, subgraywacke, graywacke, and "greenstone" lava flows; lowest formation of Chilhowee Group
——?——		
Cambrian-Precambrian?	Catoctin	Greenstone, altered spilitic lava flows, and interbedded graywackes
	Swift Run	Basal conglomerate, arkose and graywacke
Precambrian	Pedlar	Chiefly granodiorite
	Marshall	Granite and gneissic granite
	Lovingston	Granite gneiss

PRECAMBRIAN ROCKS

The Virginia Blue Ridge Complex is part of a mass of Precambrian gneissic and granitic rocks that form the Blue Ridge. These rocks have been mapped and described as hypersthene granodiorite, Pedlar Formation, Marshall granite, and Lovingston granite-gneiss (Watson and Taber, 1913; Watson and Cline, 1916; Virginia Geological Survey, 1928; Furcron, 1934; Jonas, 1935; Jonas and Stose, 1939; Knechtel, 1943; Bloomer and Werner, 1955; and Virginia Division of Mineral Resources, 1963). In some of the published literature each of these formations is described as a genetically separate body of orthomagmatic origin. Bloomer and Werner (1955, p. 581) take exception to this and point out the gradational boundaries between the masses and suggest that these rocks originated through granitization of metasedimentary rocks.

Pedlar Formation

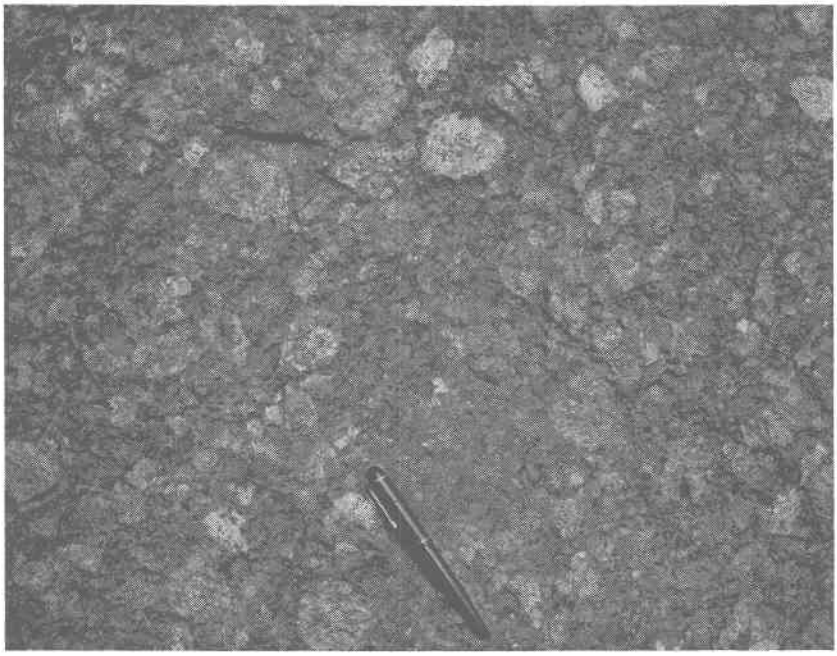
Prior to Bloomer and Werner (1955), the prevailing literature on the geology of the Blue Ridge stated that the dominant rock is a hypersthene granodiorite mass. However, they showed that there is a great variation in the composition of the lithology previously mapped as hypersthene granodiorite and proposed the name Pedlar Formation to include all the various rock types that are exposed along the headwaters of the Pedlar River in the southeastern part of the Vesuvius quadrangle. The formation is predominantly green, but locally red or light gray, and is medium to coarse grained. In places it is porphyritic with phenocrysts as large as 4 inches across. Whereas much of the mass previously classified as granodiorite or hypersthene granodiorite contains perthitic potassic feldspar, quartz, and oligoclase-andesine (An_{30}), there are distinctive variations that have the composition of alkali granite (potassic feldspar, 70 percent; quartz, 30 percent), quartz diorite (oligoclase-andesine, 70 percent; quartz, 17 percent; potassic feldspar, 3 percent; diopside, 5 percent), granite (potassic feldspar, 65 percent; quartz, 25 percent; oligoclase-andesine, 10 percent), and unakite (potassic feldspar, 55 percent; epidote, 25 percent; quartz, 20 percent). Accessory minerals are generally scant except in localized variations where hypersthene and diopside in about equal amounts comprise as much as 10 percent of the rock. A readily accessible exposure of the coarsely porphyritic rock occurs along State Highway 56 about 2 miles northwest of Tye River Gap (Figure 2).

FIGURE 2. Porphyritic granodiorite of the Pedlar Formation exposed in roadcut along State Highway 56, 2 miles northwest of Tye River Gap.

Marshall Formation

The Marshall Formation is a gray to green, uniformly medium-grained, gneissic granite composed of light-colored granite layers that average 0.13 inch thick separated by biotite developed along foliation planes. The granitic portion consists of an equigranular assemblage of potassic feldspar, quartz, and oligoclase-andesine (An_{30}) with traces of biotite and chlorite. The micaceous portion, which comprises about 20 percent of the rock, consists of bleached and chloritized biotite, potassic, feldspar, quartz, and oligoclase-andesine (An_{30}) in about equal amounts.

Along the southeastern scarp of the Blue Ridge, the Pedlar Formation grades, with changes in composition, granularity, and structure in a zone about 100 feet wide, into the Marshall Formation. Readily accessible outcrops of the Marshall Formation occur along the secondary roads in the vicinity of Woodson (Plate 1).



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Lovingston Formation

The Lovingston Formation, an augen gneiss, occurs in the southeastern part of the Vesuvius quadrangle. The boundary between the Lovingston and Marshall formations is gradational with change in composition, granularity, and structure through a zone at least 100 feet wide. The gneiss is composed of potassic feldspar, quartz, oligoclase-andesine (An_{30}), and characteristic biotite developed along foliation planes. In places, the feldspar porphyroblasts are as much as 2 inches across (Figure 3). Good exposures of the Lovingston Formation may be seen along State Road 56 south of Tyro (Plate 1).

FIGURE 3. Augen gneiss of the Lovingston Formation exposed along Tye River 1 mile south of Tyro.

CAMBRIAN-PRECAMBRIAN ? ROCKS

One of the problems of Blue Ridge stratigraphy concerns the age of the rocks that occur between the Virginia Blue Ridge Complex and the overlying sandstones, shales, limestones, and dolomites of undoubted Cambrian and Ordovician ages. The rocks of particular concern are the Swift Run, Catoctin, and Unicoi formations. These stratigraphic units are barren of fossils. In fact, the lowest stratigraphic occurrence of fossils in the Vesuvius area, with the exception of the problematic

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Scolithus tubes, is in beds of Late Cambrian age. However, the formations above the Unicoi Formation yield diagnostic Cambrian fossils in other areas (Butts, 1940), so there is little doubt concerning the age of the post-Unicoi formations.

All of the formations in the Vesuvius area occurring above the Virginia Blue Ridge Complex appear to be part of a gradational and continuous sequence of deposition ranging in composition from arkoses, graywackes, and basaltic (greenstone) flows in the lower part of the section upward through siltstones and quartzose sandstones into shales, limestones, and dolomites in the upper part of the sequence. No evidence of an unconformity or major interruption in deposition within the sedimentary units between the Virginia Blue Ridge Complex and the Ordovician Beekmantown Formation was recognized. However, King (1949) and Stose and Stose (1949) report an unconformable relationship between the Unicoi and Catoctin formations in northern Virginia.

The problem arises as to where to assign the base of the Cambrian System. As King (1964, p. 78) points out, the Cambrian System differs from all other systems that succeed it in that the base of the Cambrian is undefined paleontologically. Some geologists define the base at the lowest occurrence of diagnostic fossils (Howell and others, 1942; Snyder, 1947, p. 152; Wheeler, 1947, p. 157). Other geologists extend the base to some pronounced unconformity (Bloomer and Bloomer, 1947, p. 102-106) or refer to the unfossiliferous strata below the lowest occurrence of diagnostic fossils as "Cambrian (?)" (King, 1964, p. 78), "Cambrian or Precambrian," "Precambrian and Cambrian" (Bick, 1960, p. 6), "age unknown" (Rodgers, 1956, p. 410), or "Late Precambrian" (Bloomer and Werner, 1955, p. 582-593).

It might be argued that the Unicoi Formation should not be grouped with the underlying Catoctin and Swift Run formations because the Unicoi is usually considered as the basal formation of the Chilhowee Group (Butts, 1940; King, 1949; Bloomer and Werner, 1955), which also includes the Hampton (Harpers) and the Antietam (Erwin) formations of generally accepted Cambrian age. A more serious objection to grouping the Unicoi with the Catoctin and Swift Run formations is the contention that the Unicoi is separated from the underlying Catoctin Formation by an unconformity of significant magnitude (Stose and Stose, 1949; King, 1949). However, in the Vesuvius area the Swift Run, Catoctin, and Unicoi formations, along with the Hampton (Harpers) and Antietam (Erwin) formations, are all part of a conformable, gradational sequence. In view of the stratigraphic relationships

that exist in the Vesuvius area (Plate 1), the unconformable relationships that have been observed at other places, may be local features. The assignment of these formations to a particular system is only of academic interest. However, the existence or non-existence of an unconformity of regional magnitude between the Catoctin and the Unicoi is important and has a significant bearing on the interpretation of Appalachian regional geology (Bloomer and Werner, 1955).

Swift Run Formation

The Swift Run Formation consists of 0 to 400 feet of clastic sedimentary and volcanic rocks that unconformably overlie the Pedlar Formation and is conformably overlain by the Catoctin Formation. The contact of the Swift Run with the Pedlar is difficult to locate in many places. The lowermost, crudely stratified sedimentary rock grades downward into a poorly sorted, unstratified zone that resembles the underlying Pedlar in both composition and texture. Except for occasional subrounded, clearly detrital pebbles of quartz and feldspar, the predominantly granitoid portion of this zone could be mistaken for the granodiorite. This gradational contact between the Swift Run and the Pedlar indicates that the Swift Run was deposited on a deeply weathered surface of the Pedlar.

In the Vesuvius area, the Swift Run Formation occurs discontinuously and with variable thicknesses in a manner that indicates it overlaps the Pedlar Formation, generally from east to west. The Swift Run Formation in the Blue Ridge is the western margin of an overlapping succession of rocks represented by the Lynchburg Formation in the southeastern limb of the Blue Ridge-Catoctin Mountain anticlinorium (Bloomer and Werner, 1955, p. 587), and, therefore, is equivalent to some upper part of the Lynchburg Formation.

The Swift Run Formation occurs in beds from a few inches to about 20 feet thick and consists of graywackes, subgraywackes, phyllites, epidotized sandstones, tuffs (Figure 4), and basaltic lava flows, commonly referred to as "greenstones." Of these rock types, only graywacke is invariably present in the formation. Directly above the Pedlar Formation, the Swift Run lithology is a conglomeratic graywacke composed of quartz, potassic feldspar, and granitic clasts in a matrix of quartz, potassic feldspar, oligoclase-andesine fragments, and a fine-grained aggregate of sericite and chlorite (Figures 5-7). In places where the Swift Run Formation attains a thickness of 100 feet or more, the graywackes grade upward into uniformly fine-grained, thin-bedded subgraywackes that are indistinguishable from similar beds in the Unicoi Formation.

FIGURE 4. Sharply defined contact between tuff (under hammer) and graywacke in the Swift Run Formation.

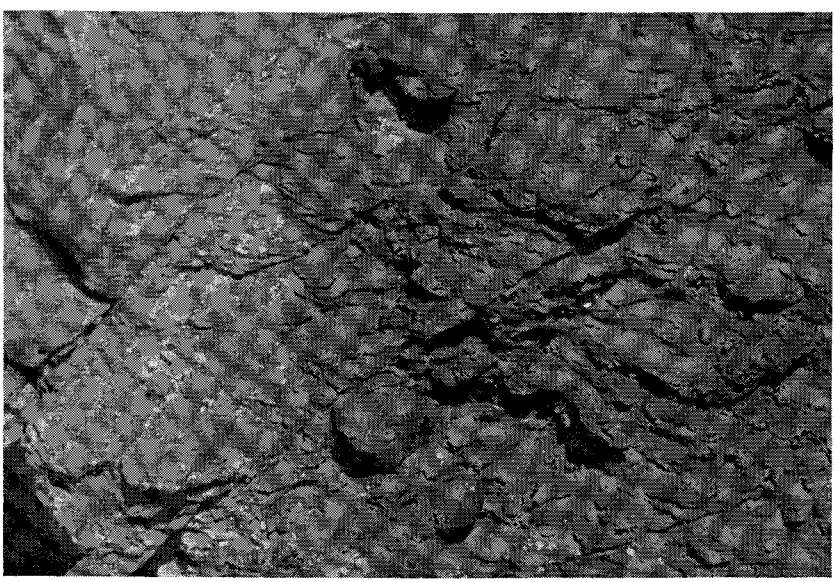
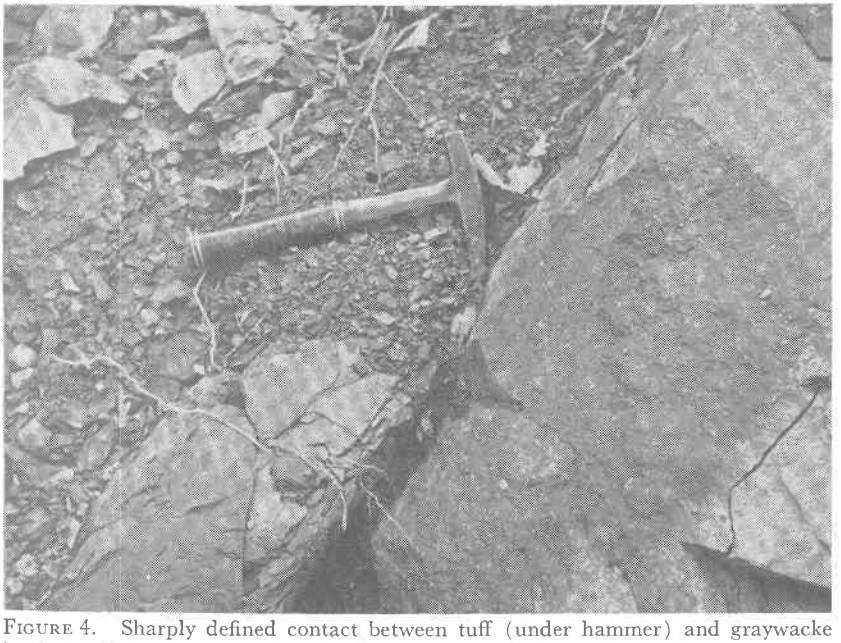


FIGURE 5. Conglomeratic graywacke in the Swift Run Formation composed of quartz and granite pebbles and cobbles in an arkosic matrix that resembles the underlying granodiorite of the Pedlar Formation. The largest cobble is approximately 3 inches in diameter.



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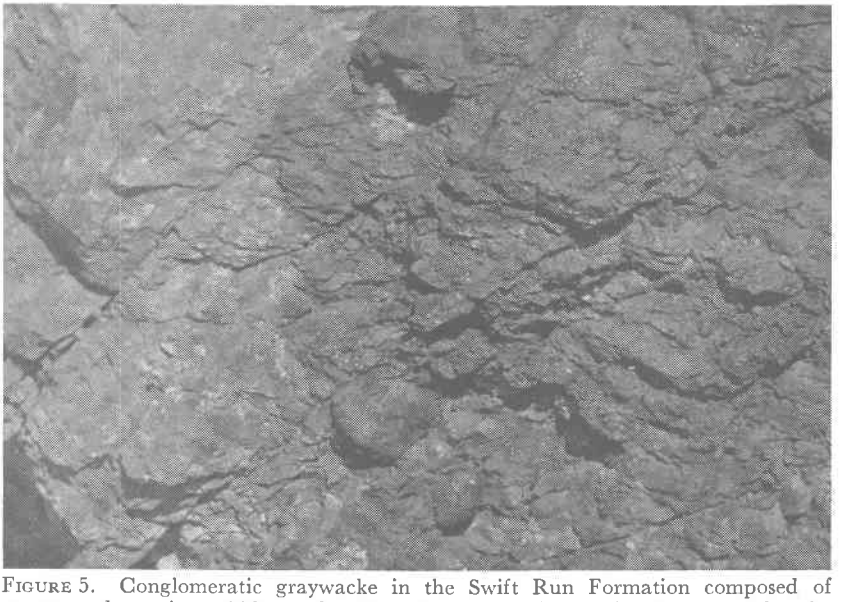


FIGURE 5. Conglomeratic graywacke in the Swift Run Formation composed of quartz and granite pebbles and cobbles in an arkosic matrix that resembles the underlying granodiorite of the Pedlar Formation. The largest cobble is approximately 3 inches in diameter.

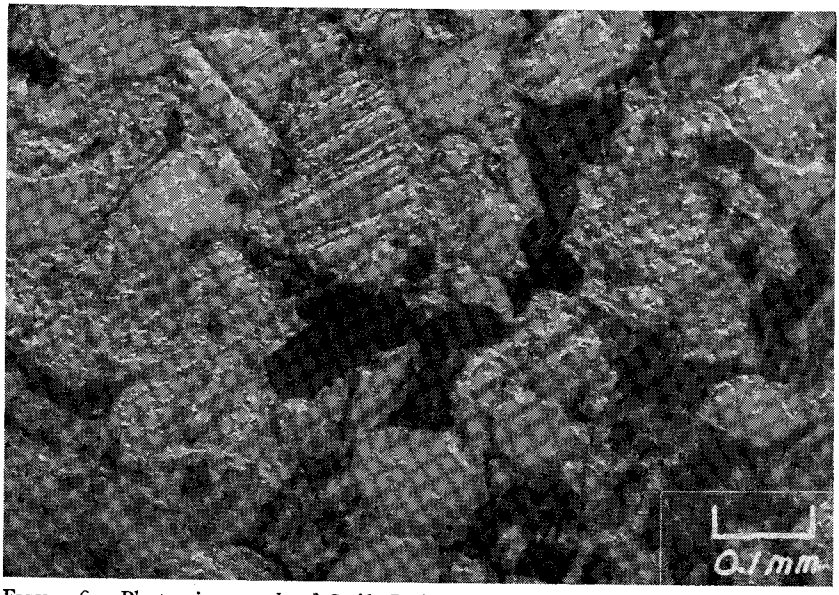


FIGURE 6. Photomicrograph of Swift Run graywacke composed of angular clastic grains of quartz and potassic feldspar in a matrix of sericite. Black material is iron oxide. Plane light, oblique illumination.

