

VIRGINIA DIVISION OF MINERAL RESOURCES
PUBLICATION 170

GEOLOGY OF ROCKBRIDGE COUNTY, VIRGINIA

Gerald P. Wilkes, Edgar W. Spencer, Nick H. Evans, and Elizabeth V. M. Campbell



COMMONWEALTH OF VIRGINIA
DEPARTMENT OF MINES, MINERALS AND ENERGY
DIVISION OF MINERAL RESOURCES
Edward E. Erb, State Geologist and Division Director

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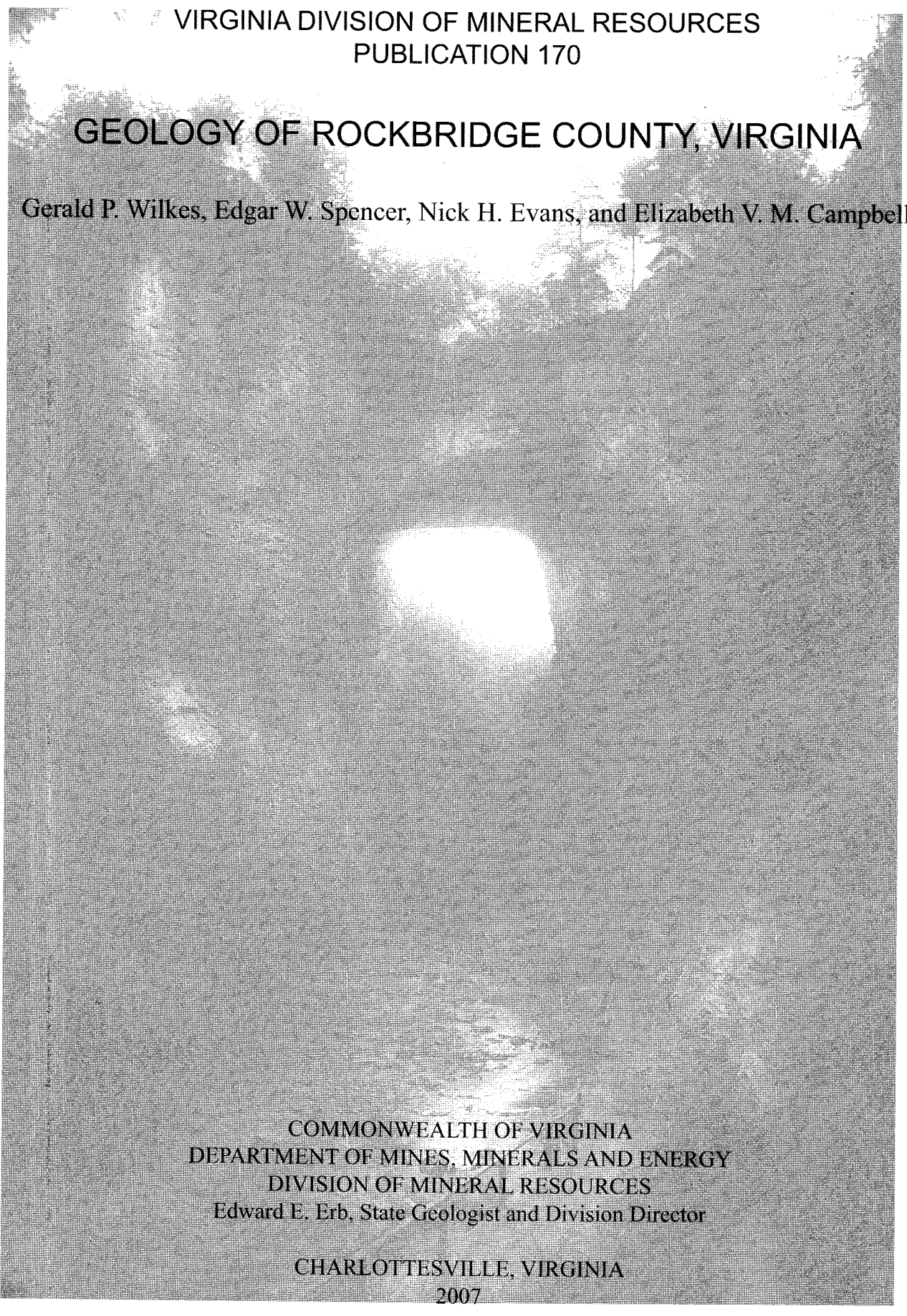
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FRONT COVER: Natural Bridge, circa 1900. One of the “Seven Natural Wonders of the World” and the namesake of Rockbridge County. For interpretations of the geologic development of the bridge and nearby Natural Bridge Caverns, refer to Spencer (1985) and Woodward (1936).



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TITLE PAGE: Natural Bridge, circa 1930.

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GEOLOGY OF ROCKBRIDGE COUNTY, VIRGINIA

Gerald P. Wilkes¹, Edgar W. Spencer², Nick H. Evans¹,
and Elizabeth V. M. Campbell¹

INTRODUCTION

Rockbridge County, located in west-central Virginia (Figure 1), includes portions of the Blue Ridge and the Valley and Ridge geologic provinces. Excellent rock exposures in the Blue Ridge display Proterozoic igneous and metamorphic rocks that were altered during the Grenville Orogeny over a billion years ago. The Valley and Ridge province displays equally well-exposed sequences of marine sandstone, shale, and carbonate rocks. These sedimentary rocks were deposited on the continental margin during the early and middle Paleozoic.

All of these rocks provide evidence of the structural and stratigraphic evolution of the Central Appalachians. Crustal deformation, initiated as extension during the early Paleozoic, culminated in the formation of thrust faults and folds during the Alleghanian Orogeny. A much later event of extension during the Mesozoic was accompanied by igneous activity.

Because of the wide span of geologic history it contains, Rockbridge County boasts

distinctive landforms and a variety of mineral resources. Some of the mineral resources have been utilized in the past while others may be developed in the future.

The map and cross-sections that accompany this report demonstrate the distribution and spatial relationships of rock units exposed in the county (Plate 1). Each of the map units is identified by its age and a symbol that indicates the formation name. Alluvium has been mapped along major streams. Other surficial deposits are not shown on the map or cross-sections. These deposits will appear on a county soil map, in preparation, to be published by the United States Natural Resources Conservation Service.

PREVIOUS AND CURRENT WORK

Charles Butts assembled the first comprehensive geologic map and stratigraphic synthesis of the Appalachian Valley of Virginia (Butts, 1938, 1940). This work provided nearly complete geologic map coverage of Rockbridge County at a scale of 1:250,000. During the 1960s, geologic maps were published at a scale of 1:62,500 for the Lexington (Bick, 1960), Millboro (Kozak, 1965), and Vesuvius (Werner, 1966) quadrangles. More recent geologic maps, published at a scale of 1:24,000 include the Natural Bridge, Sugarloaf Mountain, Buchanan, and Arnold Valley quadrangles (Spencer, 1968), the Craigsville quadrangle (Kozak, 1970), a portion of the Snowden quadrangle (Brown and Spencer, 1981), the Longdale and Millboro quadrangles (Lesure, 1987), and the Glasgow and Buena Vista quadrangles (Spencer, 2000). An unpublished 1:12,000-scale map by Hudson (1981) in the Irish Creek area is also available.

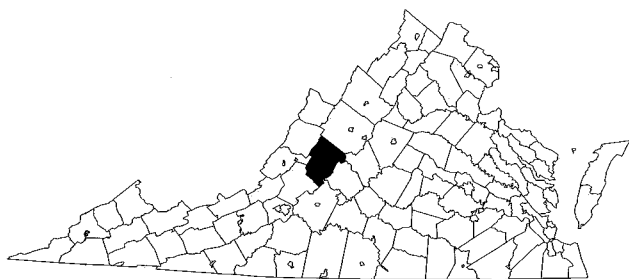


Figure 1. Location of Rockbridge County.

¹Virginia Department of Mines, Minerals and Energy, Division of Mineral Resources

²Washington and Lee University

In order to complete modern geologic coverage of the county, mapping on a scale of 1:50,000 was conducted by the authors in the Brownsburg, Collierstown, Cornwall, Goshen, Green Valley, Lexington, Longdale Furnace, Millboro, Montebello, and Vesuvius quadrangles.

ACKNOWLEDGEMENTS

Much assistance and insight was given to the authors during this project by Thomas M. Gathright II, Eugene K. Rader, William S. Henika, Roy S. Sites, and D. Allen Penick of the Virginia Division of Mineral Resources (DMR). Mary Ellen Cook of the United States Natural Resources Conservation Service was an invaluable help, as was David Bell, University College, Oxford University, England. David Harbor, Chris Connors, Bob Thren, and several students of Washington and Lee University enhanced this report. Vernon N. Morris, and Edwin W. Marshall, also of DMR, provided assistance with map preparation and technical support. Aid in mapping was given by H. Eugene Sours of the Virginia Department of Game and Inland Fisheries, Dr. Raymond Ford, and Christopher E. Wilkes.

Our special thanks are given to the citizens of Rockbridge County, whose congeniality and hospitality made our mapping a pleasure.

STRATIGRAPHY

In general, the ages of rocks exposed in the County become younger from east to west. The eastern quarter of the County is composed of the oldest rocks, those of the Blue Ridge basement complex, which are Proterozoic igneous and metamorphic rocks. The remainder of the Blue Ridge rocks are earliest Paleozoic in age. The Valley and Ridge is composed of Paleozoic carbonate and clastic rocks. Igneous intrusive rocks occur in the county and are probably Mesozoic and Eocene in age. Surficial sediments of Cenozoic age are found within the county. Recent deposits of travertine and marl are closely associated with faulting in carbonate terrain.

PROTEROZOIC

Blue Ridge Basement Complex (Yb)

The Blue Ridge basement complex extends southwestward from South Mountain in Maryland, along the Virginia Blue Ridge, and into North Carolina and Georgia. The basement complex is an assemblage of igneous and metamorphic rocks that are largely granitic in composition. The rocks in the basement complex of eastern Rockbridge are the oldest rocks exposed in the county, yielding radiometric ages of approximately 1.1 billion years (Sinha and Bartholomew, 1984).

Within the basement complex the oldest rocks are layered granulites and gneisses; in Rockbridge these include pyroxene granulite and a lighter-colored quartzofeldspathic layered rock called leucocratic granulite. Layered granulites in the basement complex have been intruded by a suite of plutonic igneous rocks including a variety of pyroxene-bearing granitic rocks, or charnockite, named the Pedlar River Charnockite Suite by Bartholomew and Lewis (1984). These rocks intruded the basement complex deep in the crust during the Grenville Orogeny, approximately 1.1 billion years ago. Two varieties of charnockite have been distinguished and mapped within Rockbridge County: porphyritic charnockite, and leucocratic charnockite. These are broad groupings, distinguished on the basis of mineralogy and rock fabric recognizable in the field; further detailed mapping could possibly delineate distinct plutons within each of these mapping units.

A second, younger series of igneous rocks also intrudes the basement complex in Rockbridge County. Rock types include granite along with a suite of felsite and greenstone dike rocks. These rocks are interpreted to have formed during a period of continental rifting that occurred during latest Proterozoic time. Within Rockbridge County, the younger granite includes a small, fluorite-bearing biotite granite pluton on the southeastern flank of Nettle Mountain, and a small, hornblende granite in the same vicinity. Greenstone and felsite dikes within the basement complex of eastern Rockbridge County are too

small to portray on the county geologic map. The greenstone dikes are temporally and genetically related to the Catoctin Formation that overlies the basement complex. The felsite dikes are spatially related to the biotite granite and have similar mineralogy; these rocks are considered contemporaneous.

Granulite (Ypg and Ylg)

Pyroxene-bearing and leucocratic granulites are exposed in the basement complex in the Blue Ridge of Rockbridge County. Pyroxene granulite (Ypg) is medium- to dark-greenish-gray (fresh), fine- to coarse-grained, and compositionally layered quartzofeldspathic gneiss. Major minerals include quartz, plagioclase feldspar, and potassium feldspar (orthoclase or microcline). Ferromagnesian minerals, orthopyroxene, clinopyroxene, and magnetite-ilmenite, constitute less than 10 percent of the mode. Accessories include apatite, garnet, hornblende, reddish-brown biotite, and zircon. The gneissic fabric in the granulite is defined by flattened lenses of quartz and by metamorphic compositional banding in which quartz and feldspar-rich zones are interlayered with darker concentrations of ferromagnesian minerals.

The mineral assemblage quartz + perthite + plagioclase + orthopyroxene + clinopyroxene is an anhydrous assemblage that is stable within the granulite facies of regional metamorphism. This facies forms at temperatures of 700 to 900 degrees centigrade and pressures of 7 to 10 kilobars. These temperatures and pressures indicate that these rocks equilibrated at depths of 12 to 18 miles beneath the earth's surface.

Pyroxene granulite in the western Blue Ridge commonly shows a high degree of hydrothermal alteration. Pyroxene is heavily altered to actinolite amphibole, opaque oxide minerals are rimmed by sphene and leucoxene, and feldspar is altered to epidote and white mica. In outcrop, hydrothermally altered feldspars are white (plagioclase) and pink (K-feldspar), in contrast to the dark green feldspars in unaltered granulite. Unakite is a product of hydrothermal alteration of granulite and other high-grade quartzofeld-

spathic basement rocks. During the alteration, the anorthite component of plagioclase feldspar is entirely converted to green epidote. Unakite is most extensively developed in close proximity to contacts with the overlying Catoctin and Unicoi formations.

Leucocratic granulite (Ylg) is a greenish gray (fresh), weathering to pinkish white, fine- to medium-grained, banded quartzofeldspathic gneiss. Major minerals are quartz and perthite. Accessory minerals include apatite and zircon. Magnetite-ilmenite, orthopyroxene, clinopyroxene, biotite, and hornblende are also present locally as accessory minerals. Gneissic banding is defined by elongate quartz grains that are less than 0.13 inch thick. In most exposures, feldspars are altered to white mica and epidote, giving the rock a distinctive pink appearance. Fabric elements, mineral assemblage, and contact relations with charnockite and other plutonic rocks are similar for leucocratic granulite to those of pyroxene granulite. It is inferred that the two granulites formed under similar pressure and temperature conditions, and are broadly contemporaneous.

Field relations indicate that pyroxene granulite is the oldest rocks exposed in the Blue Ridge basement complex (Figure 2). In nearby Amherst County, the Lady Slipper granulite gneiss has been dated at 1130 million years old,

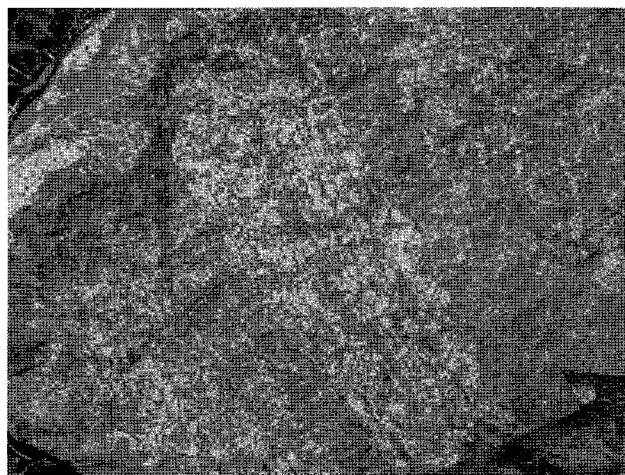


Figure 2. Layered granulite along the east flank of the Blue Ridge on U. S. Highway 60. A 1-billion-year-old date from this locality was obtained by radiometric dating (Sinha and Bartholomew, 1984). Field of view is about 1 foot wide.

