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

GEOLOGIC INVESTIGATION OF THE LINCOLN AND BLUEMONT QUADRANGLES, VIRGINIA

PIERRE E. PARKER

REPORT OF INVESTIGATIONS 14

VIRGINIA DIVISION OF MINERAL RESOURCES

James L. Calver
Commissioner of Mineral Resources and State Geologist

CHARLOTTESVILLE, VIRGINIA
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Commonwealth of Virginia
Department of Purchases and Supply
Richmond
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PUBLISHER'S NOTE

This will acknowledge the good work of one of Loudoun County's public spirited citizens. Pierre E. Parker, a recognized professional geologist, spent many hours becoming acquainted with the geologic environment of his county and prepared this map and manuscript on his own time and without remuneration. He was most gracious in supplying these materials to the Division of Mineral Resources. This study is a significant contribution to the knowledge and understanding of the geologic history of northern Virginia.

—J.L.C.

CONTENTS

	Page
Abstract	1
Introduction	1
Rocks in the area	3
Precambrian rocks	3
Marshall Formation	3
Cambrian or Precambrian rocks	7
Swift Run Formation	7
Catoctin Formation	13
Cambrian rocks	15
Weverton Formation	15
Hampton (Harpers) Formation	15
Erwin (Antietam) Formation	16
Triassic rocks	16
Structural geology	17
Geologic history	18
Economic geology	20
References	21
Index	22

ILLUSTRATIONS

PLATE PAGE

1. Geologic map of the Lincoln and Bluemont quadrangles, Virginia ..... In pocket

FIGURE

1. Index map showing locations of Lincoln and Bluemont quadrangles 2
2. Marshall gneiss that has marked schistosity and lineation.... 4
3. Felsite dike in metabasalt of the Catoctin Formation..... 5
4. Marshall gneiss that has pronounced lineation..... 6
5. Marshall Formation with well-developed lineation in gneiss.. 6
6. Boulder beds in the Swift Run Formation..... 8
7. Boulder beds in the Swift Run Formation..... 8
8. Platy-bedded, fine-grained arkosic sandstone in the Swift Run Formation 9
9. Boulder bed in the Swift Run Formation..... 10
10. Cross-bedding in a fine-grained arkosic sandstone in the Swift Run Formation..... 10
11. Phyllite in the Swift Run Formation..... 11
12. Limestone in the Swift Run Formation..... 12
13. Swift Run limestone..... 13
14. Tuff of dacitic or andesitic composition in the Catoctin Formation 15

GEOLOGIC INVESTIGATION OF THE LINCOLN AND BLUEMONT QUADRANGLES, VIRGINIA

By

PIERRE E. PARKER[1]

ABSTRACT

Reconnaissance mapping of the Lincoln and Bluemont quadrangles in Loudoun County in northern Virginia has clarified relationships between the Precambrian Marshall Formation, the overlying Swift Run Formation, and metabasalt of the Catoctin Formation which intruded fractures in the older formations and flowed over them. The Catoctin is overlain by the Weverton Formation; no intervening Loudoun-type rocks were found. Hampton (Harpers) and Erwin (Antietam) formations are present in the northwest portion of the Bluemont quadrangle. Basalt dikes of Triassic age occur throughout much of the area, and Triassic sedimentary rocks are present in the southeast part of the Lincoln quadrangle.

Gneiss, alaskite, greenstone, and graywacke have been quarried in the area for use as road metal. Limestone in the Swift Run Formation was burned for the production of lime, and this material has also been worked for marble.

INTRODUCTION

The Lincoln and Bluemont quadrangles are located in northern Virginia in Loudoun County and are bounded by parallels 39°00′ and 39°07′30″ and meridians 77°37′30″ and 77°52′30″ (Figure 1). The quadrangles include small portions of the Piedmont and Valley and Ridge physiographic provinces, but most of the area is within the Blue Ridge province. The principal physiographic features are the Blue Ridge Mountains on the west, a southward extension of Catoctin Mountain on the east, and a dissected intervening valley locally known as Loudoun Valley. All drainage flows into Goose Creek, which ultimately drains eastward into the Potomac River. The greenstone and gneiss weather to rich heavy soils that make excellent pasturage, although in many places the land is too hilly for corn growing. Prosperous dairy, beef, and horse farms abound.

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[1] Paeonian Springs, VA 22129.

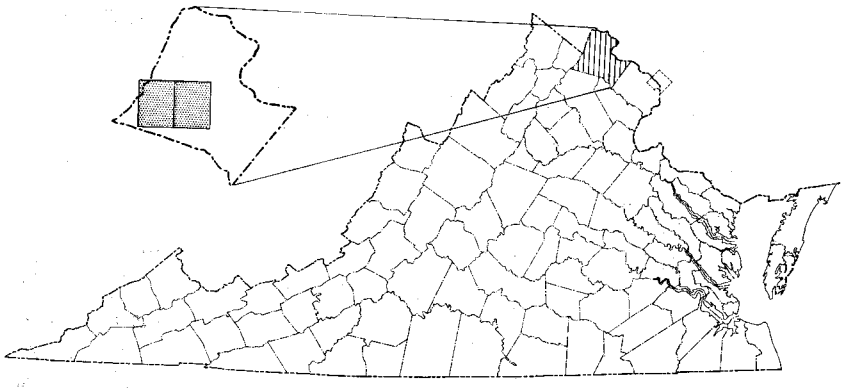

Figure 1. Index map showing locations of Lincoln and Bluemont quadrangles.

The geologic map of the Lincoln and Bluemont quadrangles (Plate 1) is the result of a reconnaissance areal study made intermittently from 1960 to 1966. Because of deep weathering, there are few outcrops in the more level areas; however, along Goose Creek and Beaverdam Creek there are some excellent exposures. The author felt it desirable to complete the generalized phase of the mapping in order to provide a basis for more detailed studies in the area. With few exceptions, all the data on the map were based on field determinations. Numbers preceded by "R" in parentheses (R-3436) correspond to sample localities on Plate 1. These samples are on file in the repository of the Virginia Division of Mineral Resources where they are available for examination.

The author's work confirms the southward extension of the Blue Ridge-Catoctin Mountain anticlinorium as interpreted by Cloos (1951) and Nickelsen (1956). It also confirms conditions observed farther south and described by Bloomer and Bloomer (1947), King (1950), and others. The principal effort in this mapping program was to clarify the relationships within Loudoun Valley between the Marshall, Swift Run, and Catoctin formations.

Much of the confusion over the succession of formations in this area has arisen from the widespread occurrence of the Catoctin Formation, and its various aspects. Not only was it intruded through the Marshall gneiss and Swift Run Formation, but also during subsequent stages of intense folding the feeder dikes and ramifying veins were broken up into isolated blocks and masses contained within the Marshall and the Swift Run. Where the basalt was the predominant rock, the

host gneisses were isolated as blocks within the Catoctin. These relations of the basalt to the host rock, combined with the fact that along zones of greatest movement the basalt was sheared into phyllites and almost completely chloritized, make detailed mapping a necessity for determining the superposition of beds. Therefore, on the basis of a preliminary investigation, portions of Loudoun Valley would appear to be underlain by the Catoctin Formation because all the conspicuous outcrops are greenstone. Yet a more detailed study of some of these areas may reveal soils containing tiny fragments of gneiss even though greenstone is the predominant rock, or at least the most obvious rock. As a matter of mapping procedure, the Catoctin is indicated on the geologic map only where large areas of metabasalt were clearly discernible. It may be due to some of the foregoing reasons that previous investigators of the Blue Ridge province mapped the sericitic phyllites of the Swift Run within or on top of the Catoctin. In this area, where Weverton quartzite is present adjacent to Catoctin, no Loudoun Formation has been found between them.

The author gratefully acknowledges the geologic interpretation of the Potomac River Gorge and Maryland's Middletown Valley by Dr. E. Cloos and his associates of Johns Hopkins University. He had the great advantage during his first forays into the field of the able guidance and work of Dr. Richard Nickelsen and Miss Barbara Toan, two of Dr. Cloos' students. The Virginia Division of Mineral Resources generously provided thin sections and spectrographic analyses, and Dr. James L. Calver, Commissioner of Mineral Resources and State Geologist, gave ample encouragement to complete the work. Many thanks go to the landowners who allowed the author access to their property. Particular mention is due General and Mrs. Milton Arnold, who permitted numerous traverses of their property by the author and the use of their home for shelter and provisions. On and adjacent to their land, there are exposures of all of the rock types to be found in Loudoun Valley.