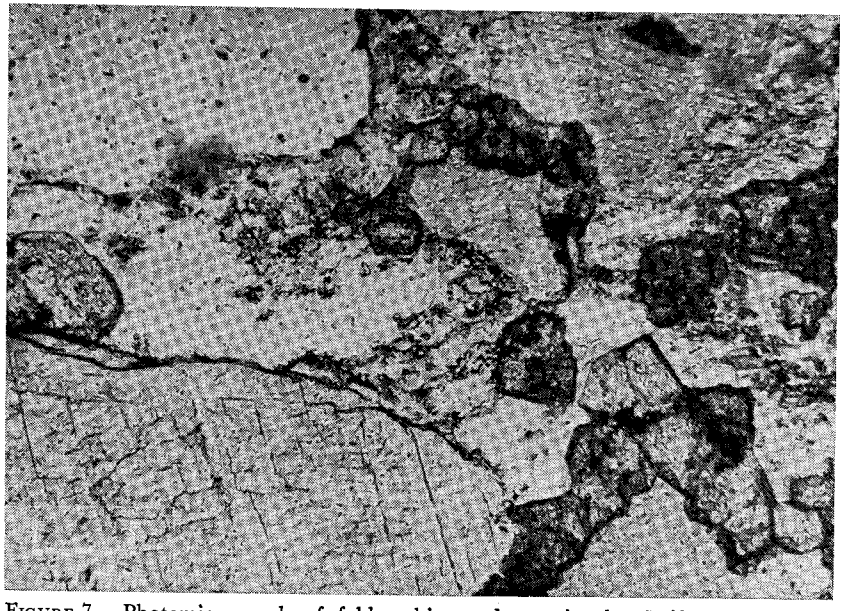
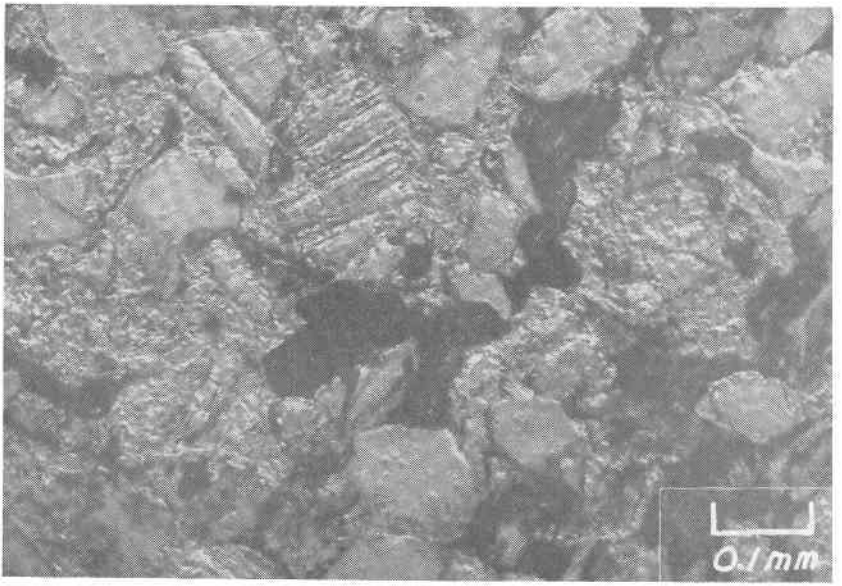


FIGURE 7. Photomicrograph of feldspathic sandstone in the Swift Run Formation containing secondary epidote (high relief) in a matrix of sericite and chlorite.



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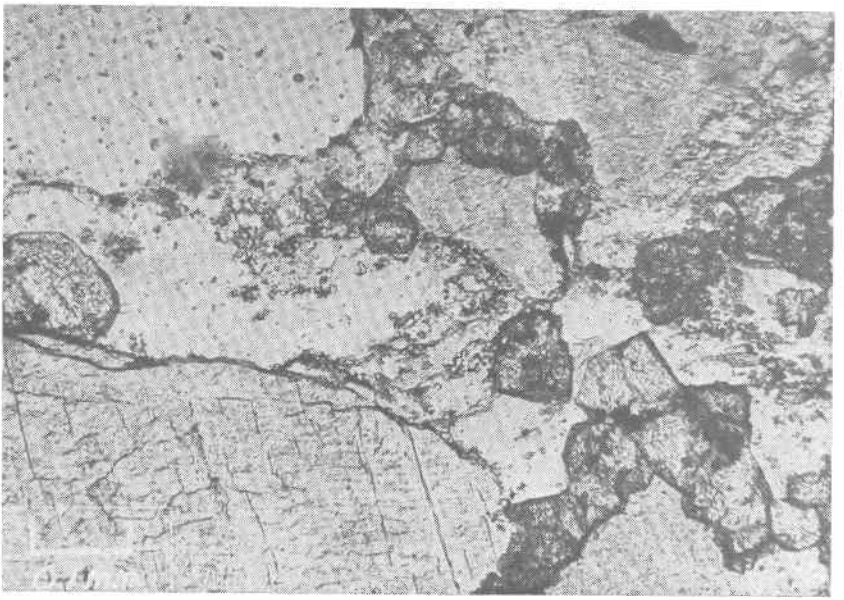

FIGURE 7. Photomicrograph of feldspathic sandstone in the Swift Run Formation containing secondary epidote (high relief) in a matrix of sericite and chlorite.

An easily accessible outcrop of the Swift Run having a gradational relationship with the Pedlar may be seen in roadcuts along State Highway 56 about 1 mile northwest of Tye River Gap. At this locality, the Swift Run is too thin to be represented on the map (Plate 1), but inspection of the outcrop shows that the graywackes are succeeded by a greenstone flow that, in turn, is overlain by reddish-purple tuffaceous sandstones and siltstones. Within the immediate vicinity the greenstone flow pinches out by overlap.

Catoctin Formation

In the Vesuvius area, the Catoctin Formation consists of an undetermined thickness of altered volcanic greenstones and several sedimentary units composed of graywackes, arkoses, and tuffaceous sandstones. Due to the lack of primary structures in the greenstones, it is exceedingly difficult to determine the attitude and the thickness of the formation. Fortunately, in some localities it is possible to map intervening sedimentary members and, thus, in a gross manner, determine a minimum thickness of the Catoctin. Within the Vesuvius quadrangle, the Catoctin is at least 200 feet thick along White Rock Creek where the lower part of the formation is truncated by faulting. Within about 2.5 miles to the northwest the Catoctin feathers out by overlap. Although the amount of movement along intervening faults is difficult to assess, it is evident that the Catoctin Formation thickens rapidly eastward and southeastward.

Greenstone is the predominant rock type in the Catoctin Formation. Greenstones also occur in the Swift Run and Unicoi formations and are indistinguishable in the field and under the microscope from that of the Catoctin. The flows are generally massive, black to dark green, fine grained and extensively altered by secondary minerals that mask the primary, orthomagmatic mineralogy of the original flows. Amygdules (Figures 8, 9) containing quartz and variable proportions of pink potassic feldspar and epidote, and minor amounts of chalcopyrite, calcite, and native copper occur in some outcrops but are so widely scattered they cannot be used for mapping purposes. Zones of volcanic breccia are also present in scattered outcrops.

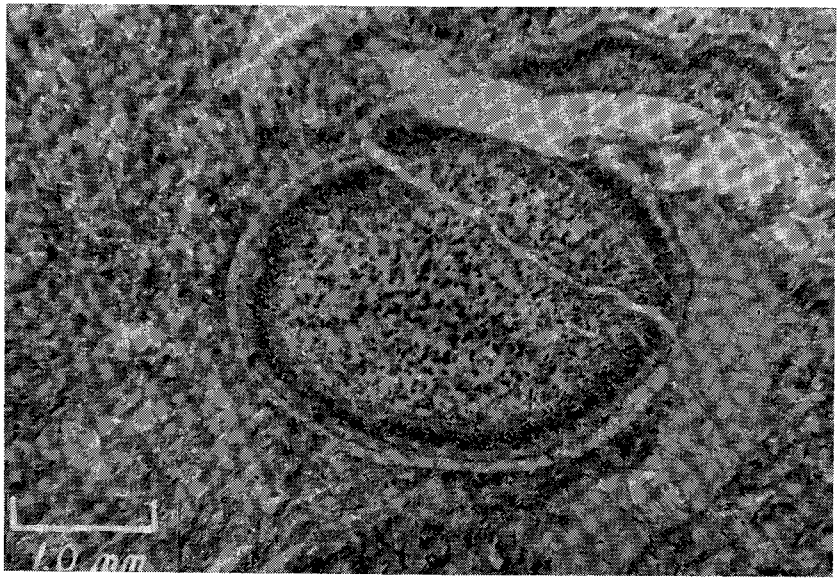

FIGURE 8. Photomicrograph of amygdule in Catoctin greenstone. The outer rim of the amygdule consists of epidote surrounding partially devitrified glass; the center consists of devitrified glass. Plane light, oblique illumination.

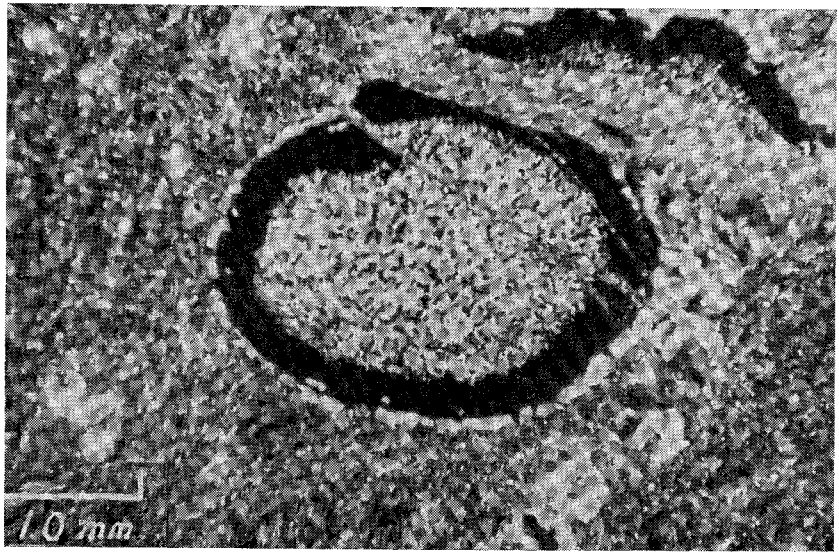

FIGURE 9. Photomicrograph of amygdule in Catoctin greenstone. Note optically isotropic character of ring of partially devitrified glass. Same as Figure 8 except with crossed nicols.

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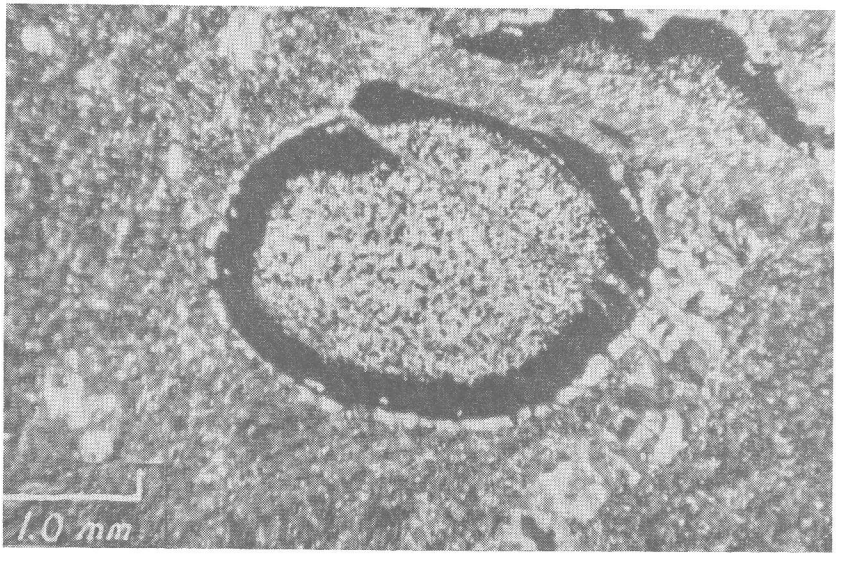


FIGURE 9. Photomicrograph of amygdule in Catoctin greenstone. Note optically isotropic character of ring of partially devitrified glass. Same as Figure 8 except with crossed nicols.

Thin sections of the greenstones (Figures 10, 11) reveal a fine-grained aggregate of albite (An_{10}), quartz, chlorite, epidote, sericite, clinozoisite, potassic feldspar, calcite, ilmenite, and leucoxene in variable proportions. Except in highly sheared specimens, an ophitic texture of feldspar laths (about 0.03 mm long) is more or less preserved. Primary feldspars of the composition of andesine (An_{40}) which would indicate an original composition of andesite are present; the groundmass material is so exceedingly fine grained that it cannot be identified (Bloomer and Werner, 1955, p. 592). In the Vesuvius area the flows are so altered that the exact classification of the rock is uncertain. Originally, it was either a basaltic or andesitic rock in which calcic plagioclase was the orthomagmatic feldspar.

In some outcrops where it is possible to observe the interbedding of Catoctin sedimentary rocks with greenstones, the associated sedimentary rocks commonly contain secondary epidote but only adjacent to the contact with the overlying greenstone. It appears that the epidote was provided as a contact-metamorphic product from the overlying greenstone flows. The mineral assemblage of the greenstone is characteristic of greenschist facies (Turner, 1948, p. 61, 93-98), whereas the clastic rocks associated with the greenstones are only slightly metamorphosed except where greenschist facies of metamorphism was induced by localized shear. Thus, the metamorphic grade of the greenstones is generally incompatible with that of the associated sedimentary rocks.

The sedimentary units of the Catoctin Formation contain beds of graywacke, arkose, sandstone, and interbedded layers of tuff. Thicknesses of the sedimentary units range from several inches to a maximum of about 100 feet. Some of the graywacke and arkose is conglomeratic and is composed of well-rounded pebbles of quartz and granodiorite (Figure 12). The graywacke is a green, coarse-grained rock composed of quartz, potassic feldspar, and plagioclase in a matrix of sericite and chlorite (Figure 13). The arkose is a white, pink, or light-green, coarse- to medium-grained rock composed of quartz, potassic feldspar, plagioclase, and a negligible amount of sericite and chlorite. Many of the thicker sedimentary units have gradational bedding, varying from coarse-grained or conglomeratic graywacke and arkose upward into subgraywacke and sandstone. In places, the graywackes and arkoses, where bedding and pebbles are indistinct, resemble granitic rocks.

The sedimentary units appear to be more numerous and thicker near the overlap margin of the Catoctin, as along White Rock Creek

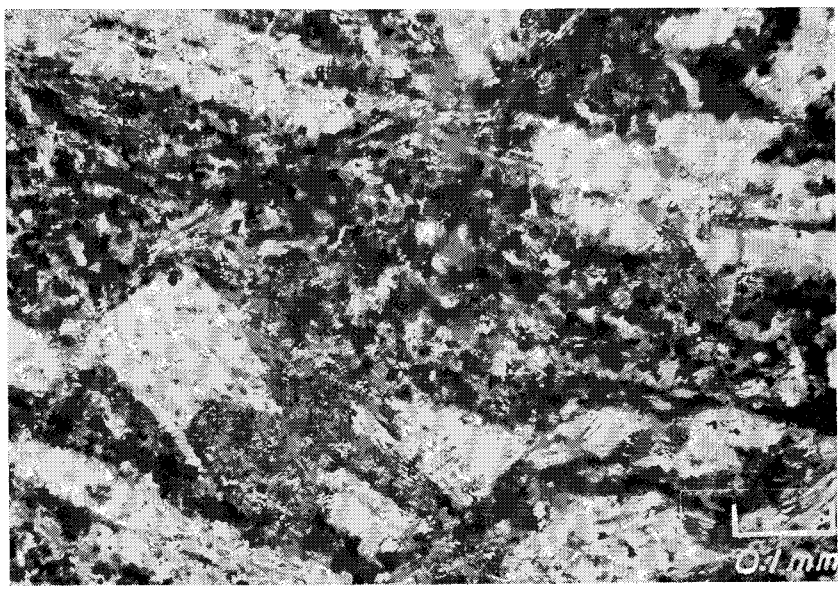


FIGURE 10. Photomicrograph of Catoctin greenstone composed of albite laths in a groundmass of chlorite, sericite, and iron oxide. Plane light, oblique illumination.

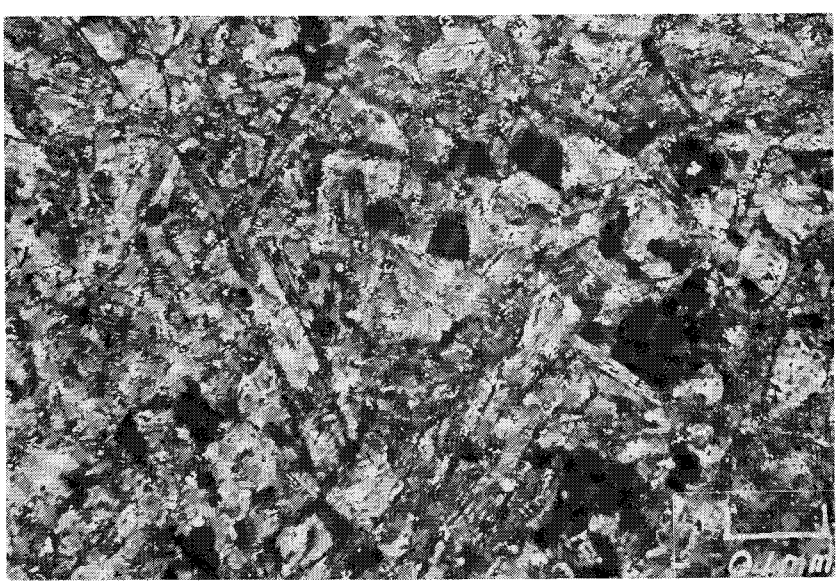
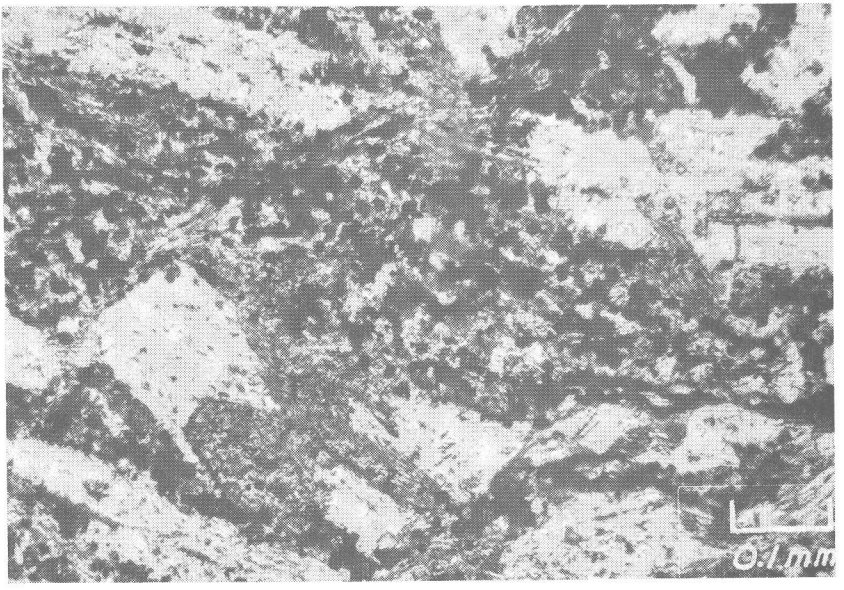


FIGURE 11. Photomicrograph of Catoctin greenstone from a dike in the vicinity of Tyro. The albite laths are in a groundmass composed predominantly of chlorite. Plane light, oblique illumination.