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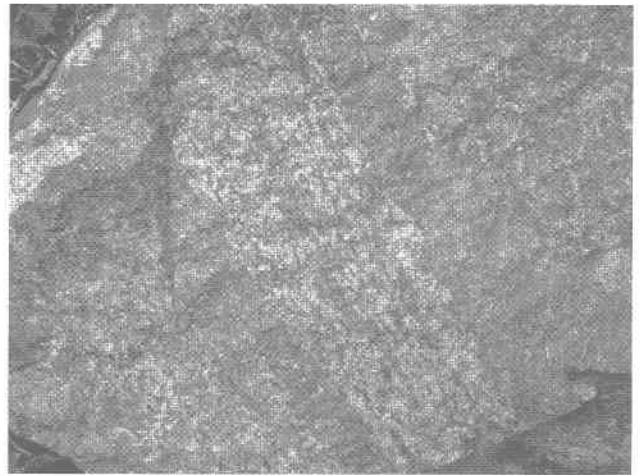


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Two varieties of charnockite have been mapped in the Blue Ridge of eastern Rockbridge County: porphyritic charnockite (Ypc) and leucocratic charnockite (Ylc). Porphyritic charnockite is medium- to dark-grayish-green (fresh), massive or weakly-foliated with crudely aligned potassium feldspar as poikiloblasts up to 3.1 inches in length. The rocks have granitic composition, containing perthite/antiperthite with quartz, plagioclase feldspar, orthoclase, orthopyroxene with or without clinopyroxene, and ferromagnesian minerals. Accessory minerals include magnetite-ilmenite, apatite, zircon, reddish-brown biotite, hornblende, and rutile. Pyroxenes are commonly altered to uralitic amphibole. Magnetite-ilmenite grains are altered to sphene and leucoxene. Feldspars weather to a chalky white, imparting a light greenish-gray and white speckled color to weathered rocks.

Leucocratic charnockite (Ylc) is a light-gray, coarse- to very coarse-grained rock containing perthitic potassium feldspar, plagioclase, and quartz. Pyroxenes, where present, are thoroughly altered to actinolitic amphibole. Leucocratic charnockite is well exposed on the walking trail at Indian Gap overlook on the Blue Ridge Parkway, approximately 2 miles south of U.S. Highway 60 (Figures 3a and 3b). This map unit includes the porphyritic quartz monzonite of Hudson (1981), which is well exposed in the upper portion of Nettle Creek drainage.

Charnockite forms under the same pressure and temperature conditions as granulite. The presence of granulite xenoliths within charnockite establishes that charnockitic plutons were emplaced into granulite country rock (Bartholomew, 1977). Charnockite in nearby Nelson County has been dated at 1075 million years (U-Pb zircon, Sinha and Bartholomew, 1984).

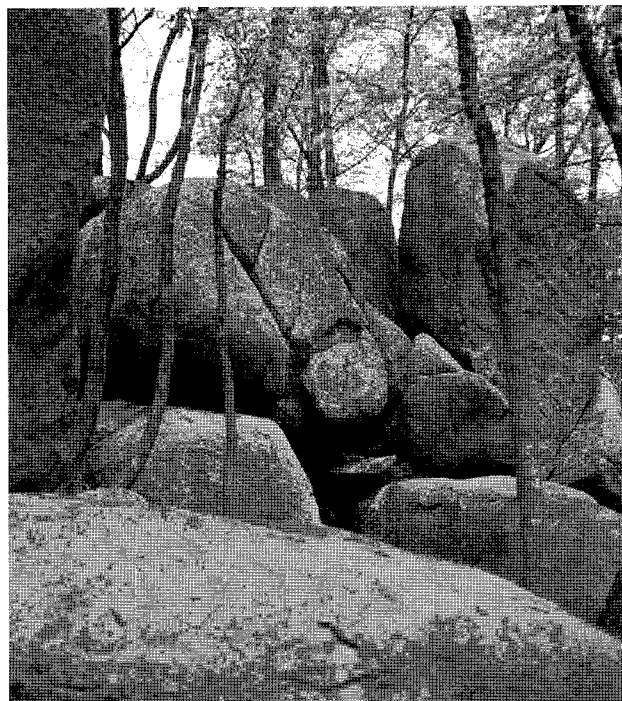


Figure 3a. These rounded boulders of leucocratic charnockite at Indian Rocks, Blue Ridge, form an interesting labyrinth of trails.

Granite (€Zg and €Zhg)

Two types of granite intrude granulite and charnockite (and therefore post-date those rock units) in Rockbridge County. Biotite granite (€Zg) is medium-gray, fine- to medium-grained, xenomorphic granular and fluorite-bearing (Hudson, 1981). The granite is porphyritic in part, with quartz and euhedral, compositionally zoned, perthitic potassium feldspar phenocrysts. Major minerals include quartz, albite, perthitic orthoclase, and biotite. Accessory minerals include fluorite, allanite, tourmaline, and zircon. Aplite and rhyolitic dikes locally cut the granite. Hudson and Dallmeyer (1982) dated muscovite from mineralized greisen along Irish Creek at about 635 million years (40Ar/39Ar incremental release), and inferred that the greisen and biotite granite along Nettle Mountain were formed at the same time. Those workers, as well as Good (1991) inferred a genetic relationship between this granite, informally named the Nettle Mountain granite, and gold and tin mineralization in the Irish Creek area.

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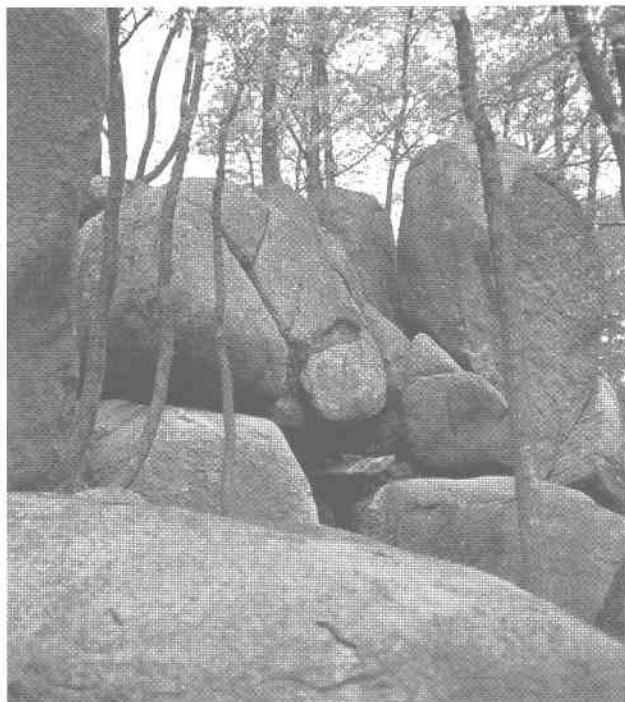


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Figure 3b. Close-up of leucocratic charnockite at Indian Rocks.

Hornblende granite (CZhg) is light-greenish-gray, coarse- to very coarse-grained, and leucocratic. Major minerals are quartz, plagioclase feldspar, and microcline. Accessory minerals include hornblende, magnetite-ilmenite, apatite, and zircon. In thin section, these rocks display a high degree of deformation and alteration. Feldspar crystals are cataclastically fractured and quartz exhibits well-developed ribbon structures. Feldspars are heavily altered to white mica and epidote; hornblende shows alteration to chlorite. Xenoliths composed of greenstone, felsite, and feldspathic arenite are enclosed within the hornblende granite in the bed of Nettle Creek (Evans, 1991; Good, 1991). This suite of xenoliths implies that hornblende granite was emplaced through a series of rocks that included Catoctin greenstone, Unicoi feldspathic arenite, as well as felsite. This suggests that this granite is of Cambrian age or younger and, therefore the youngest granitic rock yet to be discovered in the basement complex of the Virginia Blue Ridge.

Catoctin Formation (CZc)

The Catoctin Formation, named for exposures at Catoctin Mountain in Maryland, is a sequence of metamorphosed basalt volcanic flows and interlayered sedimentary rocks. These metabasalts are commonly referred to as greenstone.

Greenstone is grayish-green to dark-green, fine-grained, and massive to schistose. It contains chlorite, actinolite, epidote, albite, quartz, and magnetite. Relict pyroxene is visible in thin section. Primary volcanic features have been severely overprinted by metamorphic recrystallization (Bowring, 1987) but flow breccia, pillow lava, and vesicles are discernable in some exposures (Figure 4). A single schistosity defined by aligned chlorite and actinolite is the dominant fabric element in most outcrops.

A variety of metasedimentary rocks are interlayered with the greenstone. These include reddish-gray tuffaceous phyllite, greenish-gray laminated metasiltstone, graded feldspathic metasandstone, and metaconglomerate. Although earlier maps show a laterally continuous interval of sedimentary rock between the basement complex and Catoctin greenstone (i.e. the Swift Run Formation of Werner, 1966), our mapping suggests that these beds are lenticular and discontinuous laterally. As a result, they are



Figure 4. The Catoctin Formation along the Appalachian Trail near the Lynchburg Reservoir. Features interpreted as metamorphosed and deformed pillows are observable.

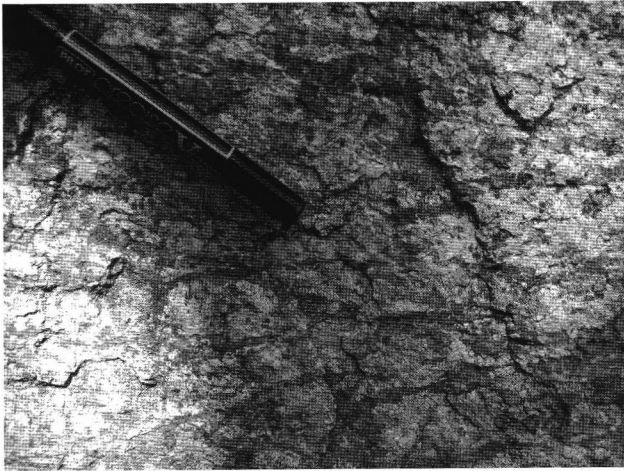


Figure 3b. Close-up of leucocratic charnockite at Indian Rocks.

Hornblende granite (€Zhg) is light-greenish-gray, coarse- to very coarse-grained, and leucocratic. Major minerals are quartz, plagioclase feldspar, and microcline. Accessory minerals include hornblende, magnetite-ilmenite, apatite, and zircon. In thin section, these rocks display a high degree of deformation and alteration. Feldspar crystals are cataclastically fractured and quartz exhibits well-developed ribbon structures. Feldspars are heavily altered to white mica and epidote; hornblende shows alteration to chlorite. Xenoliths composed of greenstone, felsite, and feldspathic arenite are enclosed within the hornblende granite in the bed of Nettle Creek (Evans, 1991; Good, 1991). This suite of xenoliths implies that hornblende granite was emplaced through a series of rocks that included Catoctin greenstone, Unicoi feldspathic arenite, as well as felsite. This suggests that this granite is of Cambrian age or younger and, therefore the youngest granitic rock yet to be discovered in the basement complex of the Virginia Blue Ridge.

Catoctin Formation (€Zc)

The Catoctin Formation, named for exposures at Catoctin Mountain in Maryland, is a sequence of metamorphosed basalt volcanic flows and interlayered sedimentary rocks. These metabasalts are commonly referred to as greenstone.

Greenstone is grayish-green to dark-green, fine-grained, and massive to schistose. It contains chlorite, actinolite, epidote, albite, quartz, and magnetite. Relict pyroxene is visible in thin section. Primary volcanic features have been severely overprinted by metamorphic recrystallization (Bowring, 1987) but flow breccia, pillow lava, and vesicles are discernable in some exposures (Figure 4). A single schistosity defined by aligned chlorite and actinolite is the dominant fabric element in most outcrops.

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not shown separately on the map. This part of the section is well exposed in the eastern half of the Buena Vista quadrangle (Spencer, 2000) and is described as the Oronoco Belt (Spencer, 1994, and Spencer, Bowring, and Bell, 1989). The top of the Catoctin has been mapped at the top of the uppermost greenstone; metasedimentary rocks in the upper Catoctin are, in the field, indistinguishable from rocks in the overlying lower Unicoi Formation.

The Catoctin was deposited nonconformably on the basement complex in the late Proterozoic, about 570 million years ago (Badger and Sinha, 1988), and deposition continued into the earliest Paleozoic. The chemistry of Catoctin lavas is similar to modern volcanic rocks that are erupted in a continental rift environment (Rankin, 1976; Spencer, Bowring, and Bell, 1989). The Catoctin is at least 3300 feet thick in northern Virginia and Maryland but thins to the southwest and is absent along strike a few miles southwest of the James River.

PALEOZOIC

Cambrian

Chilhowee Group

The Chilhowee Group encompasses about 2450 feet of latest Proterozoic and earliest Paleozoic age siliciclastic rocks that include, in ascending order, the Unicoi, Harpers, and Antietam formations (Walker and Simpson, 1991). The Chilhowee Group conformably overlies the Catoctin greenstone, where present, and is nonconformable on the Blue Ridge basement complex in other parts of the County (Schwab, 1986, Simpson and Eriksson, 1989). The occurrence of the trace fossil *Rusophycus* about 330 feet above the base of the Unicoi (Simpson and Sundberg, 1987) is an indication that most of the Chilhowee Group is no older than Early Cambrian (about 540 million years old). The lower or middle Cambrian trace fossil *Skolithos* (Sundberg, 1983) is found in abundance in Antietam quartzites in the upper Chilhowee Group and in the Snowden Member of the Harpers Formation.

Unicoi Formation (Ecu)

In central Virginia, the Unicoi Formation is exposed in two belts. The western belt is along the Blue Ridge flank, the eastern belt is located near the border between Rockbridge and Amherst counties. In the western belt, the Unicoi lies nonconformably on the Blue Ridge basement. A basal conglomerate composed of rounded pebble- to cobble-size pieces of basement rock is present at some locations.

The Unicoi straddles a facies transition from active rift sedimentation (non-marine, alluvial and braided stream deposits, lower Unicoi Formation) to progradational drift, or passive margin sedimentation (marine, outer shelf to shoreface deposits, upper Unicoi, Harpers and Antietam Formations) (Simpson and Eriksson, 1989; Spencer, 1994). The Unicoi varies in thickness in both the eastern and western belts reflecting relief of the topography on which it was deposited. Greater thickness variations are present in the eastern belt.