ROCKS IN THE AREA

PRECAMBRIAN ROCKS

Marshall Formation

The oldest recognizable unit in this region is the Marshall Formation. There are many variations in texture and structure; however, its general composition appears to approximate that of granodiorite and it is gneissic in structure. Excellent petrographic descriptions of

this gneiss have been presented by Nickelsen (1956, p. 242-243). It is characteristically porphyroblastic, with white feldspar phenocrysts having very diffuse outlines 0.5 inch or more in diameter. In the eastern half of Loudoun Valley, considered to be the shallower portion of the basement, the feldspar phenocrysts do not exceed 0.5 inch in cross section (Figure 2). In the western and deeper portion the feldspars are as much as 2 inches in diameter, and some pink feldspars (R-3439) are present as well as zones of garnet and some biotite. Both the gray color of the fresh gneiss and the whitish color of the weathered rock are modified by a green tinge imparted by ubiquitous chlorite films and by epidote granules. The presence of garnet and biotite and a coarser gneissic texture in the western portion of Loudoun Valley suggest a higher level of metamorphism than that of the eastern part; this is believed to be due to deeper location within the crust during the formation of the gneiss.

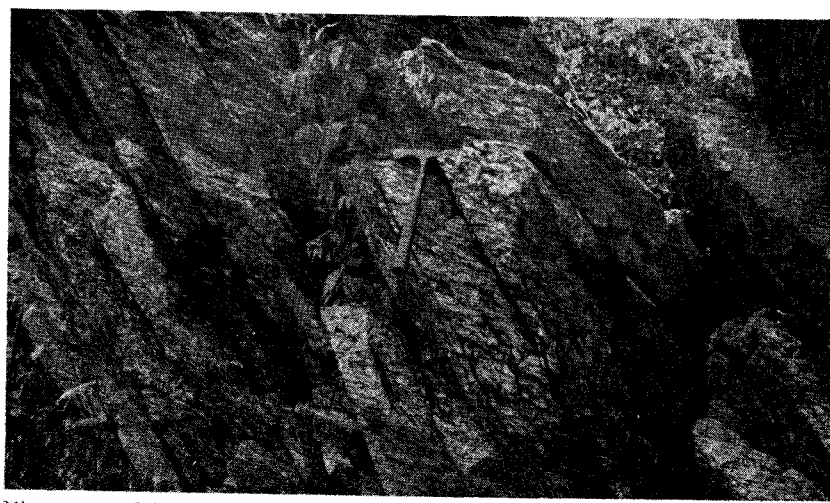

Figure 2. Marshall gneiss that has marked schistosity and lineation about 0.2 mile northwest of the junction of a farm road and State Road 725, 0.7 mile east of Silcott Spring.

Through the eastern portion of Loudoun Valley there are scattered occurrences of alaskite. All alaskite localities are deeply weathered, and relations to adjacent rock are obscured. Although sheared, the alaskite does not have a gneissic texture; therefore, it is thought to be younger than the gneiss. At one locality (Figure 3), felsite has filled narrow fractures in the Catoctin metabasalt, and this may be equivalent to the more massive alaskite intrusions.

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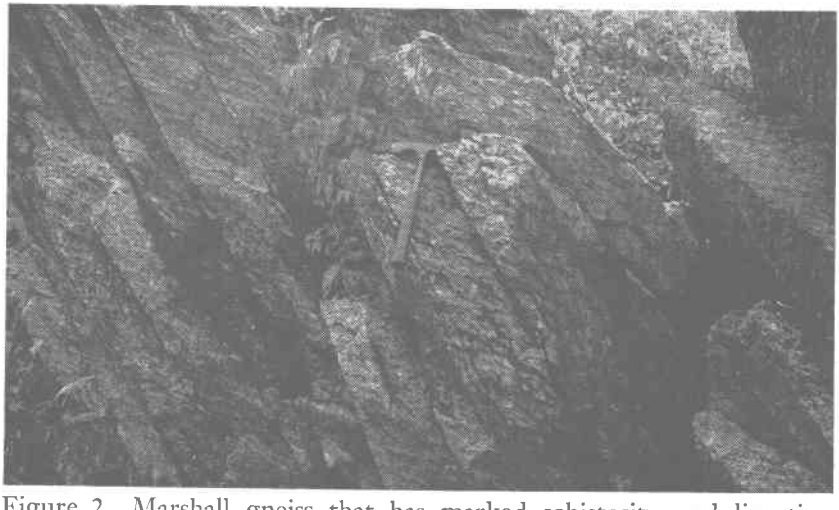

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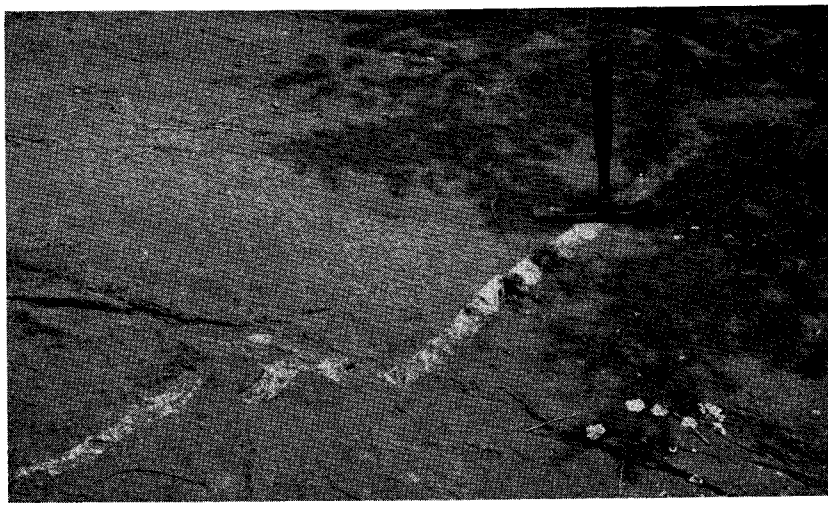

Figure 3. Felsite dike in metabasalt of the Catoctin Formation about 0.9 mile northeast of the junction of State Roads 626 and 745, 2.3 miles southeast of Unison.

Lineation in the gneiss (Figures 4, 5), which is visible as the elongation of chlorite grains as well as flattening of the feldspars, is visible in hand specimen and is present in outcrops throughout Loudoun Valley. The plane of lineation generally dips about 60 degrees to the southeast and strikes northeastward, parallel to the regional structural trends. The dip of the regional schistose cleavage is 40 to 50 degrees or less. In the southwest corner of the Bluemont quadrangle, a portion of the gneiss has lineation at about right angles to the regional trend, dipping northeastward and striking northwestward. This is possibly due to rotation of a block along a wrench fault or a fold within the gneiss. The gneiss contains an extensive vein system of blue quartz in the eastern half of the valley. These veins are numerous, and after weathering of the gneiss, residual masses of deep-blue quartz, some as much as 2 feet in diameter although generally smaller, remain in the soil. Some outcrops of the gneiss have blue quartz as a common constituent of the rock matrix, and these areas generally occur close to veins of blue quartz. This quartz is of great value in field mapping because it is restricted to the Precambrian gneisses and remains in the soil after all other vestiges of the gneiss have been obliterated. Several zones of dark, glassy, dense mylonite occur in the gneiss.

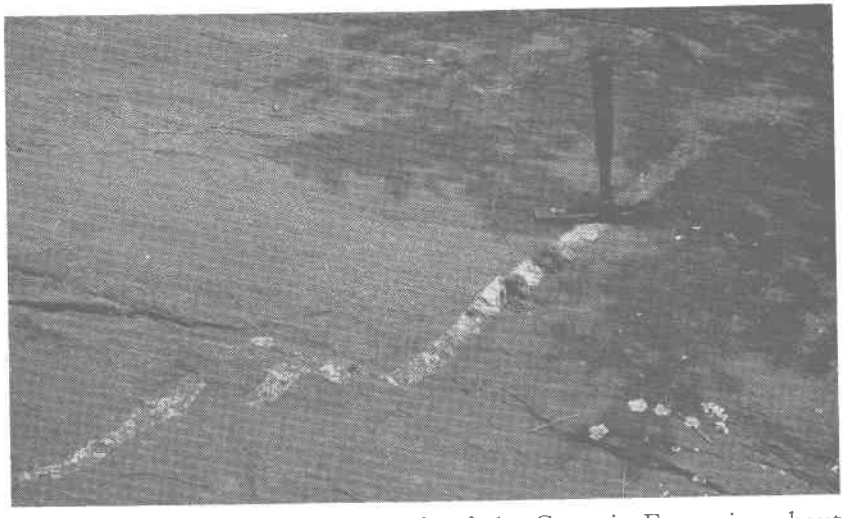

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Figure 4. Marshall gneiss that has pronounced lineation in a roadcut along State Road 734, 0.1 mile northwest of Carters Bridge.