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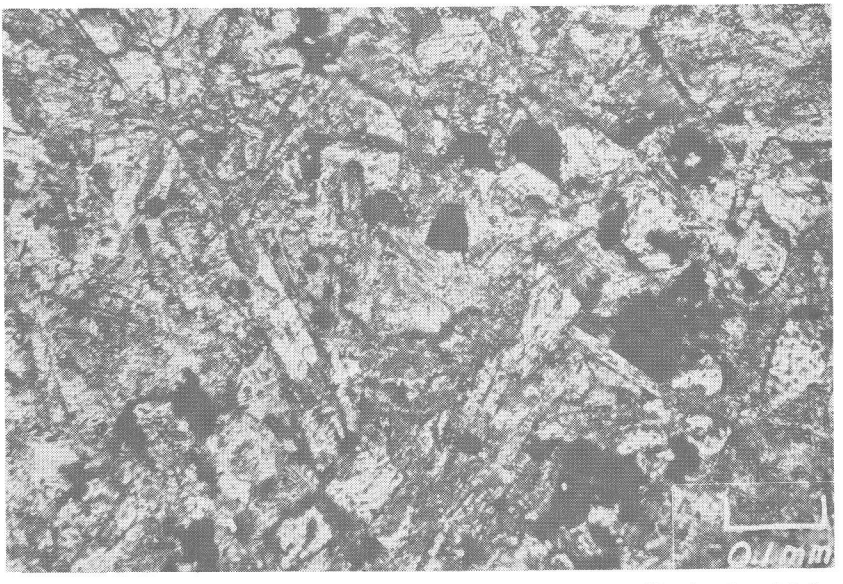

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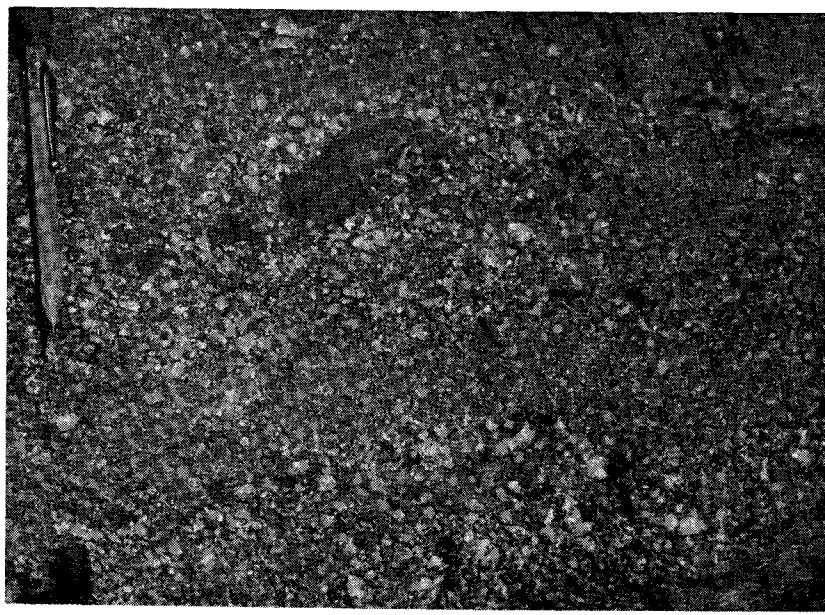


FIGURE 12. Pebbly graywacke of the Catoctin Formation exposed along White Rock Creek.

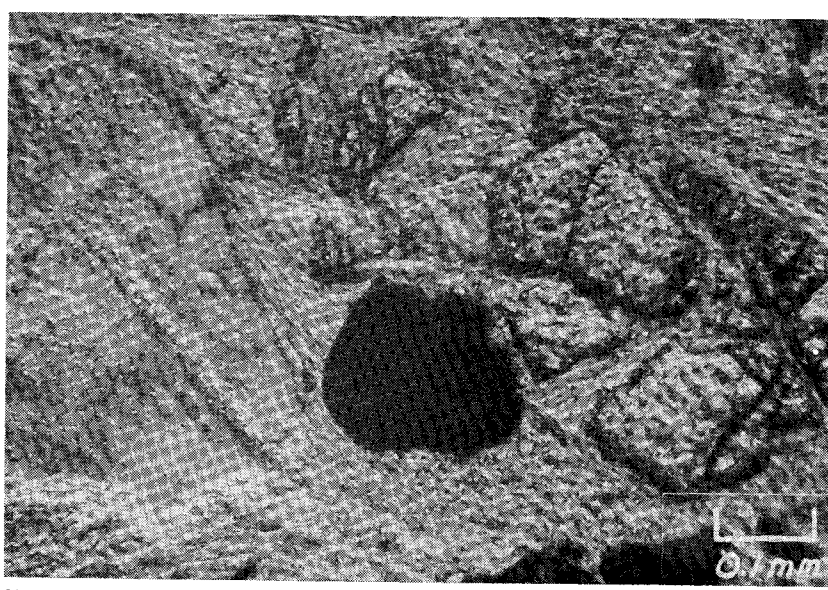


FIGURE 13. Photomicrograph of Catoctin graywacke consisting of clastic grains of garnet, ilmenite, quartz, and feldspar in a matrix of sericite. Plane light, oblique illumination.

FIGURE 12. Pebbly graywacke of the Catoctin Formation exposed along White Rock Creek.

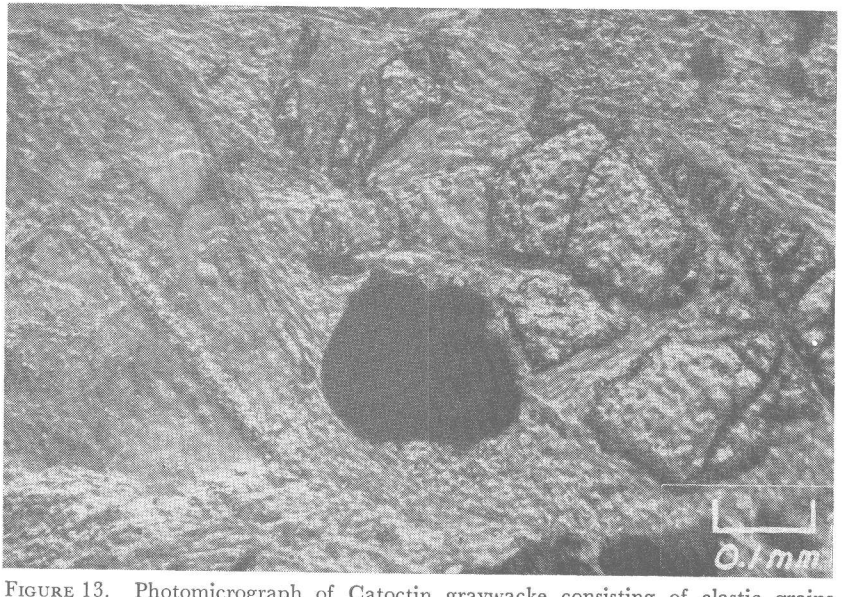


FIGURE 13. Photomicrograph of Catoctin graywacke consisting of clastic grains of garnet, ilmenite, quartz, and feldspar in a matrix of sericite. Plane light, oblique illumination.

where at least four sedimentary units within the Catoctin are exposed. These are shown schematically on the map (Plate 1). One well-defined sedimentary unit occurs at the base of the formation in an outlier approximately 0.75 mile north of Tyro. The sedimentary units appear to represent fan-like sheets of sediments that spread over the Catoctin flows generally from west to east. The sedimentary rocks lack any detritus attributable to the flows and are thought to have been derived from a source west of the overlap margin.

Tuffs, in beds from a few inches to about 5 feet thick, are interbedded with the clastic sedimentary rocks in the Swift Run, Catoctin, and Unicoi formations (Stose and Stose, 1946, p. 18-24; Bloomer and Werner, 1955, p. 590). These tuffs are purplish maroon to reddish brown, uniformly fine grained, and commonly possess a slaty cleavage that almost completely obliterates the original sedimentary features of the rock.

CAMBRIAN ROCKS

Unicoi Formation

The Unicoi Formation as defined and mapped in the Vesuvius area consists of about 500 feet of graywacke, subgraywacke, arkose, greenstone flows, tuff (Figures 14, 15), and pebbly quartzite beds. It overlies the Catoctin Formation and underlies the Hampton Formation. Beyond the overlap margin of the Catoctin, the Unicoi overlies the Virginia Blue Ridge Complex. The lithologies of the Unicoi, except for the pebbly quartzite that occurs in the upper part of the section, are for the most part indistinguishable from those of the Swift Run and Catoctin Formations, and, except for field relationships, it is difficult to distinguish one formation from another. For example, along State Highway 56 northwest of Tye River Gap, the Swift Run cannot be recognized as a mappable unit. Beyond the overlap margin of the Catoctin, the basal graywackes directly overlying the Virginia Blue Ridge Complex are mapped as Unicoi; where the Catoctin is present the basal graywackes are mapped as Swift Run. These relationships strongly suggest that the Swift Run, Catoctin, and Unicoi are genetically related; more convincing evidence of the interrelationship is present along White Rock Creek where the Catoctin and Unicoi occur in stratigraphic continuity. In the Vesuvius area, along White Rock Creek, the Unicoi is related to the main mass of the Catoctin Formation by an alternating succession of greenstone and sedimentary beds. This is part of an uninterrupted sequence that includes all of the Unicoi and possibly part

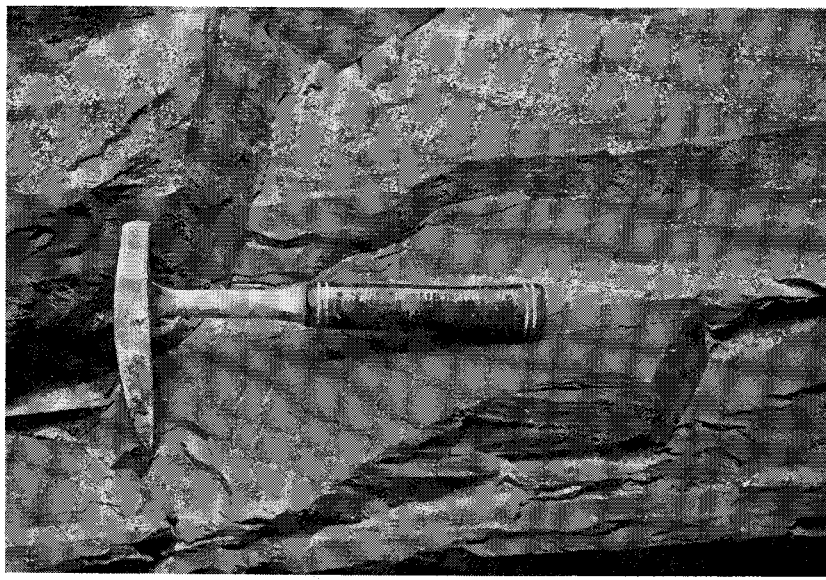
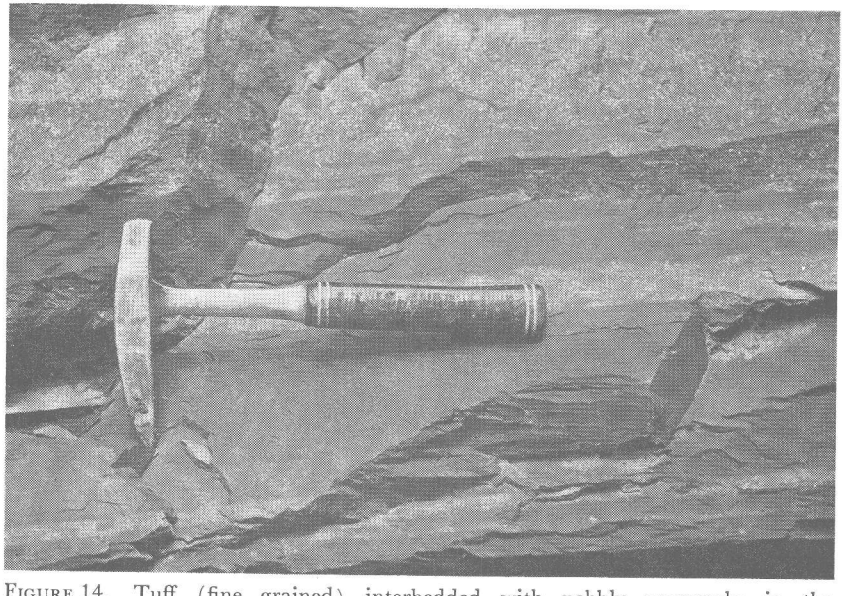


FIGURE 14. Tuff (fine grained) interbedded with pebbly graywacke in the Unicoi Formation in a roadcut along State Highway 56, 1.5 miles northwest of Tye River Gap.

FIGURE 15. Beds of tuff in the Unicoi Formation exposed along the Blue Ridge Parkway 2.5 miles northeast of Whites Peak (Lexington quadrangle). Bedding (horizontal) is almost masked by the dominant southeastward-dipping cleavage.



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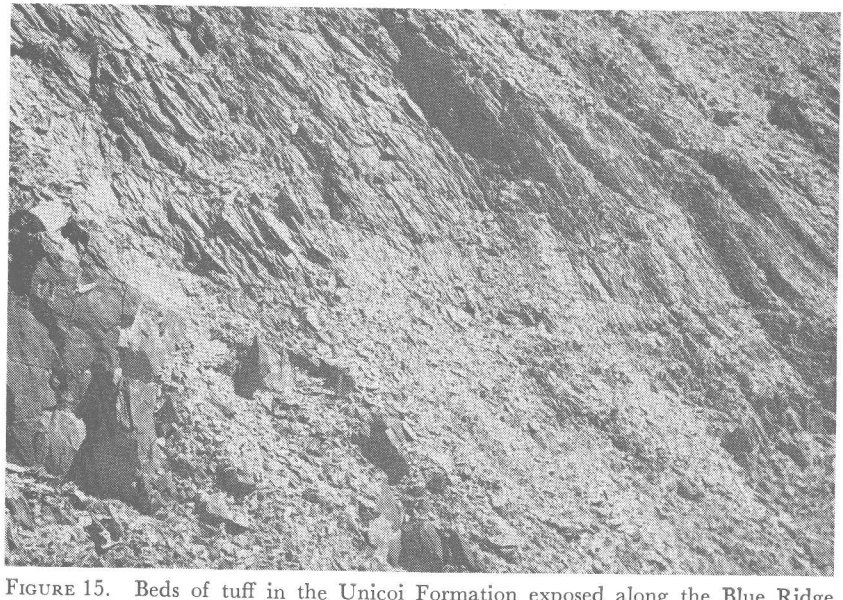


FIGURE 15. Beds of tuff in the Unicoi Formation exposed along the Blue Ridge Parkway 2.5 miles northeast of Whites Peak (Lexington quadrangle). Bedding (horizontal) is almost masked by the dominant southeastward-dipping cleavage.

of the Hampton Formation. The contact between the Catoctin and Unicoi, therefore, is gradational. For mapping purposes, the boundary between these formations is arbitrarily placed at the top of the uppermost occurrence of greenstone. In the Vesuvius area, and evidently elsewhere (King, 1949, p. 518-528; Stose and Stose, 1946, p. 31-34), the Unicoi Formation significantly lacks detritus attributable to the Catoctin Formation.

Generally, poorly graded graywackes are present in the lower 100 feet of the Unicoi above which the rock type changes to predominantly well-graded subgraywackes (Figure 16). Pebbly quartzite forms lenses and beds from a few inches to 25 feet thick and is sporadically intercalated throughout the formation. The quartzite (Figure 17), however, is increasingly abundant upward through the formation and occurs as a distinctive unit separating the Unicoi from the overlying Hampton Formation.

Where the basal graywacke rests on the granitic Virginia Blue Ridge Complex, it grades downward, like the Swift Run Formation, into a poorly sorted, unstratified zone that resembles the underlying granitic rock in both composition and texture. Above this zone, the graywackes (Figure 18) consist of well-rounded clasts of granite, quartz, and feldspar in a coarse-grained matrix of quartz, feldspar, chlorite, sericite, and iron oxide. Heavy minerals include ilmenite, rutile, apatite, sphene, tourmaline, and zircon.

The subgraywacke is a dark-gray to green, fine- to medium-grained rock composed of subrounded and angular grains of quartz in a matrix of chlorite, sericite, and iron oxide. Much of the subgraywacke resembles similar rocks in the overlying Hampton Formation. Some of the fine-grained subgraywacke, in hand specimens particularly, contains abundant finely disseminated chlorite and resembles greenstone.

Much of the pebbly quartzite, especially at the top of the Unicoi, consists almost solely of quartz that occurs in rounded white, greenish, and reddish pebbles about 0.5 inch in diameter in a coarse arenaceous matrix. Although some of the quartz in the Unicoi displays evidence of recrystallization, there is generally little indication of metamorphism. Locally, where the Unicoi, and the subgraywacke in particular, is faulted and intensely sheared, it has been transformed into a phyllite in the greenschist facies. These sheared rocks contain crystalloblastic oligoclase (An_{20}), sericite, and biotite.

FIGURE 16. Subgraywacke of the Unicoi Formation exposed in Whetstone Ridge 1 mile north-northwest of Montebello. Bedding is vertical and cleavage has a dip of 50° SE.

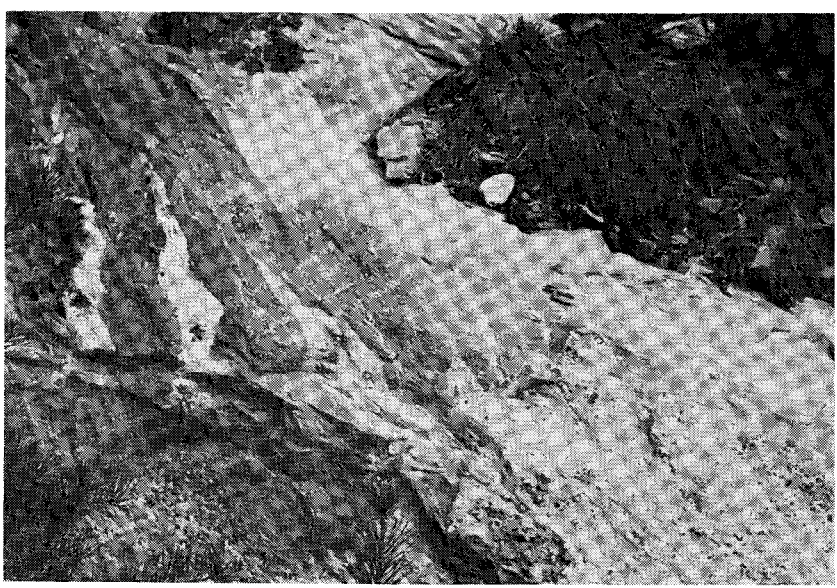
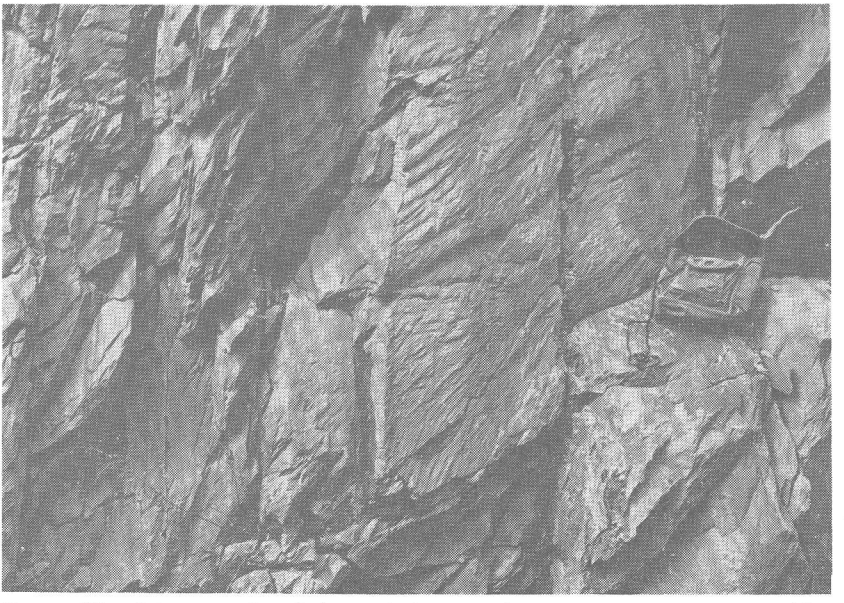


FIGURE. 17. Quartzite in the Unicoi Formation exposed in the vicinity of White Rock Overlook on the Blue Ridge Parkway. Alignment of the quartz veins is perpendicular to the direction of major fold axes.