Northeast along strike from Rockbridge County, rift-facies sedimentation is absent in the sedimentary deposits above the Catoctin, and rocks between Catoctin greenstones and the basal Harpers Formation are mapped as Weverton Formation. In the eastern belt the Unicoi interfingers with the Catoctin Formation and is thought to be temporally equivalent to the Swift Run and Catoctin Formations to the northeast (Spencer, 1994).

The lower Unicoi, above the basal conglomerate, generally consists of reddish-gray and greenish-gray fine-grained beds that contain feldspar fragments and locally contain crossbedding. These have been interpreted as water laid tuffs (Spencer, 2000). These tuffs and thin layers of greenstone similar to that of the Catoctin Formation are exposed in the western belt. Fragments of these tuffs are present in overlying sandstones and conglomerates. The middle and upper Unicoi Formation include feldspathic to lithic conglomerate and sandstone, quartzite, granule conglomerate, metasiltstone, and phyllite (Figure 5). Sand grains are dominantly quartz with lesser amounts of feldspar; individu-

al grains are subrounded to subangular, with feldspar grains interstitial to quartz. Identifiable rock fragments are polycrystalline quartz-feldspar aggregates. Matrix material is predominantly feldspar. Tourmaline, zircon, apatite, and magnetite-ilmenite are minor constituents. Greenish-gray, fine- to coarse-grained, thin- to medium-bedded horizontally stratified quartz sandstone is interbedded with crossbedded sandstone, and reddish-gray to dark-greenish-gray laminated to thinly-bedded metasiltstone interlayered with reddish-gray phyllite.

A persistent quartzite ledge (Ccus) is present through the Unicoi outcrop belt in Rockbridge County. The quartzite is reddish-gray, medium- to coarse-grained, medium- to very thick-bedded, trough-crossbedded, quartzarenite that occasionally contains feldspar.

Metamorphic mineral assemblages indicate that Unicoi rocks have been subjected to lower greenschist facies conditions (around 400 degrees Centigrade and 3 kilobars; Miyashiro, 1973). This implies burial at depths on the order of 6 miles beneath the earth's surface. The metamorphic overprint is most apparent in meta-siltstones and phyllites, which have a penetrative schistosity defined by chlorite and biotite. The schistosity cuts bedding at variable angles.

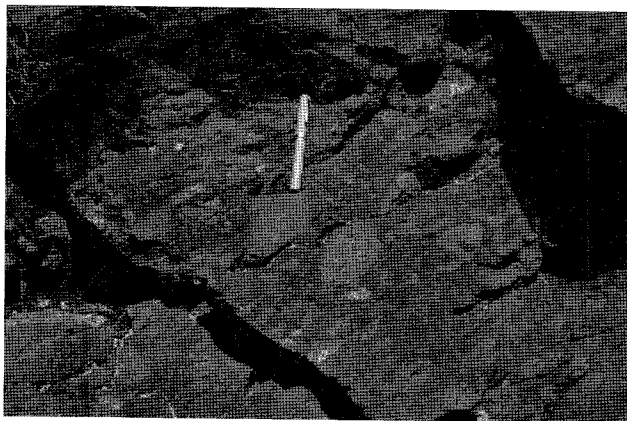


Figure 5. Basal Unicoi Formation displays well-rounded conglomeratic clasts that are interpreted to be channel lag deposits.

Harpers Formation (Ech)

The Harpers Formation (Ech) consists of metamorphosed siltstone, shale, and sandstone (Figure 6). Siltstones are medium gray (fresh) to pale yellowish-orange (weathered) and are laminated to thin-bedded. These are interbedded with shale and thin- to medium-bedded, horizontally stratified, fine- to medium-grained sandstone. Where visible, laminations and other sedimentary structures are commonly intensely disturbed by a combination of dewatering processes and bioturbation. Quartzites are thin- to thick-bedded, fine- to coarse-grained, trough crossbedded quartzarenites and can be on the order of 30 to 100 feet thick. The trace fossil *Skolithos* is locally present. A laterally persistent quartzite has been mapped within the Harpers that is named the Snowden Member (Echs) by Bloomer and Werner (1955). A 15- to 30-foot-thick hematitic sandstone commonly occurs below the Snowden Member.

The Harpers is comprised of a series of two or more progradational sequences, in which offshore deposits (thinly bedded sandstone, siltstone and mudstone) are overlain by progressively nearshore deposits (cross-bedded sandstone and quartzite). Within each progradational sequence, the overall percentage of sandstone and the thickness of sandstone beds increase up section. Each progradational sequence is capped

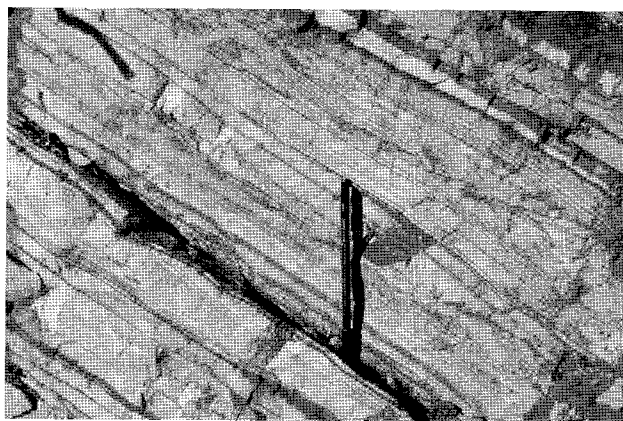


Figure 6. Harpers Formation rocks occur along U. S. Highway 60 east of Buena Vista.

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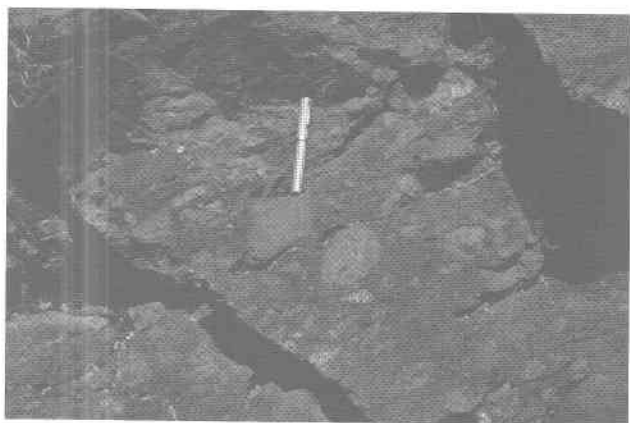


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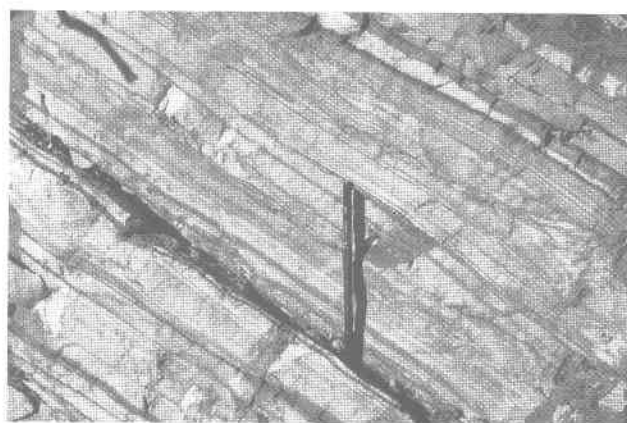


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by quartzite (nearshore or shoreface deposition) which is, in turn, overlain by offshore deposits reflecting a transgressive phase where relative sea level rose and drowned the shoreface (Reading, 1978; Simpson and Eriksson, 1990; Evans and others, 1998). The uppermost progradational sequence in the Harpers is capped by a thick sequence of quartzites that comprises the Antietam Formation. Structural complexity makes it difficult to measure a complete section of Harpers, but overall thickness appears to range from 1000 to 1500 feet.

Antietam Formation (Eca)

The Antietam Formation is a light colored, thick- to very thick-bedded, cross-bedded, silica-cemented quartzarenite, composed almost exclusively of quartz grains, with trace amounts of zircon and tourmaline. Quartzite is interbedded with thick- to very thick-bedded, quartz-rich sandstone and with calcareous sandstone in the upper portion of the formation. Antietam quartzites were deposited in a nearshore or shoreface marine environment (Bloomer and Werner, 1955; Simpson and Eriksson, 1989). The trace fossil *Skolithos* (Sundberg, 1983), is ubiquitous in these quartzites, and can be seen in most outcrops. The burrows, which were originally vertical, are oriented within a few degrees of perpendicular to bedding. This can be very helpful in determining bedding attitudes where the rock is massive. These rocks are highly resistant to weathering and form prominent ledges and hogbacks throughout the outcrop belt (Figure 7). The Antietam is approximately 500 feet thick and is conformably overlain by carbonate rocks of the Shady Dolomite.

Shady Dolomite (Es)

The Shady Dolomite includes dark grayish-blue, fine- to medium-grained, thick-bedded to weakly laminated, impure dolostone, which locally contains black chert stringers. At Natural Bridge Station, the dolostone is light gray and saccharoidal. Within Rockbridge County, the



Figure 7. Flatirons, formed from resistant layers of Antietam quartzite, are well-defined landforms along the west flank of the Blue Ridge in Rockbridge County. This view, looking east, is typical of the Antietam's effect on the landscape.

Shady Dolomite is sufficiently exposed for mapping purposes only in the vicinity of the James River, southwest of Glasgow. There, it is approximately 1300 feet thick (Spencer, 1968). North of Glasgow, the Shady is not exposed in Rockbridge County either because this interval is covered by colluvial Antietam quartzite shed from adjacent ridges or that it has been faulted out. In this case, the Shady is included with the Waynesboro mapping unit (Cwbs). From Vesuvius southwestward to at least Midvale, the Waynesboro is in fault contact with the Antietam Formation, and apparently the Shady Dolomite is absent. The Shady is conformably overlain by the Waynesboro Formation.

Waynesboro Formation (Cwbs)

The Waynesboro Formation is a heterogeneous unit composed of maroon, green, and gray shale interbedded with impure limestone and dolostone (Figure 8). Minor beds of buff, thin- to thick-bedded sandstone are present. The dolostones of the Waynesboro are in part dark gray, medium grained and tend to resemble some Elbrook dolostones. Dolomitic limestones, with an unusual mottled texture, are distinctive to the Waynesboro. This texture resulted from significant concentrations of silt thought to have been mixed into the carbonate sediments by

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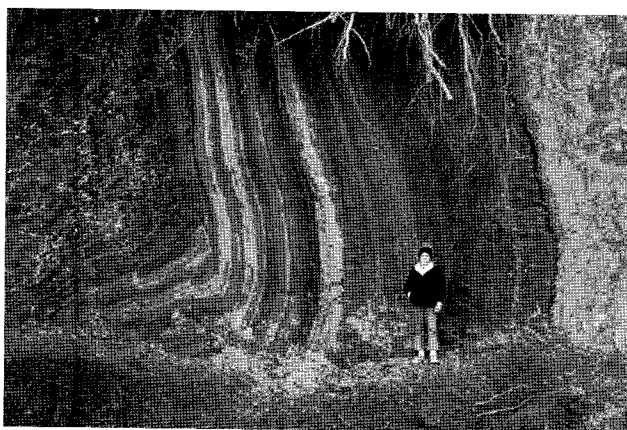


Figure 8. This once excellent exposure of the Waynesboro Formation near Buena Vista is now covered by vegetation. Note the alternating layers of rocks which have been structurally deformed.

burrowing of worms. Reports of thickness for the Waynesboro vary greatly. Spencer (2000) reported a thickness of about 1000 to 1500 feet in the Buena Vista quadrangle; Campbell (1882) reported a thickness of 2000 feet near Natural Bridge; Edmundson (1958) measured over 1000 feet of the upper part of the Waynesboro near Indian Rock. Haynes (1991) measured several sections of Waynesboro near Buchanan. Based on mapping, the authors believe that variations in the thickness of the Waynesboro result, at least in part, from duplications in the section caused by intraformational faulting. To the north and south of the county, the Waynesboro is conformable with the overlying Elbrook Formation. Poor exposure prohibited the observation of the contact of the two units in the county.

Elbrook Formation (Ce)

The Elbrook Formation is primarily a thinly bedded, light buff-gray, platy dolostone that readily weathers to a chippy soil. This dolostone is interbedded with a heterogeneous mixture of light-gray, thinly laminated, thick-bedded dolostone (closely resembling Beekmantown Formation dolostone), and blue limestone interbedded with silt layers. Stromatolites are present in places (Figure 9). The lower part of the Elbrook contains pink and greenish shale that resembles

the shale of the Waynesboro, suggesting that the contact between them is transitional. The contact of the Elbrook Formation with the overlying Conococheague Formation is conformable. The Elbrook Formation is 1325 to 2300 feet thick.

Conococheague Formation (OCco)

The Conococheague Formation consists mainly of limestone with interbedded dolostone and sandstone in the lower part of the unit. The limestone is generally dark blue-gray, fine-grained, and weathers light- to medium-gray. Algal masses, flat-pebble conglomerates and other primary features occur in the limestones and form repetitive cycles that are diagnostic of this formation. Small nodules and thin stringers of black chert occur in some parts of the Conococheague. Both the limestones and dolostones contain fine laminae of sandstone and siltstone and “floating” sand grains that are characteristic of the formation (Figure 10). Sandstone, found in the lower part of the unit, is very thick-bedded, medium- to coarse-grained, calcareously cemented, and ranges from less than 1 inch to 20 feet thick. Several thick layers of yellow siltstone also occur in the Conococheague, but are readily weathered and are poorly exposed. The Conococheague forms low, linear hills, which



Figure 9. Stromatolites, or blue-green algae, are found in the Elbrook Formation and their growth position is useful for determining tops of bedding. This well exposed right-side-up specimen is located in outcrop near Cedar Grove.

