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

GEOLOGY OF THE NATURAL BRIDGE, SUGARLOAF MOUNTAIN, BUCHANAN, AND ARNOLD VALLEY QUADRANGLES, VIRGINIA

EDGAR W. SPENCER

REPORT OF INVESTIGATIONS 13

VIRGINIA DIVISION OF MINERAL RESOURCES

James L. Calver
Commissioner of Mineral Resources and State Geologist

CHARLOTTESVILLE, VIRGINIA
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GEOLOGY OF THE NATURAL BRIDGE, SUGARLOAF MOUNTAIN, BUCHANAN, AND ARNOLD VALLEY QUADRANGLES, VIRGINIA

By

EDGAR W. SPENCER[1]

ABSTRACT

The quadrangles considered in this report are located in southwestern Rockbridge and northeastern Botetourt counties, west-central Virginia, and include portions of the Blue Ridge and Valley and Ridge physiographic provinces. Natural Bridge, a well-known scenic feature, is in the east-central part of the area.

Structural relationships are complicated by imbricate thrust sheets and faulted anticlines and synclines. Rocks of the Precambrian Virginia Blue Ridge Complex and Lower Cambrian units have been moved westward over younger formations along several thrusts, causing a narrowing of the Appalachian Valley in the vicinity of Buchanan where Precambrian and Silurian rocks are less than 2.5 miles apart. During this displacement Cambrian units were thrust westward over Ordovician strata along much of the Pulaski-Staunton fault. In the Arnold Valley area erosion of Precambrian rocks in a thrust sheet has exposed the overridden Erwin and Shady formations to produce a window-like feature. In the southwestern portion of the area, Cambrian units in the thrust sheet are present west of ridge-forming Silurian clastic rocks and Devonian shales, and the displacement is estimated to be in excess of 8 miles.

Limestone and dolomite are presently being produced for chemical, metallurgical, and agricultural uses, and also for road construction. High-calcium limestones are present in the New Market Limestone and Lincolnshire Formation. Clay of Quaternary age is being produced at one locality for use in the manufacture of brick; clay materials at other localities are potentially suitable for use in brick, tile, and lightweight aggregate. Iron and manganese ores have been mined in the past.

INTRODUCTION

The area included in this report is located in west-central Virginia in southwestern Rockbridge, northeastern Botetourt and northeastern Bedford counties (Figure 1). It is shown on the Natural Bridge

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(Plate 1), Sugarloaf Mountain (Plate 2), Buchanan (Plate 3), and Arnold Valley (Plate 4) 7.5-minute quadrangles; 1961 and 1962 topographic maps were used as bases. The area is bounded by longitudes 79°30′ and 79°45′ and by latitudes 37°30′ and 37°45′.

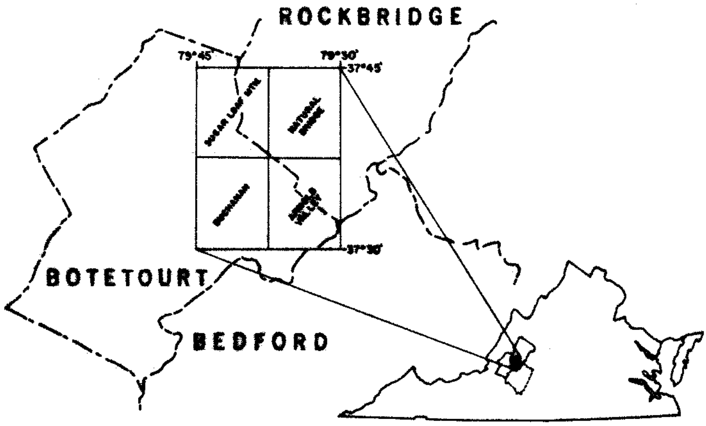


Figure 1. Index map showing locations of the Natural Bridge, Sugarloaf Mountain, Buchanan, and Arnold Valley quadrangles.

Several noteworthy studies of the geology have been made. Of these the most comprehensive is the work of H. P. Woodward (1936a), who mapped the Natural Bridge area. Included in his report are descriptions of the rock units, lists of fossil localities, numerous structure cross-sections, a comprehensive bibliography, and discussions of economic resources of the area. The classic work of Charles Butts (1940), "Geology of the Appalachian Valley in Virginia," includes rock-unit descriptions, measured sections, and discussions of the physiography, structure, and resources of the Natural Bridge area. More recently Edmundson (1958) discussed the industrial limestones and dolomites and prepared descriptions of several measured sections. R. B. Leonard (1962) has studied portions of the area along the Blue Ridge front in Arnold Valley.

Numbers preceded by "R" in parentheses (R-3254) correspond to sample localities on Plates 1, 3, and 4. These samples are on file in the repository of the Virginia Division of Mineral Resources where they are available for examination.

The kind consideration of the property owners in this area who allowed freedom of access to outcrops is greatly appreciated. The author is indebted to Dr. H. P. Woodward who provided field notes and sketch maps made of the region in 1929-30. Dr. S. J. Kozak and

Dr. Odell S. McGuire were most helpful in discussions and on field trips in the area. Thanks are extended to my students at Washington and Lee University, James Head, Sherwood W. Wise, Jr., John Waters, Stephen Hancock, Harry Brookby, and Andrew Raring who assisted in the field work.

PHYSIOGRAPHY

The area of study includes portions of the Blue Ridge and Valley and Ridge physiographic provinces. In this area the Blue Ridge has a maximum elevation of 4225 feet at Apple Orchard Mountain (Plate 4), and the lowest elevation, less than 720 feet, is along the James River near Natural Bridge Station (Plate 4). A dendritic drainage pattern is developed on the Precambrian Virginia Blue Ridge Complex, but distinct linear ridges are present along the mountain front where the Lower Cambrian units are exposed. Arnold Valley, which is in both provinces, is a window, or fenster, where younger rocks are surrounded by older ones.

The Appalachian Valley is unusually narrow in the Buchanan area (Plate 3); it is less than 1 mile wide near the southward projection of Purgatory Mountain. The Valley is developed on Cambrian and Ordovician rocks that are folded and thrust faulted; those west of Purgatory Mountain are part of a major thrust sheet. The Valley has rolling topography and a modified trellis drainage system in the northeast portion. The James River flows southeastward around Purgatory Mountain and from there northeastward toward Natural Bridge Station. Prominent meander loops are developed on the James River in the western portion of the Buchanan quadrangle (Plate 3). Short Hills and Camp Mountain are excellent examples of synclinal mountains. Purgatory Mountain is a southward-plunging anticline, one of the rare examples of an anticlinal mountain in this area. All of the remaining ridges are structurally complex.

NATURAL BRIDGE

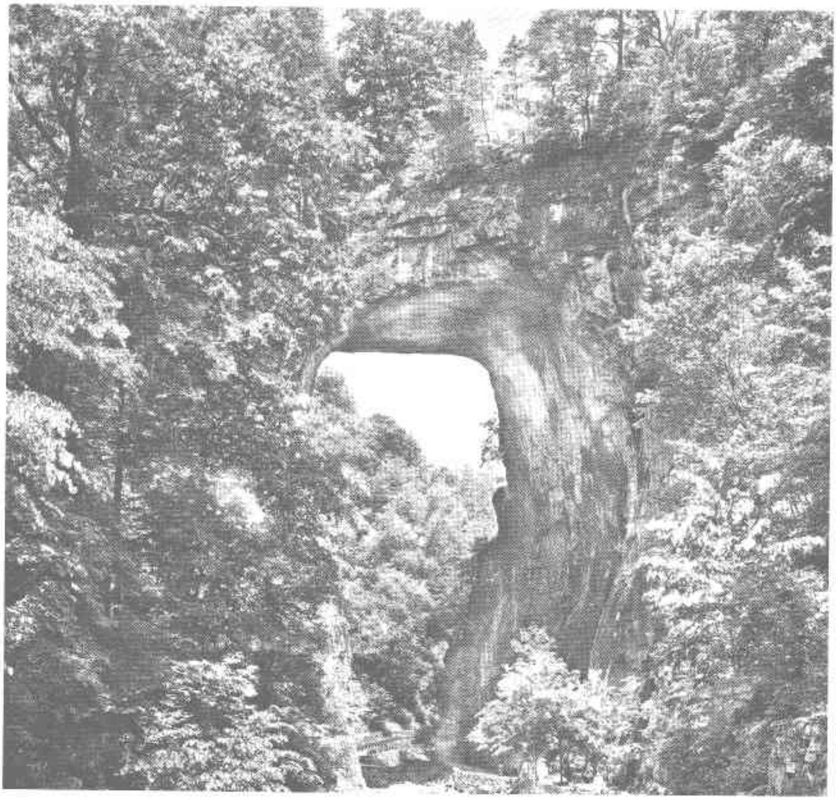
The most notable feature of geomorphic interest is Natural Bridge (Figure 2). It is located beneath U. S. Highway 11 where the highway is over Cedar Creek (Plate 1). The bridge is composed of massively bedded light-gray arenaceous dolomite, probably the lowest beds of the Beekmantown Formation, and dark-blue limestone of the Chepultepec Formation. The arch has a minimum thickness of 45 feet, ranges in width from approximately 50 to 150 feet, and is about 90 feet long. The top of the arch is approximately 190 feet above Cedar Creek.

Cedar Creek is entrenched from its mouth at the James River near Gilmore Mills for a distance of about 4 miles upstream to Red Mills.

Photograph courtesy of the Virginia State Chamber of Commerce.

Figure 2. Natural Bridge, located beneath U. S. Highway 11 where it crosses Cedar Creek (Plate 1). The arch, composed of light-gray dolomite and dark-blue limestone, is about 90 feet long and approximately 190 feet above Cedar Creek.

Upstream from Red Mills the main stream and its tributaries flow in broad open valleys. Two of these tributaries, which occupy northeast-southwest trending valleys on either side of Cedar Creek, enter it near Red Mills. The valleys of these tributaries are in line with the valley of Poague Run that flows northeastward near Interstate Highway 81. It is likely that the upper portion of Cedar Creek was at one time a part of Poague Run. The drainage pattern in the area is shown on Figure 3. Cedar Creek is entrenched at a level well below the valley of Cascade Creek in which U. S. Highway 11 is located. Cascade Creek drops rapidly from the main portion of its valley in a series of cascades and waterfalls and enters Cedar Creek just below Natural Bridge.



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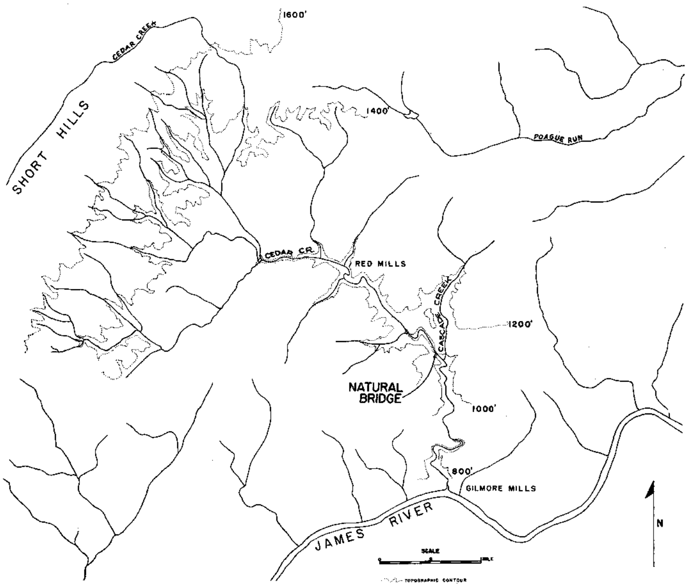

Figure 3. Map illustrating drainage pattern in the vicinity of Natural Bridge.

The rock units in the vicinity of the bridge are nearly horizontal because they are in the trough of a broad, open syncline. However, about 100 yards west of the bridge along U. S. Highway 11 the rocks are folded sharply, becoming vertical and then overturned. All of the rock units are fractured, and there are a number of small faults.

Spencer (1964) has presented a historic account of the development of ideas concerning the origin of Natural Bridge. Woodward (1936b) and Wright (1934) advanced the theory that Natural Bridge is the remnant of the roof of an underground channel that diverted the waters of the upper portion of Poague Run into Cascade Creek, thereby forming present Cedar Creek. The addition of these waters to the volume of the creek enabled it to more deeply incise its course, while the roof of the former conduit largely disintegrated and collapsed through erosion and weathering. Gradually the obvious elements of the underground channel disappeared until, at the present time, only the span of Natural Bridge preserves a portion of the original roof.

Prior to the formation of the bridge, the upper portion of the drainage of modern-day Cedar Creek was carried by Poague Run to the northeast parallel to the regional strike of the rock units. The lower portion of modern Cedar Creek was then part of Cascade Creek, presently a small tributary which flows into Cedar Creek just below the bridge. Cascade Creek flowed down a steep slope, and because of its high gradient it was able to erode rapidly in a headward direction. Eventually the head of Cascade Creek reached the course of Poague Run, the valley of which was much more deeply incised. At this time diversion of water from Poague Run through an underground passage started. This diversion was aided by the southeasterly regional dip of the strata, the existence of fractures in the limestones and dolomites, and the difference in the degree of entrenchment of the two major streams. These underground waters emerged into the valley of Cascade Creek near the vicinity of the bridge. Because the roof of this tunnel was thicker in a downstream direction, that portion was stronger and has more effectively resisted erosion and collapse; and it remains as the present-day Natural Bridge.

STRATIGRAPHY

PRECAMBRIAN ROCKS

Virginia Blue Ridge Complex

Exposures of Precambrian rocks occur southeast of the Blue Ridge front and southwest of Arnold Valley and Cave Mountain (Plate 4). The best exposures are located along the road south of Cave Mountain Lake and in roadcuts along the Blue Ridge Parkway (R-3243). Deep residual soil covers large areas of the Blue Ridge, and fresh rock is generally difficult to find. Woodward (1936a) distinguished the Marshall granite from the hypersthene granodiorite. This granodiorite and associated rocks were called Pedlar Formation by Bloomer and Werner (1955). The Pedlar includes granodiorite, syenite, quartz diorite, granite, and large amounts of hypersthene granodiorite (Table 1). All of these Precambrian rocks are part of the Virginia Blue Ridge Complex.

Table 1.—Geologic formations in the area of study.

Age	*Name*	*Description*	*Estimated Thickness in Feet*
Quaternary	Alluvium	Recent stream deposits and some terrace gravel and colluvium.	
Paleozoic	Ultramafic rock	Stock-like mass of weathered olivine-mica rock, peridotite(?).	
Devonian	Brallier Formation	Olive-gray shale interbedded with gray sandstone.	1500–2000

Age	*Name*	*Description*	*Estimated Thickness in Feet*
Devonian	Millboro Shale and Needmore Formation	Millboro Shale—black, fissile, thin-bedded; Needmore Formation—olive-gray shale.	1000–1500
	Lower Devonian and Upper Silurian rocks	Coarse-grained sandstone—calcareous and ferruginous, with a few conglomerate beds; Tonoloway Formation—dark-gray limestone, thin-bedded; Keefer Sandstone—white, fine- to medium-grained, some reddish iron oxide stain, with a few conglomerate beds, about 200 to 300 feet thick.	300–600
Silurian	Cacapon Formation	Maroon hematitic sandstone; shale; and a few white sandstone layers.	200–300
	Tuscarora Formation	White to gray, massive sandstone, and pebble conglomerate. Map unit includes gray and reddish-gray, medium-grained, cross-bedded sandstone with pebbles (Juniata and Oswego formations?).	100–250
Ordovician	Martinsburg Formation	Green and brown fissile shale and sandstone; gray fossiliferous limestones interbedded with shale occur at base, and thin sandstone layers interbedded with shale near top.	1000–2000
	Edinburg Formation	Black limestone interbedded with shale (Liberty Hall); massive black limestone and nodular limestone (Lantz Mills); and massive, coarse-grained, blue-gray limestone with reddish cast to weathered surfaces (Botetourt Member).	500–1000
	Lincolnshire Formation	Massive, coarse-grained, light-gray fossiliferous limestone (Murat); thin-bedded, dark-gray limestone with stringers of black chert.	200–400

Age	*Name*	*Description*	*Estimated Thickness in Feet*
Ordovician	New Market Limestone	Massive, fine-grained, dove-gray limestone.	0–160
	Beekmantown Formation	Light- to medium-gray dolomite with interbedded dove-gray and dark-blue limestones near the base and top, and some massive white chert beds.	1500
	Chepultepec Formation	Thin-bedded to massive bluish-gray limestone with layers of magnesian limestone and massive light-gray dolomite.	300–500
Cambrian	Conococheague Formation	Thin-bedded blue-gray limestone with some sandstones and massive light-gray dolomite.	2000
	Elbrook Formation	Thin-bedded platy dolomite with slabby weathered surfaces; thin-bedded, dark-blue limestone; thin-bedded white limestone; and shale.	1000–2000
	Rome Formation	Maroon, buff, and green shales, and massive limestone.	1000–1500
	Shady Formation	Massive finely laminated whitish and blue dolomite with massive limestone and thin sandy dolomite near base.	1000–1500
	Erwin Formation	Thin-bedded to massive buff and blue-gray to white sandstone and quartzite with a few thin beds of shale.	400–600
	Hampton Formation and Unicoi Formation	Hampton Formation—laminated shale, graywacke, and quartzite; Unicoi Formation—graywacke, sandstone, and pebble conglomerate with a few tuffaceous beds.	1000–1500
Precambrian	Virginia Blue Ridge Complex	Pedlar Formation—granite, hypersthene granodiorite, diorite, and unakite; Marshall Formation—biotite granite.	

CAMBRIAN SYSTEM

Unicoi Formation

The Unicoi Formation (Campbell, 1899) is described as ranging from a few hundred to a thousand feet of volcanic rocks, intergradational conglomerate graywackes, pebbly arkoses, and pebbly quartzites (Bloomer and Werner, 1955). The best exposures occur along State Highway 43 southeast of Buchanan (R-3244), in Gilmore Hollow, along State Road 790 north of Cave Mountain, and along State Road 614 east of Arcadia (Plate 4). In the contact zone with the underlying Precambrian rocks there is generally a saprolite, and in some places a conglomeratic layer of variable thickness containing rounded fragments of crystalline rocks is present. The volcanic rocks consist of reddish tuffs and some greenstones which are reported to be 4 to 30 feet thick near the base of the formation. The upper part of the Unicoi is predominantly subgraywacke with lenses of greenish pebbly quartzite ranging in thickness from 4 to 50 feet. The upper contact is placed at the top of the uppermost pebble conglomerate (Bloomer and Werner, 1955). The quartzite ranges from 1 to 50 feet in thickness.

Hampton Formation

The Hampton Formation (Campbell, 1899) consists of from several hundred to more than a thousand feet of fine-grained subgraywacke (R-3245) interbedded irregularly with quartzite (Bloomer and Werner, 1955). In the James River gorge there are three quartzite members, each 25 to 50 feet thick; the lowest of these contains *Scolithus* near Snowden (Bloomer and Werner, 1955). The subgraywacke in both the Hampton and Unicoi is "gray or green, thin-bedded, locally laminated siltstone consisting of subrounded and angular grains in a fine-grained, micaceous matrix. . . ." (Bloomer and Werner, 1955, p. 596).

In this report the Unicoi and Hampton formations have been mapped as one unit (Plates 3, 4). The contact between these formations is difficult to recognize. Bloomer and Werner (1955) placed the contact at the first pebbly conglomerate that in places is a 1-foot-thick quartzite in a sequence of up to a thousand feet of subgraywacke interbedded with quartzite lenses of variable thickness. Exposures are discontinuous and at many localities the units are complexly folded and faulted. Many of the beds within the Hampton and Unicoi are lenticular, and a complex interfingering of lithologies occurs laterally. The contact between the Erwin and the Hampton is drawn at the base of the lowest massive bed of quartzite in the Erwin.

Erwin (Antietam) Formation

The Antietam was first described by Keith (Williams and Clark, 1893); this name is applied to the thick clastic section immediately below the Shady Formation to the north of the area studied, whereas the name Erwin (Campbell, 1899) is applied to the arenaceous rocks in the same stratigraphic position to the south; it appears likely that a distinct transition does occur. The Antietam at Balcony Falls (Buena Vista quadrangle) is about 600 feet thick and is composed largely of massive beds of sandstone and orthoquartzite containing clean, well-rounded sand. These bluish-gray beds are generally cross bedded and contain abundant *Scolithus*. The clean, well-sorted sands and the cross-bedding suggest a reworked deposit. Along State Highway 43 southeast of Buchanan (Plate 3), the unit mapped as Erwin (R-3246) is quite different from that at Balcony Falls. Bedding is thinner (Figure 4), the sand is less well-sorted, there are abundant interbeds of shale, there are very few *Scolithus,* and the sands are not clean. Woodward (1936a) reported this section as being 845 feet thick.