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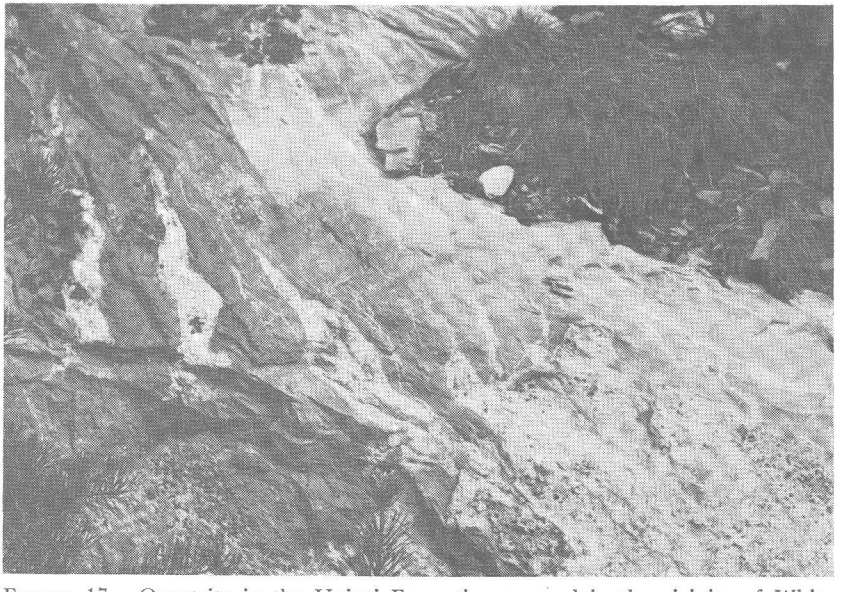

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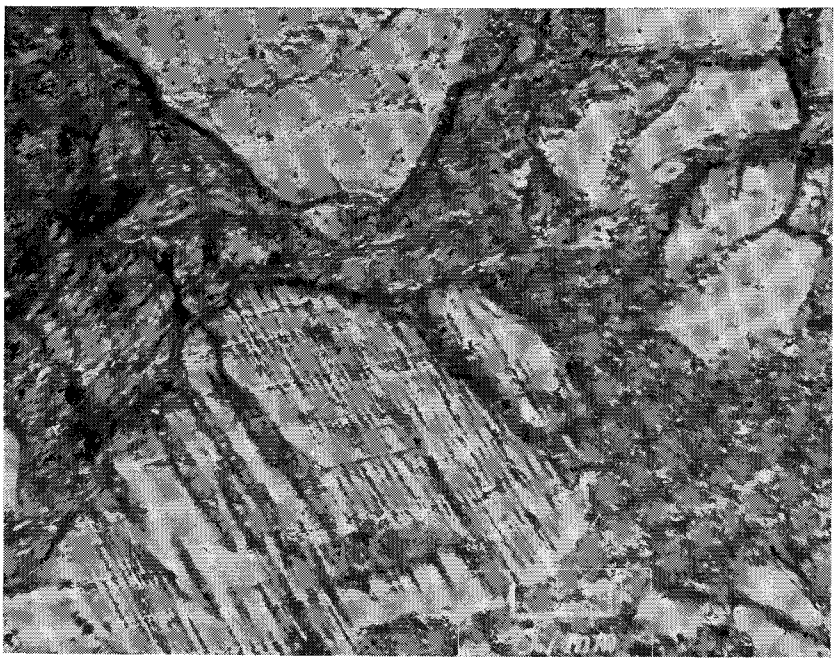

FIGURE 18. Photomicrograph of graywacke from the basal portion of the Unicoi Formation. Clastic potassic feldspar grains have been selectively replaced by sericite along cleavage planes, and sericite has replaced clastic quartz grains along fringed borders. Plane light, oblique illumination.

Hampton Formation

The Hampton Formation as defined and mapped in the Vesuvius area overlies the pebbly quartzites of the Unicoi Formation and is overlain by the Antietam Formation. The upper and lower contacts of the Hampton are gradational. The Hampton is essentially a transitional formation between the heterogeneous Unicoi Formation below and the homogeneous Antietam quartzite above. It consists of several hundred feet and possibly more than a thousand feet of alternating siltstone and fine-grained subgraywacke interbedded with quartzose sandstone in variable proportions (Figure 19).

The subgraywacke is greenish gray, thin bedded, and, in a few places, laminated. It consists of subrounded and angular finely arenaceous grains in an argillaceous matrix. About 90 percent of the grains are quartz; 10 percent or less are potassic feldspar. Accessory minerals include ilmenite, rutile, pyrite, sphene, tourmaline, and zircon. The matrix is mainly sericite with some chlorite and iron oxide.

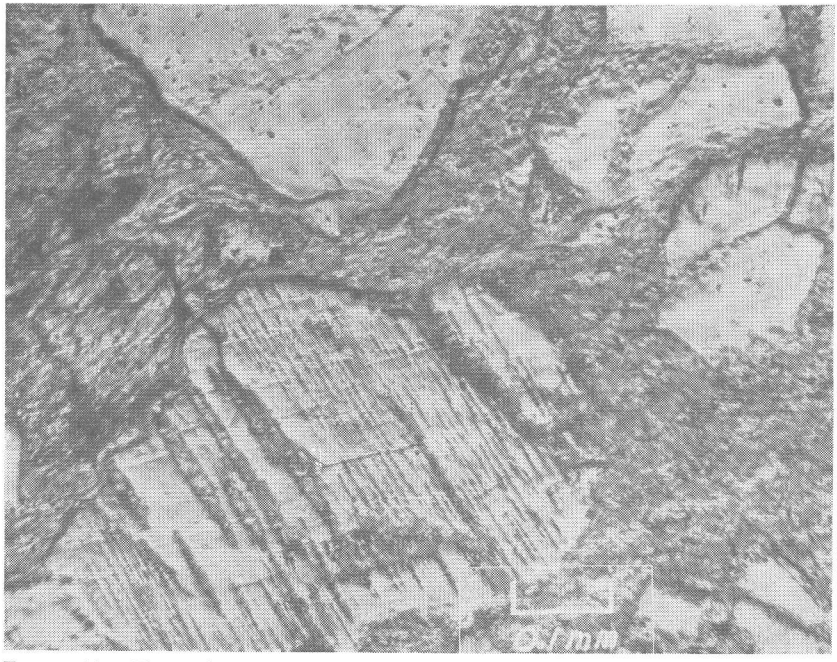

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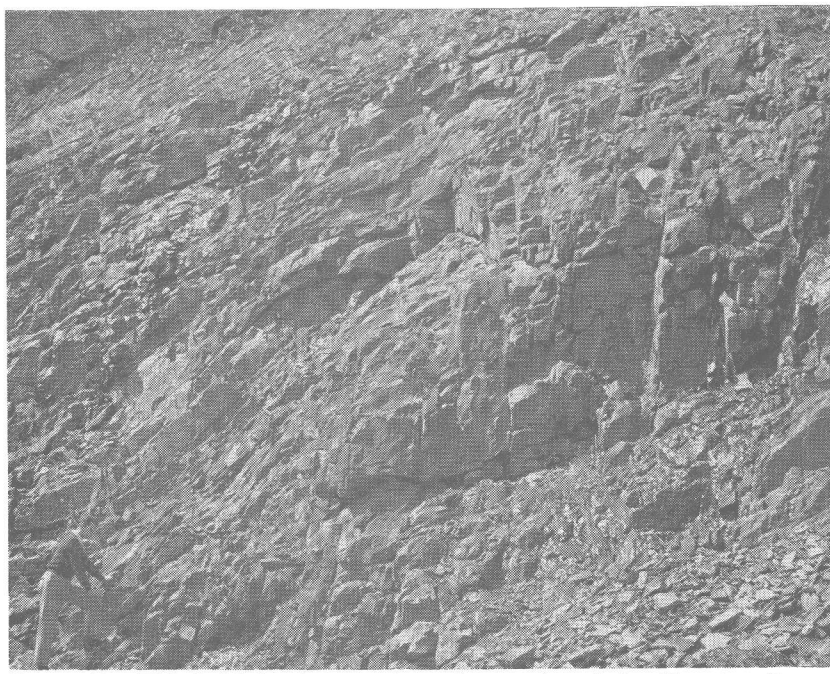
FIGURE 19. Thin-bedded subgraywacke and quartzite of the Hampton Formation exposed along the Blue Ridge Parkway in the vicinity of Bald Mountain.

Quartzite in the Hampton forms lenses and beds. In the upper part of the formation, about 75 percent of the section is quartzite, whereas in the lower part, only about 10 percent is quartzite. Where the quartzite is most abundant, it forms beds that average about 1 foot in thickness separated by layers of finely laminated, fine-grained graywacke and siltstone 2 to 3 feet thick. The quartzite is fine to medium grained with rounded, subrounded, and angular grains of quartz in a siliceous matrix. In hand specimen and thin section, the Hampton quartzites are similar to those of the Antietam. Accessory minerals include rare grains of potassic feldspar, tourmaline, zircon, rutile, and ilmenite.

Within the Hampton of the Vesuvius area there are four massive beds of quartzite. One of these, named the Snowden Member (Bloomer and Werner, 1955, p. 596), is about 80 feet thick and can be traced throughout the area. It invariably forms a topographic ridge between the less resistant subgraywackes and contains *Scolithus* tubes that are unknown in other beds of the Hampton.

The Hampton, except where locally sheared, is only slightly metamorphosed. In the highly quartzose rocks, the only indication of recrystallization is poorly defined grain elongation and sutured grain



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boundaries. Where the Hampton is sheared, it is locally transformed to slate and phyllite with an abundance of sericite and chlorite, some crystalloblastic oligoclase (An_{20}), and biotite.

Antietam Formation

In the Vesuvius area, the Antietam Formation as defined and mapped consists of about 600 feet of quartzose sandstone that occurs conformably between the underlying Hampton Formation and the overlying Shady Formation. The formation forms a bold ridge along the northwest front of the Blue Ridge. The contact with the Hampton is gradational where massive beds of Antietam quartzite rest on thin beds of Hampton subgraywacke. The contact of the Antietam with the Shady Formation is obscured in the Vesuvius area. In the vicinity of South River, southwest of Vesuvius, the Antietam is in fault contact with the Rome Formation. Elsewhere along the Blue Ridge front the Antietam supplies a great sheet of boulder wash that mantles the outcrop of the Shady. However, southwest of the Vesuvius area, the contact between the Antietam and the Shady is clearly a transition zone consisting of about 25 feet of dolomitic sandstone (Bloomer and Werner, 1955, p. 597).

The Antietam is a remarkably homogeneous formation consisting of uniform white to bluish-gray quartzose sandstone in beds from about 1 to 20 feet thick (Figure 20). The rounded to subrounded quartz grains are in a silica cement. Accessory minerals of potassic feldspar, rutile, ilmenite, tourmaline, and zircon are extremely rare. Except in local areas where the Antietam is sheared, there is little evidence of metamorphism. The only suggestion of recrystallization is poorly defined grain elongation and sutured grain boundaries (Figure 21). The only fossils that occur in the Antietam of the Vesuvius area are the so-called worm borings, *Scolithus linearis* (Figure 22) (James, 1892; Fenton and Fenton, 1934).

Shady Formation

Although the Shady Formation is not well exposed in the Vesuvius area, it is known to be gradational with the underlying Antietam Formation (Bloomer and Werner, 1955, p. 597-598) and the overlying Rome Formation (Butts, 1940, p. 57; Edmundson, 1958). Throughout most of the outcrop belt in the Vesuvius area, the Shady is covered by talus material derived from the highlands of Antietam quartzite. Beneath the talus material the Shady is extensively and deeply weathered, forming a

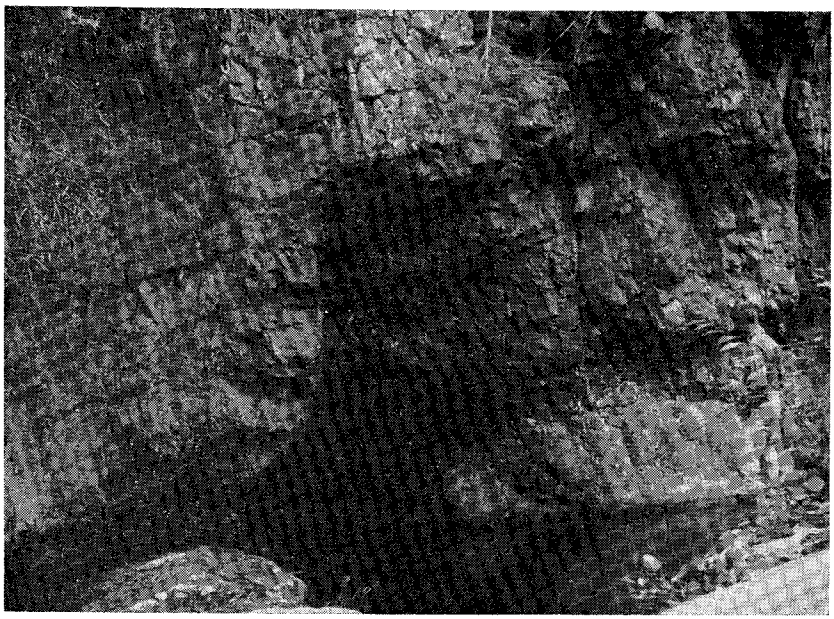


FIGURE 20. Massive beds of Antietam quartzite exposed along Saint Marys River.

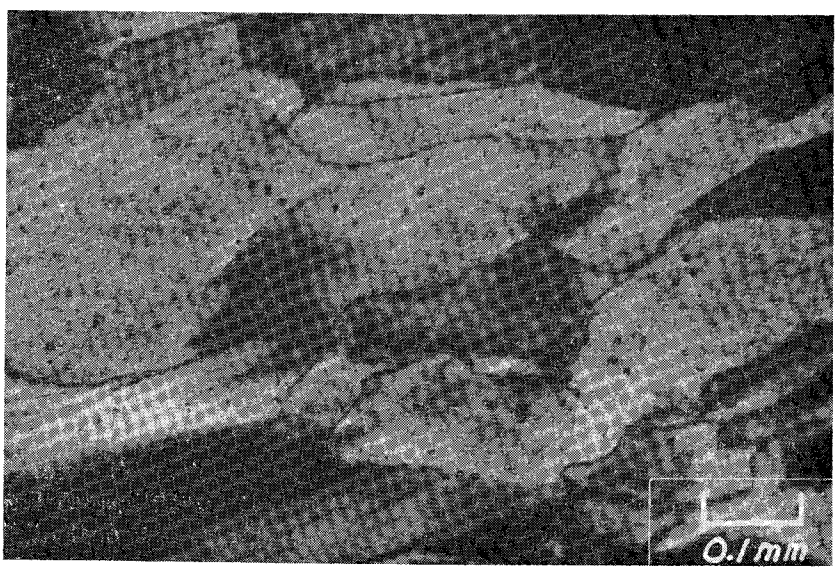
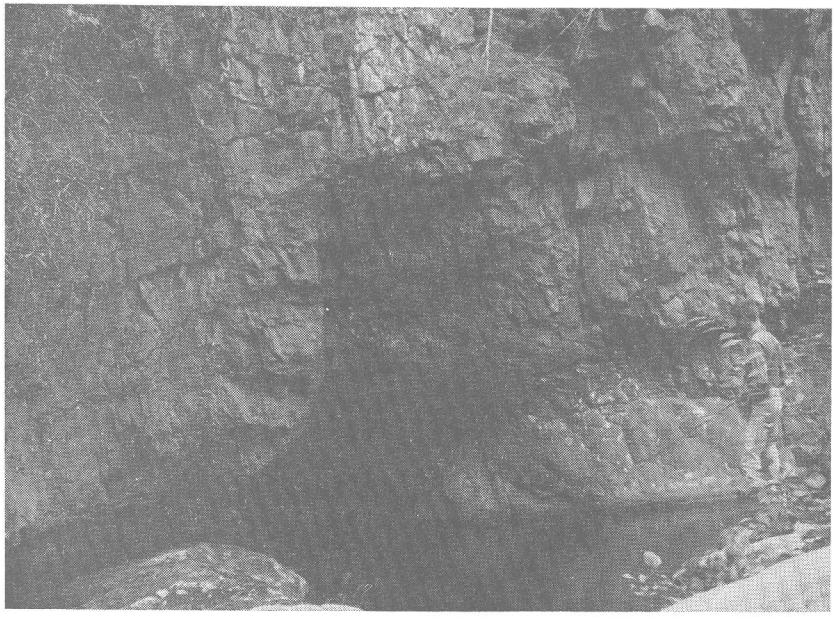


FIGURE 21. Photomicrograph of Antietam quartzite from an intensely cleaved zone. The quartz grains are strained and elongated. Crossed nicols.



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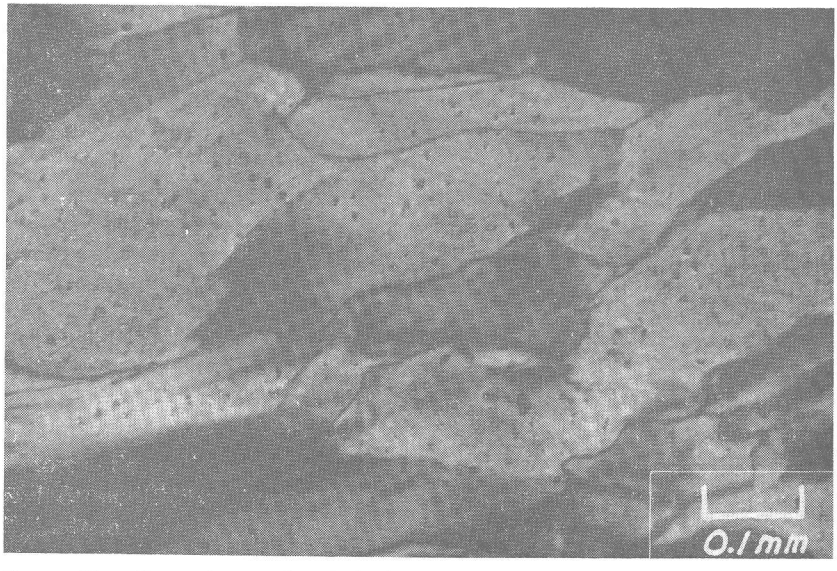

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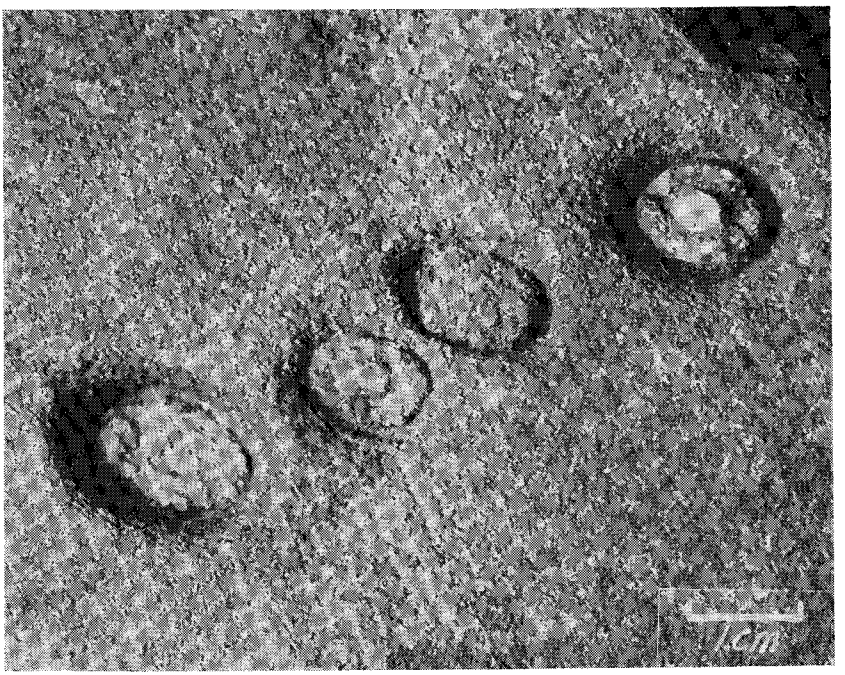
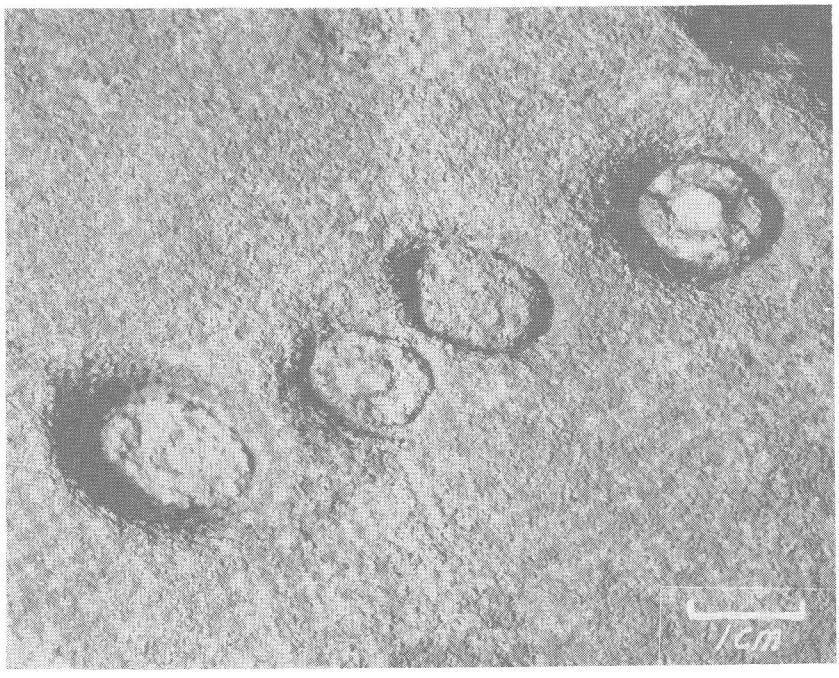


FIGURE 22. Top view of *Scolithus linearis* (worm burrows) in Antietam quartzite.

white clayey saprolite. Along the outcrop belt southwest of Vesuvius parallel to South River, the Shady is missing due to a thrust fault that carries Antietam onto the red shales of the Rome Formation. The nearest unweathered exposures of Shady known to the writer occur near Natural Bridge Station, where Edmundson (1958, p. 13) reports an incomplete section of about 1200 feet of light- to bluish-gray, fine- to medium-grained dolomite.