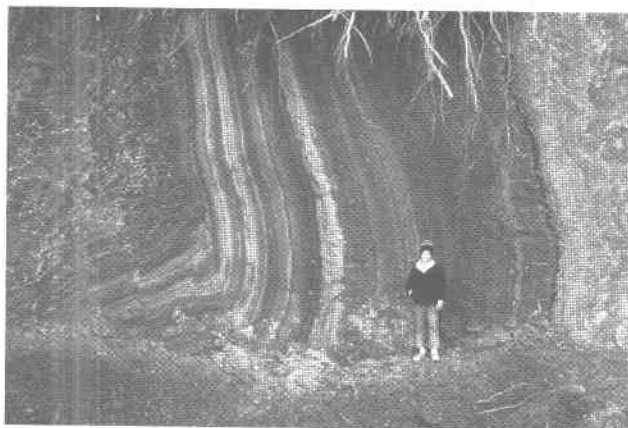


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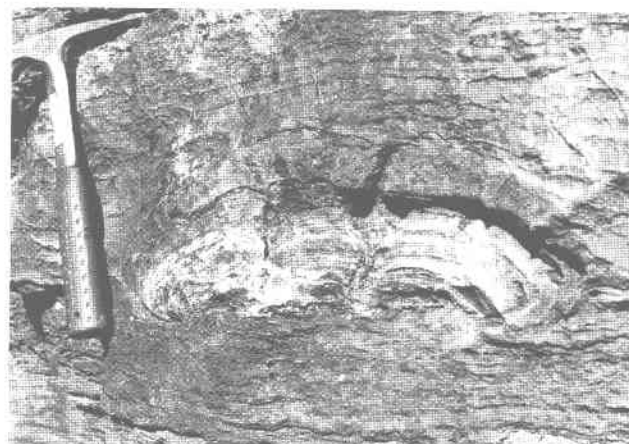


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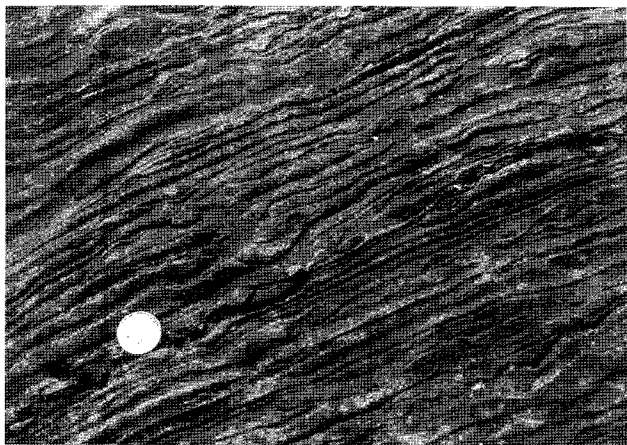


Figure 10. Differential erosion of preserved layers of sand and silt form a unique ribbing effect to weathered Conococheague outcrops.

often have apple orchards on them. The lower contact of the Conococheague is placed at the base of the lowest cyclic interval. Where the contact is obscure, it has been drawn where sandstone float becomes prominent in the soil. The Conococheague is 2000 to 2500 feet thick and is conformable with the overlying Stonehenge Limestone. The Cambrian-Ordovician boundary is in the upper Conococheague. Good exposures of the Conococheague occur beside Interstate 81 south of Lexington and along portions of the Chessie Trail.

Ordovician

Stonehenge Limestone (Ost)

The Stonehenge Limestone is composed of fine-grained limestone that is dark bluish-gray to almost black on fresh surfaces and light gray on weathered surfaces. Flat-pebble conglomerates occur in some beds and small black chert nodules are common in some horizons. Limestone near the base of the unit displays fine silt laminae. Contact with the overlying Beekmantown Formation is conformable. Low rolling topography and karst development are characteristic of the outcrop belt (Figure 11). East of the Staunton fault the Stonehenge Limestone is 300 to 500 feet thick except in the Natural Bridge syncline.

There, the typical lithology of the Stonehenge is discontinuous and poorly exposed and has been mapped as Conococheague and Stonehenge formations, undivided (Ocsu). West of the Staunton fault, the Stonehenge Limestone is 10 to 150 feet thick and is included with the Beekmantown Formation.

Beekmantown Formation (Ob)

The Beekmantown Formation consists of a thick sequence of medium- to light-gray, thick-bedded dolostones. Distinctive to the Beekmantown are light colored, massive chert beds up to 15 feet thick (Figure 12). These chert beds are resistant to weathering and underlie conical-shaped hills east of the Staunton fault and linear ridges west of the fault. Bedded black chert also occurs in this formation. Weathered surfaces of the dolostones often have distinctive fractures that form an intersecting “butcher-block” pattern (Figure 13). Fine-grained, dove-gray limestone beds that resemble the New Market Limestone occur near the top of the Beekmantown. Darker and more coarsely crystalline limestones are also present.

On Brushy Hill, west of Lexington and elsewhere west of the Staunton Fault, the Beekmantown Formation is similar to, and believed to be correlative with, the Knox Formation of southwest Virginia. Also west of the Staunton



Figure 11. Karst features, such as this sinkhole, develop in the Stonehenge Limestone.

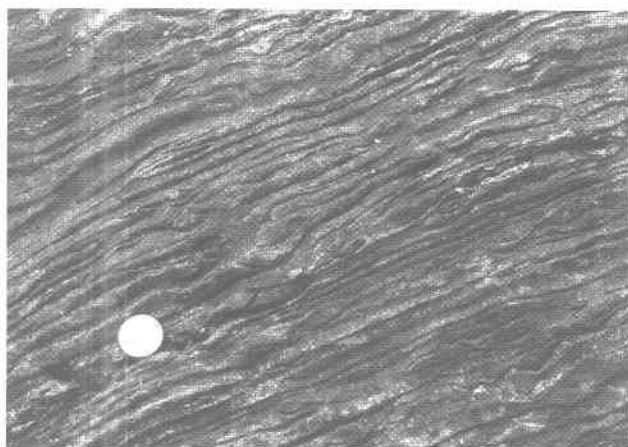


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Figure 11. Karst features, such as this sinkhole, develop in the Stonehenge Limestone.



Figure 12. Massive white chert beds in the Beekmantown. These can be several feet thick and weather with a “gnarly” texture, as seen in this exposure near Fredericksburg. The resistance to weathering of this chert explains the linear hills of Beekmantown west of the Staunton fault.

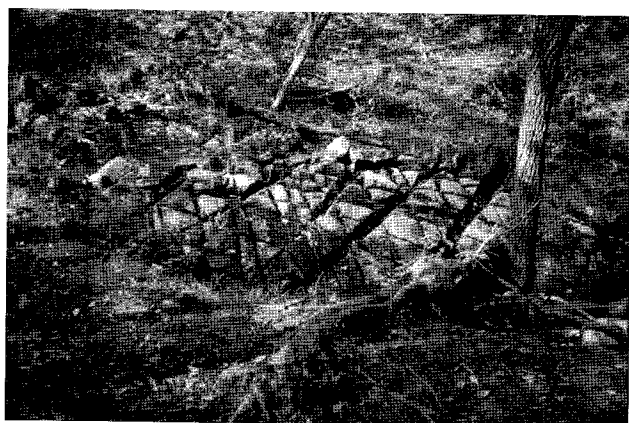


Figure 13. “Butcher-block” weathering of the Beekmantown Formation near Brownsburg. This weathering phenomena is characteristic of dolostone of the Beekmantown and is related to the joint pattern imposed on the rock.

fault, the Stonehenge Limestone is included as a basal member of the Beekmantown Formation because of its lack of mappable thickness. The Beekmantown is approximately 1500 to 2000 feet thick and is unconformable with the overlying New Market Limestone. This unconformity is exposed along Virginia Highway 251 east of its junction with State Road 644 in a section

measured and described by Cooper and Cooper (1946). The Beekmantown is often conspicuous by its absence of outcrop; it readily weathers to an orange, clayey soil often containing chert fragments. However, good exposures of the Beekmantown occur along U.S. Highway 60, west of Lexington, and along Buffalo Creek near Effinger School.

New Market and Lincolnshire Limestones (Oln)

Because of scale restrictions, the New Market and Lincolnshire Limestones were combined together as one map unit. West of the Staunton fault, these lower middle Ordovician rocks have characteristics that are similar to rocks of the same age in western and southwestern Virginia.

The New Market Limestone is a massive, aphanic, dove-gray limestone that weathers to light gray and often breaks with a conchoidal fracture. The limestone is thick-bedded and generally forms massive outcrops. A “bird’s eye” texture is caused by scattered grains of transparent calcite in a matrix of microcrystalline limestone. The New Market Limestone is 10 to 75 feet thick (Bick, 1960) and conformable with the overlying Lincolnshire Limestone.

The Lincolnshire Limestone consists of thinly-bedded, dark-gray limestone with black chert that occurs as nodules and lenses (Figure 14). A locally occurring unit, the Murat facies, consists of light-gray, coarse-grained, massive calcarenite. The Murat is composed mainly of fossil fragments of bryozoans and crinoids and thus is biostromal in character. The type locality of the Murat is on Buffalo Creek at the community of Murat. The Whistle Creek member of the Lincolnshire is a black, cherty, argillaceous limestone and calcareous shale locally found near the base of the formation. The Whistle Creek was named by Cooper and Cooper (1946) for a locality along U.S. Highway 60 where the highway crosses Whistle Creek. The Lincolnshire is approximately 200 to 400 feet thick (Bick, 1960) and is conformable with the overlying Edinburg Formation.



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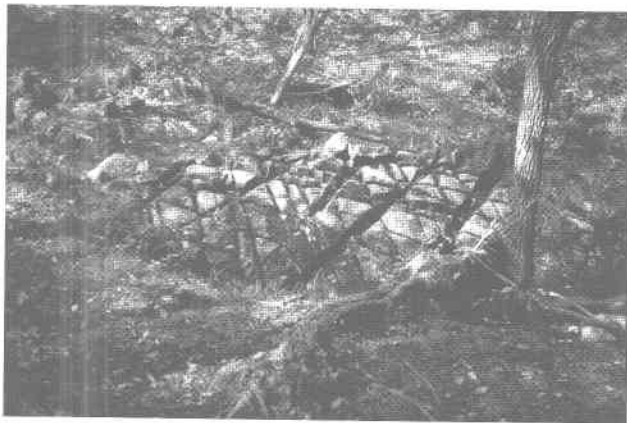


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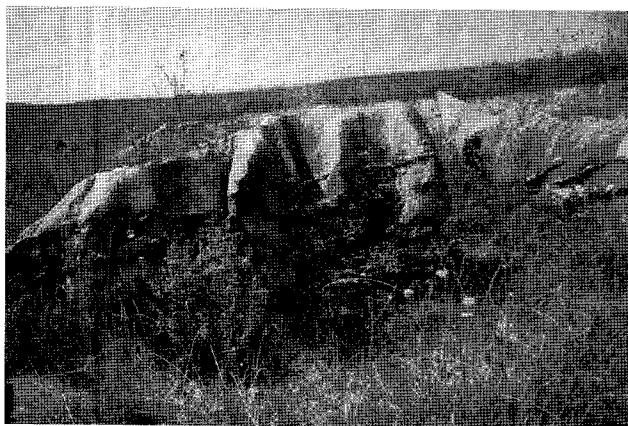


Figure 14. Limestone with stringers of black chert, typical of the Lincolnshire Limestone, near Brownsburg. The pinnacled nature of this outcrop alludes to the formation's susceptibility to form karst features.

Edinburg Formation (Oe)

Two principal lithologies are present in the Edinburg Formation. Most prevalent is the Liberty Hall lithofacies, a fine-grained, dense, black, thinly-bedded limestone interlayered with buff-weathering, fissile, black shale (Figure 15). The Lantz Mills lithofacies is a massive to nodular, medium- to coarse-grained, black limestone. A locally occurring unit, the Botetourt member (Cooper and Cooper, 1946), is a reddish-weathering, medium- to coarse-grained, fossiliferous, blue-gray limestone that can provide a useful marker separating the Edinburg from underlying middle Ordovician rock units. Lowest Edinburg also includes thick sections of dark-gray to black shale and limestone that were formerly called the "Athens Shale." The Athens is present in, and south of, Lexington. A distinctive unit, the Collierstown Limestone (Cooper and Cooper, 1946), occurs locally at the top of the Edinburg Formation. This unit is coarse-grained and richly fossiliferous (Figure 16). The Edinburg Formation contains significant intraformational deformation including thrust faults and folds making its thickness difficult to estimate. It may be from 800 to 1250 feet thick. The Edinburg

Formation has an interfingering relationship with the overlying Martinsburg Formation and as such, the mapped boundary between the two is only approximate. The Edinburg is well exposed in many parts of the county, including the Barger quarry and the cliffs of the Maury River west of Lexington.

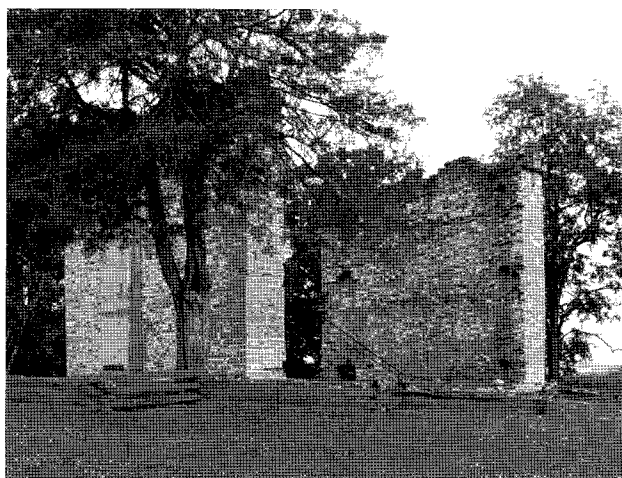


Figure 15. Liberty Hall ruins on the grounds of Washington and Lee University, Lexington. Near this location is the type-section of the Liberty Hall Formation as described by Cooper and Cooper in 1946.

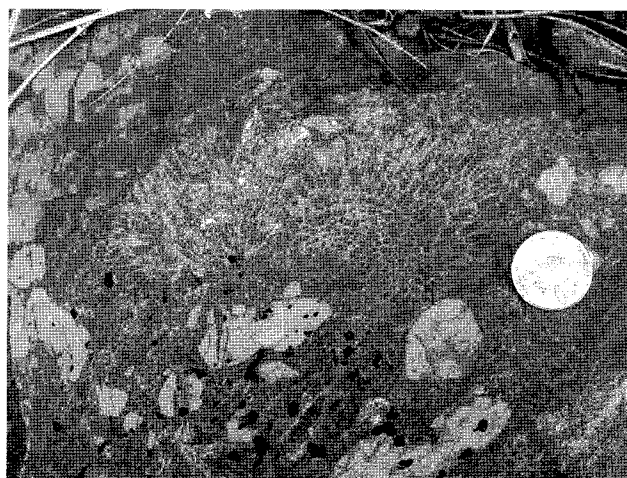


Figure 16. Fossilized coral heads in the Collierstown Limestone of the Edinburg Formation on U. S. 11, southeast of Lexington. Where exposed, the Collierstown is a useful marker bed between the Edinburg and Martinsburg Formations.



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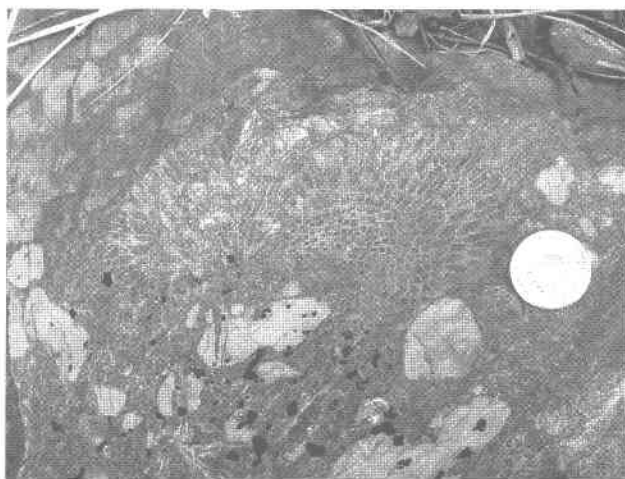


Figure 16. Fossilized coral heads in the Collierstown Limestone of the Edinburg Formation on U. S. 11, south-east of Lexington. Where exposed, the Collierstown is a useful marker bed between the Edinburg and Martinsburg Formations.