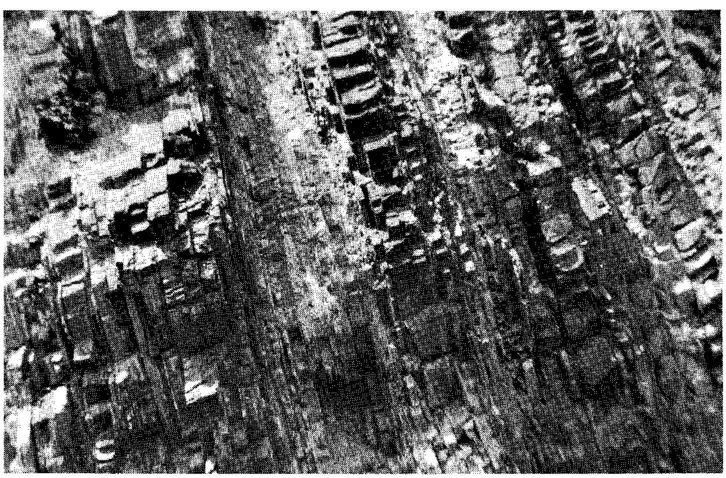

Figure 4. Erwin Formation exposed along State Highway 43 southeast of Buchanan (Plate 3). The unit consists of thin- to medium-bedded sandstone, shale, and quartzite.

The contact between the Erwin (Antietam) and Hampton formations is transitional at every locality examined by the writer; these may be seen at Balcony Falls, Gilmore Hollow, Arcadia, and Bearwallow Creek. The massive white to bluish-gray quartzites are interbedded with thinly laminated sandstones, sandy shales, or siltstones in the contact zones at these localities.

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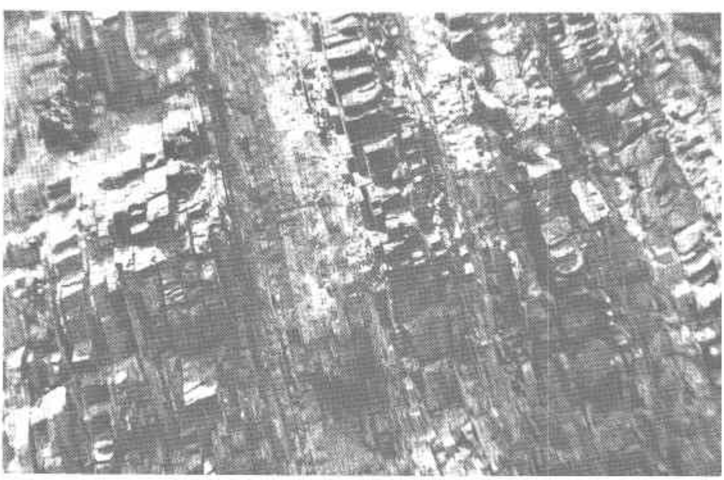

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Shady Formation

Exposures of the Shady Formation are located primarily along the James River. The best of these are located in the cuts along the Chesapeake and Ohio Railway at Natural Bridge Station; on the south side of the James River, 0.5 mile south of Gilmore Mills; on the south side of the James River about 1 mile east of Rocky Point; on the north side of the James River, 2 miles southwest of the mouth of Sprouts Run; 0.5 mile north of Dillon (R-3247); and in the quarry face at the Liberty Limestone Corporation quarry just east of Buchanan. Edmundson (1958, p. 79-81) has described sections that include parts of the Shady.

The Shady Formation (Keith, 1903) is approximately 1200 feet thick. The lower contact is not exposed in this area; the unit is conformable with the overlying Rome Formation. The dolomite is generally dark blue and impure; a distinctive, whitish, fine- to medium-grained dolomite that occurs in no other part of the section occurs near the middle of the formation. In many places the unit is finely

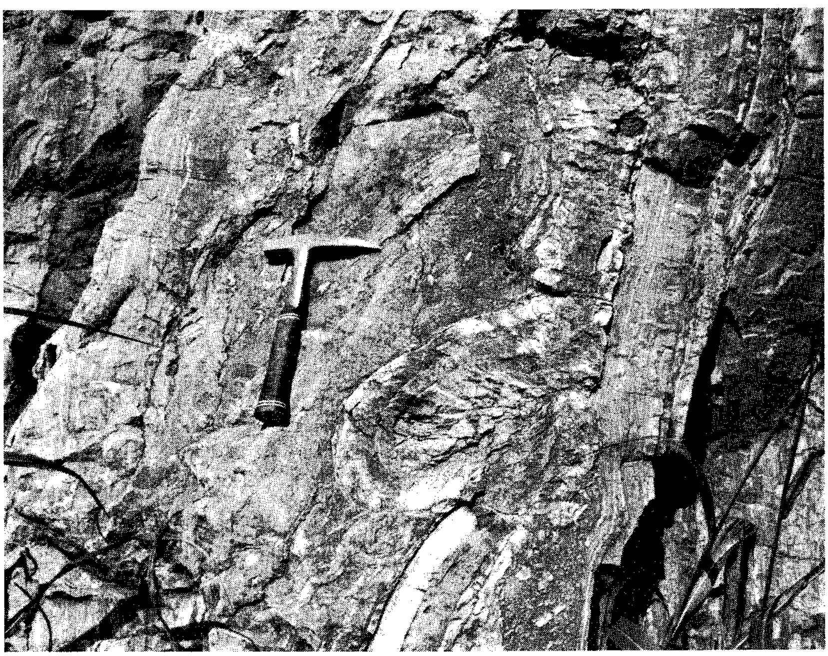

Figure 5. Finely laminated dolomite in the Shady Formation along the Chesapeake and Ohio Railway 0.6 mile east of Buchanan (Plate 3). Beds above and below this zone of intraformational deformation are not brecciated or folded.

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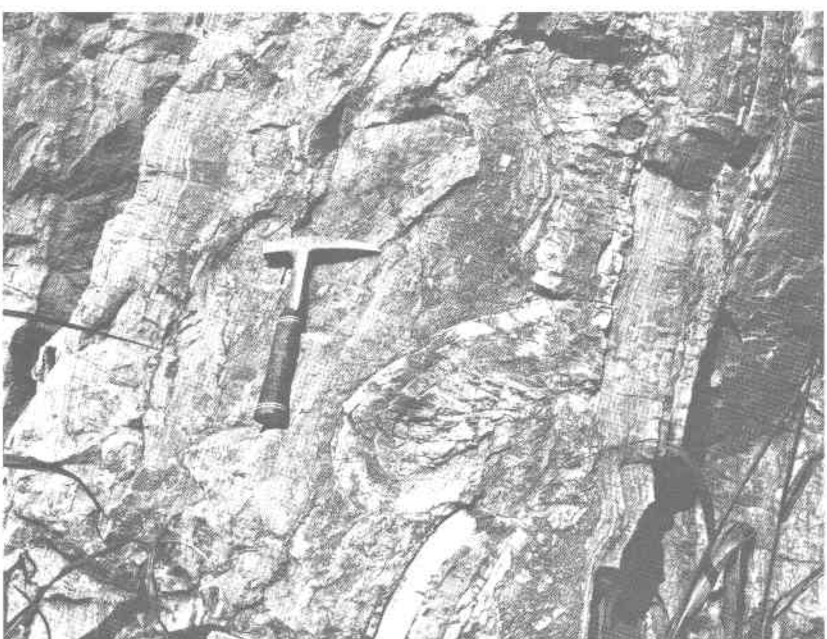

Figure 5. Finely laminated dolomite in the Shady Formation along the Chesapeake and Ohio Railway 0.6 mile east of Buchanan (Plate 3). Beds above and below this zone of intraformational deformation are not brecciated or folded.

laminated (Figure 5), but it generally forms massive ledges; in some exposures bedding is very difficult to determine. Black chert stringers are common in some of the dolomites.

Rome Formation

The outcrop width of the Rome Formation ranges from 0.5 to nearly 2 miles. The James River meanders across these outcrops exposing the Rome. Good exposures occur along roads and railroad cuts in the James River valley (Figure 6). The best exposed sections are located near Gilmore Mills (R-1724, R-3248), 0.5 mile south of Rocky Point, and 0.5 mile east of Buchanan (Figure 7); at this last location Butts (1940, p. 61) described 1886 feet of Rome. Edmundson (1958, p. 80) described part of the Rome (Waynesboro) 0.25 mile west of Natural Bridge Station. The Rome Formation (Hayes, 1891) is a heterogeneous unit composed of red, purple, green, and gray shale

Figure 6. Interbedded red and tan to buff shales and siltstones in the Rome Formation exposed along the James River 0.25 mile southeast of Indian Rock (Plate 3).

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(Figure 8) with some impure limestone, dolomite, and a few layers of sandstone. Thickness measurements vary considerably. Woodward (1936a) reported a thickness of 1093 feet near Natural Bridge Station, and Campbell (1882) reported a thickness of 1800 feet near Natural Bridge.

The lower and upper contacts of this unit are both conformable and transitional in character. The lower contact was selected at the first prominent shale above the dominantly dolomitic units of the

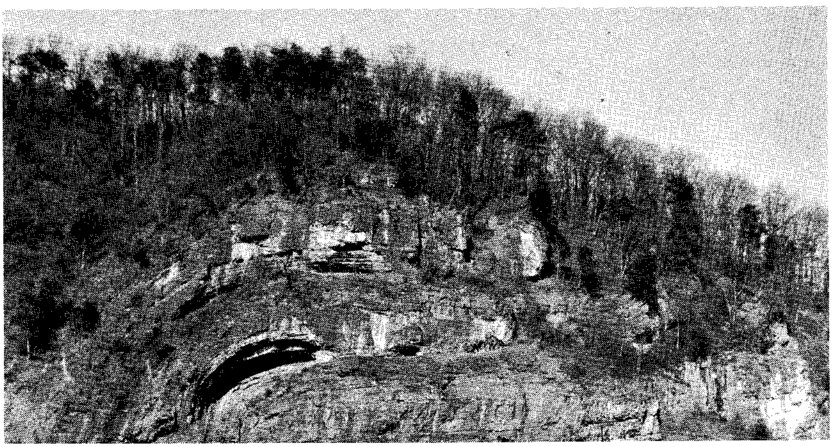

Figure 7. Flexure in the Rome (above and to left of cave) and Shady formations, 0.5 mile east of Buchanan (Plate 3).

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Shady Formation and the upper contact, at the uppermost occurrence of prominent dark-red or purple shales up to 15 feet thick. Thin layers of reddish and greenish shale occur in the overlying Elbrook, but most of the red shales in the Elbrook are pink or light red, not the characteristic deep maroon-red or purple of the Rome Formation. The dolomites of the Rome are in part similar to some of those in the Elbrook and the Shady. Dolomitic limestones with an unusual mottled texture (Figure 9) are in the Rome and Shady, but in no other formations.

Figure 9. Mottled dolomitic limestone typical of the Rome Formation, exposed 0.25 mile southeast of Indian Rock (Plate 3).

Elbrook Formation

The Elbrook Formation (Stose, 1906) is exposed extensively in the area mapped, but no section is adequate for stratigraphic studies because of the complex internal structure that includes overturned folds, bedding faults, tectonic inclusions, isoclinal folds, (Figures 10, 11), brecciated dolomites, and mylonites. The Elbrook lies on the overthrust side of the Pulaski-Staunton fault throughout most of the area mapped. The best exposures are located along State Road 622 between Rocky Point and U. S. Highway 11 (Plate 4), along the upper part of the northwest tributary of Big Hollow Branch (Plate 4), and along State Highway 130 between U. S. Highway 11 and Natural Bridge

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Figure 9. Mottled dolomitic limestone typical of the Rome Formation, exposed 0.25 mile southeast of Indian Rock (Plate 3).

Elbrook Formation

The Elbrook Formation (Stose, 1906) is exposed extensively in the area mapped, but no section is adequate for stratigraphic studies because of the complex internal structure that includes overturned folds, bedding faults, tectonic inclusions, isoclinal folds, (Figures 10, 11), brecciated dolomites, and mylonites. The Elbrook lies on the overthrust side of the Pulaski-Staunton fault throughout most of the area mapped. The best exposures are located along State Road 622 between Rocky Point and U. S. Highway 11 (Plate 4), along the upper part of the northwest tributary of Big Hollow Branch (Plate 4), and along State Highway 130 between U. S. Highway 11 and Natural Bridge

Station (Plate 1). Excellent, but faulted, exposures occur south of Saltpetre Cave along the Chesapeake and Ohio Railway and along State Highway 43 about 0.6 mile southwest of Rich Hill (Plate 3). Edmundson (1958, p. 105) described part (1347 feet) of a section of Elbrook near Indian Rock (Plate 3).

The formation is composed of shaly dolomite, thin-bedded shaly limestone (R-3250), some massive dark-gray, medium-grained limestone, and green sericitic shales. Some of the dolomites resemble the light-gray, medium-grained dolomites in the overlying units, but there are, in addition, some dark-gray dolomites that are thin bedded and

Figure 10. Isoclinal folds in shaly dolomite of the Elbrook Formation along State Road 622, 0.25 mile north of Rocky Point (Plate 4).

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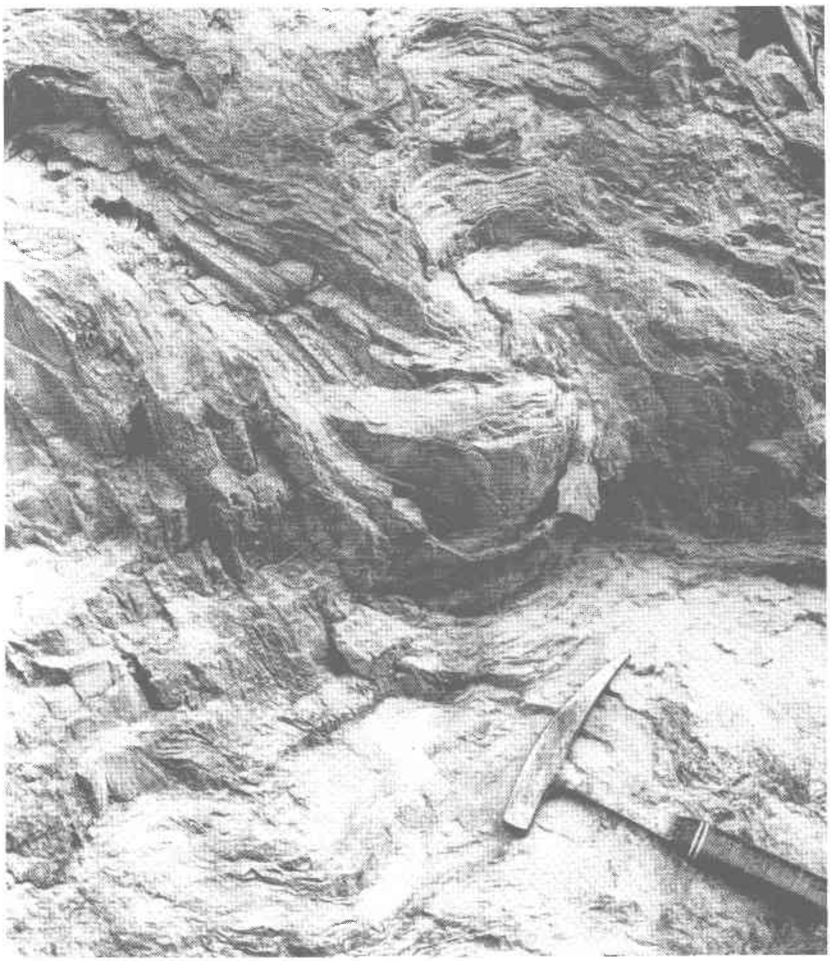

Figure 10. Isoclinal folds in shaly dolomite of the Elbrook Formation along State Road 622, 0.25 mile north of Rocky Point (Plate 4).

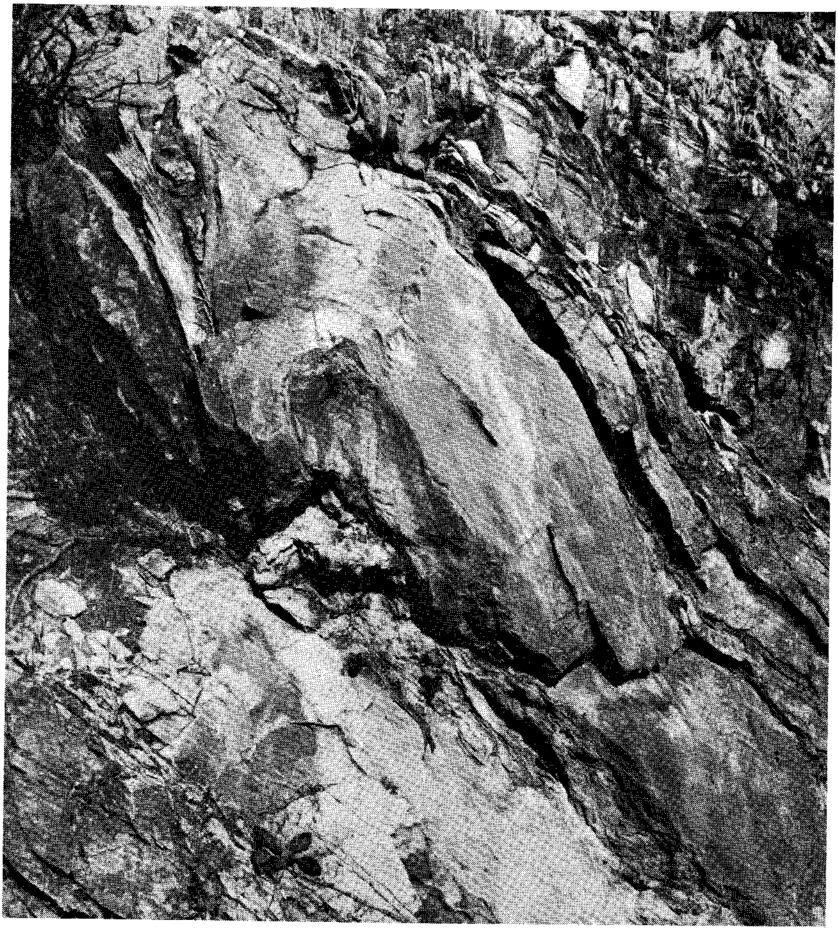

Figure 11. Fold hinge in blue limestone of the Elbrook Formation located just east of Indian Rock (Plate 3). The fold has been sheared off and moved along bedding.

weather to form massive ledges several feet thick. They are darker in color than those found higher in the section, and in some exposures are brecciated and contain secondary calcite (R-3251). Black chert occurs in some beds. A ridge just southeast of Springfield and just east of the Pulaski-Staunton fault trace (Plate 4) is covered by float of white chert that is in part oolitic. This lithology may represent a residuum left after erosion of the Conococheague or Beekmantown.