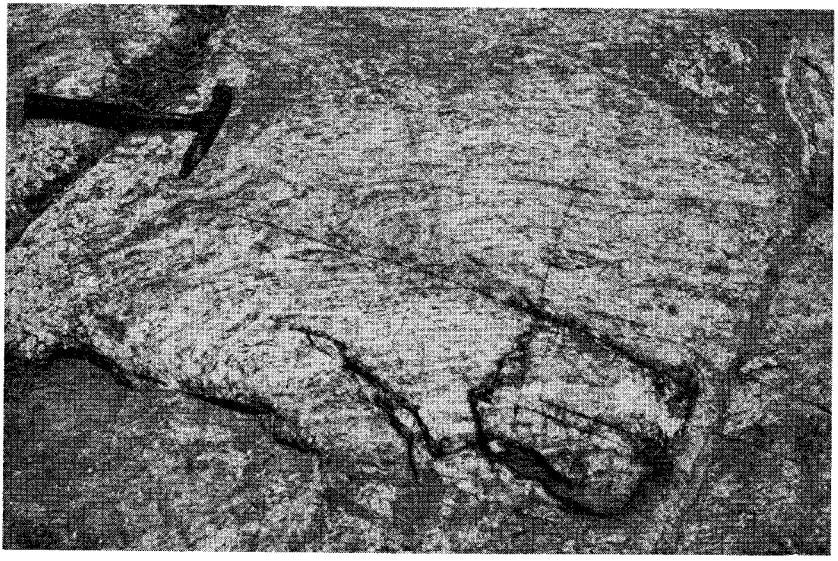
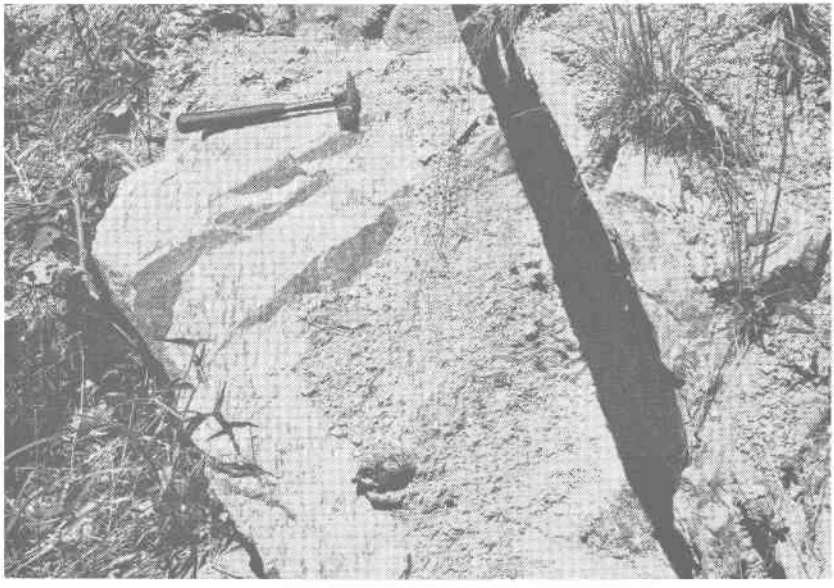


Figure 5. Marshall Formation with well-developed lineation in gneiss on the northwest side of a farm road 0.2 mile northeast of its junction with State Road 743, 2 miles northwest of Willisville.



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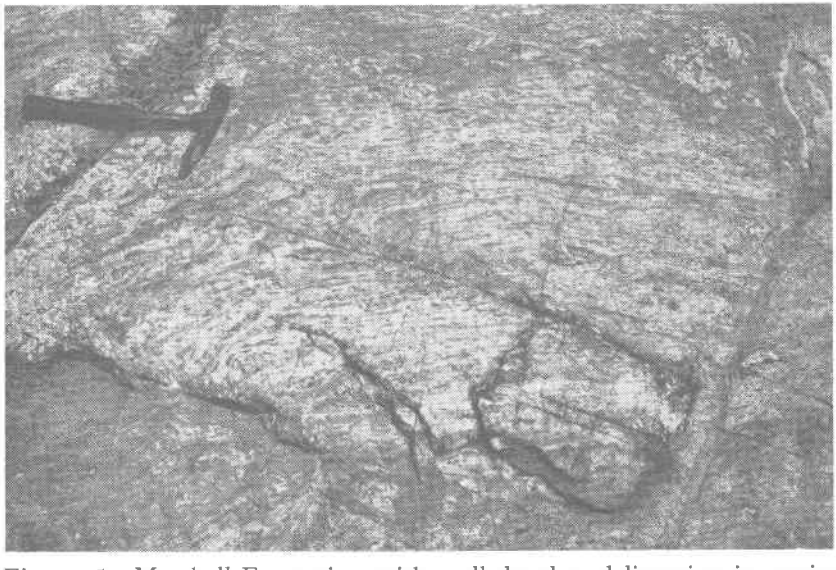

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CAMBRIAN OR PRECAMBRIAN ROCKS

Swift Run Formation

The Swift Run tuff was named by Stose and Stose (1944) for tuffaceous and arkosic sedimentary rocks that underlie Catoctin metabasalt and overlie the crystalline basement at Swift Run Gap near the crest of the Blue Ridge in Rockingham and Greene counties, Virginia. King (1950) used the term Swift Run Formation in describing this unit at Elkton, Virginia. Much earlier, Keith (1894) included slate, limestone, sandstone, and coarse conglomerates in the Loudoun Formation in northern Loudoun County. These rocks were mapped as overlying the Catoctin Formation, as well as the gneiss, because Keith believed the Catoctin to be the oldest unit in the region. In the light of more recent studies of the structure in this area, the relative position of these two formations has been reversed, thus causing some confusion regarding the use of the term Loudoun Formation. Recent workers have restricted the term Loudoun to phyllites occurring above the Catoctin, and have used Swift Run for sedimentary rocks beneath the Catoctin.

In the Lincoln and Bluemont quadrangles the base of the Swift Run Formation grades almost imperceptibly from blocks of weathered gneiss to boulder beds (Figures 6, 7) derived from the subjacent gneiss; these merge upward into cobble beds, into coarse-grained arkoses containing a few boulders, and near the top become cross-bedded, medium-grained arkoses and platy-bedded, fine-grained arkosic sandstone (Figure 8). Changes in bedding type and grain size may be abrupt or gradual, and each type tends to be lenticular and of limited lateral extent. In some areas, transitions occur from gneiss to phyllitic gneiss, to highly indurated arkosic sandstone. All phases have essentially the same grain size, mineralogy, and gray color so that it is very difficult to draw a contact between the sedimentary rocks and the gneiss from which they were derived. In many places, bands or zones of blue detrital quartz occur within the arkosic beds. The thickness of these coarse-grained and arenaceous beds is uncertain but must be at least several hundred feet in the vicinity of Mountville. Isoclinal folding succeeded by fold axial plane slippage obscures both true thickness and sequence of beds.

About 1.2 miles southwest of Mountville, along Goose Creek near State Road 731, a boulder bed (Figure 9) is exposed close to the

Figure 6. Boulder beds in the Swift Run Formation on the left bank of Goose Creek 0.4 mile northeast of Carters Bridge. Boulders of Marshall gneiss, up to 8 inches in diameter, are in an arkosic matrix. Photograph taken parallel to the plane of schistosity.

Figure 7. Boulder beds in the Swift Run Formation. Same as Figure 6 except photograph taken normal to the plane of schistosity.

Figure 6. Boulder beds in the Swift Run Formation on the left bank of Goose Creek 0.4 mile northeast of Carters Bridge. Boulders of Marshall gneiss, up to 8 inches in diameter, are in an arkosic matrix. Photograph taken parallel to the plane of schistosity.