Martinsburg Formation (Omb)

The Martinsburg Formation consists of two different lithologies, but is mapped as one unit for this report. The lower part (Trenton Limestone equivalent) consists of thin- to thick-bedded, argillaceous limestone interbedded with coarse-crystalline, fossiliferous limestone, and minor shale beds (Figure 17). The upper part (Reedsville Shale equivalent) is medium- to light-gray, interbedded sandstone, siltstone, and shale (Figure 18). Included near the top of the formation is a fossiliferous marker bed, the "*Orthorhynchula* zone" of Butts (1938). Intraformational faulting and folding is common in the Martinsburg making

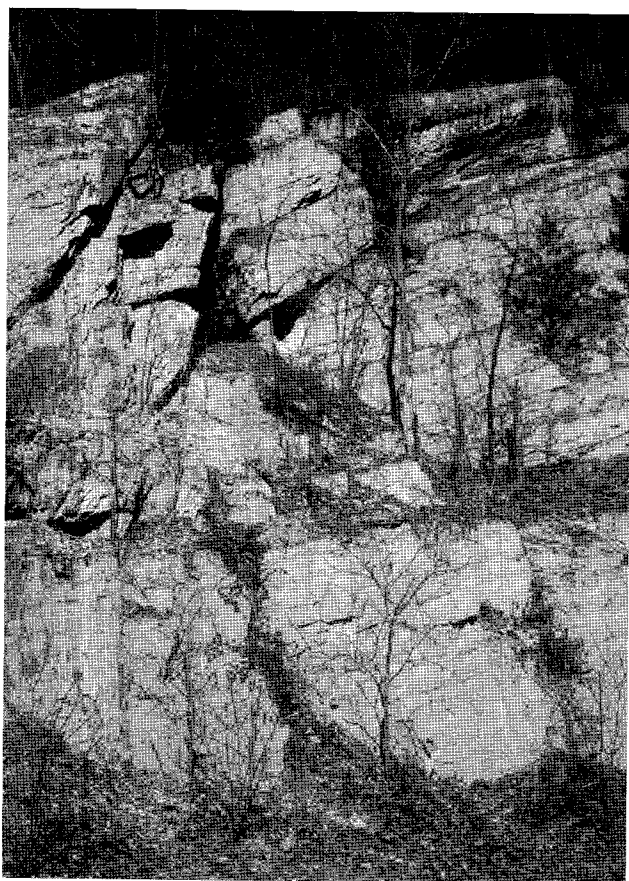


Figure 17. Good exposures of the lower Martinsburg occur along Big Hill Road (State Road 646) between Denmark and Colliertown. The Martinsburg is a zone of structural weakness and displays many faults and folds. Jointing in the rock can be easily mistaken for bedding such as in this photograph where what appears to be bedding dipping to the left is actually jointing.

total thickness difficult to estimate, but it is probably near 1500 feet thick. This map unit includes, in some locations, the Oswego Formation, a dense, greenish-gray, fossiliferous sandstone lying above the "*Orthorhynchula* zone" and below the Juniata Formation. Where the Juniata is absent, the Oswego may be in unconformable contact with the overlying Tuscarora Formation, as in Panther Gap and Goshen Pass.

Juniata Formation (Oj)

Interbedded yellowish-brown to red sandstone, and olive-gray shale and mudstone typify the Juniata Formation. These interbedded rocks occur in cycles, indicating rhythmic rising and lowering of Ordovician sea level. For this reason, the Juniata Formation is approximately 300 feet thick on Brushy Mountain southwest of Little California, but elsewhere in the county, it is absent from the rock section. The Juniata Formation's contact with the overlying Tuscarora Formation is suspected to be unconformable.

Silurian

Tuscarora Formation (Stu)

The Tuscarora Formation is a white to light-gray, medium- to coarse-grained, thin- to very thick-bedded, ledge-forming sandstone and

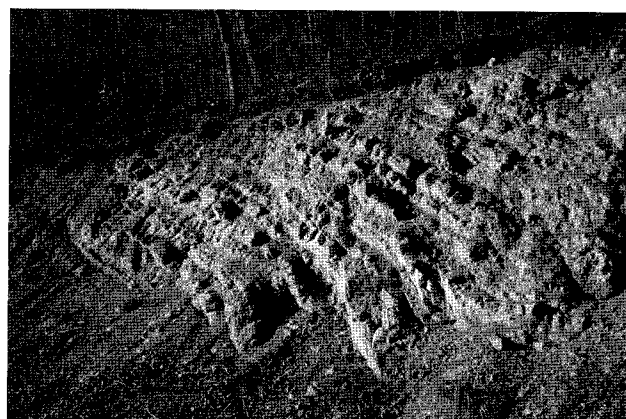


Figure 18. The upper Martinsburg can be seen along the Sand Road on the crest of North Mountain, east of The Cockscomb. Typical of this part of the formation are cyclic interbeds of shale and siltstone, as shown here.

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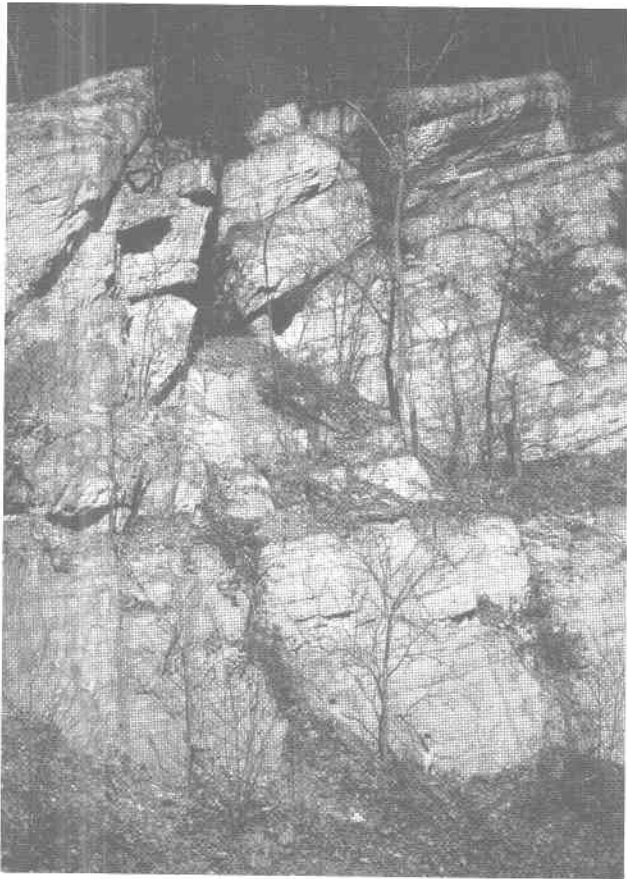


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orthoquartzite (Figure 19). Minor beds of quartz-pebble conglomerate occur in the lower half of the formation. The Tuscarora displays cross bedding and contains the trace fossils *Arthropycus alleghaniensis* (Figure 20) and *Skolithos*. The Tuscarora is conformable with the overlying Rose Hill Formation and is 100 to 260 feet thick.

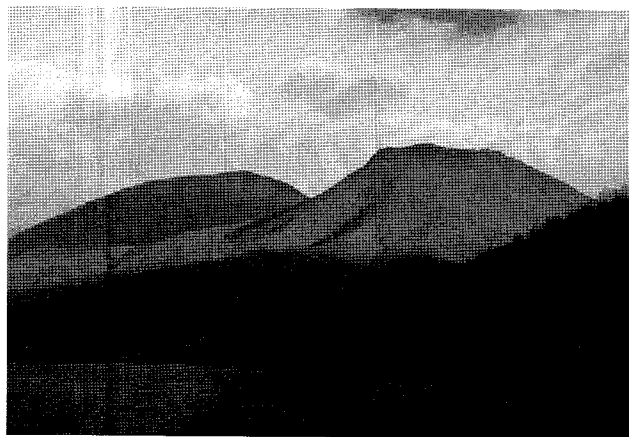


Figure 19. Because the Tuscarora Formation is much more resistant to weathering than the underlying formations, it is very well exposed on Big House and Little House mountains (shown here), in Goshen Pass, on North and Little North mountains, and the Short Hills.

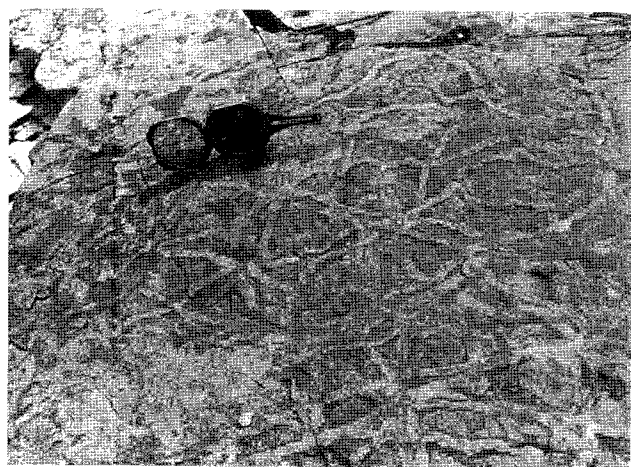


Figure 20. The trace fossil, *Arthropycus alleghaniensis*, is diagnostic of the Tuscarora. They are burrows formed by worm-like animals living in the early Silurian sea. The burrows are preserved on bedding surfaces.

Rose Hill Formation (Srh)

Dark-red to gray, thick bedded, hematitic sandstone is unique in the Silurian section to the Rose Hill Formation. This sandstone is bounded above and below by greenish-gray to red shale with gray sandstone interbeds, some of which are very fossiliferous. The presence of shale in the Rose Hill evidently offers a convenient slip zone for ancient and recent landslide-prone areas, such as those on Brattons Mountain. The lower contact of the Rose Hill is sharp and occurs at the top of the last orthoquartzitic sandstone of the Tuscarora Formation. In the Short Hills area, the Rose Hill Formation and the Keefer Sandstone are lumped together as one map unit (Skrh) because of scale limitations. The Rose Hill sandstone was an important iron ore source rock further to the south in Alleghany and Craig counties and was prospected for in the 1800's in Rockbridge County, but not mined. The Rose Hill is 200 to 250 feet thick and caps much of Brattons Mountain.

Keefer Sandstone and Cayugan-age rocks undivided (Sck)

This map unit incorporates the Keefer Sandstone and those rocks lying immediately above it. These latter, younger rocks, are the McKenzie Formation, Williamsport Sandstone, Wills Creek Formation, and the Tonoloway Limestone. All units are conformable with each other and the overlying Keyser Formation.

The Keefer Sandstone forms massive ledges and cliffs in most of the mountains where it crops out (Figure 21). It is white to light-gray, medium-grained, thick-bedded, orthoquartzitic sandstone with minor interbeds of conglomerate and green-mottled and buff siltstone. The sandstone beds exhibit *Skolithos*, ripple marks, clay rip-up clasts, and cross-beds. Included with the lower Keefer is one red, 12-foot-thick sandstone marker bed ("leopard rock") distinctive for its red and white mottled appearance created by abundant *Skolithos*. This bed may relate to the Bloomsburg Formation of the northern Valley. The Keefer is 200 to 350 feet thick.

Above the massive Keefer Sandstone is

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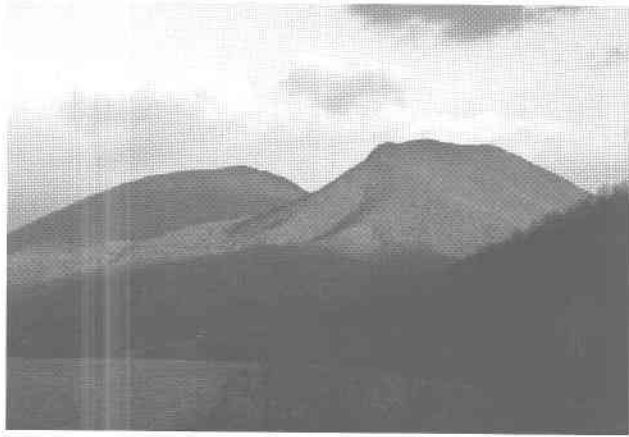


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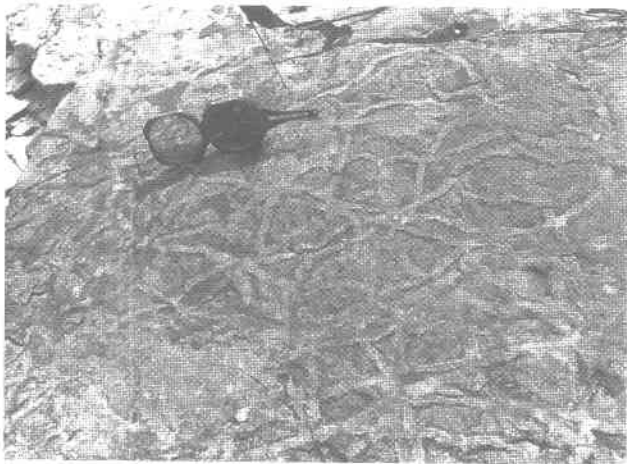


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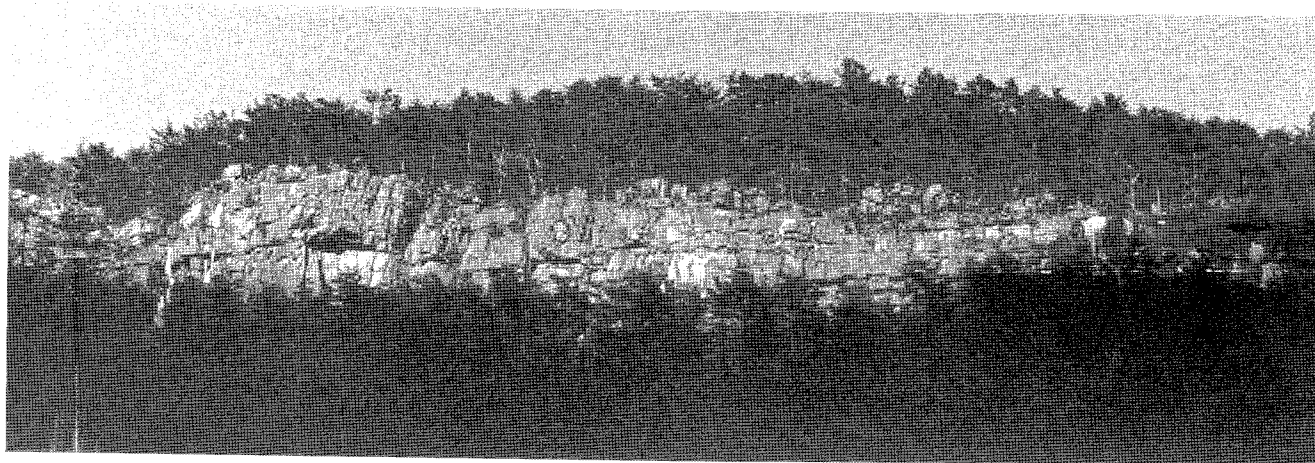


Figure 21. The Keefer Sandstone is well exposed throughout Goshen Pass. It forms notable cliffs easily seen from State Road 39 in the Pass. The Keefer gains thickness south of Rockbridge County and nearly disappears to the north.

the McKenzie Formation, a calcareous, cross-bedded sandstone that is interbedded with knob-by-weathering, abundantly fossiliferous, dark-gray limestone (Figure 22).