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The top of the Elbrook Formation is not well exposed anywhere in the mapped area. The units immediately below the lowest exposed sandstone unit in the Conococheague east of Natural Bridge (Plate 1) are alternating blue limestones with siliceous laminae and thin-bedded light-gray dolomites, which make up a section several hundred feet

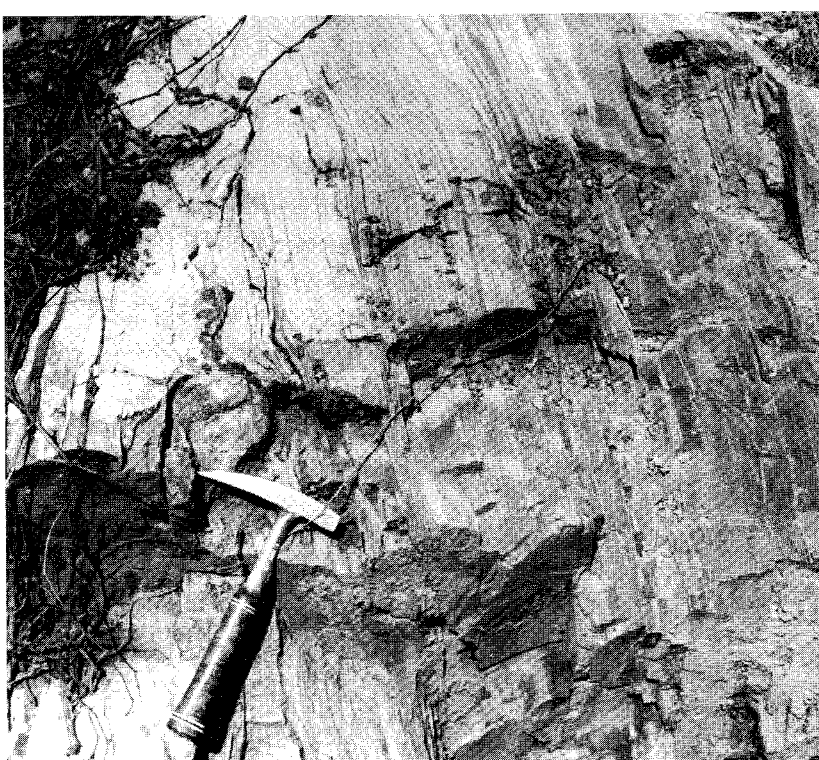

Figure 12. Thin-bedded, light blue-gray limestone in the Elbrook Formation just east of Indian Rock (Plate 3).

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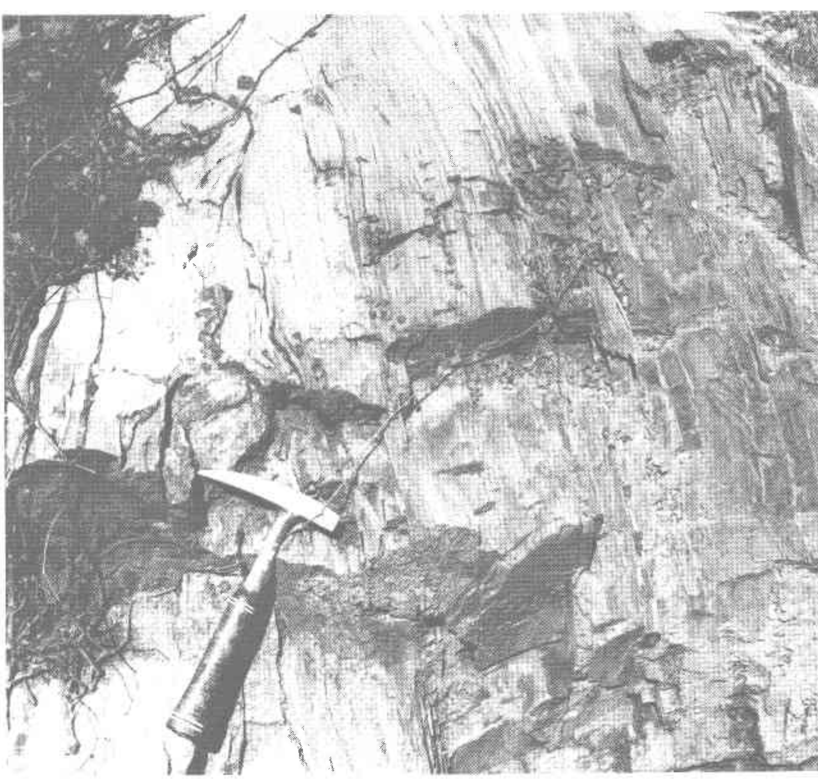

Figure 12. Thin-bedded, light blue-gray limestone in the Elbrook Formation just east of Indian Rock (Plate 3).

thick. Although the dolomites here are thin bedded, they have not weathered to form the very thin platy beds or the shaly beds such as those exposed at Indian Rock or north of Rocky Point (Figure 13). Where the thin-bedded, blue-gray, medium- to fine-grained limestones with siliceous laminae should be placed in the stratigraphic section is uncertain. They resemble the blue limestones in the Conococheague, and probably occur at several levels in the Elbrook.

Figure 13. Intricate folds developed in thin-bedded, platy dolomite of the Elbrook Formation near the Pulaski-Staunton fault along State Road 622 north of Rocky Point (Plate 4).

Conococheague Formation

The Conococheague Formation crops out in the vicinity of Natural Bridge and south of Fancy Hill (Plate 1). The best exposed sections of the Conococheague occur along State Road 608 southeast of Natural Bridge (Edmundson, 1958, p. 104-105) and along U. S. Highway 11 both north and west of Natural Bridge.

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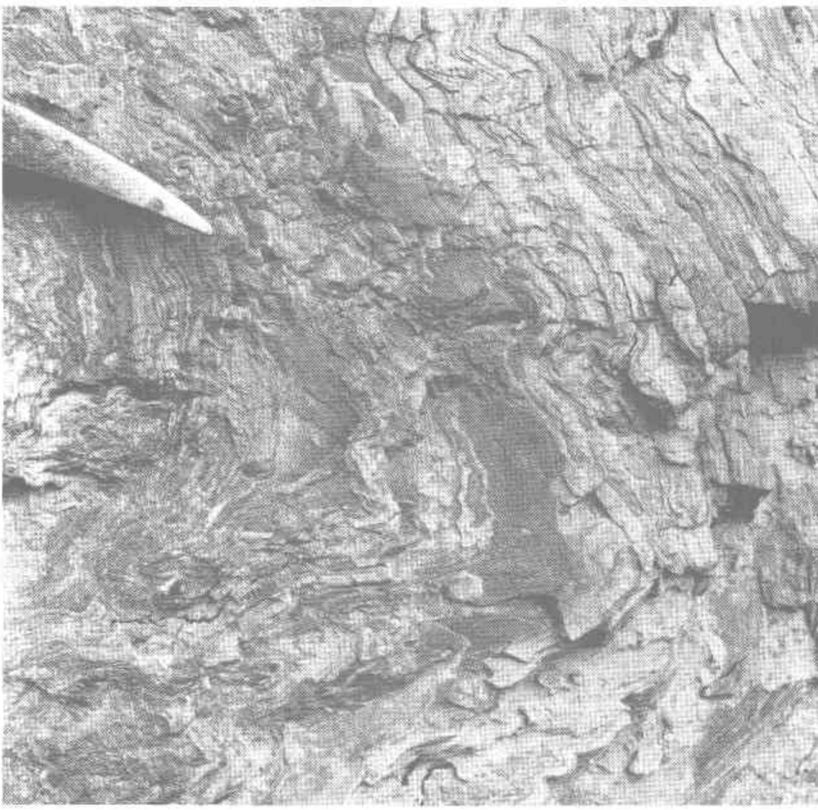

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The Conococheague (Stose, 1908) is approximately 2100 feet thick near Natural Bridge (Edmundson, 1958, p. 104). The formation is composed of impure limestone, dolomite, and sandstone. Sandstones, oolitic limestones, sandy laminae in dark-blue limestones, and a thick unit of arenaceous light-gray dolomite are distinctive features of the Conococheague. This formation has massive beds of medium- to coarse-grained sandstone that are 10 to 20 feet thick; thin beds of medium-grained sandstone (Figure 14) within limestone and dolomite; fine laminae of sandstone and siltstone; and "floating" sand grains in limestone and dolomite. The massive sandstone layers are generally porous (R-3252) because the cement has been removed, leaving loose, friable, buff-yellow sands that can usually be traced by means of surfical fragments. Yellow siltstones also occur in massive layers but only small portions are exposed, so that an accurate estimate of their extent is impossible.

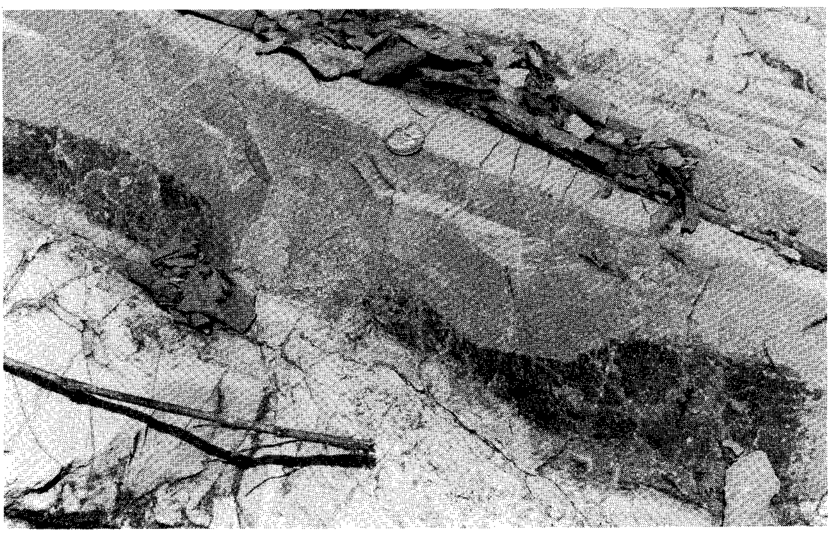

Figure 14. Thin beds of medium-grained sandstone in the Conococheague Formation along U. S. Highway 11, 1 mile west of Natural Bridge (Plate 1). Small cut-and-fill structures are present.

The limestones are medium to dark blue-gray and fine grained, and weather to light to medium gray (Figure 15). The typical limestones are dark in color and contain siliceous laminae (Figure 16), silty layers, a few thin sandstone layers, or some "floating" sand grains. The very thick section of limestone that occurs in Cedar Creek near Natural Bridge is thin bedded, dark bluish gray, and fine grained. Flat-pebble conglomerates and other features indicative of shallow-

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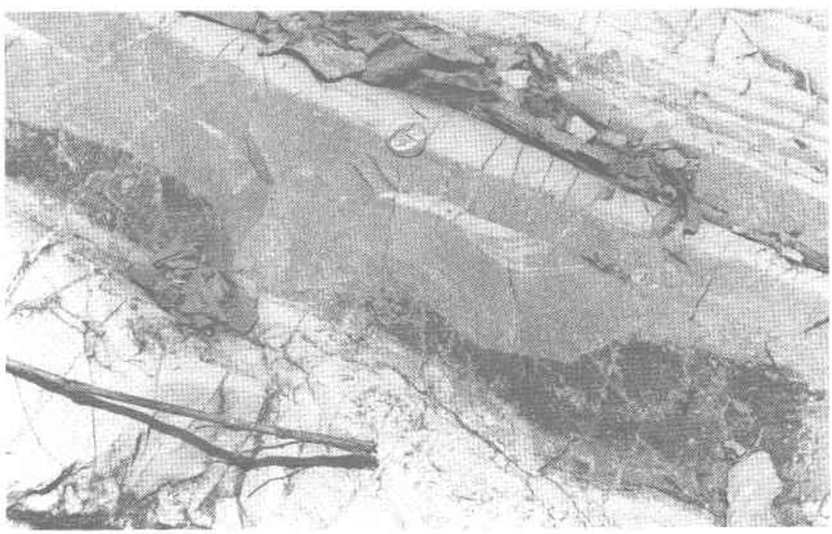

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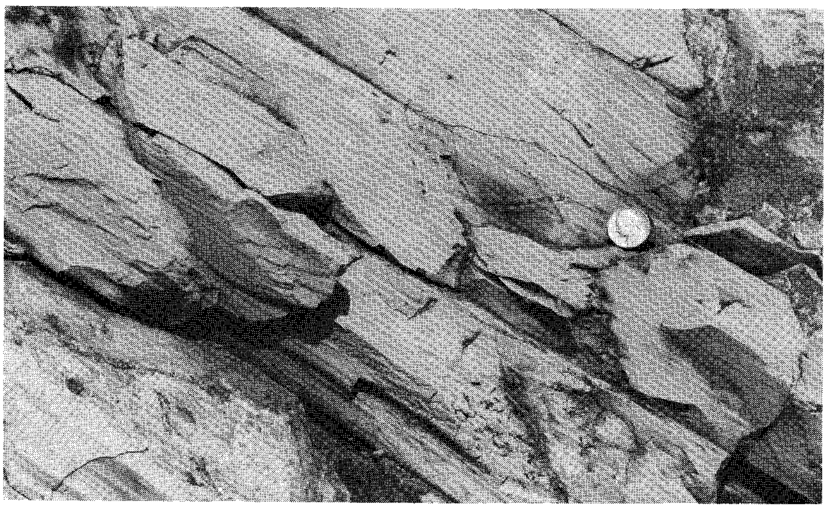

Figure 15. Dark blue-gray laminated limestone in the Conococheague Formation along U. S. Highway 11, 1 mile west of Natural Bridge (Plate 1).

Both the lower and upper contacts are conformable and transitional. The lower contact of the Conococheague is selected at the base of the lowest sandstone bed stratigraphically above typical thin-bedded dolomites of the Elbrook. It is doubtful that this sandstone is at the same stratigraphic horizon throughout the area; there is also a problem in that the contact is poorly exposed and small quantities of sand have been recognized in the Elbrook Formation in this area. Where the contact is not exposed, it has been drawn where sandstone float becomes prominent in the soil. Where the contact was found, sandstone beds several feet thick are common. The contact is exposed along the western border of a syncline in a topographic low which is well defined from Fancy Hill to Red Mills. Good exposures of the lower massive water deposition occur in the limestones. The complex patterns of the siliceous laminae are thought to be due to prelithification disturbance of bedding (Figure 17). Slump features, cut-and-fill structures (Figure 14), and cross-bedding are all present. There are also many places where the strata have numerous small asymmetric folds, many of which are drawn out along cleavage directions as possible secondary structures. The dolomites that occur within the Conococheague are generally light gray on fresh surfaces. Some sections are massive and thick, but thin-bedded dolomite interlayered with limestone, siltstone, shale, or sandstone is more common. Dark bluish-gray dolomites are few.

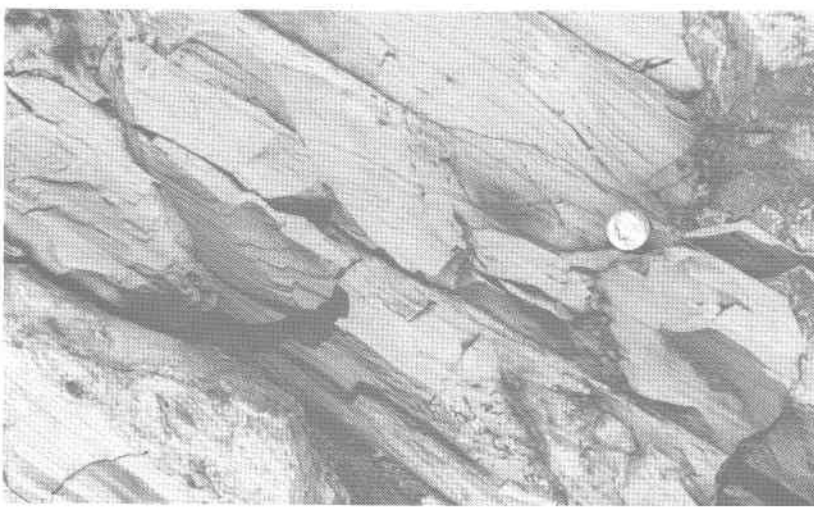

Figure 15. Dark blue-gray laminated limestone in the Conococheague Formation along U. S. Highway 11, 1 mile west of Natural Bridge (Plate 1).

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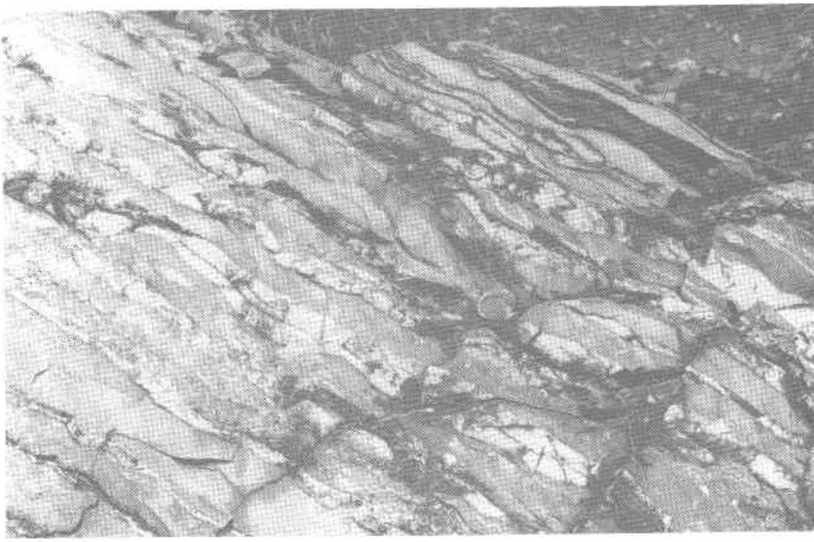
Figure 16. Conococheague limestone with siliceous laminae that stand out in relief on weathered surfaces, exposed along U. S. Highway 11, 1 mile west of Natural Bridge (Plate 1).

Figure 17. Laminated dolomitic limestone in the Conococheague Formation along State Road 610 south of U. S. Highway 11 (Plate 4). The complex deformation of siliceous laminae may have been caused by prelithification disturbance of bedding.



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light-gray sandy dolomites occur along the Chesapeake and Ohio Railway just north of Springwood. Conococheague may be exposed on the overthrust sheets on the east side of the Pulaski-Staunton fault within the wide areas mapped as Elbrook (Plate 1). The structure is complex; blue limestones with siliceous laminae are common, but sandstone was not found.

ORDOVICIAN SYSTEM

Chepultepec Formation

The Chepultepec Formation (Ulrich, 1911) occurs at and northeast of Natural Bridge (Plate 1), in a long narrow exposure bounded by thrust faults from Buchanan to Springfield (Plates 1, 3, 4), and in isolated patches south of Oakdale (Plate 1). Exposures in the first two areas are located on the east side of the Pulaski-Staunton fault and the last, on the west. The character of the rocks exposed immediately below the Beekmantown is very different on the east and west sides of the fault. There appears to be a marked facies change in the Chepultepec from east to west across the area.

The best exposed sections of Chepultepec are near Natural Bridge. Massive, light-gray dolomite containing "floating" grains of sand forms the arch at Natural Bridge. This unit may be the lowest part of the Beekmantown Formation or the uppermost portion of the Chepultepec. Limestones below this massive dolomite are positively identified as Chepultepec on the basis of fossil fragments and a large straight-shelled cephalopod (Figure 18). Dolomites above the bridge-forming unit contain light-gray chert that is typical of the Beekmantown.

Figure 18. Straight-shelled cephalopod, about 18 inches long, in Chepultepec limestone west of U. S. Highway 11 about 0.25 mile north of Natural Bridge (Plate 1).

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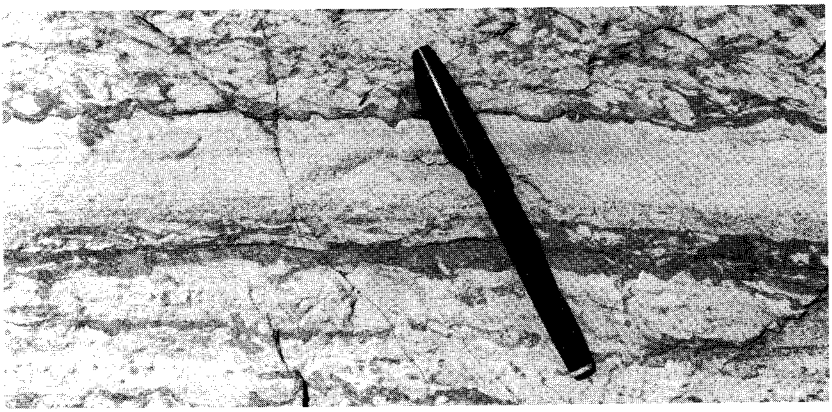
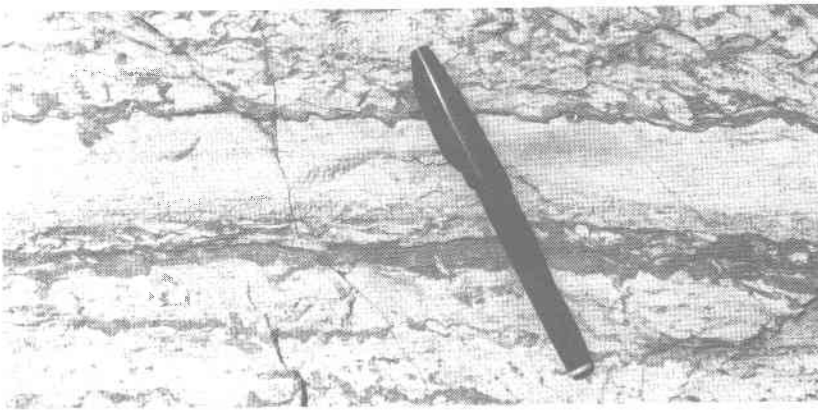


Figure 19. Laminated limestone in the Chepultepec Formation along U. S. Highway 11, 0.25 mile north of Natural Bridge (Plate 1).