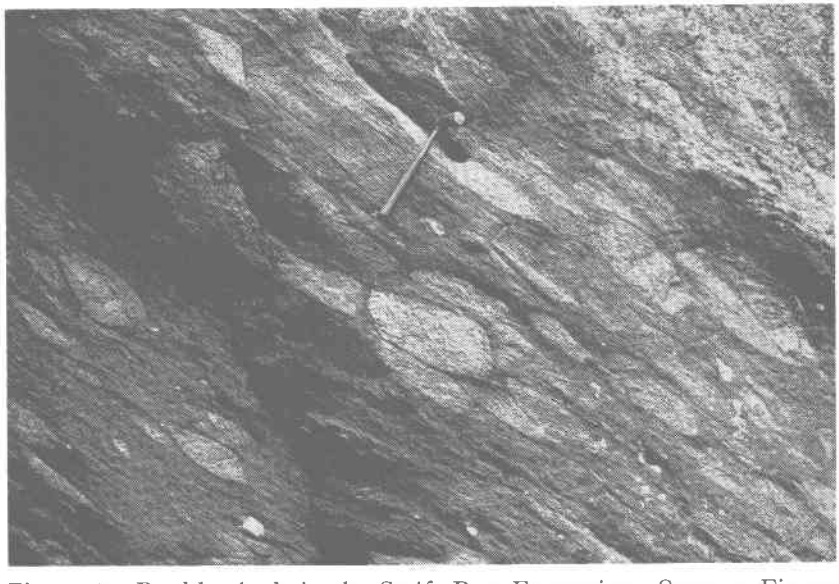

Figure 7. Boulder beds in the Swift Run Formation. Same as Figure 6 except photograph taken normal to the plane of schistosity.

Figure 8. Platy-bedded, fine-grained arkosic sandstone in the Swift Run Formation on the east side of a farm road about 0.6 mile north of its junction with State Road 734, 1.6 miles southeast of Carters Bridge.

Swift Run-Marshall contact. Subrounded boulders of gneiss, 1 to 2 feet in diameter, are sporadically distributed in an arkosic matrix; these boulders are randomly oriented with respect to the gneissic lineation. That is, the pronounced lineation of the light and dark minerals in each boulder has a different orientation. Furthermore, most of the boulders have been fractured and pulled slightly apart at one or more places. The plane of fracturing is common to all the boulders and is roughly normal to the plane of schistosity. A force acting upon the boulders similar to that which produces boudinage in hard brittle sedimentary rocks is believed to be responsible for the distention of the rock and development of parallel open clefts within individual boulders. The open clefts do not extend to the surface of the boulders and contain no infilling by arkose or secondary mineralization. Cross-bedding (Figure 10) is visible in fine-grained sandstones just above the boulder bed.

In the upper part of the Swift Run Formation there are phyllitic arkoses. These rocks, in some places light gray and shiny due to the sericite content, though more commonly dark gray with a greenish cast imparted by traces of chlorite, also contain ubiquitous blue quartz

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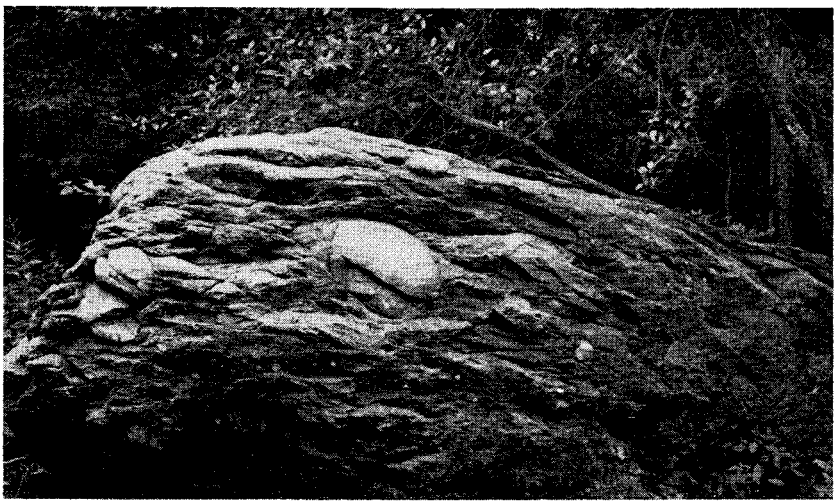

Figure 9. Boulder bed in the Swift Run Formation along Goose Creek near State Road 731, about 1.2 miles southwest of Mountville. The gneissic boulders, 1 to 2 feet in diameter, are in an arkosic matrix and contain open tension fractures.

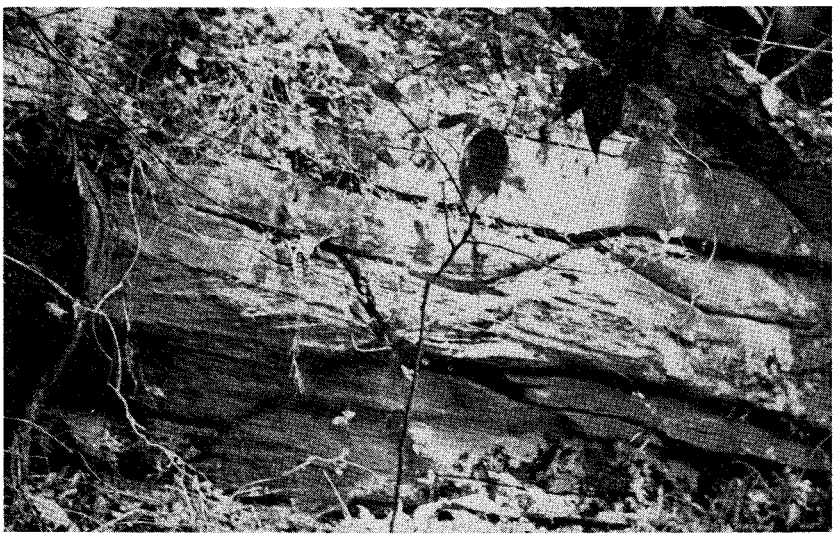

Figure 10. Cross-bedding in a fine-grained arkosic sandstone in the Swift Run Formation just above the boulder bed shown in Figure 9.

grains (R-3374) that are characteristic of the Swift Run Formation. At some places blue quartz pebbles (R-3371, R-3373), and even cobbles

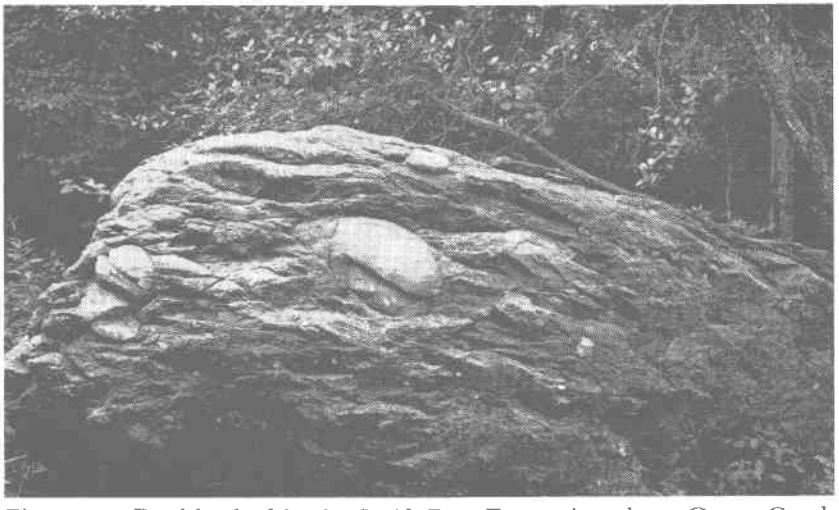

Figure 9. Boulder bed in the Swift Run Formation along Goose Creek near State Road 731, about 1.2 miles southwest of Mountville. The gneissic boulders, 1 to 2 feet in diameter, are in an arkosic matrix and contain open tension fractures.

Figure 10. Cross-bedding in a fine-grained arkosic sandstone in the Swift Run Formation just above the boulder bed shown in Figure 9.

grains (R-3374) that are characteristic of the Swift Run Formation. At some places blue quartz pebbles (R-3371, R-3373), and even cobbles

up to 6 inches in diameter, are present in the fine-grained phyllitic arkose. In the more phyllitic rocks (R-3375, R-3376), fine-grained clear quartz is present in addition to the gray and blue detrital grains. The thickest development and best outcrops of these metasedimentary rocks are in the immediate vicinity of Mountville. In many places pyrite or limonite pseudomorphs, up to 0.5 inch across, occur in the phyllite. About 1.1 miles southwest of Mountville (Plate 1) along State Road 731, a 1-foot-thick zone of phyllite (Figure 11; R-3436) contains as much as 25 percent by volume of perfect magnetite octahedra, some as large as 0.75 inch in diameter.