Rome Formation

The Rome Formation throughout most of the Vesuvius area is covered by colluvial gravels derived from the Antietam Formation. The upper part of the formation is exposed along tributary streams of South River southwest of Vesuvius; part is exposed along the Pulaski-Staunton fault in the northwestern part of the quadrangle (Plate 1). The contact of the Rome with the underlying Shady Formation has not been observed in the Vesuvius area; however, a few miles to the southwest at Buchanan, Butts (1940, p. 57) reports a gradational relationship between the two formations. The gradational upper contact with the Elbrook Formation



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is exposed along the Norfolk and Western Railway track adjacent to South River (Plate 1). For mapping purposes, the contact between the Rome and the Elbrook is drawn at the top of the highest stratigraphic occurrence of maroon shale, a characteristic lithology of the Rome Formation.

The Rome Formation is a heterogeneous sequence of limestone, dolomite, and green and maroon shales. Although other lithologies predominate, the maroon shale is the most distinctive feature of the formation; no other formations within the area contain this lithology. Except at the transitional contacts with the overlying Elbrook, only a minor amount of carbonate is present in the Rome Formation in the Vesuvius area. The outcrop belt at the foot of the Blue Ridge is 3000 feet wide in some places, but in these areas the formation has probably been repeated by folding and faulting. A few isolated exposures within the outcrop belts indicate that the formation is severely distorted and intricately folded.

In thin section, the maroon shales consist of quartz and feldspar clasts in a clayey material that is darkly stained with hematite (Figure 23). Small crystalloblastic grains of calcite are also present. Within the

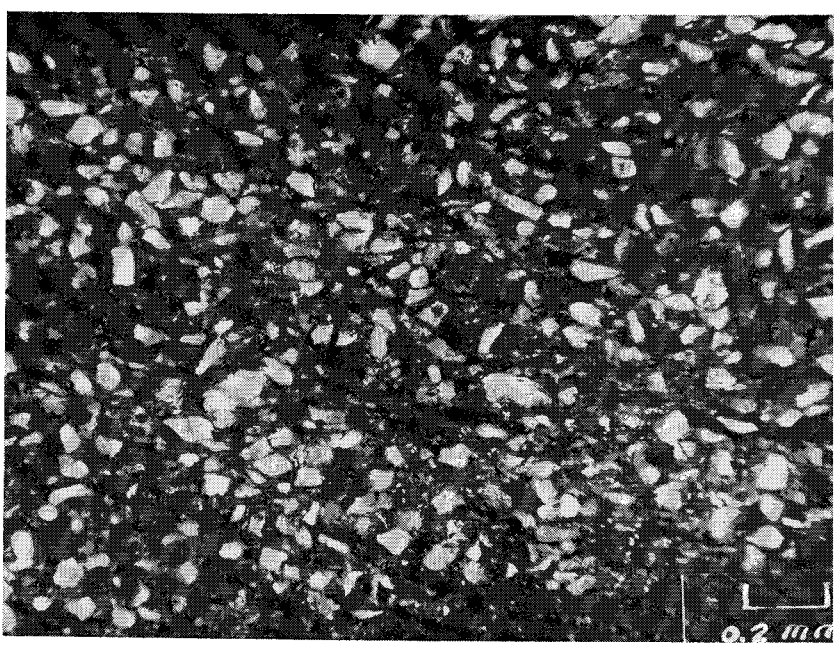

FIGURE 23. Photomicrograph of Rome Formation consisting of angular, fine-grained quartz in an opaque, iron-oxide-stained clay matrix.

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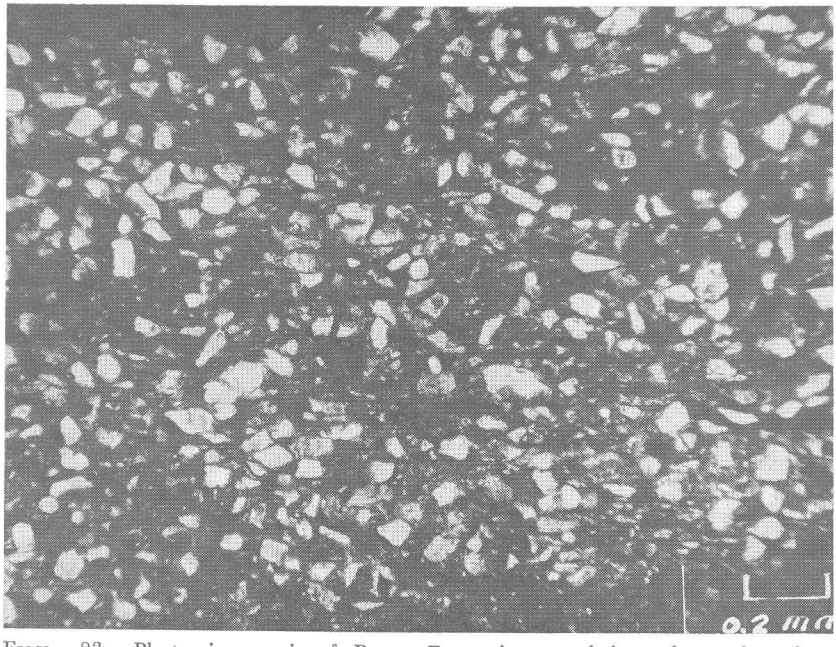


FIGURE 23. Photomicrograph of Rome Formation consisting of angular, fine-grained quartz in an opaque, iron-oxide-stained clay matrix.

clayey material there are fine stringers of silt-size angular quartz grains and a minor amount of albite (An_{10}) feldspar. The clastic stringers are folded and distorted, probably as a result of structural deformation. Gray to greenish shales in the Rome owe their color to an abundance of sericite.

Butts (1940, p. 63-67) reports a list of trilobites found elsewhere in the Rome Formation which indicate a Middle and Late Cambrian age. Unidentifiable trilobite fragments occur in Rome outcrops along the Norfolk and Western Railway about 2 miles south of Lofton (Plate 1).

Elbrook Formation

The Elbrook Formation is conformable with the underlying Rome Formation and the overlying Conococheague Formation. The boundaries, both above and below, are transitional and are difficult to recognize in isolated outcrops. For mapping purposes the contact with the underlying Rome has been drawn at the top of the highest stratigraphic occurrence of maroon shales characteristic of the Rome Formation. The Elbrook-Conococheague contact is mapped at the base of the lowest occurrence of sandstone beds which occur sporadically throughout the Conococheague Formation.

The Elbrook Formation consists predominantly of dolomite with some interbedded limestones and thin-bedded siltstones and shales. Thick dolomite beds are light to dark gray and medium to fine grained. Thin-bedded, light- to dark-gray, medium- to fine-grained dolomite is generally interlayered with thin shaly partings along bedding planes and weathers to tan slabs that are characteristic of Elbrook float. In thin section, the dolomite consists of an even-grained mosaic of euhedral dolomite. Near the base of the formation, the Elbrook contains minor amounts of intercalated bluish-gray limestone that in thin section is a fine-grained micrite.

Edmundson (1958, p. 101-102) reports that the Elbrook is at least 1500 feet thick along State Highway 56 between Vesuvius and Steeles Tavern, which is essentially in accord with Plate 1; however, this does not represent a complete section of the formation. Judging from the widths of outcrop belts, it probably attains a thickness in excess of 2000 feet which approximates measurements reported by Butts (1940). Fossils are rare in the Elbrook Formation, and, except for finely laminated structures that resemble algal (cryptozoan) structures (Figure 24), none have been found in the Elbrook of the Vesuvius area.

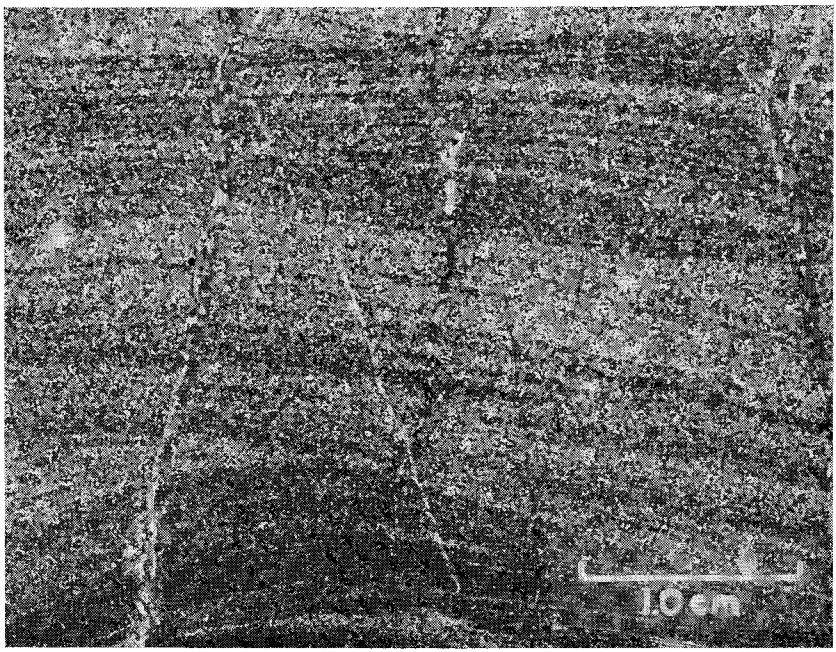
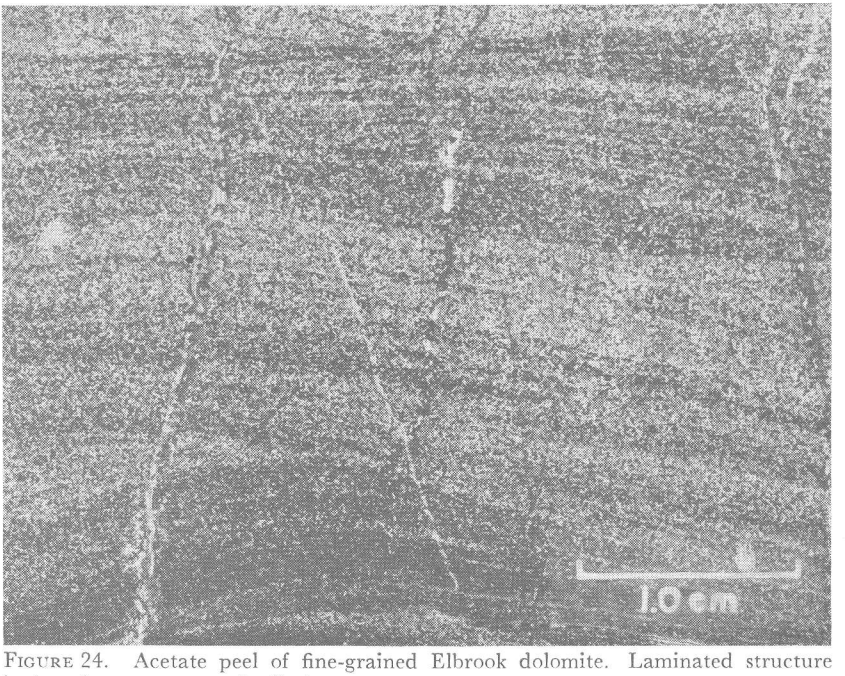


FIGURE 24. Acetate peel of fine-grained Elbrook dolomite. Laminated structure is thought to represent fossil algae.

Conococheague Formation

The Conococheague Formation consists mainly of limestones and dolomites with distinctive beds of quartz sandstone from a few inches to 10 feet in thickness. The carbonate portion of the formation is about evenly divided between blue-gray, fine-grained limestone and light-gray, medium- to fine-grained dolomite (Figure 25). Some beds are coarsely clastic and have graded bedding (Figure 26). For the most part, the limestones and dolomites of the Conococheague are indistinguishable from those in the underlying Elbrook Formation. The Conococheague is distinguished mainly on the basis of the interbedded sandstone. The contacts, above and below, are conformable. Other criteria helpful in distinguishing the Conococheague from the Elbrook are: 1) the Conococheague contains about equal amounts of limestone and dolomite, whereas the Elbrook is mainly dolomite, 2) beds of Conococheague carbonate are generally 3 to 5 feet thick, whereas the Elbrook is commonly thin bedded and yields on weathering a slab-like float, and 3) the Conococheague carbonate rocks commonly contain thin silicious laminae that stand out as crinkled ridges on weathered surfaces, a feature not noticed in the underlying Elbrook Formation.



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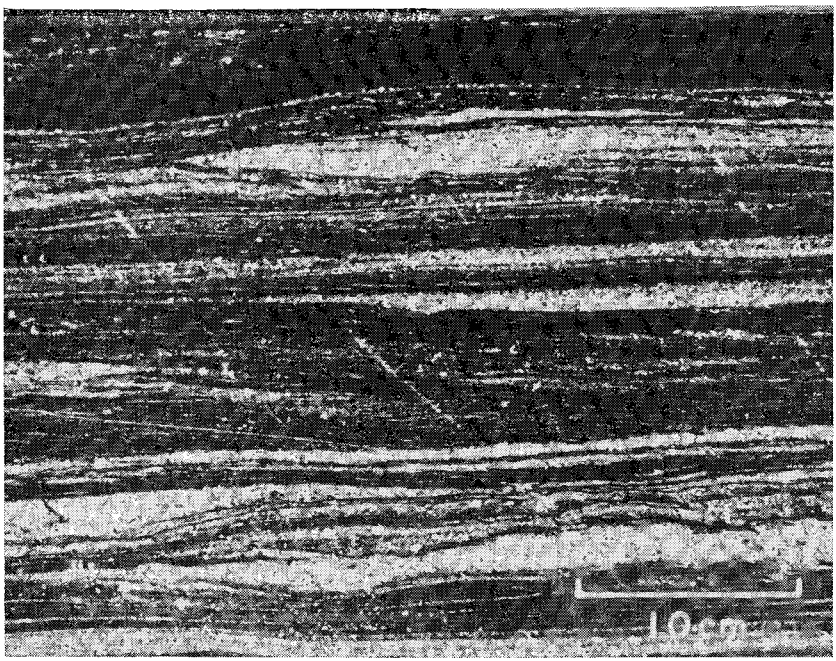


FIGURE 25. Acetate peel of Conococheague Formation. Finely laminated alternation of clastic, fine-grained dolomite (light colored) and calcite (dark colored) intersected by fracture cleavage that has an approximate dip of 50 degrees.

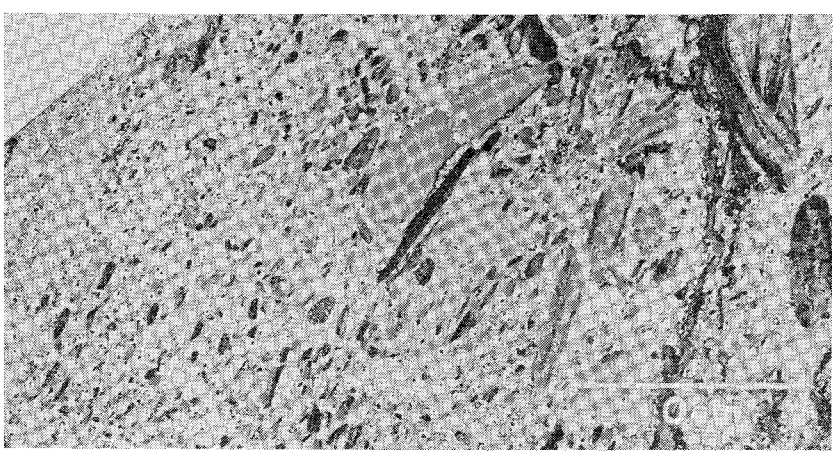
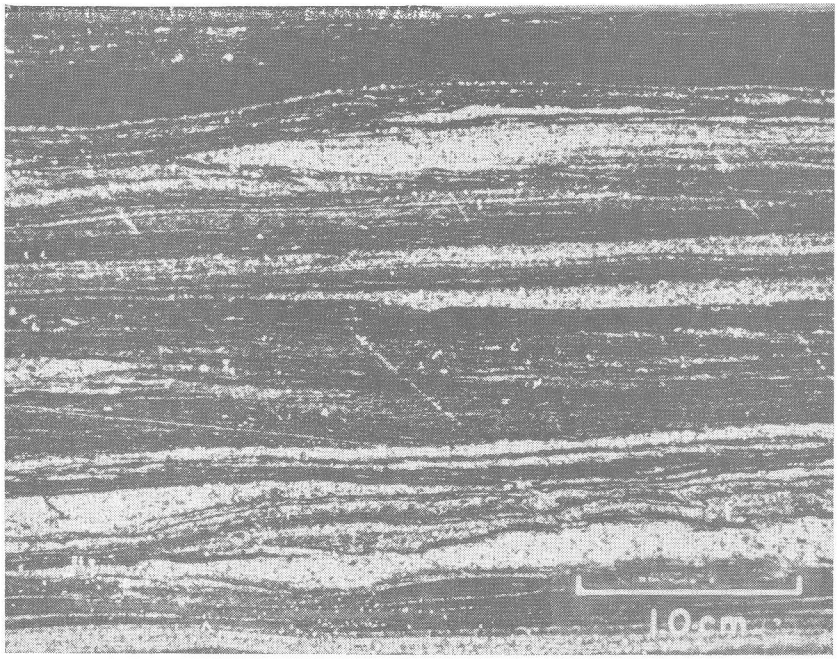


FIGURE 26. Acetate peel of Conococheague Formation showing graded bedding from right (bottom) to left (top). Clastic particles of limestone and chert (light gray) are in a fine-grained calcite matrix.