Figure 20. Irregularly dolomitized limestone in the Chepultepec Formation along U. S. Highway 11, 0.25 mile north of Natural Bridge (Plate 1).

There is no well-defined lithologic change between the limestones of the Chepultepec and the Conococheague along Cedar Creek (Plate 1); the contact is drawn at the first occurrence of thin sandstone beds. The fine- to medium-grained limestones of the Chepultepec in the vicinity of Natural Bridge (R-3253) are dark bluish gray on fresh



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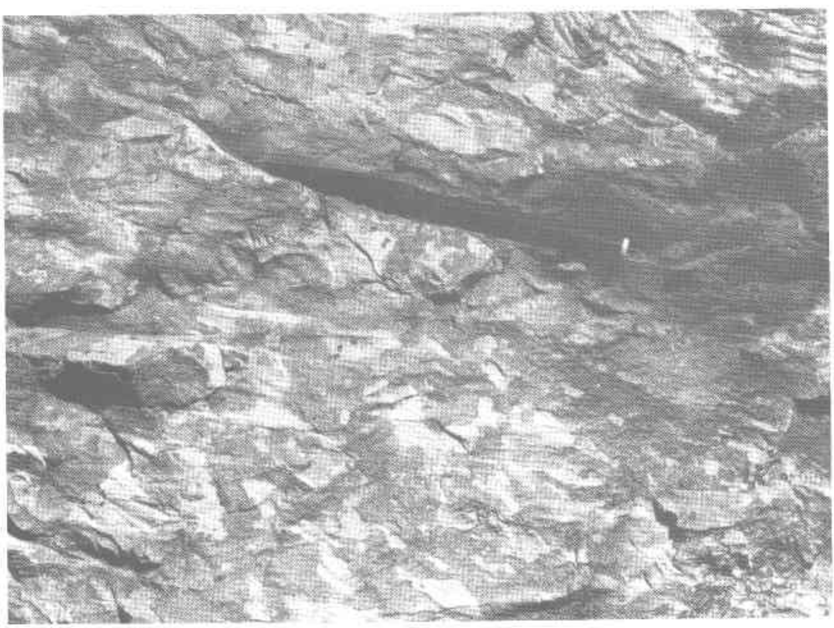

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A sandstone about 10 feet thick that resembles those of the Conococheague; sandy and coarsely oolitic, dark-blue, fine-grained limestone; beds containing flat-pebble conglomerates; and dark-blue, thinly laminated limestones are exposed along State Road 611, 0.5 mile south of Rapps Mill (Plate 2). Fossil fragments occur within some of the oolitic limestones. Only a few tens of feet of section are exposed below the Beekmantown at this locality.

Beekmantown Formation

The Beekmantown is exposed in a broad area extending from a point south of the Mount Joy Church (Plate 3) to an area north of Moore and North Buffalo creeks (Plate 1). A section of Beekmantown is well exposed along the farm road about 1 mile north of Saville Hill. The upper portion of the Beekmantown crops out along Buffalo Creek just north of Kiger Hill (Plate 1). Edmundson (1958, p. 91) measured and described a section that contains more than 1400 feet of dolomite and limestone. The formation also crops out along the tributaries of Roaring Run (Plate 4). Where the unit is exposed along State Road 610 there is less than 300 feet of section. The upper contact is clearly evident, but it is possible that the abnormal thickness is due to faulting at the base of the exposed Beekmantown where a covered interval separates it from Conococheague (?) limestones.

The Beekmantown (Clarke and Schuchert, 1899) is conformable with the Chepultepec and is disconformable with the overlying New Market. The thickness is approximately 1500 feet (Edmundson, 1958). The unit is composed of a thick sequence of medium- to light-gray massive dolomites (R-3254). The weathered surface generally has distinctive etched fractures that form an intersecting pattern.

The base of the Beekmantown is exposed at Natural Bridge (Plate 1) and 1.5 miles north of Rapps Mill (Plate 2). The Beekmantown-Chepultepec contact is selected at the base of the thick massive dolomites that compose Natural Bridge and are exposed directly north of the U. S. Highway 11 and State Highway 130 intersection northeast of the bridge. These massive light-gray dolomites contain some "floating" sand grains, a few thin layers (about 1 inch thick) of coarse well-rounded sand, and minor amounts of light-gray translucent chert.

There are some limestone layers (up to several feet thick) in the Beekmantown. Toward the top these resemble the New Market, but darker and more coarsely crystalline limestones are also present. Layers of pink to white chert are locally abundant and weather to form resistant caps on many of the hills and ridges underlain by Beekmantown. Very little black chert was found in the Beekmantown, and in this respect it differs from the underlying Chepultepec, Conococheague, and Elbrook and the overlying Lincolnshire.

Detailed stratigraphic studies of the Middle Cambrian and Lower Ordovician are needed in this region. Both the lower contact with the Rome and the upper contact with the Conococheague are transitional. Edmundson (1958, p. 99-104) reported a thickness of 2271 feet of Elbrook along the Chesapeake and Ohio Railway west of Buena Vista, and 1505 feet east of Steeles Tavern. He pointed out that there is no distinct difference in rock character between the Elbrook and Conococheague near the contact. There are a number of similarities in the lithologies of the Elbrook, Conococheague, and Chepultepec in the area of study. The recurring lithologies include thin-bedded blue limestone that is interbedded with siliceous laminae and banded limestone and dolomite. The limestone weathers light gray. All three of these units also include different amounts of light-gray dolomite. Identification of these units, each of which has some distinct lithologies, would probably present no problem except that the exposures in which they occur are complexly faulted and folded. In the area there is no complete section of the three, and one or both boundaries are generally absent because of the faults present. The distinctive character of each is as follows:

Beekmantown Formation—massive ledges of light-gray thin-bedded dolomite with a few interbedded fine-grained dove-gray limestones.

Chepultepec Formation—interbedded light-gray massive to thin-bedded dolomites and dark blue-gray limestones. The limestones are banded or straticulate with siliceous laminae; the most distinctive limestones are massive, fine-grained, blue-gray units with abundant fossil fragments.

Conococheague Formation—interbedded limestones and dolomites. Parts of the unit are thick sequences of blue-gray limestone and straticulate limestone with thin beds of sandstone and a few oolitic limestones. There are a few quite distinctive medium- to coarse-grained sandstones and thick sections of sandy or silty dolomites. These sandy, light-gray dolomites occur near the bottom of the unit.

Elbrook Formation—the distinctive feature is the shaly character of the unit and the presence of dark-gray massive dolomites, some pink shaly dolomites, and white thin-bedded limestones.

New Market Limestone

The New Market Limestone crops out in narrow exposures along the tributaries of Roaring Run, along State Road 622, 0.7 mile northwest of Rocky Point (Plate 4), and along State Highway 251 just west of Murat (Plate 1, R-3255). The New Market has been described by Edmundson (1958, p. 30-35, 42, 46-50).

The New Market (Cooper and Cooper, 1946) is one of the most distinctive rock units in the area mapped. It is an aphanitic, dove-gray limestone that weathers to a very light gray. The limestone is thick bedded and breaks with a conchoidal fracture; the outcrops are massive. There is generally a "bird's eye" texture because of scattered grains of transparent calcite in the matrix. The maximum thickness is 160 feet. Where the unconformity with the underlying Beekmantown is not exposed, the contact is placed at the top of the uppermost dolomite of the lower formation.

The New Market is mapped to include a sequence named Murfreesboro Formation by Butts (1940) and Stones River by Woodward (1936a). These rocks are best exposed along State Road 622 about 0.7 mile northwest of Rocky Point (Plate 4). The units are composed of dark-blue limestone with some black members, and some members identical to the New Market. In the thin-bedded shaly black limestone there are abundant lenticular layers of chert (Figure 21). This sequence is nearly 100 feet thick near Indian Rock (Woodward, 1936a). Woodward described the Stones River as being unconformable with the underlying dolomites and disconformable with the overlying Mosheim limestone (New Market).

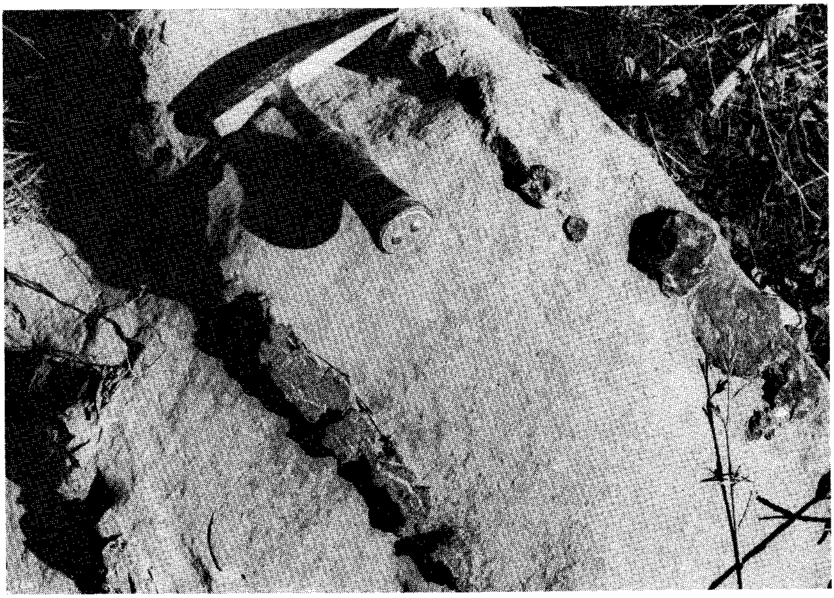
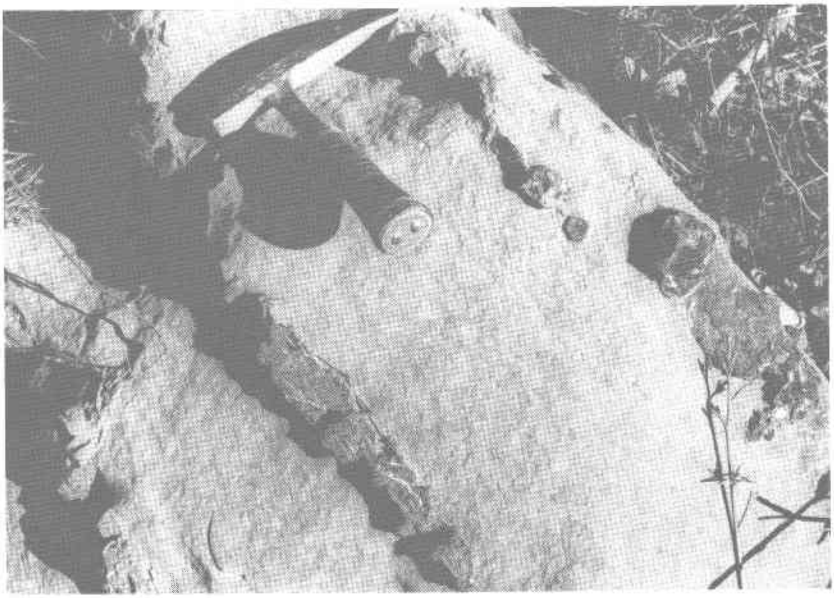


Figure 21. Black chert in the New Market Limestone along State Road 622 about 0.7 mile northwest of Rocky Point (Plate 4).

Lincolnshire Formation

The best exposed sections of the Lincolnshire Formation are located along the tributaries of Roaring Run (Plate 4); at Murat (Plate 1, R-3256), the type section for the Murat facies; and at Mount Joy Church (Plate 3). Edmundson (1958, p. 32, 42, 44, 46-50) described measured sections of Lincolnshire. The thickness in these sections ranges from 206 feet at the Rocky Point quarry (Plate 4, No. 6) to 412 feet northwest of Murat (Plate 1).

The Lincolnshire (Cooper and Prouty, 1943) is conformable with both the New Market and the Edinburg. It is here mapped to include the Whistle Creek Formation (Cooper and Cooper, 1946) which lies below the Lincolnshire. The Whistle Creek is composed of dark-blue to gray irregularly bedded limestone. Beds are thin and generally contain abundant black chert nodules and lenses. The dark limestones are fine-grained and fossiliferous. Irregularly bedded siltstone with lenses of black chert occurs in exposures along State Road 611 north of Mount Joy Church (Plate 3). The Whistle Creek is 82 feet thick at the type section near Lexington, and 165 feet at the Colliers Creek section (Edmundson, 1958, p. 46-48), but it is commonly much thinner.



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The Murat facies of the Lincolnshire is a coarse-grained gray limestone resembling a marble. It is massive and poorly stratified; in a few localities it has a pink color. The coarse-grained portions of the unit are composed of fossil fragments and are light to dark gray. Bryozoans and crinoids are particularly abundant; in fact, the Murat facies is biostromal in character. In addition to the Murat facies and the Whistle Creek, there are black or dark-blue, medium- to coarse-grained fossiliferous limestones interbedded with dark-gray shales and locally containing abundant lenses, layers, or stringers of black chert. This part of the unit is thin, irregularly bedded, and in many places has a nodular appearance.

Edinburg Formation

The Edinburg Formation (R-3257) occurs on both limbs of the faulted anticline that extends along South Buffalo Creek (Plates 1, 2); near the base on the east and west sides of Short Hills; and on a thrust slice just west of Highbridge Church (Plate 1). Excellent exposures crop out in streams flowing from The Knob south of Mount Joy Church (Plate 3). Outcrops are scarce in the area northwest of Short Hills (Plate 2) because the unit is covered by Silurian sandstone float. The Edinburg (Cooper and Cooper, 1946) is conformable with the underlying Lincolnshire and the overlying Martinsburg. The base of the formation consists of 10 to 70 feet of reddish-weathering, medium- to coarse-grained, fossiliferous, blue-gray limestone, the Botetourt Member. Cooper and Cooper (1946) described the type section of the Botetourt at a locality just south of Mount Joy Church (formerly Dunkard Church) as being 67 feet thick in a complete section of Edinburg that has a thickness of 556 feet.

Above the Botetourt there are two rather distinctive lithologies in the Edinburg. One is a fine-grained, dense, black, thin-bedded limestone interlayered with buff-weathering, fissile black shale and is called the Liberty Hall facies (Figure 22). The other lithology is a nodular, fine-grained, black limestone without shale partings and is called the Lantz Mills facies.

Martinsburg Formation

The Martinsburg Formation is poorly exposed in this area. The lower part of the formation crops out along State Road 674 east of Murat (Plate 1). Small scattered exposures are present in the outcrops, around Short Hills, at Cartmell Gap (Plate 3), and along State Road 622 on the northeast side of Sugarloaf Mountain (Plate 2).

Figure 22. Interbedded limestone and shale in the Liberty Hall facies of the Edinburg Formation about 0.75 mile east of Murat (Plate 1).

The Martinsburg (Geiger and Keith, 1891, p. 161) conformably overlies the Edinburg and has a disconformable contact with the Juniata. Thickness has been estimated to be from 1000 to 2000 feet (Bick, 1960); however, the complexity of folding within this unit in the area of study makes any estimate questionable. Woodward (1936a) divided the formation into three parts: a lower medium- to dark-gray shale with fossiliferous limestone partings (Figure 23), a middle unit of tan to buff shale in which fossils are common, and an upper portion composed of massive sandy strata interbedded with shale.

The most distinctive Martinsburg lithologies are buff to greenish shale and mudstone that weather to a buff to yellow soil and light-gray, fossiliferous limestones (R-3258) interbedded with buff to brownish shales. The exposures located 1 mile west of Red Mills and about 1 mile east of Murat (Plate 1) contain lithologies that are intermediate between those of the light-gray limestones of the Martinsburg and the black fine-grained limestones of the Liberty Hall. These units contain interbedded black to brown shales with slight olive-green coloration and black to medium-gray, fine- to medium-grained fossiliferous limestones with some silt. These may represent a transitional zone between the Edinburg and Martinsburg lithologies.

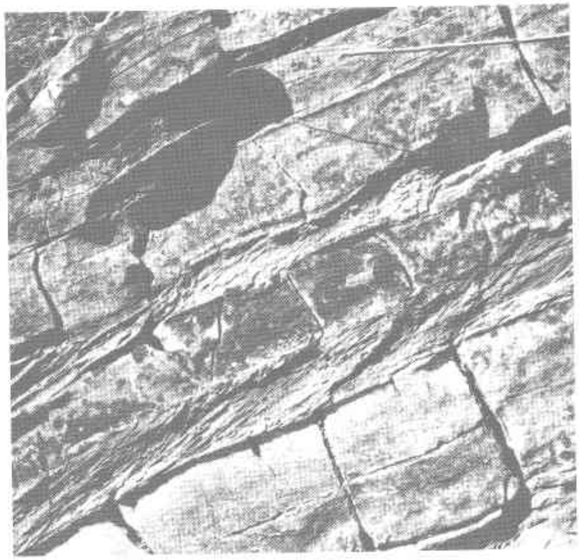

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Figure 23. Intraformational deformation within interbedded dark-gray limestone and shale in the lower part of the Martinsburg Formation along Broad Creek 1 mile northeast of Broad Creek Church (Plate 1). (Outcrop viewed from above.)

Juniata and Oswego Formations (?)

The interval between the base of the Tuscarora and green shale and sandstone typical of the Martinsburg is exposed: at the north end of Short Hills (Plate 1); at the east end of Sugarloaf Mountain, along Moore Creek, and at the south end of Little Camp Mountain (Plate 2); and along the road to the lookout tower on Purgatory Mountain (R-3259) and at Rich Hill (Plate 3). The lithologies of the units below the Tuscarora at various localities are strikingly different. At Moore Creek there is a section of Juniata similar to that described by Lesure (1957, p. 31) near Cliff Dale Chapel (Alleghany County). It consists of interbedded greenish-gray shale and grayish-red sandstone. At Rich Hill only a few beds of fine-grained, greenish-black sandstone are exposed below the Tuscarora. At Purgatory Mountain greenish shales, possibly part of the Martinsburg lie close to the Tuscarora contact.

The thick lower section of cliff-forming sandstones and quartzites commonly associated with the Tuscarora is composed mainly of medium-grained feldspathic sandstone. This weathers to a reddish-gray sandstone which in many places is cross-bedded (Figure 24). A

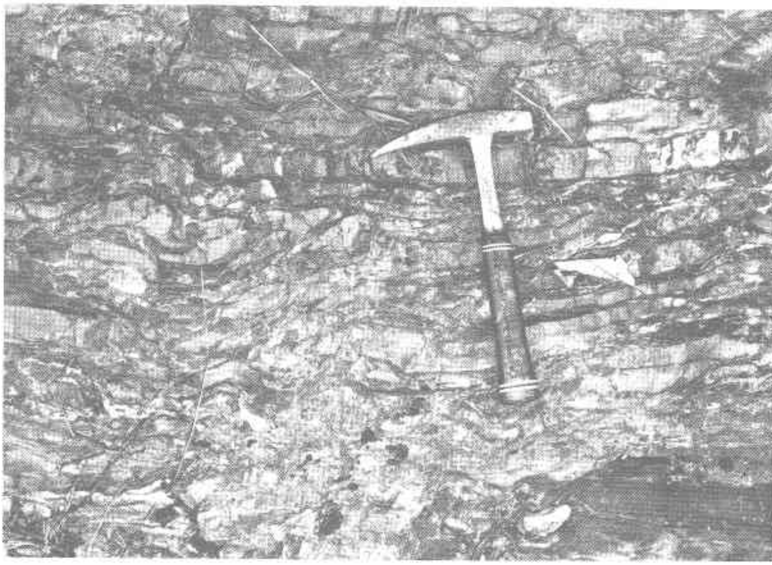

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Figure 24. Cross-bedded feldspathic sandstones beneath the Tuscarora Formation exposed in the gap between Little Camp and Orebank mountains (Plate 2).