The Williamsport Sandstone separates the McKenzie and the Wills Creek. Although not definitively identified within the county, the Williamsport is reported to have characteristics that are similar to the Keefer.

The Wills Creek Formation is a yellowish-weathering, sparsely fossiliferous, calcareous shale. Some of the beds display mudcracks and ripplemarks.

The Tonoloway Limestone is divided into three units: The lower and upper units are characterized as dark-gray to black, thinly-bedded, argillaceous limestone that is frequently interlayered with thin dolostone beds. Sand grains are noted in the lower unit. The middle unit is an aggregate of thick, irregularly bedded, limestone, and knobby-weathering, blue limestone. It is highly fossiliferous, particularly with *Stromatopora*. The Tonoloway is 100 to 200 feet thick.

Lower Devonian and Upper Silurian rocks undivided (DS)

Although lithologies included in this unit are well defined, their thickness does not allow them to be mapped at the county scale. This map unit includes all rock formations from the top of the Tonoloway Limestone to the top of the

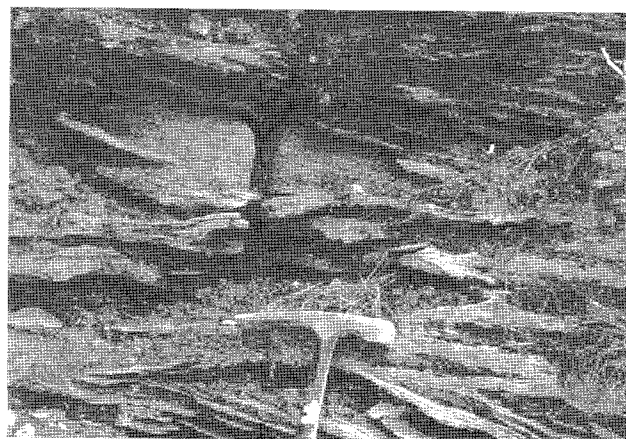


Figure 22. The McKenzie Formation is well exposed on the east flank of Knob Mountain along the Knob Mountain Road. Note the well-defined cross-bedded nature of this outcrop.

Ridgeley Sandstone (i.e. Helderburg Group and Ridgeley rocks). Good exposures of this map unit are located at the eastern end of Panther Gap, Bells Valley, and on the east flank of Knob Mountain along the Knob Mountain Road. Total thickness of the lower Devonian-upper Silurian undivided unit is 300 to 600 feet.

The lowermost Helderburg Group rock unit is the Keyser Formation which contains three members in Rockbridge County. The lowest member is an arenaceous limestone, referred to as the Byers Island member by Head (1972), and is approximately 60 feet thick.

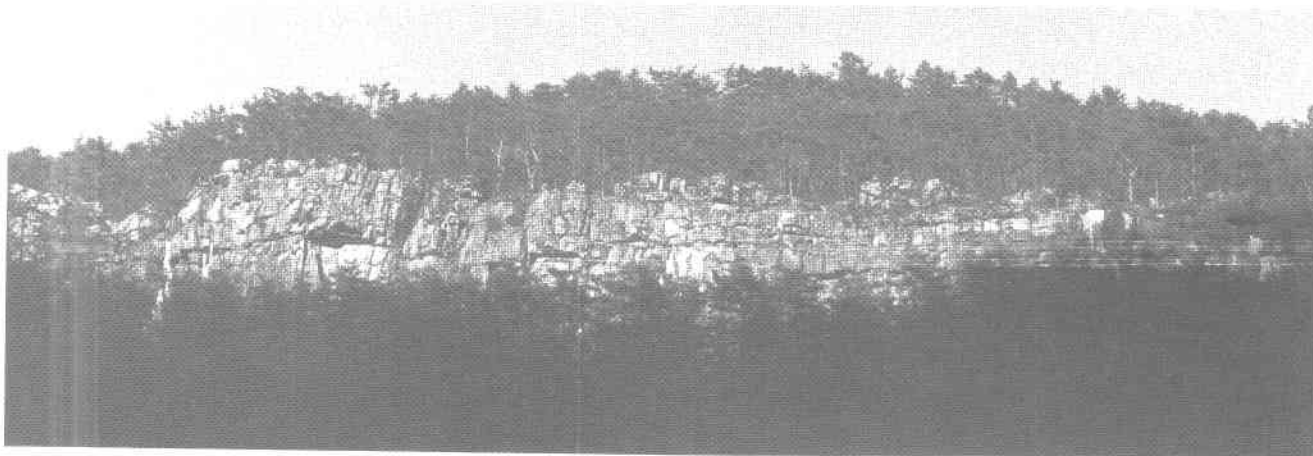


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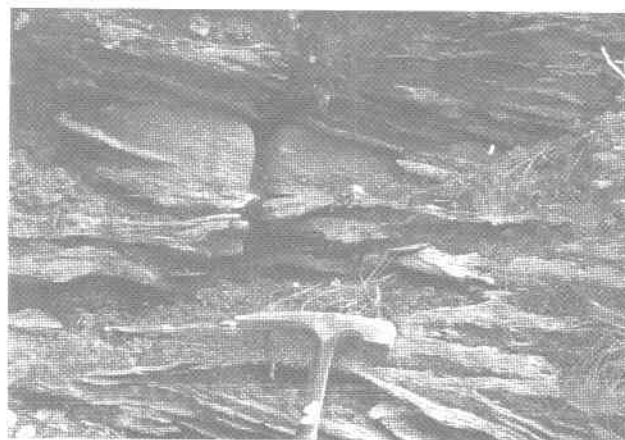


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The lowermost Helderburg Group rock unit is the Keyser Formation which contains three members in Rockbridge County. The lowest member is an arenaceous limestone, referred to as the Byers Island member by Head (1972), and is approximately 60 feet thick.

Devonian

The middle member of the Keyser Formation is the Clifton Forge Sandstone. It is a clean, resistant quartzarenite and is 20 to 40 feet thick. The upper member, referred to as the Jersey Shore member by Head (1972), is a nodular limestone that is approximately 40 to 80 feet thick. Aggregate Keyser Formation thickness is 120 to 180 feet.

Conformably above the Keyser is the New Creek Limestone, a light-gray, coarse-grained, pinkish crinoidal limestone that is 20 to 60 feet thick.

Above the New Creek is the medium-grained, calcareous-cemented and cross-bedded Healing Springs Sandstone. It is similar in appearance to the Ridgeley Sandstone, although abundant iron concentrations have not been noted in the Healing Springs. The Healing Springs is 5 to 90 feet thick and very well exposed in places along the east flank of Mill Mountain.

The uppermost Helderburg Group rock unit is the Licking Creek Limestone. It consists of the lower Cherry Run member (distinctive for its white chert limestone) and an upper Little Cove member (gray, arenaceous limestone). The Licking Creek is 50 to 130 feet thick.

The Ridgeley Sandstone is a medium-to coarse-grained, calcareously cemented sandstone. It is cross-bedded, fossiliferous (abundant *Spirifer* being diagnostic), and highly ferruginous in places. The Ridgeley was an important iron ore source that was mined in the 1800's near Little California, Guys Run, and Goshen Branch. Throughout the county it is absent to 20 feet thick.

Millboro Shale and Needmore Formation (Dmn)

Because of poor exposure and the thinness of the Needmore, the Millboro Shale and the Needmore Formation could not be consistently differentiated and were mapped as one unit. This map unit almost always underlies valley bottoms, primarily because of susceptibility to weathering of the shale. Many of the "healing springs" in the

county emanate from this unit (Figure 23). Total thickness of the Millboro Shale and Needmore Formation is estimated to be 1000 to 1500 feet.

The Needmore Formation is medium-to light-olive-gray shale with minor amounts of limestone and thin bentonite beds near the top (Tioga ash beds). Fossils are common and include ostracods, brachiopods, arthropods, and bryozoans. Contact with the underlying Ridgeley Sandstone is unconformable (Figure 24). The Needmore is well exposed east of Panther Gap along Mill Creek and Virginia State Highway 39/42, where it is approximately 20 feet thick.

The Millboro Shale is typified by black, fissile shale (Figure 25) with black microcrystalline limestone beds near its base (Purcell equivalent). It also contains thin (less than 0.5-inch-thick) bentonite beds. The Millboro contact with the overlying Brallier Formation is placed at the last black shale of the Millboro. Because of the structural deformation of the Millboro, the exact thickness of the unit is difficult to determine, however it is probably at least 1000 feet thick.

Brallier Formation (Db)

The Brallier Formation consists of green, brown, and gray, platy, micaceous shale interbedded with numerous gray, thinly bedded sandstone

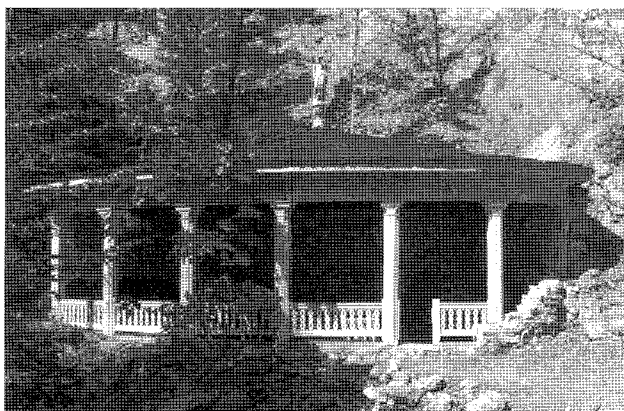


Figure 23. Rockbridge Alum Spring flows from the Millboro Shale. This and other nearby "baths" were popular destinations during the 1800s and were valued for the purported healing abilities of these mineral waters.

Devonian

The middle member of the Keyser Formation is the Clifton Forge Sandstone. It is a clean, resistant quartzarenite and is 20 to 40 feet thick. The upper member, referred to as the Jersey Shore member by Head (1972), is a nodular limestone that is approximately 40 to 80 feet thick. Aggregate Keyser Formation thickness is 120 to 180 feet.

Conformably above the Keyser is the New Creek Limestone, a light-gray, coarse-grained, pinkish crinoidal limestone that is 20 to 60 feet thick.

Above the New Creek is the medium-grained, calcareous-cemented and cross-bedded Healing Springs Sandstone. It is similar in appearance to the Ridgeley Sandstone, although abundant iron concentrations have not been noted in the Healing Springs. The Healing Springs is 5 to 90 feet thick and very well exposed in places along the east flank of Mill Mountain.

The uppermost Helderburg Group rock unit is the Licking Creek Limestone. It consists of the lower Cherry Run member (distinctive for its white chert limestone) and an upper Little Cove member (gray, arenaceous limestone). The Licking Creek is 50 to 130 feet thick.

The Ridgeley Sandstone is a medium- to coarse-grained, calcareously cemented sandstone. It is cross-bedded, fossiliferous (abundant *Spirifer* being diagnostic), and highly ferruginous in places. The Ridgeley was an important iron ore source that was mined in the 1800's near Little California, Guys Run, and Goshen Branch. Throughout the county it is absent to 20 feet thick.

Millboro Shale and Needmore Formation (Dmn)

Because of poor exposure and the thinness of the Needmore, the Millboro Shale and the Needmore Formation could not be consistently differentiated and were mapped as one unit. This map unit almost always underlies valley bottoms, primarily because of susceptibility to weathering of the shale. Many of the "healing springs" in the

county emanate from this unit (Figure 23). Total thickness of the Millboro Shale and Needmore Formation is estimated to be 1000 to 1500 feet.

The Needmore Formation is medium- to light-olive-gray shale with minor amounts of limestone and thin bentonite beds near the top (Tioga ash beds). Fossils are common and include ostracods, brachiopods, arthropods, and bryozoans. Contact with the underlying Ridgeley Sandstone is unconformable (Figure 24). The Needmore is well exposed east of Panther Gap along Mill Creek and Virginia State Highway 39/42, where it is approximately 20 feet thick.

The Millboro Shale is typified by black, fissile shale (Figure 25) with black microcrystalline limestone beds near its base (Purcell equivalent). It also contains thin (less than 0.5-inch-thick) bentonite beds. The Millboro contact with the overlying Brallier Formation is placed at the last black shale of the Millboro. Because of the structural deformation of the Millboro, the exact thickness of the unit is difficult to determine, however it is probably at least 1000 feet thick.

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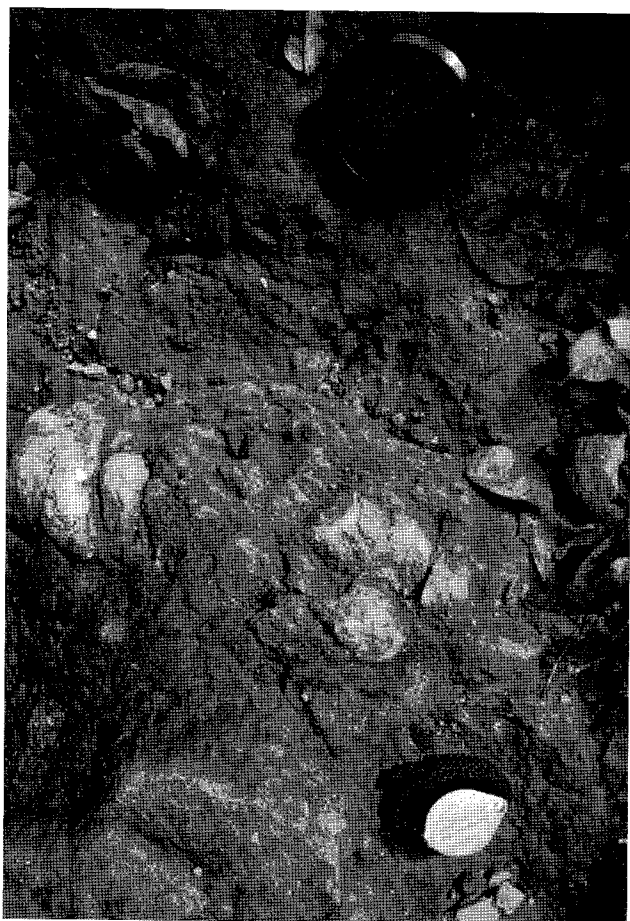


Figure 24. Contact of the Ridgeley Sandstone (handlens) with the overlying Needmore Formation (camera lens cap), west flank Mill Mountain. The irregular contact and the presence of lag pebbles in the Ridgeley indicate an erosional unconformity. This contact marks the uppermost boundary of the "Devonian-Silurian, undivided" map unit.