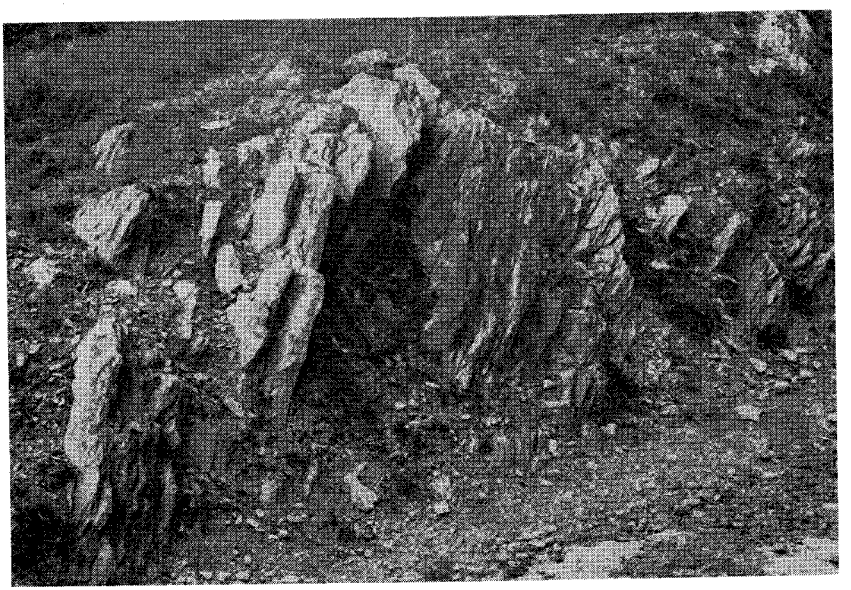

Figure 11. Phyllite in the Swift Run Formation along a farm road 0.1 mile east of its junction with State Road 731, 1.1 miles southwest of Mountville. A zone within the phyllite contains well-developed magnetite octahedra.

At the top of the phyllitic arkoses where they grade into phyllites, there is a zone of bluish-white recrystallized limestone lenses, typically a few feet thick and from 10 to 100 feet long. In some places these pods of limestone appear to be completely enclosed within the bottom layer of the Catoctin metabasalt. This appearance may be due to the fact that the limestone-phyllite contact was a particularly easy access route for the Catoctin feeder dikes or shallow sills which engulfed

up to 6 inches in diameter, are present in the fine-grained phyllitic arkose. In the more phyllitic rocks (R-3375, R-3376), fine-grained clear quartz is present in addition to the gray and blue detrital grains. The thickest development and best outcrops of these metasedimentary rocks are in the immediate vicinity of Mountville. In many places pyrite or limonite pseudomorphs, up to 0.5 inch across, occur in the phyllite. About 1.1 miles southwest of Mountville (Plate 1) along State Road 731, a 1-foot-thick zone of phyllite (Figure 11; R-3436) contains as much as 25 percent by volume of perfect magnetite octahedra, some as large as 0.75 inch in diameter.

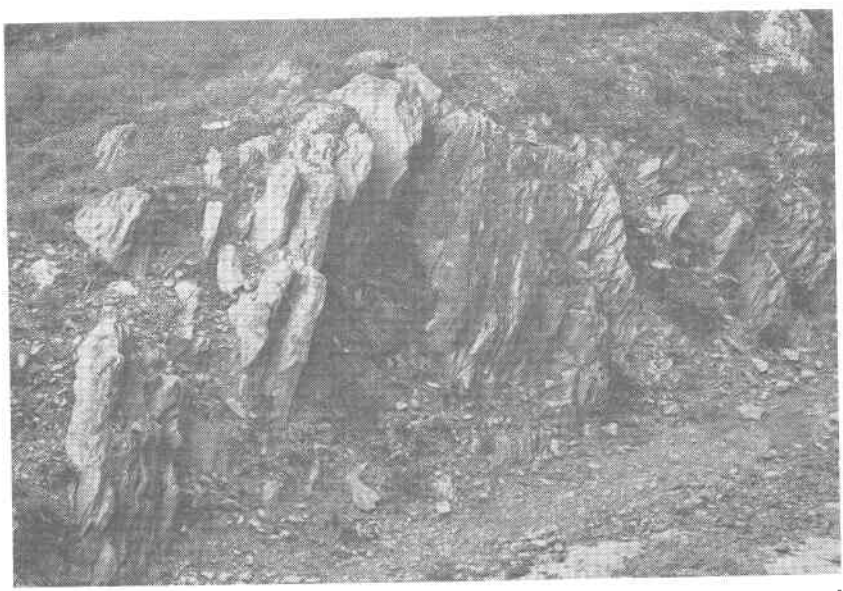

Figure 11. Phyllite in the Swift Run Formation along a farm road 0.1 mile east of its junction with State Road 731, 1.1 miles southwest of Mountville. A zone within the phyllite contains well-developed magnetite octahedra.

At the top of the phyllitic arkoses where they grade into phyllites, there is a zone of bluish-white recrystallized limestone lenses, typically a few feet thick and from 10 to 100 feet long. In some places these pods of limestone appear to be completely enclosed within the bottom layer of the Catoctin metabasalt. This appearance may be due to the fact that the limestone-phyllite contact was a particularly easy access route for the Catoctin feeder dikes or shallow sills which engulfed

the limestone; or perhaps the contact formed a plane of detachment during the period of intense folding, and the limestone was enveloped in the basalt. The limestone is present mainly along the east side of Loudoun Valley at the base of Catoctin Mountain (Figures 12, 13). Occurrences of limestone in the middle of the valley, about 0.6 mile northwest of Silcott Spring, are in a belt of phyllite along the east flank of Black Oak Ridge. At this locality, there is also a lenticular layer of cross-bedded arkose several hundred feet long and about 10 feet thick within the phyllite. It is likely that these sporadic occurrences of limestone represent the remains of a limestone bed, which now appears discontinuous because of its high solubility and the ease with which it could be mechanically incorporated into the basalt. The phyllitic beds underlie the Catoctin Formation throughout the area; and where the limestone is present, it is close to or at the Swift Run-Catoctin contact. In the belt of Swift Run at the base of the Blue Ridge along the west side of Loudoun Valley, no limestone was found, and the arkoses are much more sericitic than those in the eastern belt. In the belt extending through the middle of Loudoun Valley, phyllitic arkose predominates over the purely arenaceous phase.

Previous investigators have attributed a tuffaceous origin to these

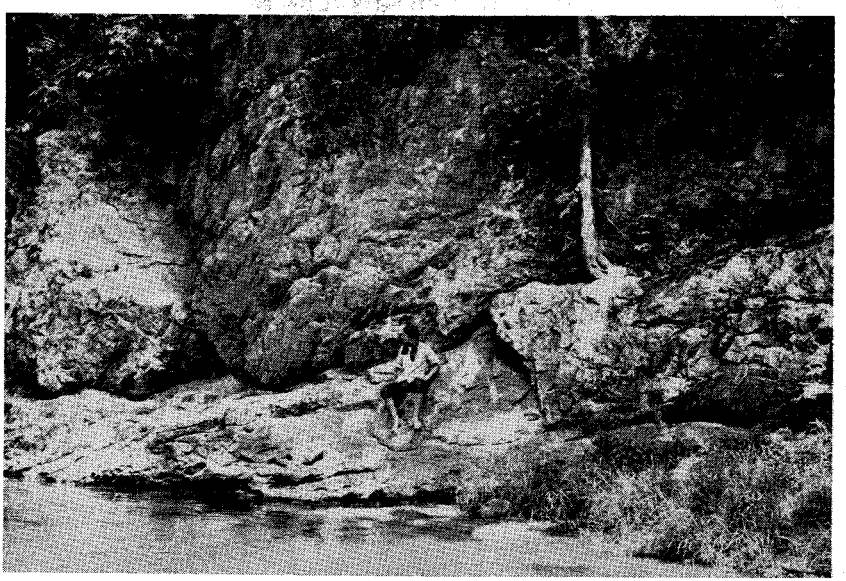

Figure 12. Limestone in the Swift Run Formation along the right bank of Goose Creek 1.25 miles east of Carters Bridge.