The deformation in this area has been so intense that it is difficult to evaluate the stratigraphic significance of the various lithologies found beneath the Tuscarora. This contact zone, especially where much shale is present, is one where movement along the base of the massive quartzitic Tuscarora might be expected. In many places the Martinsburg has a complex deformational pattern.

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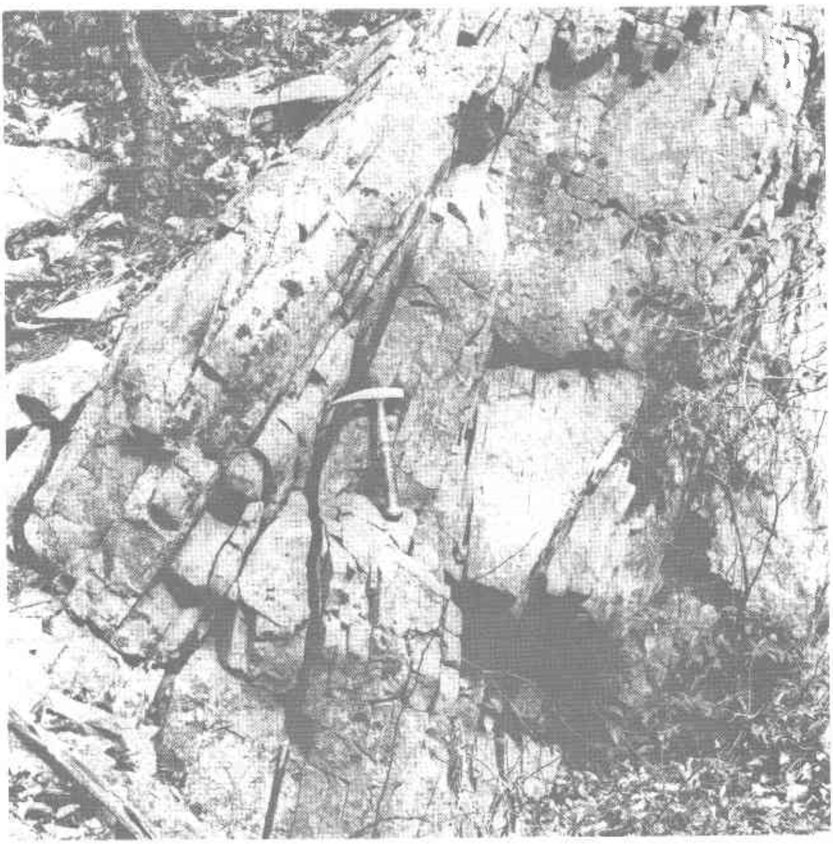

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SILURIAN SYSTEM

Tuscarora Formation

The Tuscarora (Darton and Taff, 1896) is a prominent cliff-forming sandstone. There are a number of sections where the Tuscarora and overlying Cacapon and Keefer can be examined: along Moore Creek east of the Lexington reservoir, at the gap in Painter Mountain 0.75 mile east of Jane Furnace, along State Road 622 at Prisehouse Mountain, and at the east end of Sugarloaf Mountain (Plate 2); on the east flank of Short Hills along Cedar Creek (Plate 1); and at Cartmell Gap just north of Purgatory Mountain and at the gap at the north end of Rich Hill (Plate 3; Figure 25). The contact between the Tuscarora and the underlying greenish shales of the Juniata at Prisehouse Mountain and Scurff Mountain (Plate 2) and Purgatory Mountain (Plate 3), and the reddish or greenish sandstones at Moore Creek and Sugarloaf Mountain (Plate 2) and Rich Hill (Plate 3) appears conformable.

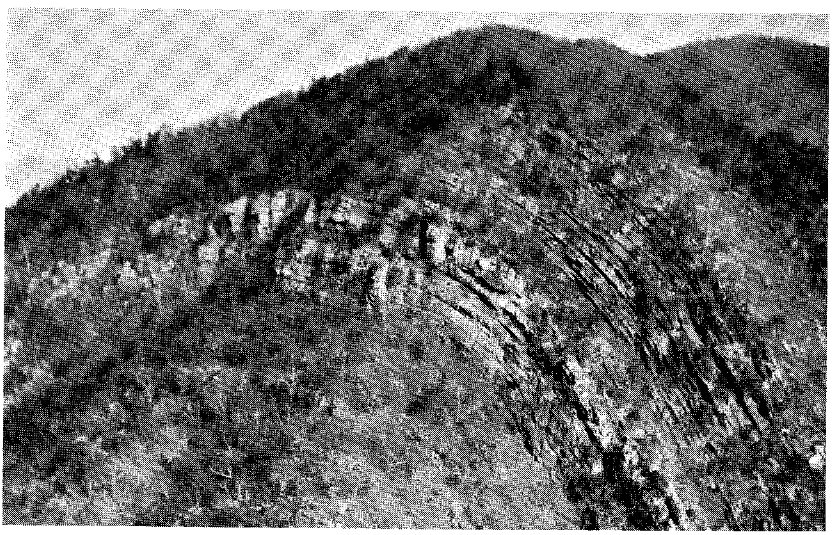

Figure 25. Tuscarora, Cacapon, and Keefer units exposed in an anticlinal structure at the gap at the north end of Rich Hill (Plate 3).

The Tuscarora is a white, fine- to coarse-grained sandstone and orthoquartzite; some pink iron oxide-stained sandstone is also present (R-3260). In many places it is cross-bedded, but most of the cross-bedding is torrential and generally not reliable for determining the tops of beds. The Tuscarora is in most aspects very similar to the Keefer. The only reliable criteria for distinguishing between the two are the presence of a few red iron oxide-stained beds which contain

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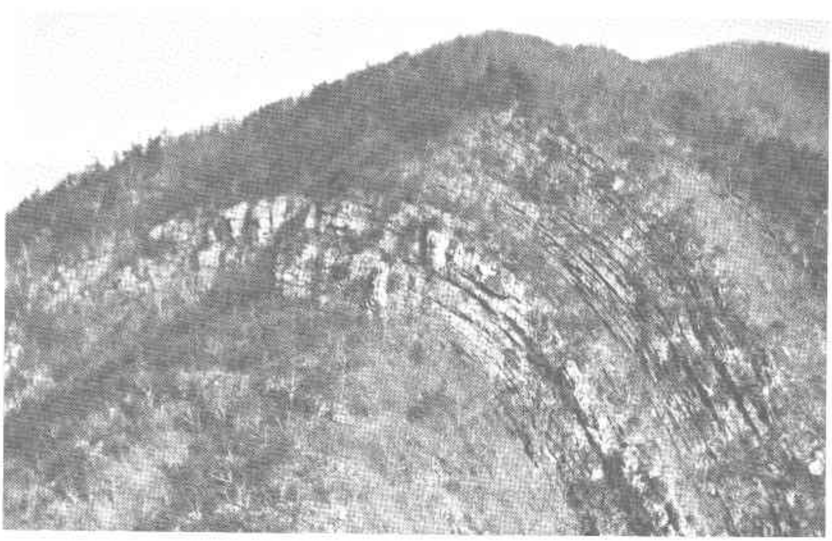

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Scolithus and some maroon hematitic beds, both in the Keefer. The Tuscarora has been described as cleaner and better sorted than the Keefer, as containing pebble conglomerate, and as forming cliffs; however, a large part of the Keefer has similar characteristics throughout the area of study.

Cacapon Formation

Localities where the Cacapon Formation (Darton and Taff, 1896) is exposed are essentially the same as those listed for the Tuscarora. The Cacapon consists of from 100 to 200 feet of deep red-purple hematitic sandstone (R-3261) interbedded with reddish and greenish shales and a few beds of white fine-grained sandstone; total thickness of the formation is 200 to 300 feet. The Cacapon has a distinctive lithology and is generally well exposed. Where the formation is covered, its presence is indicated by float and by numerous thorn bushes and scrub oak that grow in the soil developed over it. Lesure (1957) described a 240-foot section of Cacapon at Iron Gate (Alleghany County). The hematitic sandstones in the area of study are similar to those described by Lesure, but in many places the unit is thinner and contains less shale.

UPPER SILURIAN AND LOWER DEVONIAN ROCKS

Keefer Sandstone

The Keefer Sandstone (Stose and Swartz, 1912) is composed of 150 to 250 feet of sandstone and orthoquartzite; it conformably overlies the Cacapon and is unconformably overlain by the Tonoloway. At Rich Hill (Plate 3) the contact between the Tonoloway and the Keefer is exposed, but throughout most of the area this contact is covered. The Keefer crops out along Moore Creek near the Lexington reservoir and at Rocky Ford north of Scurff Mountain (Plate 2). In many places the covered interval between the last exposed Keefer bed and the first exposure of Needmore is only wide enough to have 50 to 100 feet of section.

The Keefer is largely composed of white, very fine-grained sandstone; it is generally well cemented and forms cliffs. There are a few interbeds of hematitic sandstone, and many of the beds are stained pink or green. Numerous lenses of pebble conglomerate (R-3262) are present, and torrential cross-bedding is common. A few distinctive beds containing *Scolithus* and stained deep red were found.

Exposures occur southwest of Cartmell Gap along Penn Branch (Plate 3) and at Rich Hill. The section at Cartmell Gap was measured (Woodward, 1936a) and part of it is described as follows:

Formation	*Thickness Feet*
Covered to Pulaski fault	351
Helderberg	
Dense, gray, ferruginous, calcareous sandstone	12
Covered	67
Massive white and brown crumbly sandstone	68
White quartzite	8
Covered	34
Thin-bedded, coarse-grained brown sandstone	60
Keefer	
Covered	104
Thick-bedded, coarse-grained white sandstone	113
Dense white quartzite and sandstone	31
Cacapon	127
Clinch	173

Tonoloway Formation

At Rich Hill the Tonoloway Formation is about 120 feet thick and consists of thin-bedded, platy, dark-gray, fine-grained limestone. The upper 30 feet are folded in a complex manner. The Tonoloway is overlain by a porous, coarse-grained, calcareous and ferruginous sandstone. The units between the Keefer and Needmore are thin and are commonly characterized by porous, friable, medium- to coarse-grained sandstone that has iron and manganese oxide stains. To the northwest in the Clifton Forge area the section was described as follows (Lesure, 1957, p. 20):

Formation	*Thickness Feet*
Ridgeley Sandstone	2- 25
Licking Creek Limestone	60-120
Healing Springs Sandstone	0- 25
Coeymans Limestone	0- 20
Keyser Formation	70-120
Tonoloway Formation	140-200
Wills Creek Formation	40-100
	312-600

It is concluded that there are unconformities in this part of the section and that most of the limestones which are prominent west of the area mapped (Plates 1, 2, 3) are either missing here or are represented by sandstones. However, this dominantly arenaceous sequence that lies between the distinctive shales in the Needmore and the hematitic sandstones in the Cacapon is a recognizable unit for mapping purposes.

DEVONIAN SYSTEM

Needmore Formation and Millboro Shale

The Needmore Formation (Willard, 1939) is a relatively thin unit, estimated to be 50 feet, composed mainly of olive-gray shale. The Millboro Shale (Butts, 1940) consists primarily of thin-bedded, fissile, black shales that are overlain by the Brallier Formation. The Millboro contains several zones of calcareous concretions, from a few inches to several feet in diameter, in the upper part; these occur in beds of argillaceous limestone. Barite concretions are present in the black shales at some localities.

The best exposures of the Needmore and Millboro shales occur along stream valleys such as Boggs Hollow (Plate 2). There are abundant exposures along State Road 612 in Mill Creek valley (Plate 2), and the exposures here are intensely deformed. Poor exposures and complex deformation make it difficult to estimate thickness of the Needmore and Millboro. It is reported to be about 1200 feet thick west of Iron Gate (Lesure, 1957).

Brallier Formation

The Brallier Formation (Butts, 1918) in the area mapped consists of light olive-gray shale and interbedded medium-gray to olive-gray fine-grained sandstone (Plate 2). The shale has typical pencil-shaped fragments where weathered. The internal structure is characterized by bedding slippage and complex folds.

ULTRAMAFIC ROCK

Two stock-like bodies of ultramafic rock occur near Mt. Pisgah (Plate 2). One is exposed for a distance of about 700 feet along a road northwest of Mt. Horeb Church. The rock, which contains olivine and mica, is deeply weathered and no fresh samples could be collected. The dolomites of the Beekmantown Formation adjacent to the contact with the ultramafic rock are brecciated and it seems most plausible to consider that the body was emplaced as a solid mass. The second ultramafic body is located northwest of the first along the

Edinburg-Lincolnshire contact. Its presence can be recognized by the soil which is a more olive color than that of the surrounding rock and by the rounded hill developed over the mass. The margins of this body are not exposed. These two bodies were identified as peridotite by Steidtmann (1948) and Campbell (1933). Other Paleozoic igneous rocks in the Valley have been described by Watson and Cline (1913).

QUATERNARY DEPOSITS

Unconsolidated alluvial deposits occur extensively in the area, and, in addition, large areas are covered by colluvium near all of the high mountains. Most of the deposits in the west are composed of Silurian rock fragments and boulders, and those in the east are composed of material from the Lower Cambrian rocks and Virginia Blue Ridge Complex. Talus-covered slopes are common near the ridge tops, and these merge and are mixed with products of surface wash and stream transport lower down the slopes. A characteristic topography consisting of braided or subparallel streams separated by low ridges is developed on these deposits. An excellent example of such topography occurs at the south end of Arnold Valley (Plate 4). Terrace gravels are exposed at elevations up to several hundred feet above the present alluvium-filled valleys in most parts of the area.

Tufa, or travertine, deposits have formed along a number of the streams that drain areas underlain by carbonate rocks. These massive porous deposits are formed generally at waterfalls, rapids, or cascades where the agitated water loses part of the carbon dioxide in solution and thus promotes development of the calcium carbonate precipitate. These deposits superficially resemble some fault breccias in the Elbrook. Good examples of the tufa deposits may be seen along most of the streams between the James River and the syncline near Natural Bridge.

STRUCTURAL GEOLOGY

The Appalachian Valley which is nearly 25 miles wide at Staunton, narrows to 18 miles at Lexington; and at Buchanan Precambrian and Silurian rocks are less than 2.5 miles apart. The northwest front of the Blue Ridge is unfaulted in the Lexington (Bick, 1960) and Vesuvius (Werner, 1966) quadrangles a few miles to the northeast, but a major fenster-like structure at Arnold Valley (Plate 4) indicates that the Precambrian rocks of the Blue Ridge have moved 1 mile or more to the northwest. A thrust sheet in which Middle Cambrian rocks were moved to the west over Silurian units is partially exposed northwest of Buchanan (Plate 3). The ridge-forming clastic Silurian rocks are exposed along the eroded edge of this major thrust sheet.

BLUE RIDGE AREA

Formations exposed along the northwest flank of the Blue Ridge are folded and faulted (Plates 3, 4). A major unresolved problem here is how far the rocks of the Blue Ridge province have moved over the miogeosynclinal sequences of the Appalachian Valley. If it is assumed that the Erwin now exposed at the Blue Ridge front west of Arnold Valley was originally part of the belt exposed in Arnold Valley, the minimum lateral displacement would be 1.5 miles. The structure west of the Blue Ridge front is in accord with movements of this order of magnitude. Thrust faults occur within and between many of the rock units exposed in the James River valley area. Almost all of the units dip southeastward, and bedding faults are abundant; considerable movement is thus possible despite the fact that large stratigraphic throws are not present in the rocks between the Blue Ridge front and the Pulaski-Staunton fault to the northwest.

Area Northeast of Natural Bridge Station

Only the southwest tip of Sallings Mountain (named in the adjoining Buena Vista quadrangle) extends into the Natural Bridge Station area. One of the critical exposures for interpreting the structure of the mountain is in Crawford Creek at the junction of State

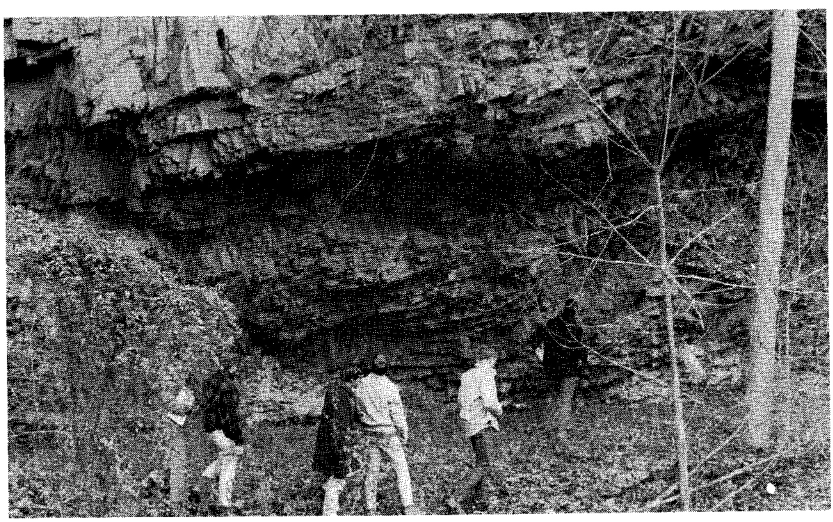

Figure 26. Shattered Erwin Formation exposed just above the flat-lying thrust fault at the south end of Sallings Mountain, along Crawford Creek at the junction of State Highway 130 and State Road 688 (Plate 4).

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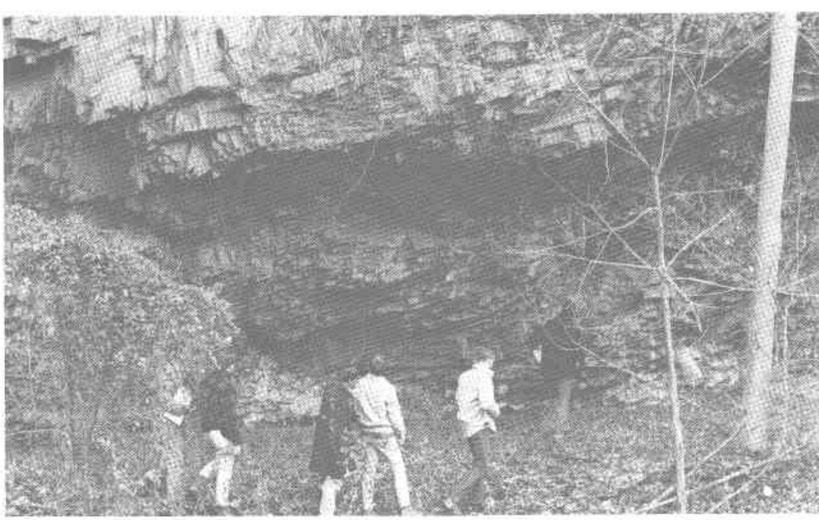

Figure 26. Shattered Erwin Formation exposed just above the flat-lying thrust fault at the south end of Sallings Mountain, along Crawford Creek at the junction of State Highway 130 and State Road 688 (Plate 4).

Highway 130 and State Road 688 (Plate 4). At this point the creek has cut through the nose of a southward-plunging anticline developed in Erwin and Shady. At the level of the creek the Erwin is shattered (Figure 26), and there is an exposure of Shady in the creek bed. The Erwin has been thrust over the Shady along a fault which appears to be nearly horizontal. A short distance to the east and south the Shady is exposed in its normal position over the Erwin. The outcrop belt of Shady surrounding Sallings Mountain lies in fault contact on Rome and Shady. This can be seen along an intermittent stream about 0.9 mile southwest of Natural Bridge Station where Shady is faulted onto Rome. Shady is also faulted onto Rome to the northeast in the Buena Vista quadrangle.

Arnold Valley

Arnold Valley (Plate 4) is of key significance to the structural interpretation of the Blue Ridge front in this area. The valley is largely filled with colluvium and river alluvium and there are a few outcrops of Shady. Along the eastern side of the valley a northwestward-dipping monocline of Erwin is exposed. The Erwin is covered in the vicinity of the Hopper Creek Group Camp near the end of State Road 759 by exposures of Precambrian gneisses. These have been thrust over the Erwin and the Shady in the south part of the valley. The Shady is exposed along the base of Furnace Mountain (Plate 4) on the northwest side of Arnold Valley; but at higher elevations on the same mountain there are exposures of Hampton and Unicoi and on Mill Mountain to the northwest there are outcrops of Erwin. A major low-angle thrust fault can be traced from the south and west sides to the northwest side of Arnold Valley. Therefore, Shady and Erwin are exposed in a fenster-like structure.