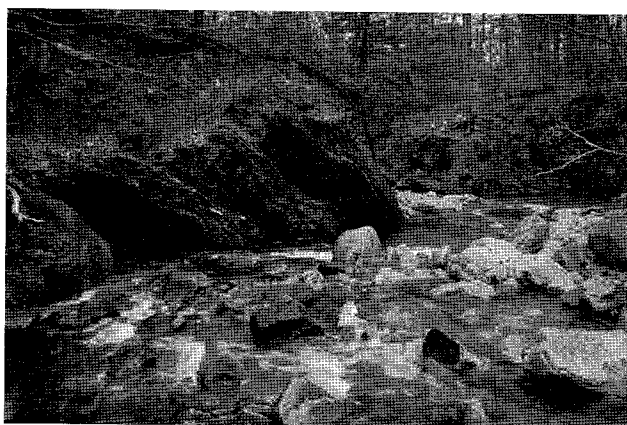


Figure 25. Good exposures of the Millboro Shale can be found along Guys Run in the Goshen Wildlife Management Area. As in this outcrop, the Millboro is often deformed, demonstrating its susceptibility as a zone of structural weakness.

and siltstone beds (Figure 26). The Brallier is sparsely fossiliferous. Contact with the overlying Foreknobs Formation is placed at the first 3-foot-thick sandstone of the Foreknobs Formation. The Brallier Formation is estimated to be 1500 to 2200 feet thick.

Foreknobs Formation (Df)

The Foreknobs Formation is composed of interbedded gray to greenish-gray sandstone, siltstone, shale, and mudstone (Figure 27). Brachiopods, pelecypods, and large crinoids are common fossils in the Foreknobs. Only the lowest 500-foot portion of this formation is exposed in the county on Great North Mountain.

MESOZOIC, CENOZOIC, AND RECENT

Intrusive rocks

Several basalt and diabase intrusions of probable Mesozoic and Eocene age occur in the County but are too small to depict at map scale. Most of these occur as dikes and are located in areas of Blue Ridge basement rocks. At least two peridotite intrusive bodies (map unit "p") are located near Mt. Horeb Church in the southwest

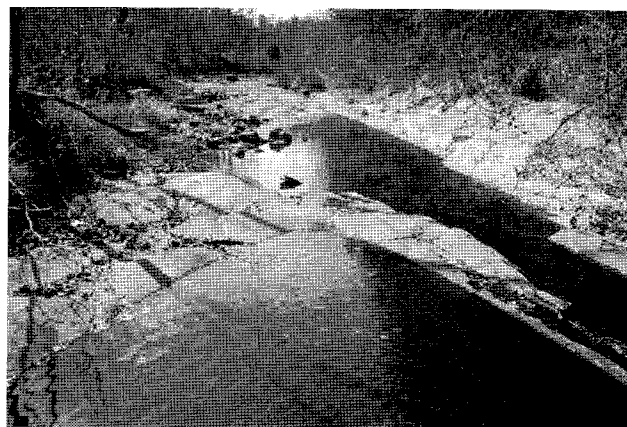


Figure 26. Exposures of the Brallier Formation can be found along Brattons Run between Goshen and Little California. This stream outcrop in Brattons Run exposes a minor syncline within the Brallier, typical of the small-scale folding and faulting of the Devonian units.



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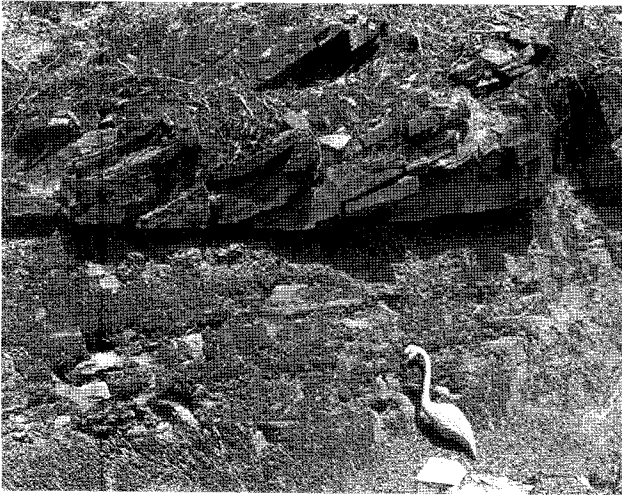


Figure 27. Excellent exposures of the Foreknobs Formation are just outside Rockbridge County in Augusta County along Ramsey Draft (State Road 687) where it is part of the Elliott Knob syncline. This photograph shows the contact of the Brallier and Foreknobs at the first 3-foot-thick sandstone of the Foreknobs Formation.

part of the county (Steidtmann, 1948, Spencer, 1968, Sears and Gilbert, 1973). The dolomites and limestones near these bodies are shattered, and the ultramafic rocks are deeply weathered. No fresh exposures of peridotite have been found. Studies by Sweet (1996) indicate these bodies were formed under relatively low pressure, and the possibility of diamond formation is poor.

Ancient Landslides

Several previously unmapped ancient landslides (map unit "L") occur on the Rockbridge geologic map. They are all intact block landslides that exhibit hummocky terrain, sag ponds, and displaced stratigraphy in relation to the surrounding geology. Most ancient landslides mapped have their slip-planes within upper or lower shale units of the Rose Hill Formation. All of the landslides are currently stable, although one shows recent movement in the form of bent trees and fresh earth exposed. The largest of the ancient landslides can be seen south of Goshen

on the northwest flank of Brattons Mountain, above the junction of Virginia Highway 39 and State Road 780. Here, several hundred acres of Keefer Sandstone broke loose as an intact block and slid downhill on the upper Rose Hill shale. During the 1940s through the 1970s, the lower part of the landslide was quarried for sand and was mistakenly thought to be the Ridgeley Sandstone because of its stratigraphic position.

Surficial deposits

Several varieties of surficial deposits in the county have been mapped by the United States Department of Agriculture soil survey (Jurney and others, 1931). The United States Natural Resources Conservation Service is currently in the process of producing an updated and more detailed surficial map of the county.

The only surficial deposits shown on this county geologic map are on the alluvial plains of the larger streams (map unit "al"). These sediments are defined as being recently deposited by an active stream and prone to flooding. Sediment may range in size from particles of fine earth (sand, silt, and clay) to boulders (Figure 28).

Recent deposits of travertine-marl occupy small areas of streams cutting through carbonate rocks. These calcium carbonate deposits are precipitated from running water that is saturated with carbonate derived from the parent rock (Figure 29). In Rockbridge County, travertine deposits are always associated with highly fractured or faulted rock. Herman and Hubbard (1990) have documented many of these deposits in the county.

Other surficial deposits found in the county include colluvium and talus. The latter occur below rock ledges on steep mountain slopes and consist of loose, angular blocks of rock formed as a result of freeze and thaw of ledges or cliffs. The thickness of talus deposits is highly variable, but greater than 50 feet of Antietam talus was observed on the flank of Sallings Mountain. Cragdingles (Outerbridge, 1987, Lovett and others, 1992), a unique form of talus deposition, are found in some hollows of Great North and



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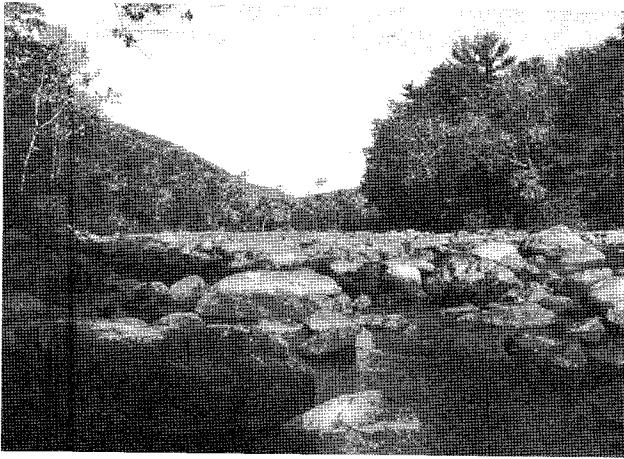


Figure 28. Goshen Pass (shown here), Balcony Falls, and Panther Gap contain alluvial deposits that are notable for the large size of the boulders. In the western mountains they are composed of Keefer and Tuscarora Sandstone, in the Blue Ridge, of Antietam and Harpers orthoquartzites.



Figure 29. Several of the most spectacular deposits of travertine in the county are along the west scarp of the South River, north of the town of South River. Here, travertine is forming on a precipitous drop of an unnamed drainage to the South River.

Little North mountains (Figure 30). The southern part of Arnold Valley is covered by colluvium. Where colluvial and alluvial deposits coalesce at the base of steep mountain slopes, fan-like forms that resemble alluvial fans in arid regions have developed. Good examples of fan deposits also occur along the northwestern flank of the Blue Ridge.

BRECCIA

Tectonic (or fault) and collapse breccia (map unit "b") occur in the county. Both are typically limited to exposures only of a limited area and their locations are indicated on the map. Only one fault breccia in Arnold Valley is of large enough extent to be delimited on the geologic map.

The character of fault breccia is closely related to the lithologies of the rock units involved. For example, breccia formed from the thick layers of orthoquartzite contain angular fragments indicating brittle failure of the unit. These are seen in the Blue Ridge (Antietam Formation) and North Mountain (Tuscarora, Rose Hill, and Keefer Formations). Another example is at Buffalo Creek where the Elbrook Formation produces two types of fault breccia: one, a fault gouge, can be seen in exposures associated with the Staunton Fault; the second variety, also influenced by the Staunton Fault, consists of massive dolostone that has been shattered and cemented by calcite.

Sedimentary breccia occurs from paleokarst processes. In one exposure just east of Rockbridge Baths, blocks of younger Ordovician

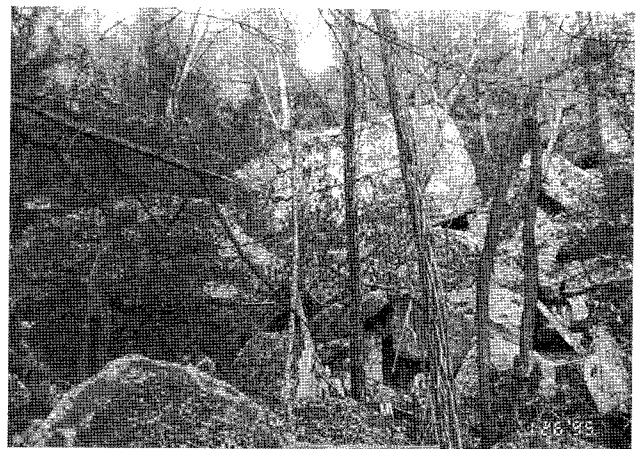


Figure 30. Cragdangles, a rare geomorphic form, exist as bowl-like depressions containing large blocks of talus such as here on the flank of North Mountain. These landforms may be unique to the Appalachians.

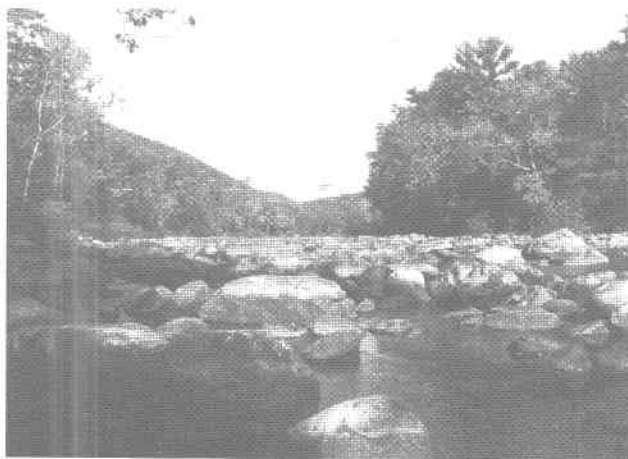


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STRUCTURAL GEOLOGY

From east to west, Rockbridge County occupies two regional geologic structural settings: the Blue Ridge and the Valley and Ridge. The boundary between the two is placed at the base of the steep slopes formed by the Antietam quartzite along the western flank of the Blue Ridge Mountains and referred to as the Blue Ridge Front (Figure 31). Rocks within the Blue Ridge have been deformed during several tectonic events. Metamorphism during these events has changed the original composition and texture of the rocks. The rocks of the Valley and Ridge are younger than those of the Blue Ridge but still have been subjected to deformation, though not to the same extent as the Blue Ridge rocks. Many of the faults and folds have been named (Figure 32).

BLUE RIDGE PROVINCE

The Blue Ridge portion of Rockbridge County is situated on the northwest limb of the Blue Ridge anticlinorium, which is a regional geologic structure extending northeast from central Virginia through Maryland and into Pennsylvania. Within the anticlinorium are significant local structures. For example, the Buena Vista anticline is a northeast-trending, southwest-plunging fold developed in the Blue Ridge basement complex southeast of the town of Buena Vista. It continues southwestward into Arnold Valley where it plunges beneath the Blue Ridge fault. This thrust fault emerges from a zone of ductile deformation in Amherst County and carries Blue Ridge basement rocks and the Chilhowee Group on its hanging wall (Spencer,

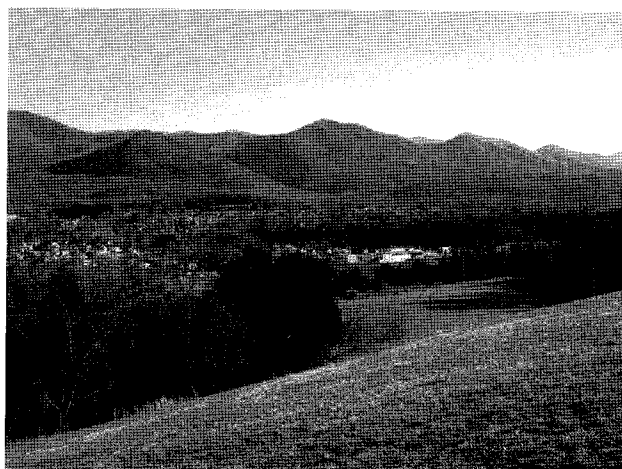


Figure 31. Blue Ridge front from Glen Maury Park, Buena Vista. At the base of the mountain is the boundary between the Blue Ridge and the Valley and Ridge geologic provinces.

1994 and 1995). The thrust, which is subhorizontal, crops out around the edge of Arnold Valley and continues southwest along the northwestern flank of the Blue Ridge to Alabama. The large syncline composed of Antietam quartzite that forms Sallings and Miller mountains is on the hanging wall of the Blue Ridge thrust. The James River cuts across the southwestern end of Sallings Mountain almost leaving Sallings Mountain as a klippe.

Another fault, also called the Blue Ridge fault by Bailey, et. al. (2002), is located along the northwestern edge of the Blue Ridge in the central and northern part of Rockbridge County and is not connected with the Blue Ridge fault described above (Spencer, 1992). The Antietam Formation is thrust onto Waynesboro Formation or Shady Dolomite along this fault. The Shady is missing along parts of this fault and Antietam breccias are exposed in several valleys that run across the mountain front. Long stretches of this fault are covered by colluvium from the Blue Ridge, and it dies out or is buried beneath alluvium in Arnold Valley.