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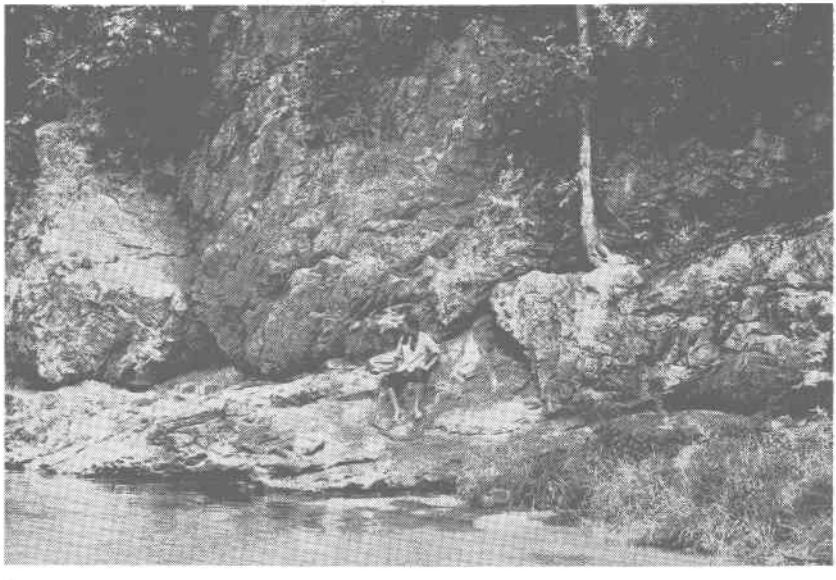

Figure 12. Limestone in the Swift Run Formation along the right bank of Goose Creek 1.25 miles east of Carters Bridge.

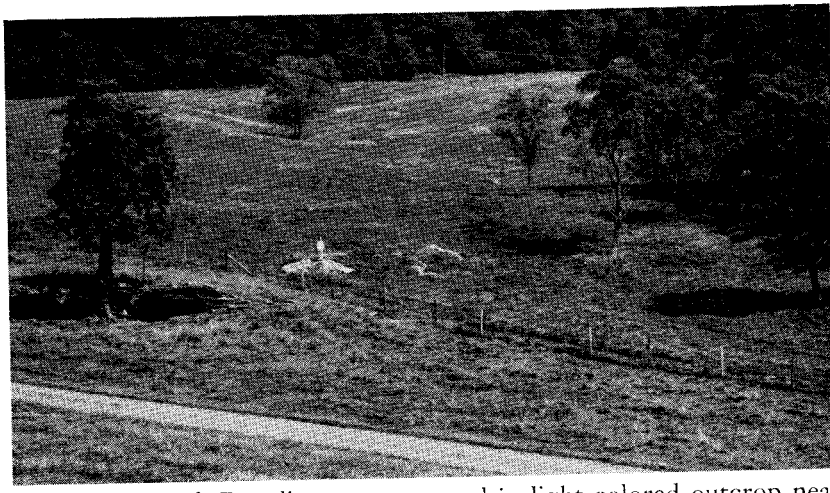

Figure 13. Swift Run limestone exposed in light-colored outcrop near center of photograph, about 1.1 miles southeast of the junction of State Roads 734 and 748, 1.4 miles southeast of Mountville.

phyllite beds, but the author believes they were formed from mud or shale without, however, ruling out the possibility that some volcanic material may have been included in them. The Swift Run Formation in this area is a sequence of sedimentary beds which is typical of a transgressive sea environment: coarse clastic materials grading upward to progressively finer and more uniform particle sizes, succeeded by colloidal-type deposits with included clastic grains, in turn succeeded by chemical precipitates. The sericite and fine-grained clear quartz are the result of metamorphism of potassic clays. The fact that the lower sandstones are only slightly deformed and cross-bedding is still preserved indicates that these beds behaved competently and that most of the movement was taken up by the kaolinitic shales that readily lent themselves to stress absorption and were consequently recrystallized.

Catoctin Formation

The Catoctin Formation, a metabasalt at the lowest stage of the greenschist facies of metamorphism (Turner and Verhoogen, 1951) and called a greenstone in the field, is the most conspicuous rock unit in this area. Three types of metabasalt are recognizable in the field: massive black metabasalt, epidosite, and chlorite phyllite. The most common type is dark gray or black with a greenish cast; it is massive in occurrence, but contains pronounced fractures that cause it to break

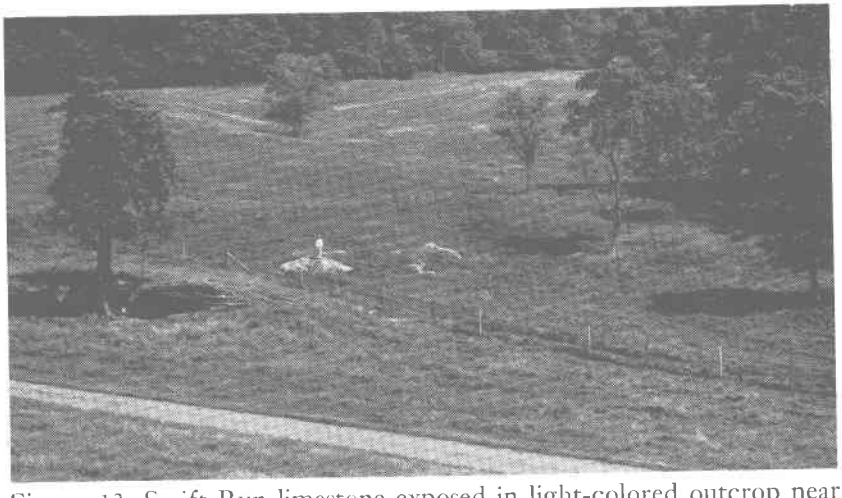

Figure 13. Swift Run limestone exposed in light-colored outcrop near center of photograph, about 1.1 miles southeast of the junction of State Roads 734 and 748, 1.4 miles southeast of Mountville.

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up into large, sharp, angular fragments. This type occurs in the extrusive portion and forms the large outcrops along the ridges; it also makes up the dikes and isolated blocks within the Marshall gneiss, where much of it is coarse textured.

The epidosite consists of nodules rich in epidote that produces a characteristic pistachio-green color in the rock. It is very resistant to both mechanical and chemical weathering. The size of these nodules ranges from a few inches up to masses tens of feet in diameter. After weathering, they tend to form cobbles and boulders strewn across the fields and abundant in the stream beds. These nodules occur in zones within the other two types but are restricted to the effusive, or lava-flow, portions of the Catoctin Formation and are not present in the intrusive portions.

The phyllitic form of the Catoctin resembles the sericite phyllite in the Swift Run Formation. However, in the Catoctin phyllite the platy mineral is chlorite which, in fresh rock, imparts a dark-green color. Where the chlorite phyllite is deeply weathered, much of the green color has been removed, and the resultant rock has a golden sheen superficially like the weathered sericite phyllites in the Swift Run Formation. The chlorite phyllites probably represent zones of maximum stress relief with the resultant mylonitization of the basalt and chlorite recrystallization. A 100-foot-thick zone of light-gray rock, a mylonitized tuff (Figure 14; R-3366, R-3368) of dacitic or andesitic composition interbedded with Catoctin phyllite, occurs in a quarry on the north side of Goose Creek along State Road 733 about 1.2 miles northwest of Oatlands (Plate 1, No. 2). This zone can be traced northeastward for a distance of 1.5 miles along regional strike.

The different types of metabasalt are expressions of varying ratios of the component minerals rather than indications of changes in the constituents themselves. A typical mineral analysis of the massive metabasalt compared to the epidosite is as follows:

	Massive Metabasalt	Epidosite
Chlorite	30%	10%
Feldspar (albite)	25%	35%
Amphibole (actinolite)	25%	20%
Epidote	10%	25%
Quartz	5%	5%
Specific gravity	2.96	3.26

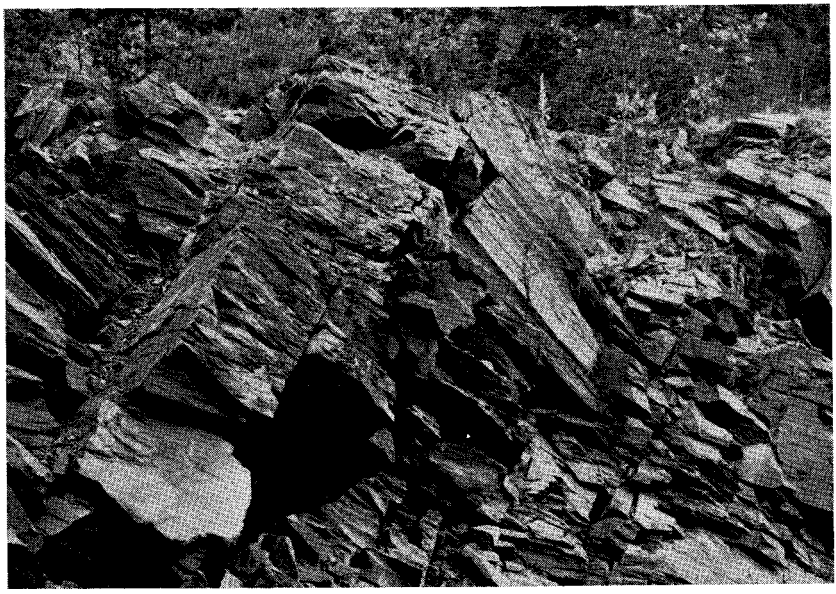


Figure 14. Tuff of dacitic or andesitic composition in the Catoctin Formation exposed in a quarry on the left bank of Goose Creek along State Road 733, 1.2 miles northwest of Oatlands.