The major low-angle fault has a northwesterly dip on the east side of Arnold Valley because it goes over an outcrop of Erwin which is at an elevation of 2600 feet, and the fault is exposed on the west side of Arnold Valley between 1000 and 1200 feet. The configuration of the fault could be due to folding, or it may be interpreted in terms of gravity tectonics. The estimated dip of the fault plane is 6 degrees to the northwest.

Cave Mountain

Cave Mountain is capped by Erwin; Shady is exposed near the base on the east side, and Precambrian rocks are exposed on the west side. A low-dipping fault zone is exposed at the southwest edge of the mountain. Cave Mountain is interpreted as a klippe because the Erwin is a gently folded syncline resting on Precambrian rocks on the west side, and the Shady dips under the Erwin on the east side. The Cave Mountain klippe is thought to have been formed after the movement that brought Precambrian rocks over Shady because the Erwin now covers the trace of this fault. The nature of the Hampton and Unicoi-Precambrian contact at the southwest end of Cave Mountain is not clearly understood. It is interpreted as a part of the klippe, but there may be a high-angle fault extending along the northwest edge of this feature and southwestward into the Precambrian rocks.

Area East of Buchanan

The first ridge east of Buchanan (Plate 3) is the west limb of a southward-plunging syncline containing Erwin and Shady; the nose of this syncline is located near Dillon. The west limb has a dip of 40 to 60 degrees, and the east limb is nearly vertical where it is exposed along State Highway 43. Evidence that this syncline has been moved to the northwest is present at The Gorge where Erwin is faulted onto Shady, and at the Liberty Limestone Corporation quarry (Figure 27) and along State Highway 43, 0.6 mile southeast of Buchanan (Figure 28) where Hampton is faulted onto Shady; just northeast of the quarry a small outcrop of Unicoi is present in the fault zone on Shady. The fault is also exposed in the James River Hydrate and Supply Company, Inc. quarry (Figure 29).

Figure 27. Thrust fault exposed in the Liberty Limestone Corporation quarry about 0.6 mile east of Buchanan (Plate 3). Hampton Formation (right) is in contact with Shady Formation.

side, and the Shady dips under the Erwin on the east side. The Cave Mountain klippe is thought to have been formed after the movement that brought Precambrian rocks over Shady because the Erwin now covers the trace of this fault. The nature of the Hampton and Unicoi-Precambrian contact at the southwest end of Cave Mountain is not clearly understood. It is interpreted as a part of the klippe, but there may be a high-angle fault extending along the northwest edge of this feature and southwestward into the Precambrian rocks.

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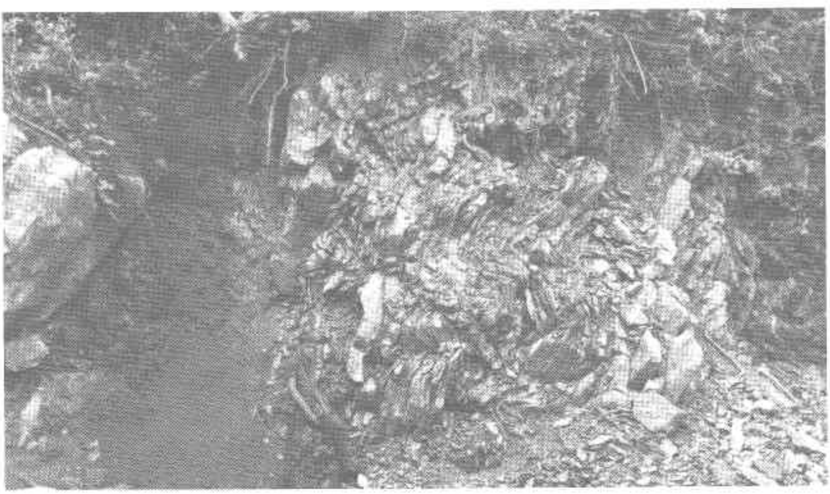


Figure 27. Thrust fault exposed in the Liberty Limestone Corporation quarry about 0.6 mile east of Buchanan (Plate 3). Hampton Formation (right) is in contact with Shady Formation.

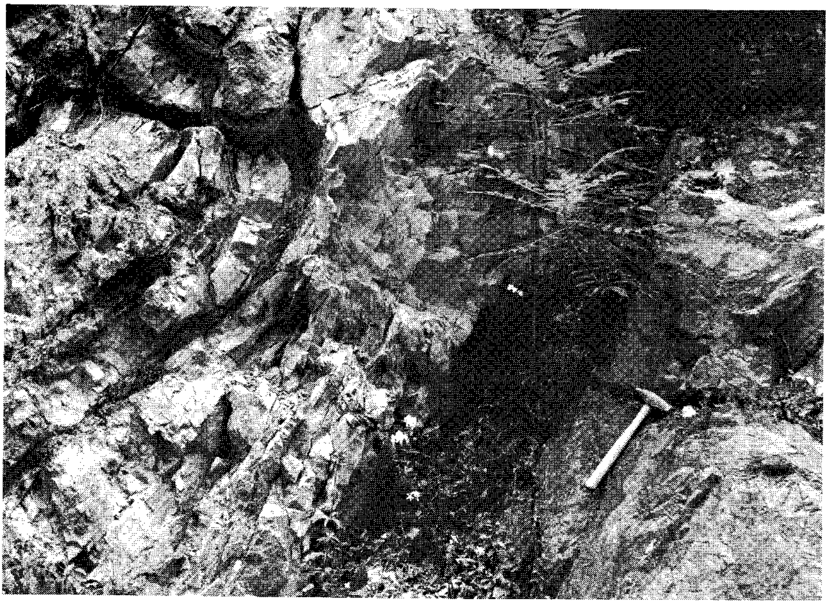


Figure 28. Northwestward-dipping thrust fault located along State Highway 43, 0.6 mile southeast of Buchanan (Plate 3). Hampton shale (left) has been thrust over Shady dolomite.

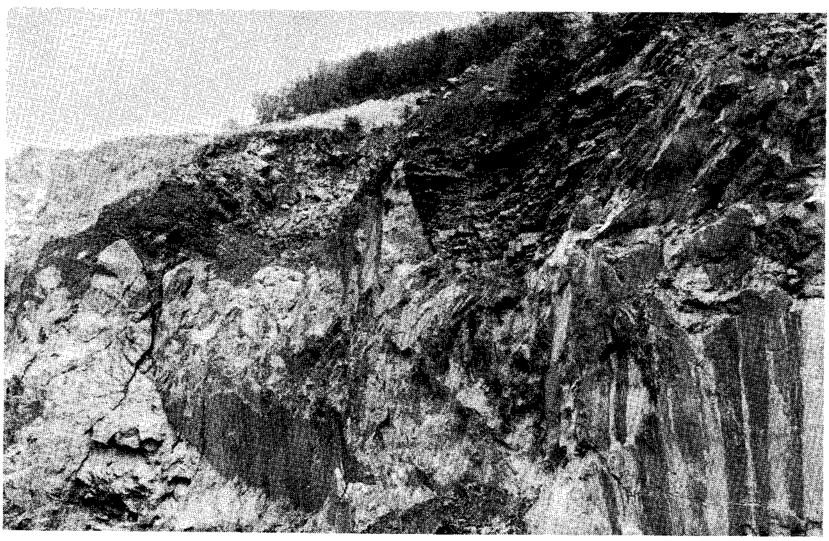
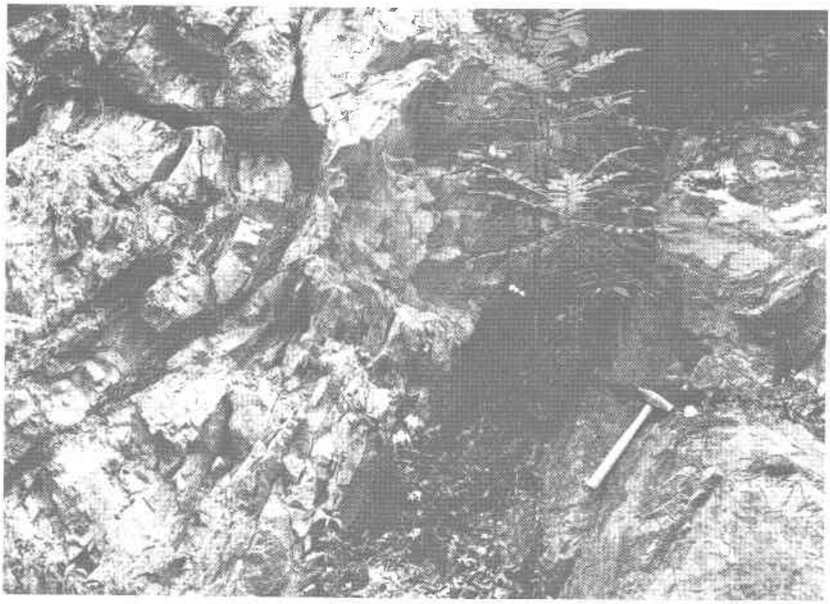


Figure 29. Thrust fault exposed in the James River Hydrate and Supply Company, Inc. quarry about 1.4 miles east of Buchanan (Plate 3). Hampton shale has been thrust over Shady dolomite.



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Between Buchanan (Plate 3) and Natural Bridge Station (Plate 4) the zone of faulting is partially covered by the James River and its alluvial plain. Exposed faults are abundant in the Rome and Elbrook outcrop belts, and from these, tentative continuous fault traces have been delineated; however, the fault zone may be even more complicated than is recognized here. It appears likely that the zone consists of many small faults that are parallel to outcrop belts and terminate laterally in folds, particularly in the shaly portions of the Rome and Elbrook formations.

Several types of faults occur along the Blue Ridge front, but none involve great amounts of stratigraphic throw. A minor fault is exposed along State Road 790 about 1 mile southeast of Gilmore Mills (Plate 4), where the Hampton is thrust over Erwin. The Erwin is present on both sides of the James River north of Wilson Mountain and crops out along the Chesapeake and Ohio Railway about 1.5 miles east of Rocky Point where it is offset approximately 0.2 mile to the southeast. It crops out along the Norfolk and Western Railway just across the James River in a high-angle normal fault that is exposed in the cliff face. The Erwin has moved down and to the west and is probably part of a huge slump block on the west slope of Wilson Mountain. This normal fault is best seen from State Road 608, 1 mile east of Alpine (Plate 4).

VALLEY AND RIDGE AREA

The Valley and Ridge portion of the mapped area consists of long northeastward-trending ridges held up by Silurian clastic rocks, separated by valleys of Devonian shales or Ordovician shales and limestones. These ridges are terminated on the south and east by the Pulaski-Staunton thrust fault. The Silurian and Devonian units continue under the thrust sheet that is present in an area which is topographically low, between 1000 and 1400 feet; whereas the Silurian-capped ridges to the north are at elevations of about 3000 feet.

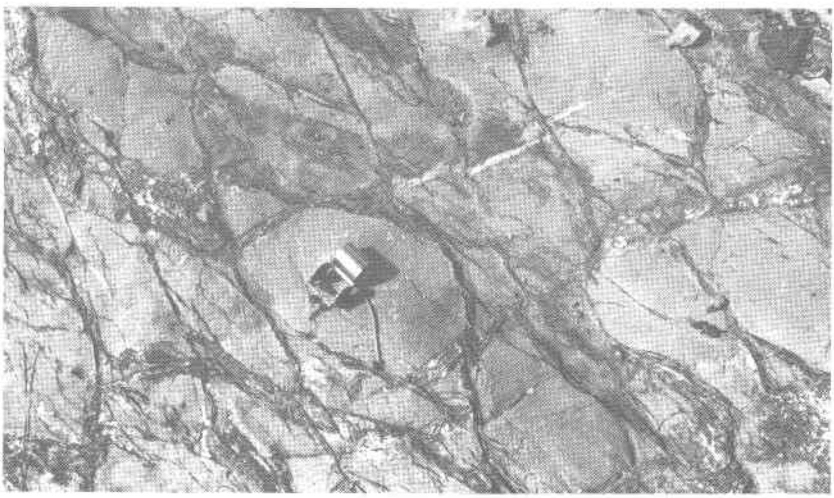
The easternmost ridge, Short Hills, is a synclinal mountain that is constricted where Cedar Creek flows off the mountain (Plate 1). This constriction occurs where the symmetry of the fold changes. Just to the north of the constriction, the west limb of the syncline dips steeply southeastward, and the east limb is eroded away or it may be faulted on the east side. To the south the structure is a simple broad open syncline.

The outcrop belt of Martinsburg is very wide along the east flank of Short Hills (Plate 1) and around Camp Mountain (Plate 2). Dips in these areas indicate that this width is in many places related to intricate folds, even where the overlying Silurian clastic rocks are only broadly folded. It is probable that some Edinburg occurs in these Martinsburg belts, either in the hinges of tight folds or as fault slices. Long narrow belts of Edinburg do occur in this manner west of the Pulaski-Staunton fault near Spring Gap (Plate 1) where the rocks are sheared (Figure 30). Exposures are not adequate to determine whether the Edinburg occurs as sheared hinges of anticlines or as fault slices; they are mapped as folds. The structural pattern of much of the remainder of the Valley and Ridge area is highly complex, consisting of strongly asymmetrical folds and thrust faults. It is probable that many of the structural complications in the area are related to movement associated with the Pulaski-Staunton thrust fault.

Figure 30. Sheared black aphanitic limestone in the Edinburg Formation west of the Pulaski-Staunton fault along Spring Gap Creek (Plate 1).

Pulaski-Staunton Fault

The major thrust fault, or more accurately fault system, within this area is identified as part of the Pulaski-Staunton fault. It can be traced southwestward along the east side of Short Hills (Plate 1). Near Springfield the fault bifurcates, and from there to the east side of Purgatory Mountain (Plate 3) there are two essentially parallel faults, interpreted as imbricate faults, all part of the Pulaski-Staunton fault system. These faults rejoin along the east side of Purgatory Mountain, and from there the zone can be traced around the south end of the mountain to the north and west to Scurff Mountain (Figure 31). The southwestern part of the area mapped (Plate 3) consists largely of to intricate folds, even where the overlying Silurian clastic rocks are only broadly folded. It is probable that some Edinburg occurs in these Martinsburg belts, either in the hinges of tight folds or as fault slices. Long narrow belts of Edinburg do occur in this manner west of the Pulaski-Staunton fault near Spring Gap (Plate 1) where the rocks are sheared (Figure 30). Exposures are not adequate to determine whether the Edinburg occurs as sheared hinges of anticlines or as fault slices; they are mapped as folds. The structural pattern of much of the remainder of the Valley and Ridge area is highly complex, consisting of strongly asymmetrical folds and thrust faults. It is probable that many of the structural complications in the area are related to movement associated with the Pulaski-Staunton thrust fault.



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Elbrook and Conococheague which has been thrust westward over Ordovician through Devonian units. The structure within this thrust sheet is more complex than indicated on the geologic maps. There are few exposures over large portions of the thrust sheet; but where the Elbrook is exposed, it is generally brecciated or highly contorted, and there are many small faults.

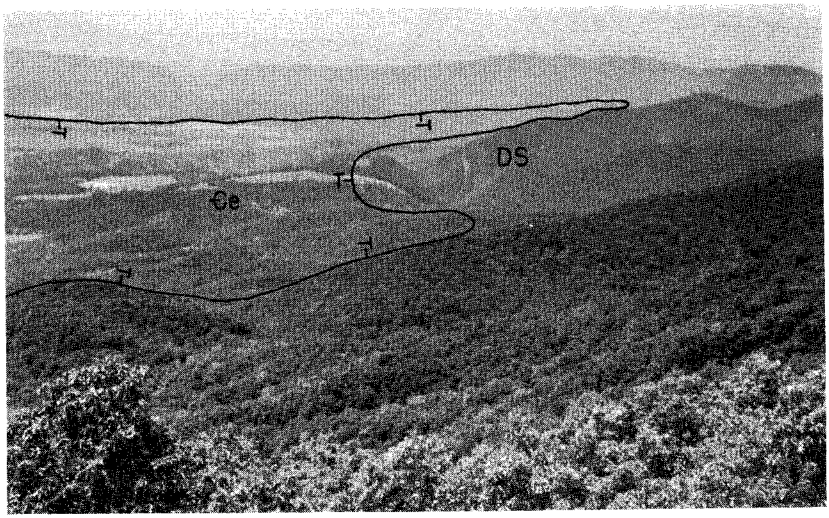

Figure 31. View to the west from Purgatory Mountain (Plate 3). In the flat area Elbrook Formation is present in an overthrust sheet bounded by the Pulaski-Staunton fault, and Silurian rocks are present on the higher ridges.

The Pulaski-Staunton fault has undergone folding, as indicated in the Purgatory Mountain area (Plate 3, Sections A-A′, B-B′). The fault crops out at an elevation of about 1200 feet on the east side of the mountain, at 1600 feet on the west side, and the top of the mountain is at 2995 feet. At Horseshoe Bend (Plate 3) the Pulaski-Staunton fault is exposed where the James River has cut through the Elbrook and exposed the underlying Devonian units; here the fault plane is nearly horizontal. The thrust sheet is part of a much larger one that extends to the west and south. If the direction of movement is assumed to be northwest, there would be more than 8 miles of horizontal transport. The displacement is partially approximated by measuring the distance from the northwesternmost to the southeasternmost exposures of the Pulaski-Staunton fault, which is at least 8 miles in the area mapped. It is believed that the thrust plate largely composed of Elbrook and Conococheague has overridden and covered Ordovician

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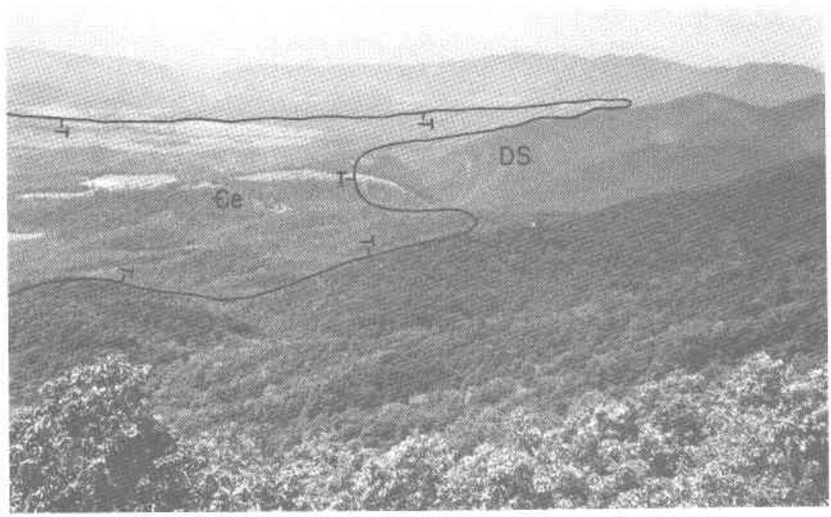

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Area North of Sugarloaf Mountain

The topography of Camp and Little Camp mountains is suggestive of a canoe-shaped synclinal mountain. The east limb of this partly faulted syncline is exposed along Little Camp Mountain which is truncated by a minor thrust fault. Good exposures are present in the stream gap between Orebank and Camp mountains where the Silurian section is repeated.

Prisehouse Mountain, Painter Mountain, Brushy Mountain (Plate 2) form the northwest limb of an anticline that is strongly asymmetrical to the northwest. At Moore Creek this limb is right side up and dips to the northwest, but it becomes overturned to the southwest in the Brushy Mountain area. Along State Road 612 south of Piny Knob, the Silurian section is so strongly overturned that the Tuscarora has a dip of 30 degrees to the southeast. Farther southwestward this overturned limb becomes very flat, and is probably faulted just north of Stamping Ground Mountain. The southeast limb is represented by the low-dipping normal sections exposed at Sugarloaf Mountain and Camp Mountain. North of Camp Mountain the east limb has been removed by erosion.

The Biggs Mountain-Middle Mountain structure is interpreted as a faulted klippe that was derived from what is now known as the Painter Mountain-Brushy Mountain area. The Millboro Shale and Needmore Formation are well exposed along the east side of Biggs and Middle mountains, and complex folds and breccia are present in most of the exposures. At the north end of Middle Mountain, Millboro and Needmore underlie a partially exposed section of Tuscarora, Cacapon, and Keefer that form a syncline at the top of the mountain. In the gap between Middle and Biggs mountains, an overturned section of Silurian and Devonian rocks is exposed. Southward along the east flank of Biggs Mountain, Upper Silurian sandstones and a few exposures of Tonoloway limestone lie between the Millboro and Needmore in the valley of Mill Creek and a repeated Millboro-Needmore outcrop belt to the northwest. The crest of Biggs Mountain is composed of Keefer Sandstone. On the west side of Biggs Mountain there is another exposure of Millboro and Needmore, and west of that there is a second belt of brecciated Keefer.