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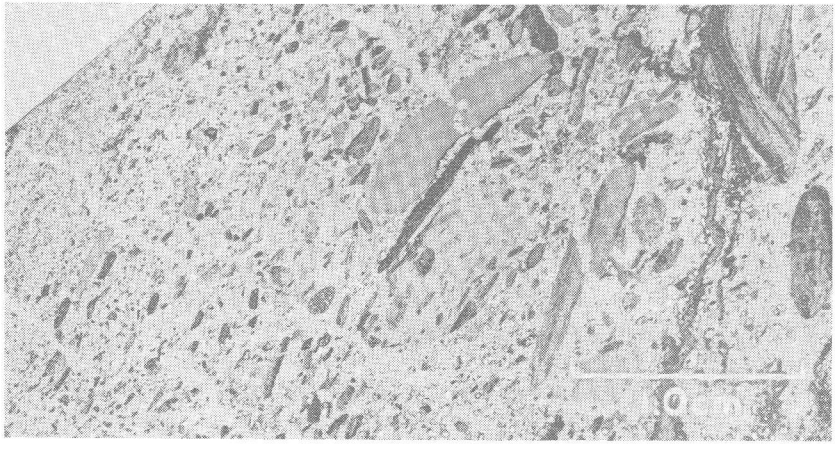

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The blue-gray limestones of the Conococheague are uniformly fine grained. In thin section they are fine-grained micrite with a few scattered grains of silt-size euhedral calcite crystals. The dolomites in thin section are composed of an even-grained mosaic of euhedral dolomite crystals. In some places, the dolomitic rocks contain isolated "floating" sand-size quartz grains embedded in the carbonate groundmass (Figure 27). In thin section the quartz grains generally have sutured edges suggesting replacement of the quartz by the carbonate minerals. Less altered "floating" quartz grains indicate that they were originally well rounded and of clastic origin. The surrounding carbonate matrix has been recrystallized, and any evidence of clastic origin that may have been present has been obliterated.

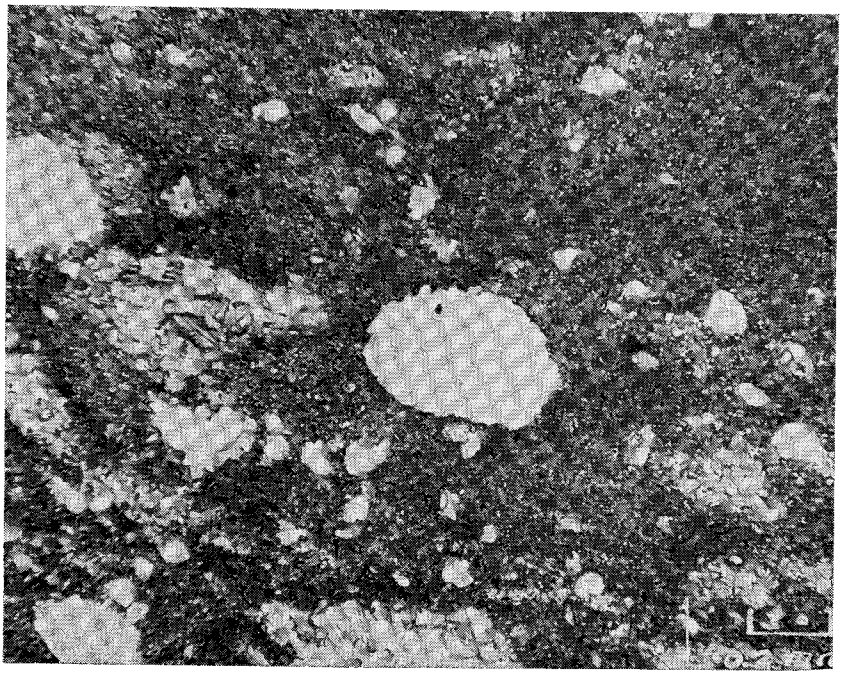

FIGURE 27. Photomicrograph of Conococheague Formation consisting of "floating" quartz clasts in a fine-grained (micritic) groundmass of calcite. Note replacement of quartz by calcite along fringed borders and secondary euhedral dolomite. Plane light, vertical illumination.

In thin section the sandstone consists of well-rounded and generally well-sorted coarse grains of quartz in a matrix of fine-grained carbonate cement (Figure 28). Where there is a predominance of carbonate cement, the quartz grains have sutured boundaries indicating replacement by carbonate. Where carbonate cement is lacking, the quartz grains

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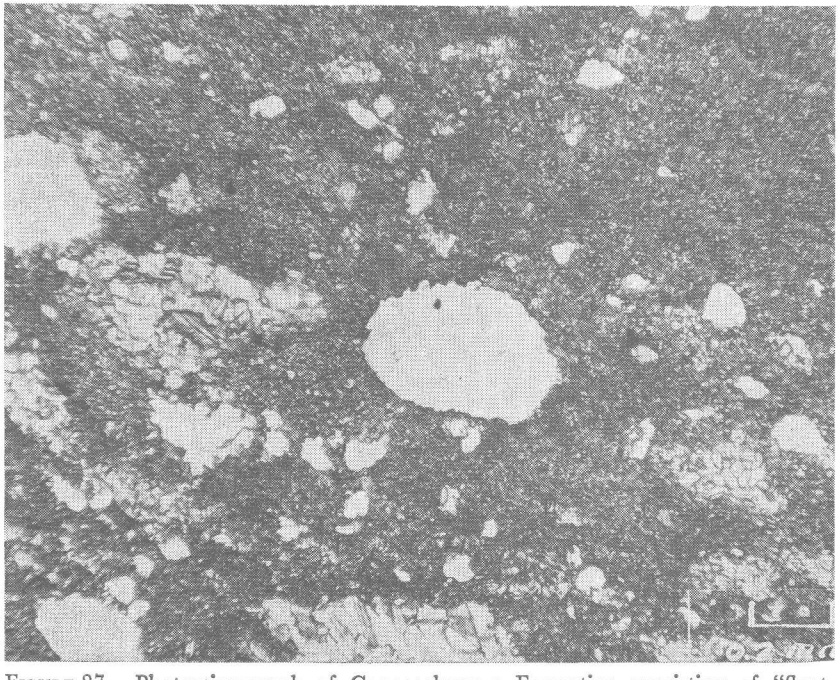

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commonly have overgrowths of clear quartz and no sutured boundaries. About 75 percent of the clastic grains have undulatory extinction with no preferred orientation of the extinction bands. The remaining grains show no evidence of having been derived from a source of tectonically distorted rocks. Also occurring as clastic constituents are coarse abraded particles of micritic limestone (Figure 28) and fine-sand to silt-size, subrounded grains of potassic and sodic (An_{10}) feldspar. The micrite particles are identical to the micrite beds that occur both in the Conococheague and the underlying Elbrook, but their source is intraformational and of no great genetic significance. The source of the quartz, however, is problematical. An attempt was made to map the individual sandstone beds in the Conococheague. The lack of success is attributed to the fact that the sandstones were found to occur in lenses and do not have extensive areal distribution, at least in the direction of the present structural strike of the formation. Edmundson (1958, p. 99) reports that the Conococheague Formation is 1898 feet thick along State Highway 56 in the immediate vicinity of Steeles Tavern. No Conococheague fossils have been found in the Vesuvius area.

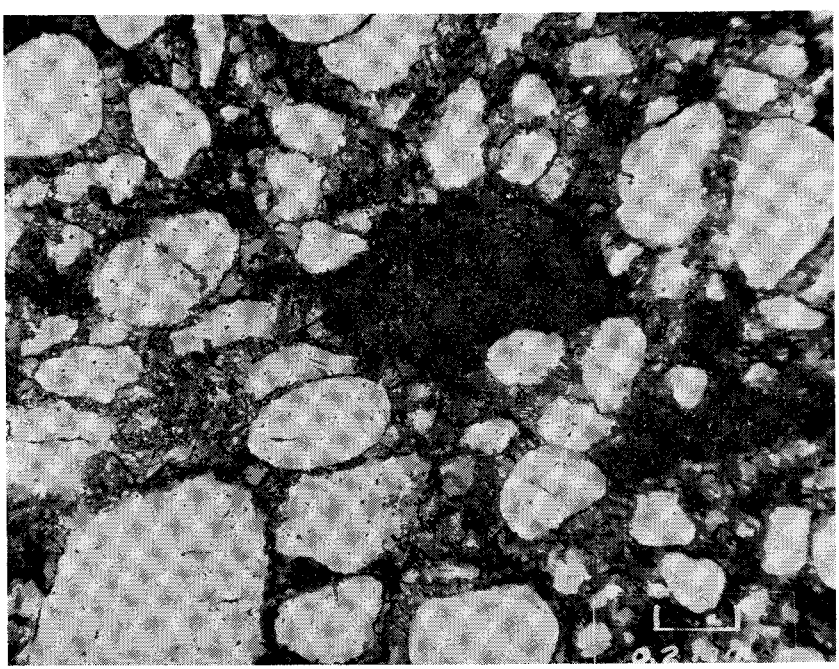

FIGURE 28. Photomicrograph of Conococheague sandstone composed of clastic grains of quartz (mostly well rounded) and limestone (center) in a recrystallized matrix of sparry calcite. Plane light, vertical illumination.

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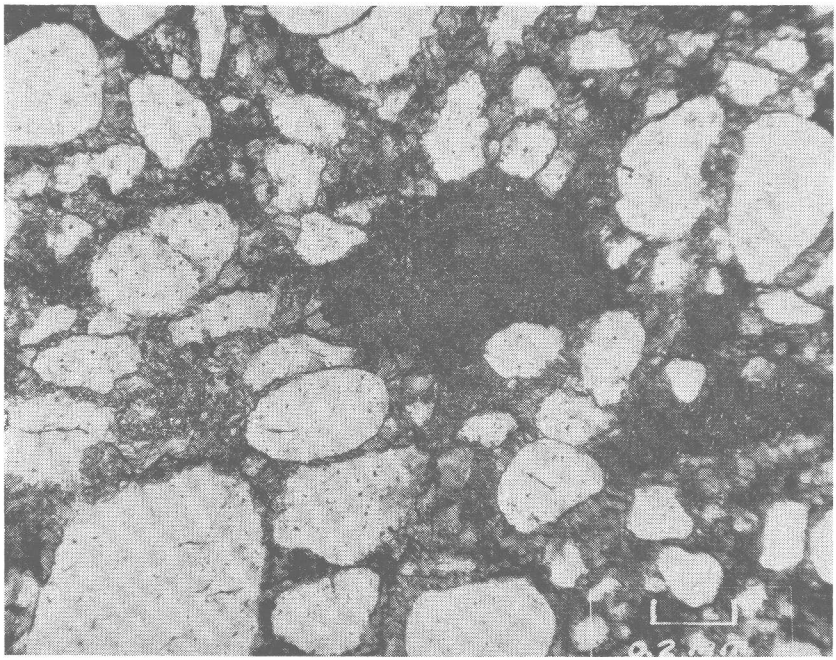

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ORDOVICIAN ROCKS

Chepultepec Formation

The Chepultepec Formation is conformable with the underlying Conococheague Formation and the overlying Beekmantown Formation. It consists mainly of distinctive thick-bedded, blue, fine-grained limestone interbedded with minor amounts of dolomite. For mapping purposes, the lower contact is placed at the base of the first thick bed of fine-grained, blue limestone and the upper contact is drawn at the base of the first light-gray, fine-grained dolomite of the Beekmantown. These contact relationships were observed only in the vicinity of Steeles Tavern; elsewhere in the area the contacts are covered. The formation crops out along U. S. Highway 11 in narrow valleys bordered by low hills that are underlain by the more dolomitic and more resistant Conococheague and Beekmantown; it occurs in similar topographic setting in two other belts in the northwestern part of the quadrangle.

The fine-grained blue limestone commonly has a finely laminated texture on weathered surfaces (Figure 29). In thin section, these laminations are seen to be due to slight differences in grain size. For the most part, the rock is exceedingly dense and fine grained, and there is little evidence of recrystallization and grain growth. Fracture fillings are composed of milky-white, coarse-grained, euhedral calcite crystals.

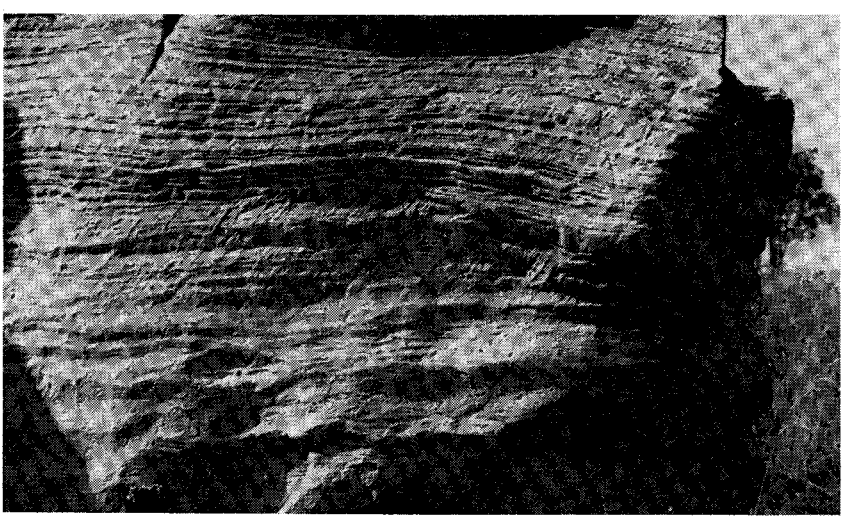

FIGURE 29. Chepultepec Formation exposed along U. S. Highway 11, 1.5 miles southwest of Steeles Tavern. Note characteristic banded bedding (horizontal) and southeastward-dipping cleavage.

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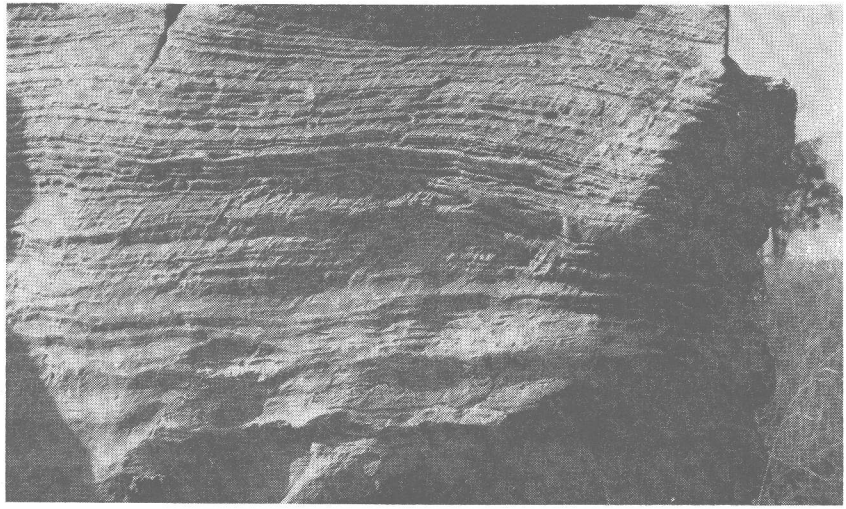

FIGURE 29. Chepultepec Formation exposed along U. S. Highway 11, 1.5 miles southwest of Steeles Tavern. Note characteristic banded bedding (horizontal) and southeastward-dipping cleavage.

Edmundson (1958, p. 92) presents a measured section of the Chepultepec in the vicinity of Steeles Tavern where it is 580 feet thick. Bick (1960, p. 14) reports that the formation is 400 to 600 feet thick in the adjacent Lexington quadrangle. Fossils from the Chepultepec indicate Early Ordovician age (Butts, 1940, p. 100-101). The loosely coiled, low-coned snail *Ophileta* sp. occurs in the middle of the formation in roadcuts along U. S. Highway 11 about 2 miles southwest of Steeles Tavern.

Beekmantown Formation

The Beekmantown Formation conformably overlies the Chepultepec Formation and is disconformably overlain by the New Market Limestone. The lower boundary is mapped at the base of thick-bedded, light-gray, fine-grained dolomite (Figure 30) that overlies thick beds of blue, fine-grained limestone of the Chepultepec Formation. This contact is exposed in roadcuts in the vicinity of Steeles Tavern but has not been observed elsewhere in the Vesuvius area. The upper contact is located at the base of the overlying fine-grained, dark-gray New Market Limestone. This contact is exposed at McCormick's mill about 0.8 mile northwest of Steeles Tavern. Elsewhere in the quadrangle, most of the Beekmantown

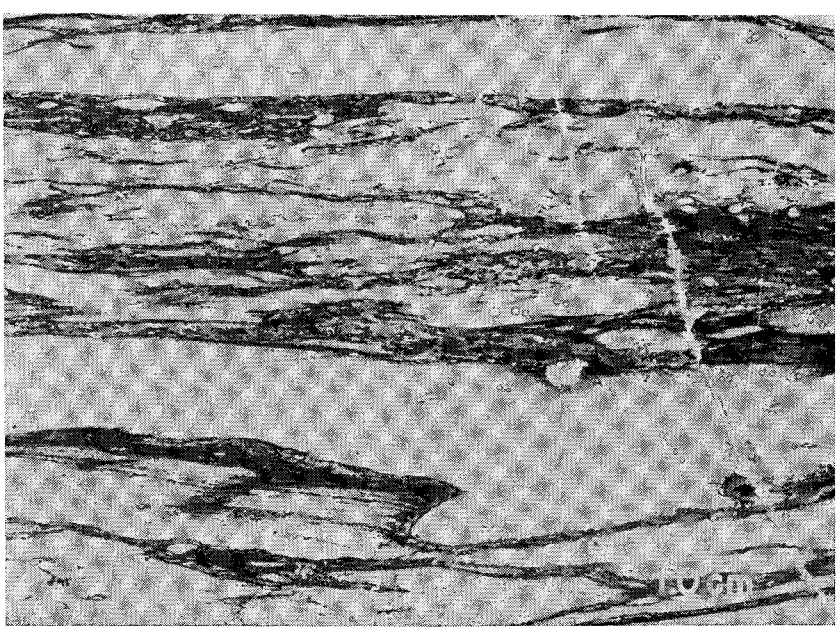

FIGURE 30. Acetate peel of Beekmantown Formation showing distorted laminations of dolomite (dark) and calcite (light).

Edmundson (1958, p. 92) presents a measured section of the Chepultepec in the vicinity of Steeles Tavern where it is 580 feet thick. Bick (1960, p. 14) reports that the formation is 400 to 600 feet thick in the adjacent Lexington quadrangle. Fossils from the Chepultepec indicate Early Ordovician age (Butts, 1940, p. 100-101). The loosely coiled, low-coned snail *Ophileta* sp. occurs in the middle of the formation in roadcuts along U. S. Highway 11 about 2 miles southwest of Steeles Tavern.