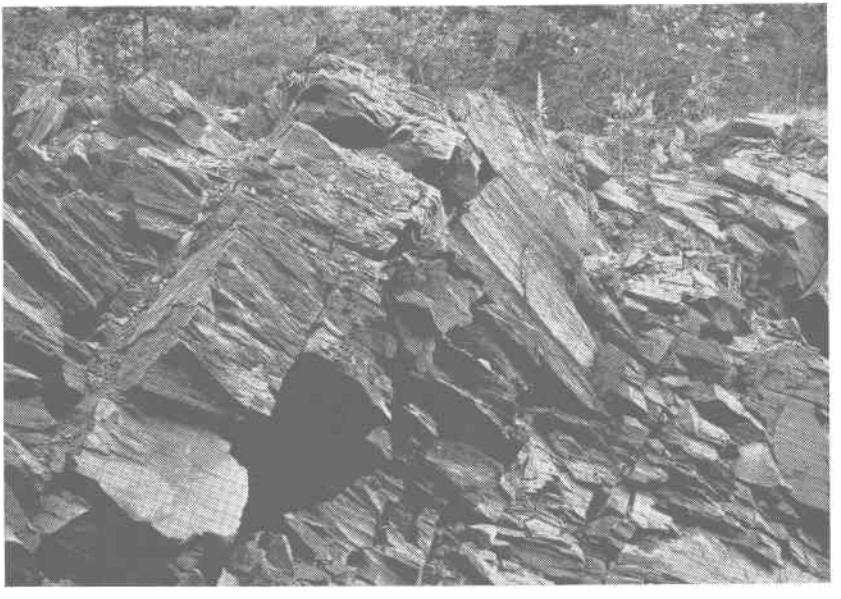
CAMBRIAN ROCKS

Weverton Formation

The Weverton Formation occurs in a narrow belt in the southeast portion of the Lincoln quadrangle where it is in contact with Triassic sedimentary rocks along the Bull Run fault and in a wider area along the northwest slope of the Blue Ridge in the Bluemont quadrangle. Throughout the area of study, the Weverton directly overlies the Catoctin Formation. Nickelsen (1956, p. 248-250) has described the Weverton in the area a few miles to the north as consisting of light-gray to dark bluish-gray quartzites with interbedded phyllites; the upper part of the formation is cross-bedded and contains conglomeratic beds. Estimated thickness of the Weverton in the Harpers Ferry area is about 500 feet.

Hampton (Harpers) Formation

The Hampton (Harpers) Formation is present in the northwestern part of the Bluemont quadrangle on the northwest flank of the Blue



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The Hampton (Harpers) Formation is present in the northwestern part of the Bluemont quadrangle on the northwest flank of the Blue

Ridge. This formation has been described by Nickelsen (1956, p. 250-251) as containing light-gray to greenish-gray phyllite interbedded with thin layers of fine-grained quartzite, some of which is calcareous. In the Harpers Ferry area, thickness of the formation is estimated to be 1500 to 2000 feet.

Erwin (Antietam) Formation

A small area that contains outcrops of Erwin (Antietam) Formation is present in the northwest corner of the Bluemont quadrangle. Nickelsen (1956, p. 251) noted that this formation is predominantly an interbedded sequence of white, fine-grained quartzite and somewhat darker silty phyllite or sericitic quartzite.

TRIASSIC ROCKS

Dikes of unaltered basalt are sporadically distributed throughout the area and intersect the Marshall, Swift Run, and Catoctin formations. They are referred to Triassic time on the assumption that they are contemporary with the extensive flows, sills, and dikes of basalt in the Newark Group which occur along the eastern margin of Catoctin Mountain. In the field, these dense black dikes vary in texture from aphanitic to diabasic, depending upon the thickness of the intrusion. In places, the basalt has intruded the Marshall gneiss along minute fractures less than an inch wide; at other sites the dikes are 50 to 100 feet wide. Some of the more conspicuous hills within Loudoun Valley owe their existence to the erosional resistance of closely spaced parallel basalt dikes, for example, an unnamed hill between the town of Lincoln and Guinea Bridge and Round Top, at the northern edge of the Bluemont quadrangle (Plate 1). This resistance to erosion is due to the fact that the basalt was intruded subsequent to the folding of the Blue Ridge-Catoctin Mountain anticlinorium, and was therefore not subject to the stresses that produced the cleavage in the older rocks. The dikes are lenticular, and cannot be traced for more than a thousand feet; however, trends can be discerned over much greater distances. Although these Triassic dikes are not shown on the geologic map, they are readily distinguished in the field from the Catoctin metabasalt by the way in which the boulders or outcrops weather. The Triassic material develops into spherical exfoliation forms, and the soil is bright red. Boulders are extremely resistant to the hammer, in contrast to the metabasalt which breaks easily along parallel cleavage planes. The dikes, which have a northeasterly trend, resulted from the filling in

of tension cracks developed by normal faulting associated with Triassic diastrophism. These faults are parallel to the plane of the cleavage axes and the similar-fold axes developed during the Paleozoic orogeny, and have southeasterly dips of about 45 degrees.

Sedimentary rocks of Triassic age, mainly sandstones and conglomerates, are present in the southeast portion of the Lincoln quadrangle. Descriptions of these rock types as they occur in the Leesburg quadrangle to the east have been given by Toewe (1966, p. 5-8).

STRUCTURAL GEOLOGY

The Blue Ridge-Catoctin Mountain anticlinorium may be envisioned as one major fold about 8 miles wide upon which is imposed a set of second-order folds 100 to 1000 feet wide, and on these still further orders of folding, each successively smaller. Initially, the folding may have begun as broad isoclinal folds brought about by gravitational sliding down the sides of a geosyncline. Subsequently, lateral compressive forces were applied from the east, resulting in an accentuation of the original folds and the development of accordion folds and overturning. This was followed by the initiation of lamellar flow with its concomitant growth of micas. Some rocks were able to compensate for the increasing pressure by recrystallization and mobilization; others of a more brittle nature were ruptured and overthrust upon them. The major folds generally strike N.20° E. as indicated by the Blue Ridge itself. Along the eastern base of the Blue Ridge, dips of the cleavage planes in the Swift Run phyllites are modified to correspond with a set of folds whose axes strike N.20° W., or about 40 degrees from the regional trend, and at one locality the lineation of the gneiss has been rotated.

Short Hill, a few miles north of the Bluemont quadrangle, was described by Nickelsen (1956) as a downdropped area containing the same sequences of rocks in the same attitudes as the Blue Ridge, and bounded on the west side by a normal fault. This fault can be traced southward into the Bluemont quadrangle where it forms the western boundary of a mass of Catoctin greenstone as far south as Black Oak Ridge. Farther southward the presence of the fault is indicated by zones of mylonite and phyllonite gneiss and a narrow elongate area of Swift Run metasedimentary rocks which extends to the southern boundary of the quadrangle. It is estimated that the dip of the fault plane may be as much as 45 degrees to the east. The effect of this fault, which is downthrown to the east, was to drop the crest of the

anticlinorium to a much lower level and move it eastward. This accounts for the preservation of narrow infolds of younger rock within the Marshall gneiss on the east side. In contrast, the area immediately west of this fault is underlain by deeper levels of the basement rock. It may be that this fault is related to the Bull Run fault which forms the boundary between the Weverton Formation and Triassic rocks in the southeast corner of the Lincoln quadrangle and extends for many miles both to the north and south. The Bull Run fault is thought to have a vertical displacement of 10,000 feet or more, and the throw of this fault appears to be of the same order of magnitude.

Although the various formations are mappable as rock units, they are a tightly folded and much distorted series of beds with greatly thickened vertical profile. It is the author's belief that the key to understanding the form in which the deformation of this sequence evolved during Paleozoic time is the Catoctin dike swarms that so completely permeated the earlier rock. During the subsequent folding, these dikes behaved as incompetent members where they were adjacent to gneiss, but as competent members where associated with some of the sedimentary rocks. The fact that the basalts were strongly folded, yet only metamorphosed to the lowest level of the greenschist stage, indicates that the rocks were subject to intense stress with little increase in temperature. It is believed that, because the mineral composition of basalt is more readily recrystallized than that of gneiss, the basalt behaved with greater mobility under stress and that the more brittle gneiss was forced into the cores of folds by means of small imbricate faults and by crushing.