One interpretation of the development of this structure would start with thrusting of a plate of Silurian clastic rocks to the west, causing it to override the Millboro and Needmore. This plate might have been partially folded into a syncline during thrusting. Later the syncline was faulted by thrusting on the east side. This thrust caused the syncline to become overturned and brought Tonoloway, Keyser, and Keefer up onto the Millboro and Needmore which had been overthrust by the klippe. A schematic diagram showing this development is illustrated in Figure 32.

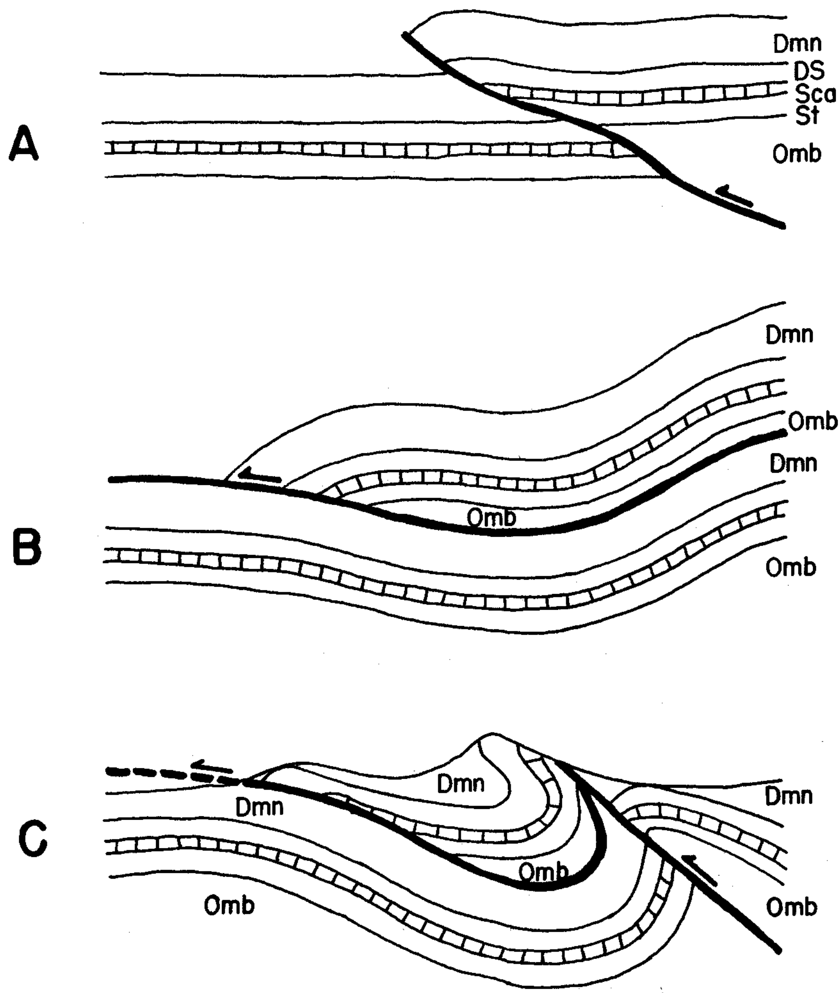

Figure 32. Diagrammatic cross-section illustrating the sequential development of the Biggs Mountain-Middle Mountain structure.

ECONOMIC GEOLOGY

At present limestone and dolomite are being produced for chemical, metallurgical, and agricultural uses, and also for road construction. There are extensive outcrops of high-calcium limestones, New Market and Lincolnshire, and other rocks suitable for road metal in the eastern part of the area mapped. Quarries in operation include those of the Liberty Limestone Corporation about 1 mile north of Rocky Point (Plate 4, No. 6) and east of Buchanan (Plate 3, No. 4) and the James River Hydrate and Supply Company, Inc. quarry near Buchanan (Plate 3, No. 5). The Rocky Point quarry is in the New Market, Lincolnshire, and Edinburg. The quarries east of Buchanan are in the Shady Formation (Figure 33). All three of the quarries are described by Gooch, Wood, and Parrott (1960), and the industrial limestones and dolomites of this region are described by Edmundson (1958). The Rome Formation that is used for manufacture of brick in other parts of Virginia is exposed. There are large quantities of sandstone and quartzite.

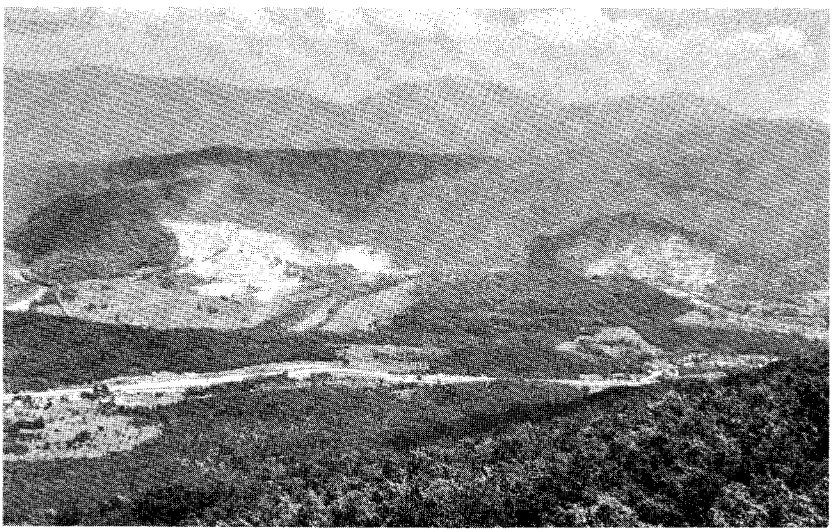

Figure 33. Quarries of the James River Hydrate and Supply Company, Inc. (left) and Liberty Limestone Corporation (right) in the Shady Formation east of Buchanan (Plate 3). The Pulaski-Staunton fault is present near Interstate Highway 81 in the foreground. View southeastward from Purgatory Mountain.

Clay of Quaternary age (R-1912) is being produced from a pit located southeast of State Road 608 approximately 2 miles southwest of Gilmore Mills (Plate 4, No. 7) and used in the manufacture of

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Figure 33. Quarries of the James River Hydrate and Supply Company, Inc. (left) and Liberty Limestone Corporation (right) in the Shady Formation east of Buchanan (Plate 3). The Pulaski-Staunton fault is present near Interstate Highway 81 in the foreground. View southeastward from Purgatory Mountain.

Clay of Quaternary age (R-1912) is being produced from a pit located southeast of State Road 608 approximately 2 miles southwest of Gilmore Mills (Plate 4, No. 7) and used in the manufacture of brick by the Locher Brick Company, Inc., at their plant at Glasgow. A report by Calver and others (1964) contains evaluation data for clay and shale samples collected in the area of study. Potential uses of raw materials from four localities are shown in Table 2.

Table 2.—Potential uses of clay materials from the Buchanan and Arnold Valley quadrangles (data compiled from Calver and others, 1964).

Repository No.	*Location*	*Formation*	*Sample Interval*	*Potential Use*
R-1724	Roadcut, 1.1 miles south of Natural Bridge, on the north side of State Road 608 approximately 0.4 mile north of the intersection with State Road 708 at Gilmore Mills (Plate 4)	Rome	Representative of exposure of shale, 8 feet in height, that extends for a distance of 180 feet	Lightweight aggregate (by the sintering method)
R-1774	Exposure, 1.5 miles northeast of Rocky Point, on the east side of State Road 609 approximately 0.8 mile north of the intersection with State Road 608 (Plate 4)	Rome	Composite sample across 70 feet of shale and siltstone	Low-grade common brick and probably sintered aggregate
R-1775	Roadcut, 3.0 miles northeast of Buchanan, on the north side of State Road 614 about 0.2 mile northeast of the crossing of the Chesapeake and Ohio Railway (Plate 3)	Rome	Sample across 65 feet of shale	Low-grade common brick and probably sintered aggregate
R-2092	Quarry of the James River Hydrate and Supply Company, Inc., on service road 2.0 miles northeast of intersection with State Highway 43, and 2.5 miles east of Buchanan (Plate 3)	Residual clay	Representative sample of 35 feet of clay	Brick and tile, with the addition of fine sand

J. L. Campbell (1882) described the iron ore prospects of the Blue Ridge area (Plates 3, 4). He reported that ore from a residual deposit of limonite was used in the Glenwood Furnace in Arnold

Valley during the Civil War. The ore consisted of nodular or mammillary masses of limonite-goethite and psilomelane, manganite, and wad. The ore occurs in residual soils at the foot of the Blue Ridge, but known prospects in the region are not of high enough grade to be mined at the present time.

Woodward (1936a) presented a detailed summary of the numerous iron and manganese ore prospects in the Natural Bridge and Eagle Rock quadrangles. His summary is the most complete available, and no new prospects have been developed since Woodward's work in 1936. Iron ore has been mined from the Cacapon Formation, and iron and manganese ore from the Oriskany and Helderberg units.

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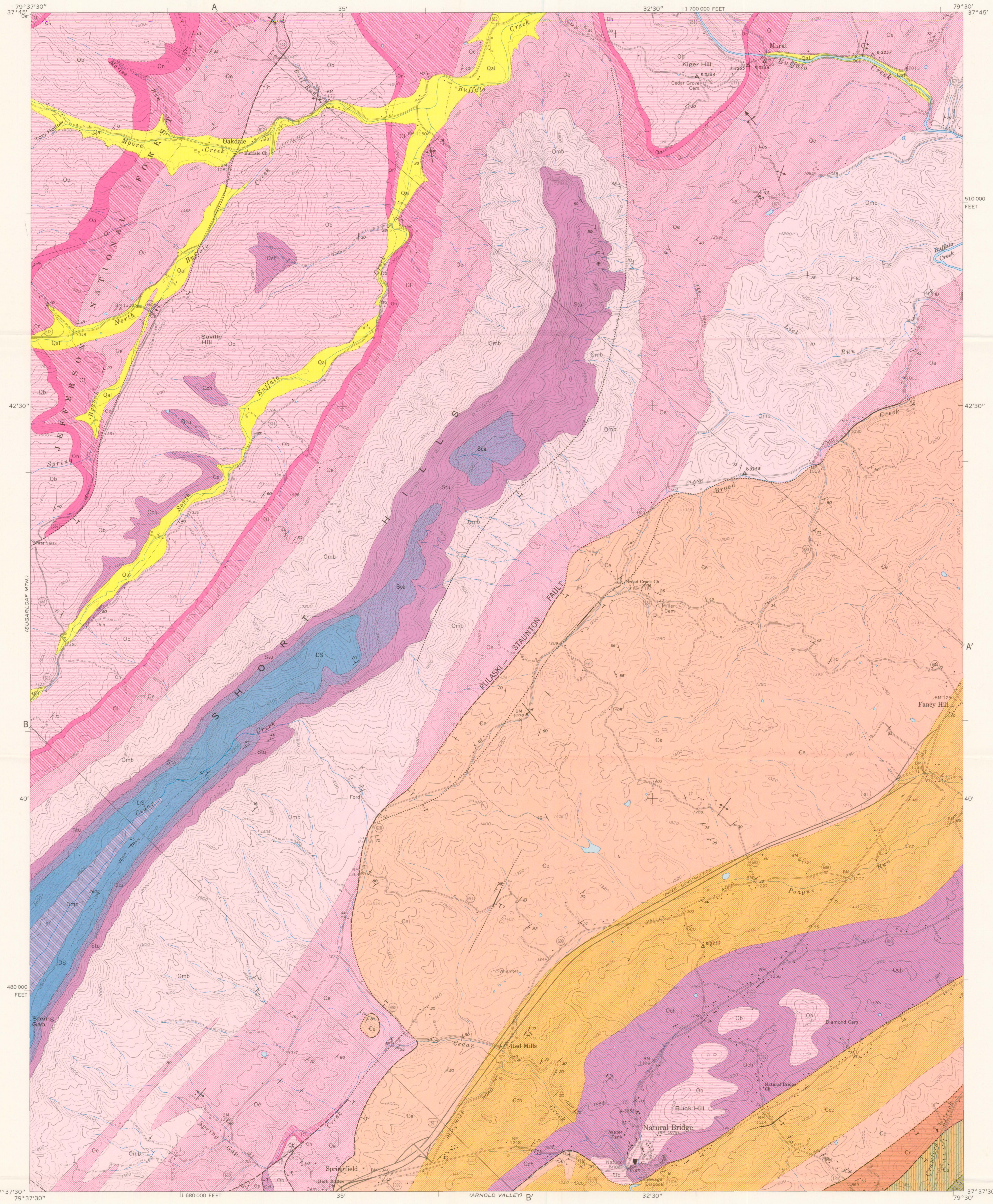
INDEX

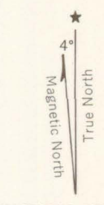
COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES
James L. Calver
Commissioner of Mineral Resources and State Geologist



Base From U.S. Geological Survey, 1961
Natural Bridge Quadrangle, 7½-Minute Series

GEOLOGIC MAP OF THE NATURAL BRIDGE QUADRANGLE, VIRGINIA

Geology by Edgar W. Spencer



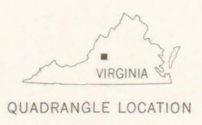
1961 MAGNETIC DECLINATION

SCALE 1:24 000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

CONTOUR INTERVAL 40 FEET



QUADRANGLE LOCATION

1967

EXPLANATION

CENOZOIC — QUATERNARY

Qal — Alluvium
Recent stream deposits and some terrace gravel and colluvium.

PALEOZOIC

DEVONIAN

Dmn — Millboro Shale and Needmore Formation
Millboro: shale, black, fissile, thin-bedded; Needmore: shale, olive-gray.

SILURIAN-DEVONIAN

DS — Lower Devonian—Upper Silurian rocks
Includes: sandstone, coarse-grained, calcareous and ferruginous, with a few conglomerate beds; Tonoloway Formation, limestone, dark-gray, thin-bedded; Keefer Sandstone, white, fine- to medium- grained.

SILURIAN

Sca — Cacapon Formation
Sandstone, maroon, hematitic; shale; a few white sandstone layers.

Stu — Tuscarora Formation
Sandstone, white to gray, massive, and pebble conglomerate. Map unit includes gray and reddish-gray, medium-grained, cross-bedded sandstone and mudstone (Juniata or Oswego formations?).

ORDOVICIAN

Omb — Martinsburg Formation
Shale, buff to greenish-brown and brown, fissile; gray fossiliferous limestone interbedded with shale at base; thin sandstone layers interbedded with shale near top.

Oe — Edinburg Formation
Includes: limestone, black, interbedded with shale (Liberty Hall); limestones, black, massive and nodular (Lantz Mills); Botetourt Member, limestone, blue-gray, coarse- grained, massive, reddish cast to weathered surfaces.

Ol — Lincolnshire Formation
Limestone, light-gray, coarse-grained, massive, fossiliferous (Murat); limestone, dark-gray, thin-bedded with stringers of black chert.

On — New Market Limestone
Limestone, dove-gray, fine-grained, massive.

Ob — Beekmantown Formation
Dolomite, light- to medium-gray, interbedded with dove-gray and dark-blue limestones, particularly near the base and top; some white chert beds, massive.

Och — Chepultepec Formation
Limestone, bluish-gray, thin- to massive-bedded, with layers of magnesian limestone and massive light-gray dolomite.

CAMBRIAN

Єco — Conococheague Formation
Limestone, blue-gray, thin-bedded, with some sandstone and massive light-gray dolomite.

Єe — Elbrook Formation
Dolomite, thin-bedded, platy, slabby weathered surfaces; limestone, dark-blue, thin-bedded; limestone, white, thin-bedded; shale.

Єr — Rome Formation
Shale, maroon, buff, green; limestone, massive.

Єs — Shady Formation
Dolomite, blue, massive; some massive limestone and thin sandy dolomite near the base.

Єer — Erwin Formation
Sandstone, buff and blue-gray to white; quartzite with a few thin interbeds of shale.

CONTACTS

- exposed
- approximate
- covered or inferred

FAULTS
THRUST

- exposed
- approximate
- covered or inferred
- T overthrust side

ATTITUDE OF ROCKS

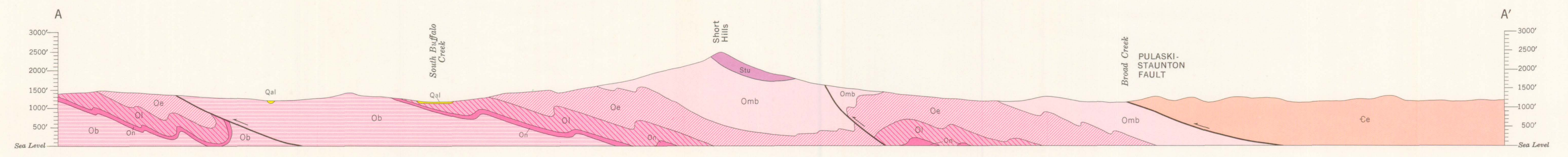
- 60 Strike and dip of beds
- 70 Strike and dip of overturned beds
- Strike of vertical beds
- Horizontal beds
- Anticlinal beds
- Overturned anticlinal beds

QUARRIES

ABANDONED QUARRY
1. Limestone quarry
2. Limestone quarry

SAMPLE LOCATIONS

△ R-3253 — Representative samples of lithologies mapped and some raw materials that have potential use in ceramic industry.



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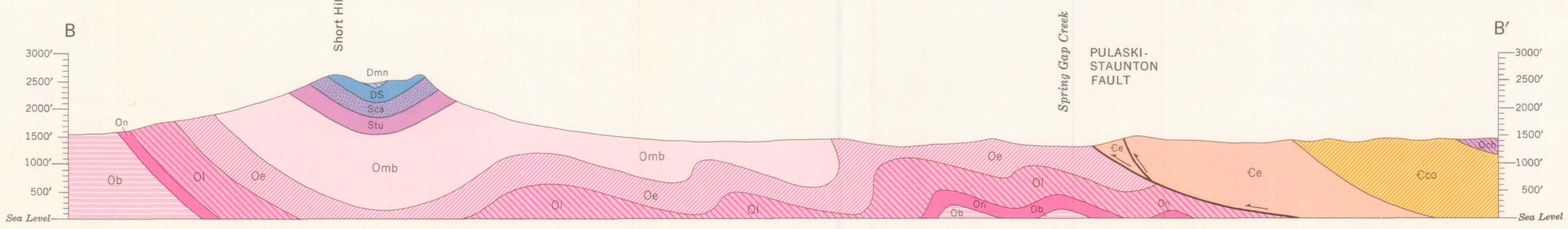
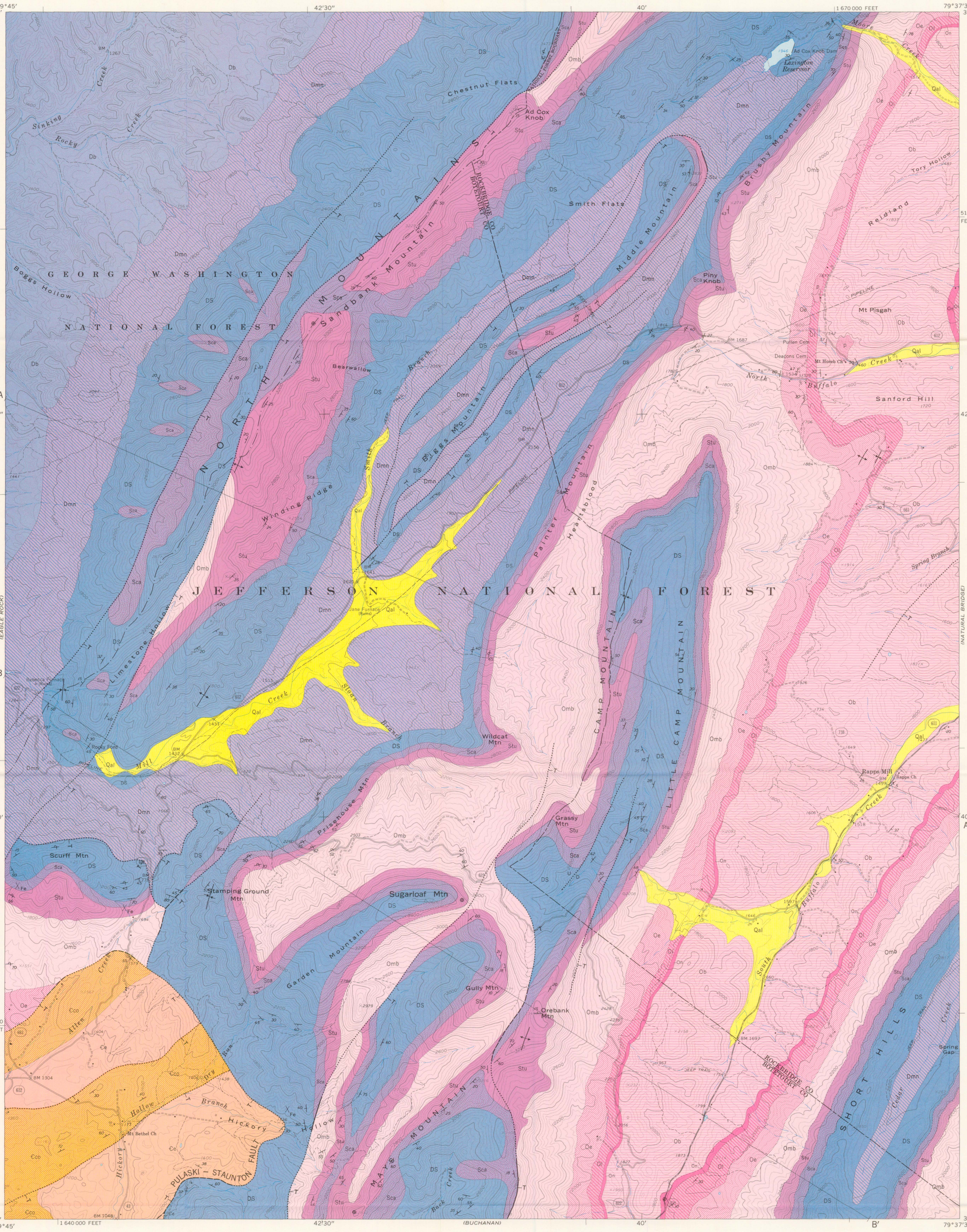


COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES
James L. Calver
Commissioner of Mineral Resources and State Geologist



EXPLANATION

CENOZOIC — QUATERNARY

Qal — Alluvium
Recent stream deposits and some terrace gravel and colluvium.

p — Ultramafic rock
Stock-like mass of weathered olivine-mica rock, peridotite(?).