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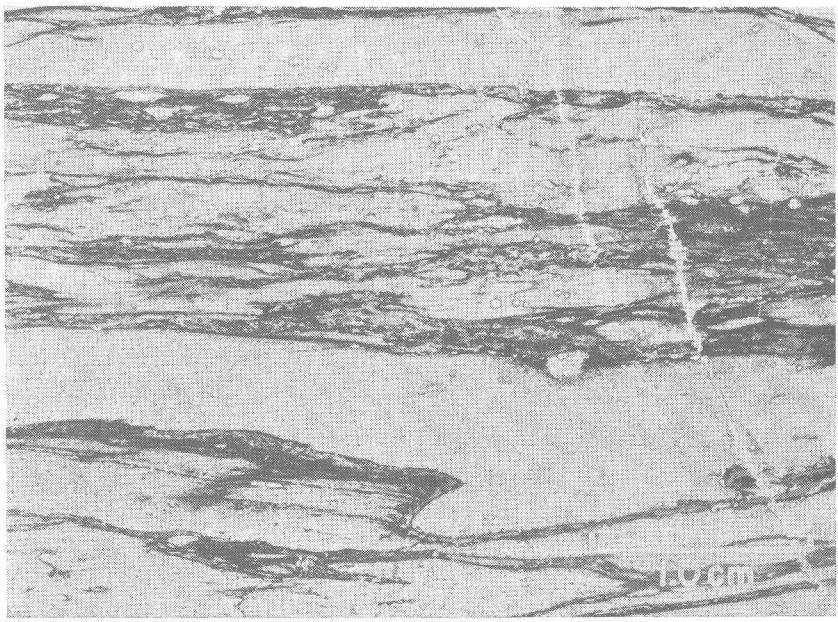


FIGURE 30. Acetate peel of Beekmantown Formation showing distorted laminations of dolomite (dark) and calcite (light).

is bounded on the northwest or southeast by faults. In the Raphine area, the formation is partially exposed in an outcrop belt more than 5000 feet wide. The stratigraphic succession may be repeated several times in folds and faults. In the vicinity of Steeles Tavern, the Beekmantown is in a fairly continuous exposure in roadcuts along State Road 606. The measured section is approximately 1400 feet thick; however, some of the formation is missing where the Beekmantown is faulted upon the Edinburg Formation. Edmundson (1958, p. 20) estimates the thickness to be about 1500 feet in central Virginia. The age of the Beekmantown Formation is Early Ordovician (Butts, 1940, p. 116-119).

New Market Limestone and Lincolnshire Formation

The New Market Limestone and Lincolnshire Formation occur in a small isolated area at McCormick's mill about 0.8 mile northwest of Steeles Tavern. The New Market is a light-gray, fine-grained limestone; the Lincolnshire, a dark-gray, coarse- to medium-grained limestone that contains an abundance of fossils. The combined thickness of these rocks near McCormick's mill is approximately 50 feet. The age of these limestones is early Middle Ordovician (Cooper and Cooper, 1946).

Edinburg Formation

A black fissile shale of the Edinburg Formation overlies the Lincolnshire Formation and is in fault contact with the Beekmantown Formation near McCormick's mill about 0.7 mile northwest of Steeles Tavern (Plate 1). Exposures are not adequate to determine the details of the lithologic nature of the Edinburg Formation in the Vesuvius area. Decker (1952, p. 65) collected graptolites that indicate Middle Ordovician age from the black shale near McCormick's mill.

TRIASSIC ROCKS

A northeastward-trending diabase dike of Triassic (?) age occurs about 0.6 mile southeast of Nash (Plate 1). In thin section, the rock consists of labradorite (An_{50}) in a uniformly fine-grained ophitic texture with augite and a minor amount of olivine in the interstices.

QUATERNARY ALLUVIUM AND GRAVEL

Deposits that include boulder wash, terrace gravels, and flood-plain alluvium are shown on Plate 1 where they are thick enough or of

sufficient areal extent to conceal the bedrock formations over a significant area. The age of these deposits is tentatively considered Quaternary. The boulder wash (Figures 31, 32) is most extensive around the periphery of the north and northwest scarp of the Blue Ridge in the vicinity of Big Level. The alluvium occurs in a fan that is as much as 3 miles wide and more than 100 feet thick; it is composed of crudely stratified gravel derived mainly from the Antietam (Erwin) Formation. At the abandoned Cold Spring clay deposit where the alluvium was removed for the purpose of mining the residuum over the Shady, two generations of alluvium are separated by a continuous layer of soil-like humus material. Contiguous to the southeast flank of the Blue Ridge, for example immediately southeast of Tyro, there are terrace benches that stand above the present stream level. These benches are largely veneered by a thin layer of cobbles derived from the Virginia Blue Ridge Complex and Catoctin greenstone.

In the immediate vicinity of Adams Peak and McClung Mountain (Plate 1, west-central part), are angular-shaped cobbles and boulders of limestone that could have come from any of the carbonate formations of the Valley and Ridge province. These occurrences of limestone cobbles and boulders in the highlands of the Blue Ridge province are recorded here as evidence that a former erosion surface may have extended across all three of the physiographic provinces (Bloomer and Werner, 1955, p. 600).

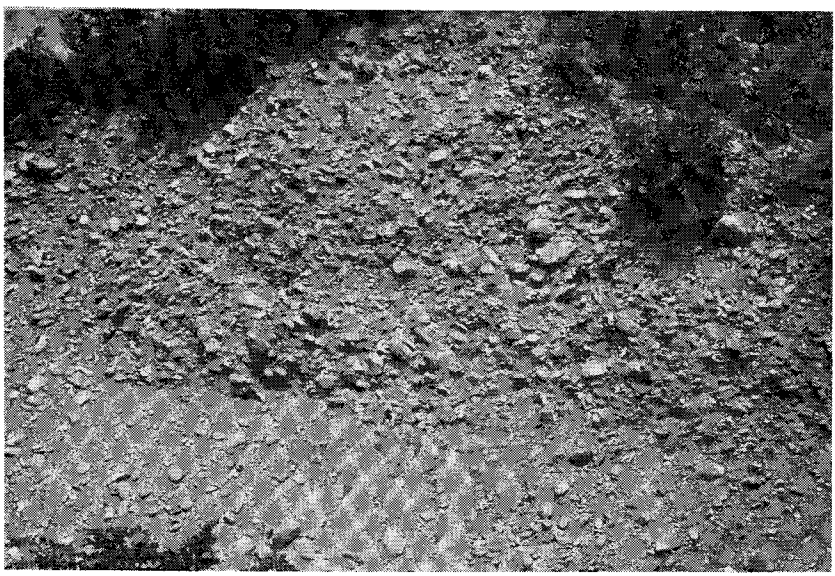


FIGURE 31. Boulder wash along Saint Marys River 2.5 miles northwest of Vesuvius. The boulder wash, composed mostly of Antietam (Erwin) quartzite, overlies deeply weathered Shady dolomite.

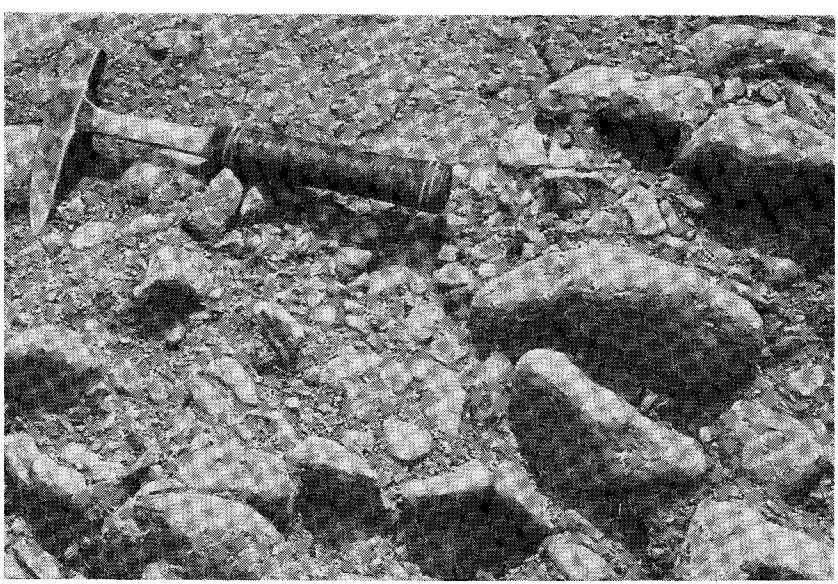
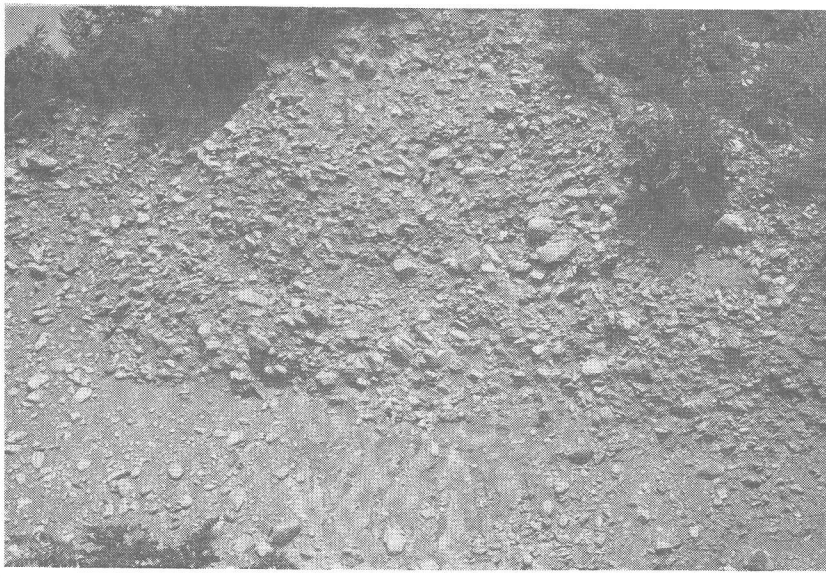


FIGURE 32. Boulder wash. Closer view of Figure 31 showing heterogeneity of fragment sizes.



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STRUCTURAL GEOLOGY

FOLDS

The principal tectonic elements in the Vesuvius quadrangle are the Buena Vista anticline and the Steeles Tavern syncline. The Buena Vista anticline (Bloomer and Werner, 1955, p. 601) is part of a larger structural feature known as the Blue Ridge-Catoctin Mountain anticlinorium which, in central Virginia, has a span of about 25 miles from the Blue Ridge province in one limb to well within the Piedmont province in the other limb. The Steeles Tavern syncline is part of the Massanutten synclinorium which is the dominant structural feature in the adjacent Valley and Ridge province (Butts, 1940, p. 443). Thus, the Buena Vista anticline and the Steeles Tavern syncline are subsidiary fold elements of a larger structural feature that extends from the Valley and Ridge on one side to the Piedmont on the other. The small infolded outlier of Catoctin and Swift Run formations in the vicinity of Tyro (Plate 1) is a remnant of the eroded Blue Ridge-Catoctin Mountain anticlinorium.

In the vicinity of Big Level the Buena Vista anticline is a more or less open, gently folded structure that forms a prominent salient along the northwest slope of the Blue Ridge. Southwestward, the folds are tighter, overturned toward the northwest and broken by at least one high-angle reverse fault. Along the North Fork of the Tye River (Plate 1) between the Buena Vista anticline and the Tye River fault zone the rocks are even more tightly folded, overturned, and broken by a number of high-angle faults.

In the northwest portion of the quadrangle (Plate 1) the Steeles Tavern syncline is broken along the trough by the Fairfield fault (Bick, 1960, Plate 1). Farther northwestward, the Steeles Tavern syncline adjoins other folds that are broken by the Pulaski-Staunton fault.

Folds, ranging in size from those which can be areally mapped down to minor folds, crenulations, and microfolds observed in outcrops and thin sections, have developed within the Buena Vista anticline. These minor folds and crenulations observed in outcrop seem to be unconformable to the larger folds determined by areal mapping. For example, from the pattern of the northwest limb of the Buena Vista anticline, the Antietam quartzite and the underlying formations have an average dip of about 25° NW. with no evidence of overturning, whereas the minor folds observed in outcrop invariably have axial planes that dip southeastward and invariably are extensively isoclinal and overturned.

A few sufficiently large outcrops along the Norfolk and Western Railway, parallel to South River, and in the vicinity of Christians Creek (Plate 1, northern part), reveal that the carbonate rocks are also contorted by extensive isoclinal and overturned folds.

THRUST FAULTS

All of the thrust faults, including the large-scale features that involve displacement of mappable stratigraphic units and the small-scale features observed in isolated outcrops, appear to be genetically related to folding and to have developed as ruptures of overturned anticlines and synclines. Displacement ranges in magnitude from slight slippage along cleavage planes to mappable displacements of a thousand feet or more.

Thrusts are concentrated in a zone between the south limb of the Buena Vista anticline and the North Fork of the Tye River (Plate 1). These faults overlap one another along the trace and either disappear in the Virginia Blue Ridge Complex or terminate with gradual diminution of displacement within overturned folds of stratified rocks. The thrusts (Plate 1, sections A-A′, B-B′) presumably caused the collapse of a synclinal segment along the southeast flank of the Buena Vista anticline. The intervening folds occur in an imbricated structure.

Proof of existence of faults in the Virginia Blue Ridge Complex is difficult to establish. The principal supporting criterion of faults in the overlying sedimentary rocks is based on the mappable displacement of stratigraphic units, but in the Virginia Blue Ridge Complex, the stratigraphy is not yet known in sufficient detail to substantiate faulting. In local areas where faulting involves the Virginia Blue Ridge Complex and overlying sedimentary rocks, the rocks of the complex are intensely sheared. However, sheared zones are more or less parallel to foliation in the complex which certainly developed prior to the deposition of the overlying sediments.

STRIKE-SLIP FAULTS

A number of transverse faults (with respect to the strike of folds, cleavage, or foliation in the area) have been mapped (Plate 1) where they offset formational contacts or the traces of thrust faults. There are, in addition to those included on Plate 1, countless faults too small to show at a 1:62, 500 scale. These strike-slip faults appear to be nearly vertical, and offsets do not exceed a few hundred yards.

On the extension of Wilkie Ridge above Big Marys Creek there is an unusual outcrop pattern involving rocks of the Virginia Blue Ridge Complex and the Unicoi Formation. Detailed mapping indicates that the rocks are intricately folded and that these folds are truncated by a transverse structure as depicted on Plate 1.

NORMAL FAULTS

Normal faults of 2 to 5 feet displacement are present in a few places. A normal fault is suspected to occur in the vicinity of Saint Marys River where the Antietam Formation is abnormally thin. It is logical to suspect that this close proximity of Shady and Hampton formations is due to faulting.

SMALL-SCALE STRUCTURAL FEATURES

Rock cleavage is by far the most prominent small-scale structural feature and can be seen in nearly every outcrop; it is evident in all of the rocks from the Swift Run Formation to the Ordovician limestones and dolomites (Figures 15, 29). In some places the cleavage is so prominent that it almost completely obliterates bedding. Most of the cleavage is fracture cleavage consisting of closely spaced fractures that cut sedimentary bedding at various angles. The cleavage planes have a consistent strike to the northeast and a consistent dip toward the southeast. In the northwest limb of the Buena Vista anticline and in the Steeles Tavern syncline, the dip of the cleavage varies according to position within a fold and has a fan-like relationship with reference to axial planes of folds (Plate 1, sections A-A′ and B-B′).

Along the southeast limb of the Buena Vista anticline, cleavage is expressed by the orientation of foliate minerals and is spaced at intervals of a few millimeters. Displacements from a fraction of an inch to several feet are commonly associated with this kind of cleavage (Bloomer and Werner, 1955, p. 604). This cleavage has a strike parallel to fold axes and a dip consistently toward the southeast. It does not necessarily assume a fan-like relationship with axial planes of folds.

Foliation in the rocks of the Virginia Blue Ridge Complex has a strike parallel to the regional northeast alignment of the fold axes in the Buena Vista anticline and a steep persistent dip to the southeast. This foliation formed prior to deposition of the Swift Run and Unicoi formations because cobbles, derived from the complex, in the basal conglomerates of these formations have a random orientation of schistosity.

There are many types of linear features such as intersections of bedding and cleavage planes and elongation of minerals along cleavage and fault planes in the rocks of the area. Other lineations occur as slickensides along fault surfaces. The intersection phenomena are useful for determining the attitude of axes of small folds. Jointing is common in all rocks of the area. Some joints are parallel to fold axes and to fracture cleavage, but most joint sets are oriented perpendicular to fold axes.

The degree and magnitude of folding are related to lithology. Thick competent beds of the Antietam and Beekmantown formations, for example, are only gently folded, whereas the incompetent thin-bedded subgraywackes of the Hampton and Unicoi formations and the thin argillaceous beds of the Elbrook Formation are severely folded. In the Catoctin Formation, the greenstones lack continuous marker horizons, hence the degree of folding is difficult to ascertain. Although the magnitude and form of these folds vary from one rock type to another, the folds are concordant along the contacts of formations (Werner, 1951).

Because of the intricate folding, it is exceedingly difficult to obtain an accurate measurement of the thickness of the various stratigraphic units. Moreover, within the minor folds the beds thicken in the axial zones and thin along the limbs so that even in a small-scale feature it is difficult to determine the original depositional thickness of individual beds. In the cores of small anticlines, such as along Big Marys Creek (Plate 1), rocks of the Virginia Blue Ridge Complex rise in structural conformity with the folds in the overlying sedimentary rocks, thus indicating that the basement did not remain an inert mass over which the stratified rocks slipped during the folding process.

ECONOMIC GEOLOGY

SAND AND GRAVEL

The large alluvial fan along the northwest slope of the Blue Ridge, particularly around the periphery of Big Levels, might be further exploited for sand and gravel. This alluvial deposit composed mainly of debris from the Antietam Formation is as much as 100 feet thick and up to 3 miles wide. For the most part the deposit is an unconsolidated, crudely stratified mixture of boulders, cobbles, and pebbles of quartzite in a matrix of coarse-grained sand. Sand and gravel are being worked at

the present time (Plate 1, Nos. 3, 14) and probably provide the greatest economic potential of the area. A list of the active and abandoned mines and quarries in the Vesuvius quadrangle is given in Table 2.

TABLE 2.—Active and abandoned mines and quarries in the Vesuvius quadrangle.

1. Mount Torry mine (manganese oxide)
2. Kennedy mine (manganese oxide)
3. *D. M. Conner Sand Co., Inc. (sand)
4. Black Shaft mine (manganese oxide)
5. Shields mine (manganese oxide)
6. Cold Spring pit (clay)
7. Weeks property (sand)
8. Lofton mine (iron oxide)
9. Red Mountain mine (iron and manganese oxides)
10. Manganese Hollow mine (iron and manganese oxides)
11. Minebank (Pulaski) mine (iron and manganese oxides)
12. Blue Bank mine (iron and manganese oxides)
13. Black Rock mine (iron oxide)
14. *Southwest Materials, Inc. (crushed gravel)
15. Mangus property (gravel)
16. Vesuvius mine (iron and manganese oxides)
17. Kelly Bank mine (iron and manganese oxides)
18. Old Dixie mine (iron oxide)
19. Hogpen Hollow mine (manganese oxide)
20. Unakite quarry
21. Marys Creek mine (iron and manganese oxides)
22. Irish Creek mine (cassiterite)

*Presently active operation.

CLAY

Below the alluvium along the northwest slope of the Blue Ridge, the Shady Formation and some of the Rome Formation are deeply weathered to a clayey saprolite. Locally, this saprolite has been worked for the clay. The Cold Spring clay pits (Plate 1, No. 6) have been worked for both kaolin and bauxite, but the operation was closed in 1951 as a result of a fire which destroyed the processing plant (Caskie, 1957). The clay has been used as a filler in the manufacture of paper, paint, and rubber.

IRON ORE

Early mining activity in the area was concerned with the development of manganiferous limonite ores that occur in deposits large enough to be worked mainly in the Shady Formation along the western foot of the Blue Ridge. Limonite has also been recovered from the Antietam and Rome formations. These ores were mined well over a hundred years ago and were worked more or less successfully until World War I. Many of the deposits were abandoned soon after discovery and initial production, because the ore contained manganese oxide. During the nineteenth century, the ores were smelted in charcoal furnaces located at the foot of the Blue Ridge. The principal production was from the Mount Torry mine (Plate 1, No. 1) located near Torry Ridge and the Red Mountain mine (Plate 1, No. 9) along the upper reaches of Saint Marys River. These mines were developed in the Shady Formation, and the ores occur as botryoidal masses (Figure 33). The iron ore in the Antietam Formation is also limonite; it locally fills fractures along joint sets.