In the light of the interpretation of the structure presented in this report, it may be possible to re-examine some of the areas previously mapped and find that what had been considered outliers of phyllite resting on Catoctin are, in fact, inliers of Swift Run forming the cores of anticlines with limbs of Catoctin, or in other instances, Swift Run sedimentary rocks intruded by large dikes or sills of Catoctin basalts.

GEOLOGIC HISTORY

It is thought that the Marshall Formation, the oldest unit in this area, developed by the gneissification of pre-existing sedimentary rocks and their incorporation into the basement complex. This process entailed deep burial, increased temperature, and dynamic stresses. A few outcrops on the west-central side of Loudoun Valley exhibit lit-par-lit injection and ptygmatic folding, suggesting deep burial and tempera-

tures permitting plastic deformation. Fracturing of the rock permitted intrusion of narrow pegmatites and the development of a system of blue quartz veins. In the western portion of Loudoun Valley some outcrops contain intricate, small-scale fracture systems that trend north-south and indicate small incremental right-lateral movements.

The next tectonic event raised these deep-seated rocks to the surface and exposed them to erosion. Fluviatile deposits derived from the crystalline basement filled regions of low relief. Quartz and feldspar grains from the gneiss and masses of the gneiss itself were the products of predominantly mechanical rather than chemical disintegration. The resultant gray arkosic sandstones and conglomerates that constitute the Swift Run Formation imply quick removal and burial. Thick beds of poorly sorted, coarse-grained, clastic material give way to cross-bedded sandstone and are in turn overlain by fine-grained, well-sorted platy beds of sandstone, indicating rapid encroachment of the sea. The area then subsided beneath the sea, resulting in the deposition of clastic sediments, colloidal deposits, and, ultimately, chemical precipitates in the form of marl or calcareous ooze. If deep subsidence were not involved, at least the shoreline migrated some distance away, to bring about this sedimentary progression.

The next major event occurred during this episode of subsidence of the crust and deposition of mud. Faulting, associated with the downwarping of the crust, produced cracks that permitted entry of basalt. Swarms of basalt dikes permeated the gneissic basement and overlying sedimentary rocks, filling joints and fissures opened by the tensional stresses. Sharp borders of the basalt in contact with gneiss indicate little chemical interaction. These Catoctin feeder dikes allowed tremendous volumes of basalt to flow out over the surface beneath the sea and accumulate to thicknesses estimated to be up to 1000 feet.

About a hundred feet of sediments consisting mostly of pure quartz sands, now represented by the quartzites in the Weverton Formation, were deposited on top of the lava flows. This was followed by deposition of mud, silt, and sand of the Hampton (Harpers) Formation, and then by the sand of the Erwin (Antietam) Formation. If younger Paleozoic sediments were deposited in the area, they have been removed by erosion.

Due to the extensive folding and faulting of the rocks in this area, it was not possible to ascertain whether one rock unit succeeded another without interruption or if large intervals of time occurred between periods of deposition, with possible uplift and erosion. No evidence

of unconformities was found, and the sequence of sedimentation seems normal for an encroaching sea with continuous deposition.

In late Paleozoic time, horizontal forces from the southeast produced compressional stresses in the rock units in this area. To compensate for the stresses, the more competent rocks underwent fracturing and faulting; the less competent ones were subject to flowage. The essentially horizontal stresses from the southeast produced a laminar flow to the northwest at an angle of approximately 45 degrees to the horizontal. The concordant planes of the fold axes, the schistosity, and the associated fracture system are the result of these stresses.

During Triassic time, normal faults, downthrown to the east and trending northeastward, developed in the area. Associated with this structural movement was the emplacement of numerous basalt dikes along openings caused by the tensional stresses. Basins formed along the downthrown sides of the normal faults, and clastic sediments were deposited in them.

ECONOMIC GEOLOGY

Gneiss, alaskite, greenstone, and Triassic graywacke have been quarried for road metal, although none is currently being produced. The locations of these quarries are shown on Plate 1. In earlier times, numerous small masses of Swift Run limestone were quarried, and the rock was burned for the production of lime.

White, pink, and green marble was produced at a site (Plate 1, No. 3; R-3437) located on Goose Creek 0.3 mile east of Zion Church. Some of the limestone contains minerals formed by the interaction with Catoctin basalt. Unfortunately, the site is only a few hundred feet from the bank of Goose Creek and only a few feet above the water level. These factors, combined with the irregular distribution and limited areal extent of the material, have limited its development. Quarrying operations were intermittent in the early 1900's; the most recent attempt to use the marble was made in the late 1940's to crush the rock for terrazzo, but this enterprise was not successful.

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INDEX

PAGE

Alaskite 4, 20

Beaverdam Creek 2
Black Oak Ridge 12, 17
Bluemont quadrangle 5, 15, 16, 17
Blue quartz 5, 7, 9, 10, 19
Blue Ridge 1, 12, 15, 17
Blue Ridge-Catoctin Mountain anticlinorium 2, 16, 17
Blue Ridge province 1, 3
Boudinage 8
Boulder bed 7, 8, 9, 10
Bull Run fault 15, 18

Carters Bridge 6, 8, 9, 12
Catoctin Formation 2, 3, 4, 5, 7, 11, 12, 13-15, 16, 17, 18, 19, 20
Catoctin Mountain 1, 12, 16
Cross-bedding 7, 9, 10, 12, 13

Erwin (Antietam) Formation 16, 19

Felsite 4, 5

Garnet 4
Goose Creek 1, 2, 7, 8, 10, 12, 14, 15, 20
Guinea Bridge 16

Hampton (Harpers) Formation 15-16, 19

Lime 20
Limonite 11
Lincoln 16
Lincoln quadrangle 15, 17, 18
Lit-par-lit injection 18
Loudoun Formation 3, 7
Loudoun Valley 1, 2, 3, 4, 5, 12, 16, 18, 19

PAGE

Magnetite octahedra 11
Marble 20
Marshall Formation 2, 3-6, 14, 16, 18
Mountville 7, 10, 11, 13
Mylonite 5, 17

Newark Group 16

Pegmatites 19
Piedmont province 1
Potomac River 1
Ptygmatic folding 18
Pyrite 11

Road metal 20
Round Top 16

Short Hill 17
Silcott Spring 4, 12
Swift Run Formation 2, 3, 7-13, 14, 16, 17, 18, 19, 20

Terrazzo 20
Triassic rocks 15, 16-17, 18
Tuff 14, 15

Unison 5

Valley and Ridge province 1

Weverton Formation 3, 15, 18, 19
Willisville 6

Zion Church 20

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

EXPLANATION

MESOZOIC — TRIASSIC

R̄n — Newark Group

PALEOZOIC — CAMBRIAN

€er — Erwin (Antietam) Formation

€h — Hampton (Harpers) Formation

€w — Weverton Formation

€p€c — Catoctin Formation

€p€s — Swift Run Formation; ls, recrystallized limestone

PRECAMBRIAN

p€ma — Marshall Formation

CONTACTS

exposed

approximate

FAULTS

U/D exposed

U/D approximate

U–upthrown side

D–downthrown side

FOLIATION

40 Strike and dip of foliation

QUARRIES

4 Abandoned quarry

1. Graywacke
2. Volcanic rock
3. Loudoun Marble Company
4. Goose Creek Lime Company
5. Alaskite
6. Gneiss

SAMPLE LOCALITIES

R-3437 △ Locations of samples representative of lithologies mapped.

Base from U.S. Geological Survey Topographic Maps

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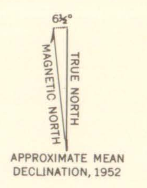
GEOLOGIC MAP OF LINCOLN AND BLUEMONT QUADRANGLES, VIRGINIA

Geology by Pierre E. Parker



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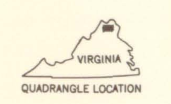
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL



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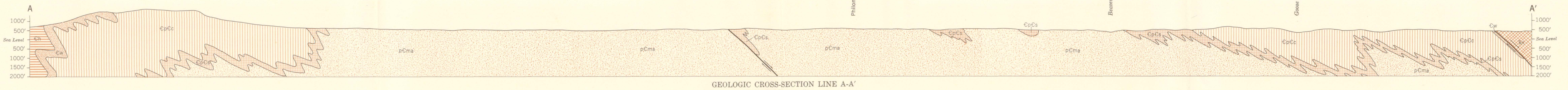

GEOLOGIC CROSS-SECTION LINE A-A'
No Vertical Exaggeration