PALEOZOIC

DEVONIAN

Db — Brallier Formation
Shale, olive-gray, interbedded with gray sandstone.

Dmn — Millboro Shale and Needmore Formation
Millboro: shale, black, fissile, thin-bedded; Needmore: shale, olive-gray.

SILURIAN-DEVONIAN

DS — Lower Devonian—Upper Silurian rocks
Includes: sandstone, coarse-grained, calcareous and ferruginous, with a few conglomerate beds; Tonoloway Formation, limestone, dark-gray, thin-bedded; Keefer Sandstone, white, fine- to medium- grained.

SILURIAN

Sca — Cacapon Formation
Sandstone, maroon, hematitic; shale; a few white sandstone layers.

Stu — Tuscarora Formation
Sandstone, white to gray, massive, and pebble conglomerate. Map unit includes gray and reddish-gray, medium-grained, cross-bedded sandstone and mudstone (Juniata or Oswego formations?).

ORDOVICIAN

Omb — Martinsburg Formation
Shale, buff to greenish-brown and brown, fissile; gray fossiliferous limestone interbedded with shale at base; thin sandstone layers interbedded with shale near top.

Oe — Edinburg Formation
Includes: limestone, black, interbedded with shale (Liberty Hall); limestones, black, massive and nodular (Lantz Mills); Botetourt Member, limestone, blue-gray, coarse- grained, massive, reddish cast to weathered surfaces.

Ol — Lincolnshire Formation
Limestone, light-gray, coarse-grained, massive, fossiliferous (Murat); limestone, dark-gray, thin-bedded with stringers of black chert.

On — New Market Limestone
Limestone, dove-gray, fine-grained, massive.

Ob — Beekmantown Formation
Dolomite, light- to medium-gray, interbedded with dove-gray and dark-blue limestones, particularly near the base and top; some white chert beds, massive.

CAMBRIAN

Ꞓco — Conococheague Formation
Limestone, blue-gray, thin-bedded, with some sandstone and massive light-gray dolomite.

Ꞓe — Elbrook Formation
Dolomite, thin-bedded, platy, slabby weathered surfaces; limestone, dark-blue, thin-bedded; limestone, white, thin-bedded; shale.

CONTACTS
exposed
approximate
covered or inferred

FAULTS
NORMAL
covered or inferred
U upthrown side
D downthrown side

TRANSVERSE
covered or inferred; arrows indicate relative movement

THRUST
exposed
approximate
covered or inferred
T overthrust side

ATTITUDE OF ROCKS
Strike and dip of beds
Strike and dip of overturned beds
Strike of vertical beds
Horizontal beds
Anticlinal beds
Synclinal beds

PROSPECTS
Prospect with symbol to indicate iron oxide minerals (Fe)

Base From U.S. Geological Survey, 1961
Sugarloaf Mtn. Quadrangle, 7½-Minute Series

Williams & Heintz Map Corporation

GEOLOGIC MAP OF THE SUGARLOAF MTN. QUADRANGLE, VIRGINIA

Geology by Edgar W. Spencer

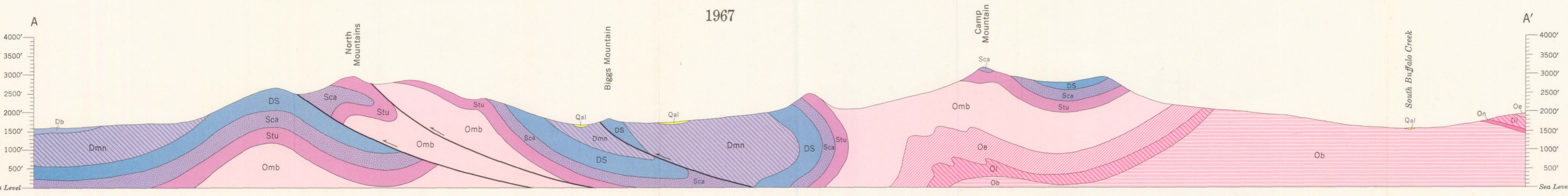
1961 MAGNETIC DECLINATION

SCALE 1:24 000

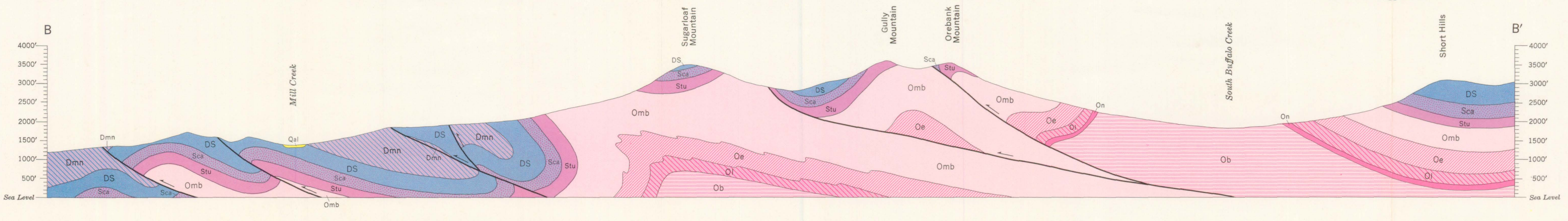
CONTOUR INTERVAL 40 FEET

QUADRANGLE LOCATION

1967



No Vertical Exaggeration



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

Base From U.S. Geological Survey, 1961
Buchanan Quadrangle, 7½-Minute Series

GEOLOGIC MAP OF THE BUCHANAN QUADRANGLE, VIRGINIA

Geology by Edgar W. Spencer

4°
Magnetic North
True North
1961 MAGNETIC DECLINATION

SCALE 1:24 000
1 ½ 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
CONTOUR INTERVAL 40 FEET

VIRGINIA
QUADRANGLE LOCATION

1967

EXPLANATION

CENOZOIC — QUATERNARY

Qal Alluvium
Recent stream deposits and some terrace gravel and colluvium.

PALEOZOIC

DEVONIAN

Dmn Millboro Shale and Needmore Formation
Millboro: shale, black, fissile, thin-bedded; Needmore: shale, olive-gray.

SILURIAN-DEVONIAN

DS Lower Devonian—Upper Silurian rocks
Includes: sandstone, coarse-grained, calcareous and ferruginous, with a few conglomerate beds; Tonoloway Formation, limestone, dark-gray, thin-bedded; Keefer Sandstone, white, fine- to medium-grained.

SILURIAN

Sca Cacapon Formation
Sandstone, maroon, hematitic; shale; a few white sandstone layers.

Stu Tuscarora Formation
Sandstone, white to gray, massive, and pebble conglomerate. Map unit includes gray and reddish-gray, medium-grained, cross-bedded sandstone and mudstone (Juniata or Oswego formations?).

ORDOVICIAN

Omb Martinsburg Formation
Shale, buff to greenish-brown and brown, fissile; gray fossiliferous limestone interbedded with shale at base; thin sandstone layers interbedded with shale near top.

Oe Edinburg Formation
Includes: limestone, black, interbedded with shale (Liberty Hall); limestones, black, massive and nodular (Lantz Mills); Botetourt Member, limestone, blue-gray, coarse-grained, massive, reddish cast to weathered surfaces.

Ol Lincolnshire Formation
Limestone, light-gray, coarse-grained, massive, fossiliferous (Murat); limestone, dark-gray, thin-bedded with stringers of black chert.

On New Market Limestone
Limestone, dove-gray, fine-grained, massive.

Ob Beekmantown Formation
Dolomite, light- to medium-gray, interbedded with dove-gray and dark-blue limestones, particularly near the base and top; some white chert beds, massive.

Och Chepultepec Formation
Limestone, bluish-gray, thin- to massive-bedded, with layers of magnesian limestone and massive light-gray dolomite.

CAMBRIAN

Ꞓco Conococheague Formation
Limestone, blue-gray, thin-bedded, with some sandstone and massive light-gray dolomite.

Ꞓe Elbrook Formation
Dolomite, thin-bedded, platy, slabby weathered surfaces; limestone, dark-blue, thin-bedded; limestone, white, thin-bedded; shale.

Ꞓr Rome Formation
Shale, maroon, buff, green; limestone, massive.

Ꞓs Shady Formation
Dolomite, blue, massive; some massive limestone and thin sandy dolomite near the base.

Ꞓer Erwin Formation
Sandstone, buff and blue-gray to white; quartzite with a few thin interbeds of shale.

Ꞓhun Hampton and Unicoi Formations
Hampton: laminated shale, graywacke, and quartzite;
Unicoi: graywacke, sandstone, and pebble conglomerate with a few tuffaceous beds.

PRECAMBRIAN

pꞒv Virginia Blue Ridge Complex
Includes: Pedlar Formation, granite, hypersthene granodiorite, diorite, and unakite; Marshall Formation, biotite granite.

CONTACTS

exposed
approximate
covered or inferred

FAULTS
THRUST

exposed
approximate
covered or inferred
T overthrust side

ATTITUDE OF ROCKS

60 Strike and dip of beds
80 Strike and dip of overturned beds
Strike of vertical beds
Horizontal beds
Anticlinal beds, arrow shows direction of plunge
Synclinal beds, arrow shows direction of plunge
Overturned anticlinal beds, arrow shows direction of plunge
Overturned synclinal beds

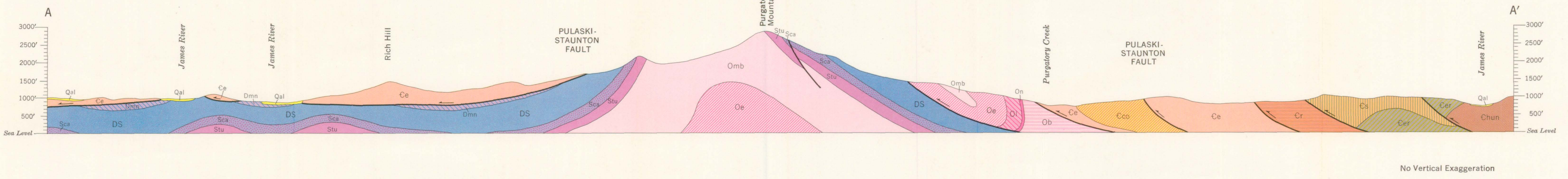
QUARRIES

ACTIVE QUARRY
4. Liberty Limestone Corp. (Sherwood quarry)
5. James River Hydrate and Supply Co., Inc.

ABANDONED QUARRY
3. Limestone quarry

SAMPLE LOCATIONS

R-2092 Representative samples of lithologies mapped and some raw materials that have potential use in ceramic industry.



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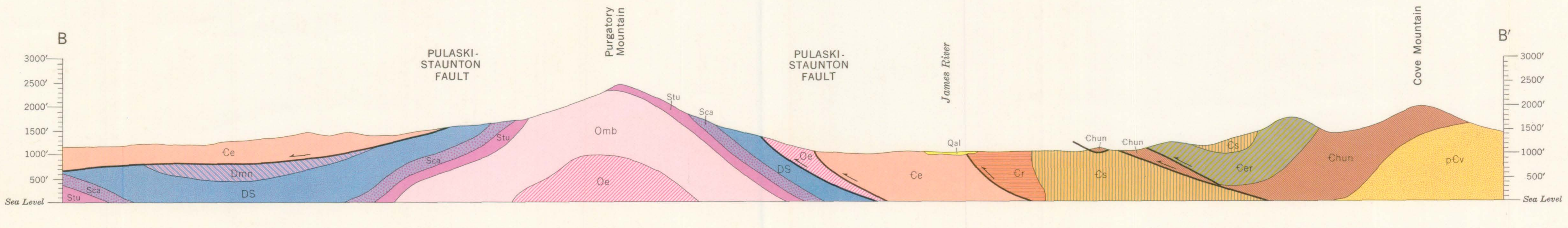

COMMONWEALTH OF VIRGINIA
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DIVISION OF MINERAL RESOURCES
James L. Calver
Commissioner of Mineral Resources and State Geologist

Base From U.S. Geological Survey, 1961
Arnold Valley Quadrangle, 7½-Minute Series

Williams & Heintz Map Corporation

GEOLOGIC MAP OF THE ARNOLD VALLEY QUADRANGLE, VIRGINIA

Geology by Edgar W. Spencer

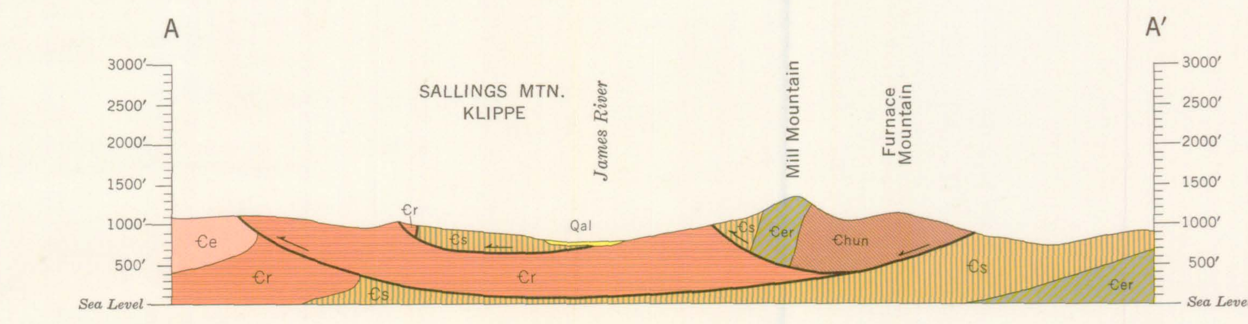
1961 MAGNETIC DECLINATION

SCALE 1:24 000

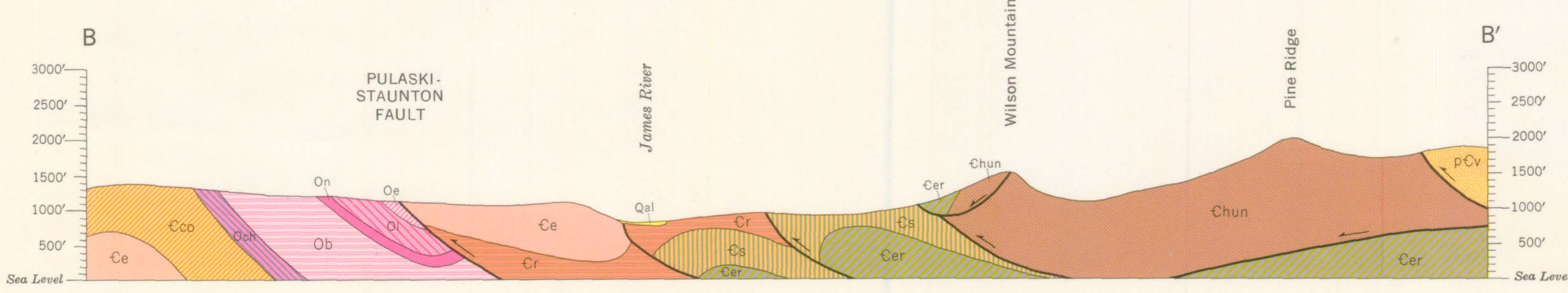
CONTOUR INTERVAL 40 FEET

QUADRANGLE LOCATION

1967



No Vertical Exaggeration



EXPLANATION

CENOZOIC — QUATERNARY

Qal — Alluvium
Recent stream deposits and some terrace gravel and colluvium.

Alluvium and colluvium
Alluvium and colluvium interspersed with outcrops of Virginia Blue Ridge Complex and Unicoi, Hampton, Erwin, and Shady formations in the Arnold Valley area.

PALEOZOIC — ORDOVICIAN

Omb — Martinsburg Formation
Shale, buff to greenish-brown and brown, fissile; gray fossiliferous limestone interbedded with shale at base; thin sandstone layers interbedded with shale near top.

Oe — Edinburg Formation
Includes: limestone, black, interbedded with shale (Liberty Hall); limestones, black, massive and nodular (Lantz Mills); Botetourt Member, limestone, blue-gray, coarse-grained, massive, reddish cast to weathered surfaces.

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Limestone, bluish-gray, thin- to massive-bedded, with layers of magnesian limestone and massive light-gray dolomite.

PALEOZOIC — CAMBRIAN

Cco — Conococheague Formation
Limestone, blue-gray, thin-bedded, with some sandstone and massive light-gray dolomite.

Ce — Elbrook Formation
Dolomite, thin-bedded, platy, slabby weathered surfaces; limestone, dark-blue, thin-bedded; limestone, white, thin-bedded; shale.

Cr — Rome Formation
Shale, maroon, buff, green; limestone, massive.

Cs — Shady Formation
Dolomite, blue, massive; some massive limestone and thin sandy dolomite near the base.

Cer — Erwin Formation
Sandstone, buff and blue-gray to white; quartzite with a few thin interbeds of shale.

Chun — Hampton and Unicoi Formations
Hampton: laminated shale, graywacke, and quartzite;
Unicoi: graywacke, sandstone, and pebble conglomerate with a few tuffaceous beds.

PRECAMBRIAN

pCv — Virginia Blue Ridge Complex
Includes: Pedlar Formation, granite, hypersthene granodiorite, diorite, and unakite; Marshall Formation, biotite granite.

CONTACTS

- exposed
- approximate
- covered or inferred

FAULTS

THRUST

- exposed
- approximate
- covered or inferred
- T overthrust side

SLUMP

- approximate
- S edge of slump block

SHEAR ZONE

ATTITUDE OF ROCKS

- 30 Strike and dip of beds
- 50 Strike and dip of overturned beds
- Strike of vertical beds
- Anticlinal beds
- Synclinal beds

QUARRY AND PROSPECT

ACTIVE QUARRY
6. Liberty Limestone Corp. (Rocky Point quarry)
7. Locher Brick Company, Inc.

X Prospect with symbol to indicate iron oxide minerals (Fe)

SAMPLE LOCATIONS

R-1724 Representative samples of lithologies mapped and some raw materials that have potential use in ceramic industry.