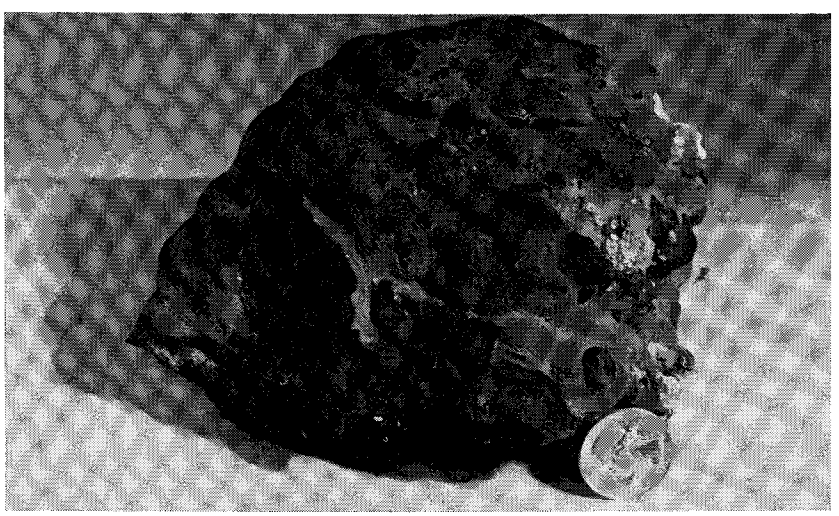

FIGURE 33. Iron ore from the Red Mountain mine along Saint Marys River. Specimen consists of botryoidal limonite coated with a thin layer of red hematite.

MANGANESE ORE

Around the turn of the century the emphasis of mineral production shifted from iron ore to the recovery of manganese oxide. Immediately prior to World War I most of the activity seems to have been centered along the Saint Marys River tract with the development of large open-

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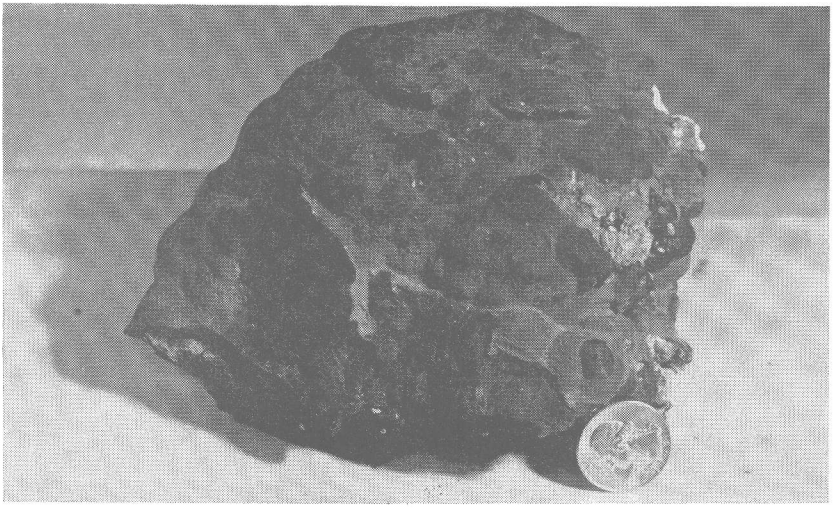

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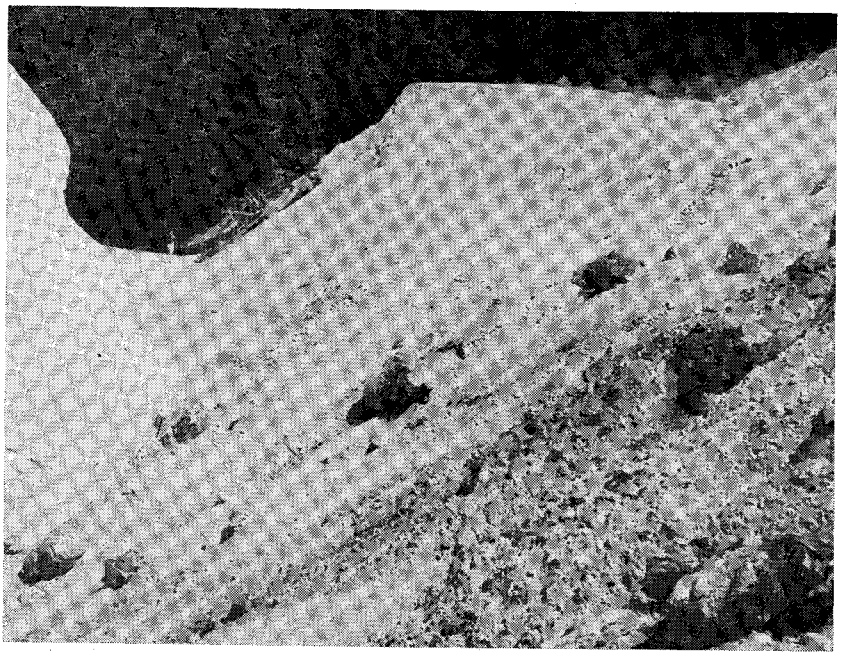


FIGURE 34. Deeply weathered residuum of the Shady Formation exposed in manganese-mining operation (Vesuvius mine) in Dogwood Hollow. Note large masses of botryoidal manganese ore that occurs in isolated pockets within the residuum.

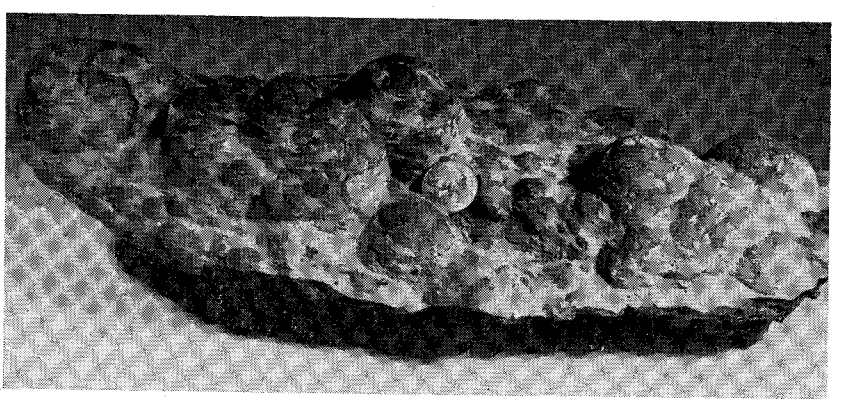
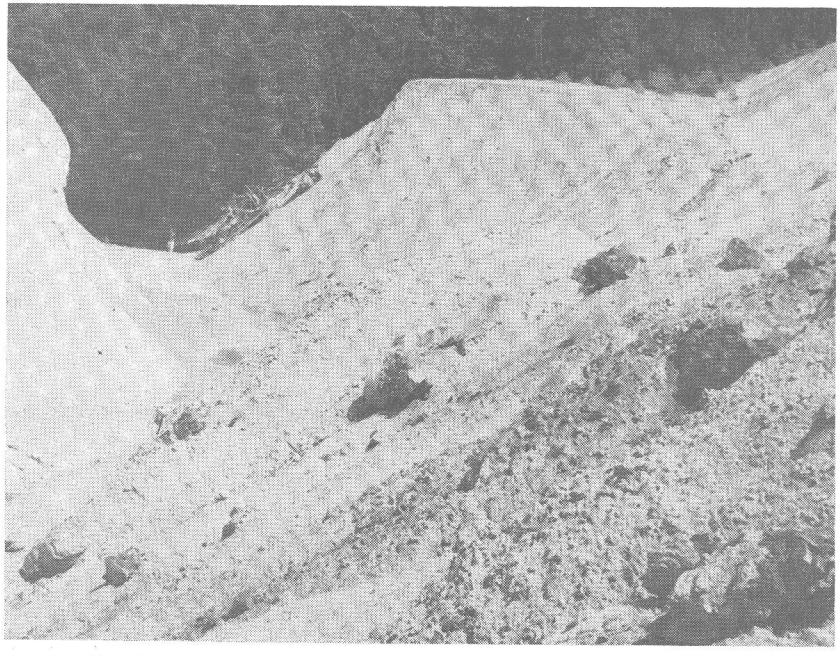


FIGURE 35. Manganese ore (psilomelane) from the Vesuvius mine in Dogwood Hollow. The botryoidal form is characteristic of the manganese ore that occurs in residual clays of the Shady Formation.



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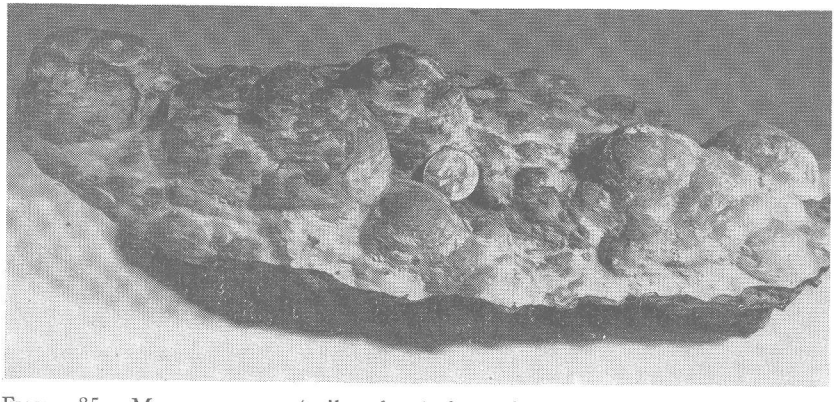

FIGURE 35. Manganese ore (psilomelane) from the Vesuvius mine in Dogwood Hollow. The botryoidal form is characteristic of the manganese ore that occurs in residual clays of the Shady Formation.

pit mines, some underground mines, and the construction of a narrow-gauge railroad. The principal mines in the area are: the Mount Torry mine (Plate 1, No. 1) along Orebank Creek at the foot of Turkey Ridge; Kennedy mine (Plate 1, No. 2) near Kennedy Creek; Red Mountain mine (Plate 1, No. 9) and Minebank mine (Plate 1, No. 11) near the headwaters of Saint Marys River; and the Vesuvius mine (Plate 1, No. 16) in Dogwood Hollow. In recent years only the Minebank mine (1957-58) and Vesuvius mine (1957-59) have been in operation.

The manganese-oxide deposits are best developed where the Shady is deeply weathered in synclinal structures underlain by impervious beds of the Antietam Formation. Although the origin of the ore is not clearly understood, it was probably related to the weathering of the Shady Formation (Figure 34). The ores consist of pyrolusite and psilomelane mixed with limonite and are in isolated pockets within residuum developed on the Shady Formation. Elongated botryoidal masses of manganese oxide (Figure 35) and joints within the masses appear to be parallel to the direction of prominent joint sets in the area. These joint sets are perpendicular to the alignment of major fold axes. Mining records indicate that the ores were richest near the surface and decreased in grade with depth, even where the Shady Formation is completely weathered. The ores appear to be concentrated about 200-300 feet above the base of the Shady.

TIN ORE

Cassiterite from Panther Hollow about 1.5 miles southwest of Montebello was identified in 1846. The locality is known as the Irish Creek mine (Plate 1, No. 22). Since the discovery of cassiterite in this area, there have been various attempts to produce the tin ore, notably during the periods 1883-85, 1889-92, and 1918-19. The cassiterite is in a greisen derived from a granodiorite of the Pedlar Formation. The fractures follow the northeast-southwest structural trend in the area. The tin-bearing zones range in width from a few inches to 5 feet. The cassiterite is dark brown and is generally heavily stained by iron oxides. Some of the cassiterite occurs as small euhedral crystals, but most of it, like other minerals in the greisen, is fractured and crushed. About 3200 tons of ore have been removed from the Irish Creek mine since the first workings in 1890 (Koschmann and others, 1942). Forty-six minerals have been described from the Irish Creek locality (Glass and others, 1958). More recently the beryllium content of the tin deposits at Irish Creek were reported (Lesure and others, 1963), and suggestions were made that additional prospecting may be warranted.

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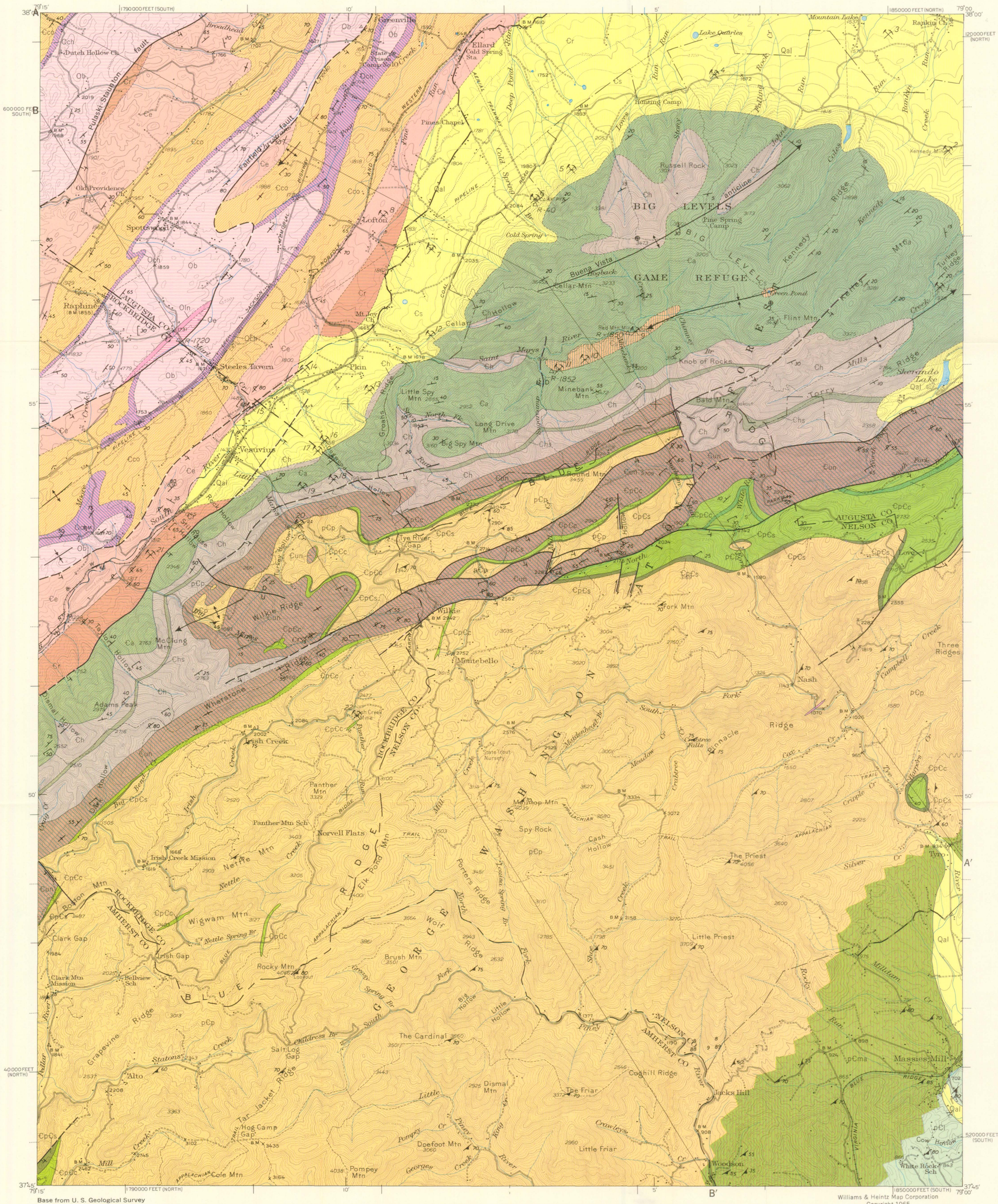
COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES
James L. Calver
Commissioner of Mineral Resources and State Geologist



GEOLOGIC MAP OF THE VESUVIUS QUADRANGLE, VIRGINIA

Geology by H. J. Werner

1965

EXPLANATION

QUATERNARY

- Qal — Alluvium

TRIASSIC

- Td — Diabase

ORDOVICIAN

- Oe — Edinburg Formation
- Oln — New Market Limestone and Lincolnshire Formation
- Ob — Beekmantown Formation
- Och — Chepultepec Formation

CAMBRIAN

- Ꞓco — Conococheague Formation
- Ꞓe — Elbrook Formation
- Ꞓr — Rome Formation
- Ꞓs — Shady Formation
- Ꞓa — Antietam (Erwin) Formation
- Ꞓh, Ꞓhs, Ꞓh — Hampton Formation; Ꞓhs - Snowden Member
- Ꞓun — Unicoi Formation
- ꞒpꞒc, s — Catoctin Formation; s - sedimentary rocks
- ꞒpꞒs — Swift Run Formation

PRECAMBRIAN (VIRGINIA BLUE RIDGE COMPLEX)

- pꞒp — Pedlar Formation
- pꞒma — Marshall Formation
- pꞒl — Lovingston Formation

CONTACTS

exposed — approximate — covered

FOLDS

Anticline—trace of axial plane and direction of plunge of axis

Syncline—trace of axial plane and direction of plunge of axis

FAULTS

NORMAL AND REVERSE

exposed — approximate

U—upthrown side
D—downthrown side

THRUST

exposed — approximate

T— overthrust side

TRANSVERSE

exposed — approximate

Arrows indicate relative movement

ATTITUDE OF ROCKS

Strike and dip of beds

Strike of vertical beds

Strike and dip of overturned beds

Horizontal beds

FOLIATION AND CLEAVAGE

Strike and dip of cleavage

Strike of vertical cleavage

Strike and dip of foliation

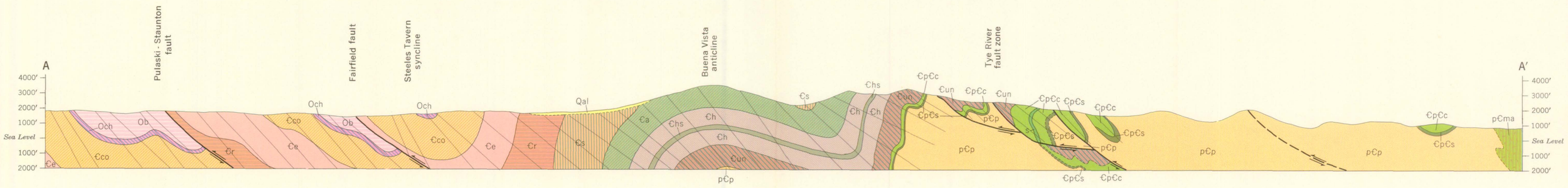
MINES, QUARRIES, AND PROSPECTS

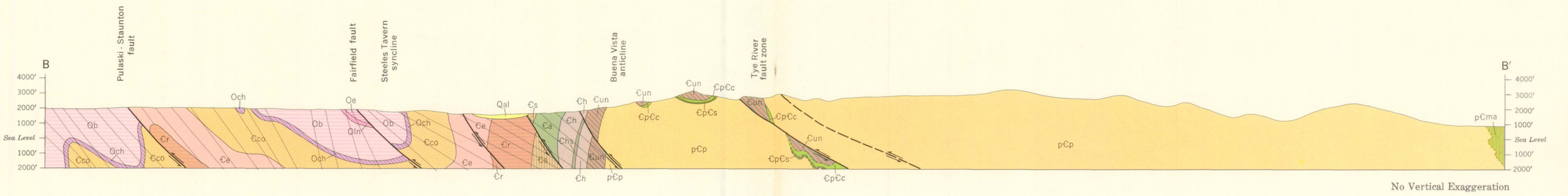
See text for names of active and abandoned operations.

Active mine or quarry

Abandoned mine or quarry

R-1852 Clay and shale localities





No Vertical Exaggeration