In northeastern Rockbridge County, basement rocks in the upper Irish Creek and Nettle Creek drainages occur in a series of structural blocks that are juxtaposed across steeply south-

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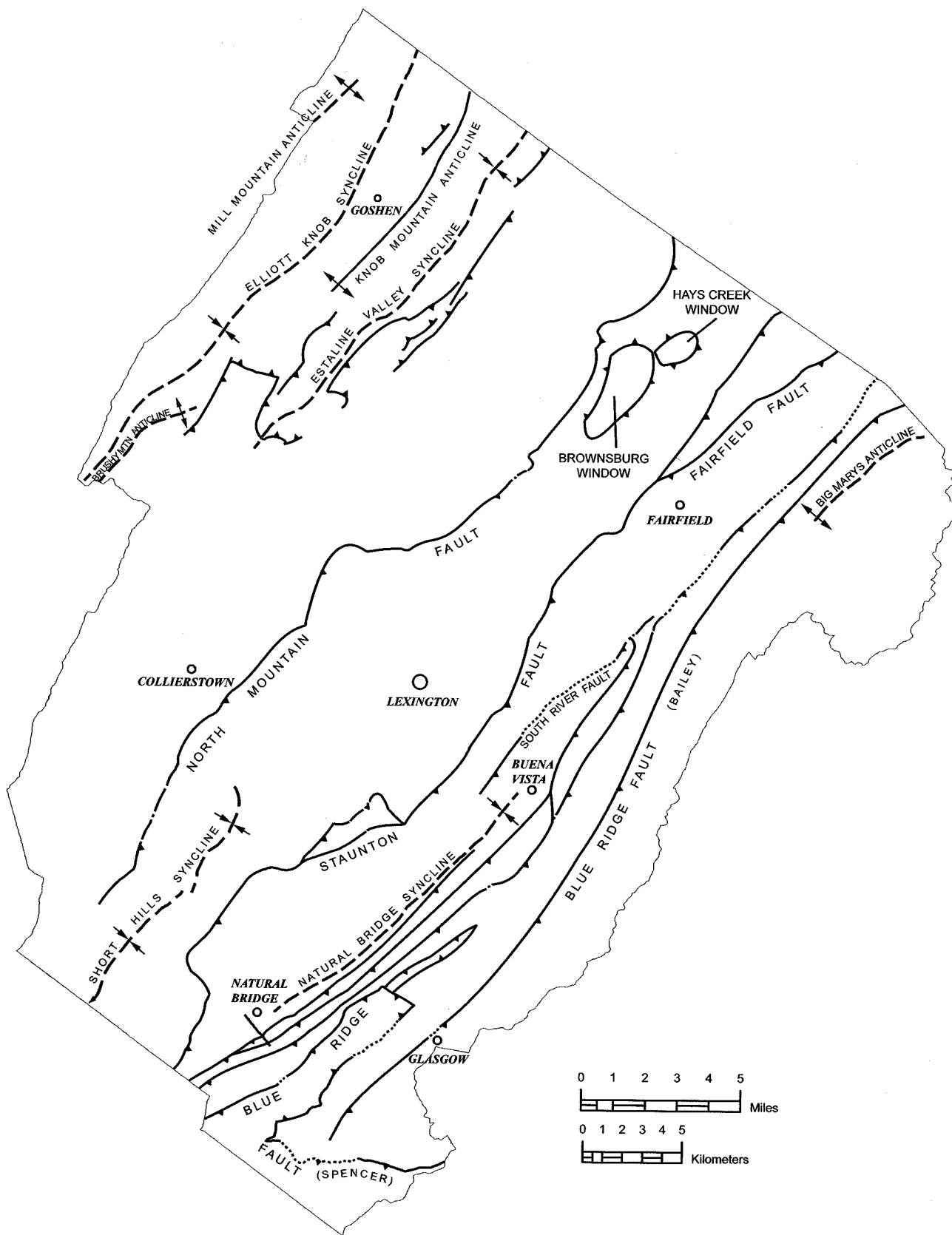


Figure 32. Generalized map of the major faults and folds in Rockbridge County.

east-dipping shear zones. For example, the Whetstone Ridge fault is a steeply southeast-dipping structure that has normal movement in northeastern Rockbridge (top plate down), and progressively shifts to a reverse fault (top plate to the northwest) along strike to the southwest. Evans interprets the kinematics of this fault as resulting from reactivation of the Paleozoic thrust plane during Mesozoic extension. Spencer, et. al. (1989), Spencer (1994), and Bailey, et. al. (2002), however, interpret the same geometry as resulting from reactivation of an older normal fault during late Paleozoic compression and northwest thrusting.

The Big Marys anticline is an asymmetric, gently southwest-plunging structure in the Vesuvius area that is disrupted on its southeast limb by a near vertical normal fault. Harpers Formation rocks on the northwest limb of the Big Marys anticline are imbricated along a series of unnamed bedding-plane reverse faults.

Up-section to the northwest, the anticline is truncated along the Midvale fault, where northwest-dipping, brecciated Antietam quartzites are faulted against overturned, southeast-dipping shales and carbonate rocks of the Waynesboro Formation. The Waynesboro is in fault contact with the Elbrook Formation on the southeast-dipping South River fault throughout the County.

The South River fault is southeast-dipping and is manifested as a zone of slippage though several hundred feet of Cambrian rocks (Figure 33). The exact relationship with neighboring structures is not completely understood although it is probably associated with the Blue Ridge fault of Bailey and others (2002).

The structure of the northwestern flank of the Blue Ridge exhibited by the Antietam quartzite flatirons southeast of Buena Vista and Glasgow is deceptively simple. The Antietam dips northwest at angles ranging from 80 degrees near Glasgow to 30 degrees near Buena Vista. Large angular folds are present in the Antietam along the mountain front near Arnold Valley. The underlying shales, sandstones, and siltstones of the Harpers Formation exhibit a much more complex structure. These structural features are disharmonic with respect to the overlying Antietam

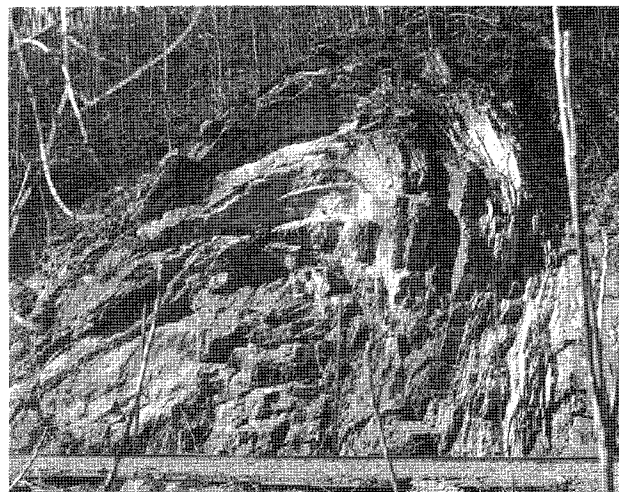


Figure 33. Steeply plunging folds in the Elbrook Formation are exposed along railroad cuts near Cornwall. This outcropping is located close to the trace of the South River fault which formed this distorted bedding.

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VALLEY AND RIDGE PROVINCE

This province begins at the base of the western flank of the Blue Ridge and continues westward into West Virginia. It consists of a series of valleys and ridges oriented in a northeast-southwest trend. The largest of the valleys, the Great Valley, lies between the base of the Blue Ridge and North/Little North Mountain. The Great Valley is nearly 12 miles wide in the northern part of the county and narrows to 4 miles where it enters Botetourt County. West of the Great Valley is a series of anticlines and synclines of Silurian and Devonian age rocks that is referred to as the "western anticlines."

The geologic structure of the Great Valley portion of Rockbridge County is influenced by two principle faults: the Staunton and the North

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The geologic structure of the Great Valley portion of Rockbridge County is influenced by two principle faults: the Staunton and the North

Mountain. These faults are regional in scale. The North Mountain fault extends into Pennsylvania, and the Staunton fault is part of a fault system that disappears beneath the Cretaceous onlap in Alabama.

The Staunton fault traverses the entire county with Cambrian Elbrook or Conococheague on the hanging wall and several Ordovician formations exposed at the immediate footwall. The fault is actually a fault system, related to the Pulaski fault to the south and having several subsidiary splays and chips. The dip of the main fault is difficult to determine, but because the trace is relatively straight, this suggests a dip southeast from 20 to 40 degrees with a roughly N30°E strike. Although fault exposures are scarce, the fault contact is either sharp or represented by brecciated rock.

The overall structure within the Staunton fault block is best exemplified by the Natural Bridge syncline. This large northeast plunging syncline is a southern extension of the Massenuttan synclinorium of the northern Great Valley. The northwestern limb of the syncline is truncated by the Staunton fault and the southeastern limb, which is overturned in the southern part of the County, is in contact with the Blue Ridge fault.

Subsidiary faults, splaying off the Staunton fault, are local in extent and rarely exceed 5 to 10 miles in length. Field relationships suggest minimal displacement along these faults. As an example, the Fairfield fault ties into the Staunton fault between Fairfield and Decatur Aqua and loses all displacement about 10 miles to the north in Ordovician rocks (Rader, 1967).

Effects of faulting within the Staunton block include shearing, brecciation, and intense folding of the rocks (Figure 34).

Horses, or fault chips, occur as either undecipherable breccias, such as west of Raphine, or as intact orphaned pieces along the Staunton fault. A fault chip located north of Buffalo Creek is interpreted as a ramp fragment from the footwall of the Staunton fault. This fault slice contains several Ordovician-aged rock formations and is structurally complex (Spencer, 1968, Spencer and others, 1989, Spencer, 1993).

Stratigraphic displacement on the Staunton fault varies between 3,500 to 6,000 feet. Because of the relatively low dip of the fault, the actual displacement is probably much greater (Bick, 1960).

The North Mountain fault is a southeast-dipping thrust that forms the western edge of the North Mountain structural block. Beginning in Franklin County, Pennsylvania, the fault traces south through Maryland and West Virginia, into the Valley and Ridge of Virginia, and enters Rockbridge County near Newport. The North Mountain fault trace continues south through the central part of the county, and its surface expression ends near Rapps Mill. The North Mountain fault dips southeast at about 30 degrees at Kerrs Creek (Bick, 1960) and attains higher and lower dips elsewhere along its trace. Near McClungs Mill the fault branches into splays, each quickly dying out to the north, and having stratigraphic displacements of several hundred feet.

Near the village of Brownsburg are two windows through the North Mountain Thrust sheet. The Brownsburg window was previously mapped by Bick (1960) (Figure 35). A second window, here referred to as the Hays Creek window, was recognized during this project. In both windows, the footwall Beekmantown and lower middle Ordovician rocks are overridden by the Cambrian Elbrook Formation. The fault at these localities is low-dipping to subhorizontal.



Figure 34. Mesoscopic folds exposed in the bank of the Maury River along the Chessie Trail. Many interesting small-scale structural features are present along the trail.

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Figure 34. Mesoscopic folds exposed in the bank of the Maury River along the Chessie Trail. Many interesting small-scale structural features are present along the trail.

To the west of the North Mountain fault and east of North and Little North mountains, outcrops often display a high degree of shearing, overturning, and faulting of the Ordovician rocks, especially those of the Martinsburg Formation. Bick (1960) suspected a fault tracking through the community of Zack within the Edinburg. Further investigation within this area could provide evidence of a suspected large through-going fault in this part of the section.

The area west of the Great Valley is best defined by a series of anticlines and synclines known as the western anticlines and has been locally disturbed by faulting. These faults may dip southeast (overthrusts) or northwest (backthrusts). For example, overthrusts occur on Little North Mountain and represent larger structural displacements. By comparison, the backthrusts in the same area typically have short lateral influence and stratigraphic displacement of only a few hundred feet.

Bick (1973) mapped two slightly folded, northwest-dipping faults in the Goshen Wildlife Management Area (Figure 36). Near this same area, faulting has brecciated Silurian sandstones (Figures 37a and 37b). These same Silurian rocks have been duplicated on North Mountain above

Lake Robertson by a backthrust that continues its trace south into Alleghany County. Also on North Mountain (south of Interstate Highway 64) are two minor folded backthrusts consistent with the structural style seen along North Mountain.

Many of the larger folds have been named and also contain local intraformational faults. The Brushy Mountain anticline was mapped by Lesure (1987) and consists of a gentle anticline with the west limb slightly steeper than its eastern limb. The Martinsburg and Juniata Formations are found in the core of the anticline, exposing the only Juniata Formation rocks in the County.

The Elliott Knob syncline enters Rockbridge in the extreme northwestern part of the county exposing Devonian-age rocks. The Foreknobs Formation, the youngest Paleozoic rock unit in the County, is exposed within the core of the syncline. The axial trace of the syncline trends through Rockbridge Alum Springs and continues south toward Alleghany County.

Named from Estaline Valley in Augusta County, the Estaline Valley syncline has Devonian-age rocks in its core. The syncline's southern extent is in the Goshen Wildlife Management Area where it has been partially overridden by an unnamed southeast-dipping thrust fault.



Figure 35. The Village of Brownsburg lies below a hill of Ordovician-age rocks that is within a structural window through the North Mountain fault. Older, Cambrian-age carbonates surround the structure. This, and a second window north of here, demonstrate the near-horizontal attitude of the North Mountain fault in this region.

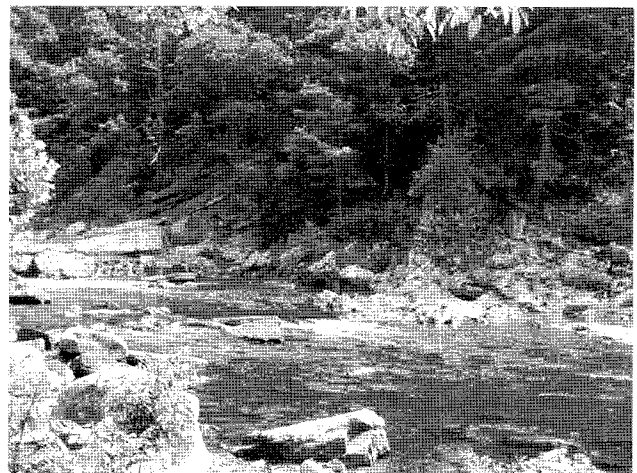


Figure 36. The Maury fault, looking northeast in the Devil's Kitchen of Goshen Pass. This backthrust in the Tuscarora sandstone is dipping to the northwest, the footwall rock having been deformed into a tight fold.

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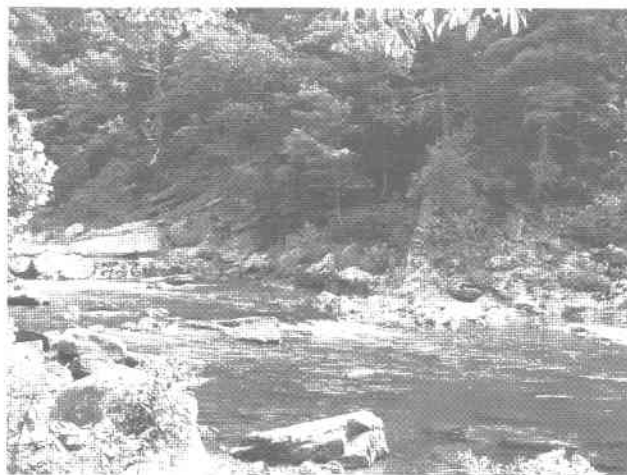


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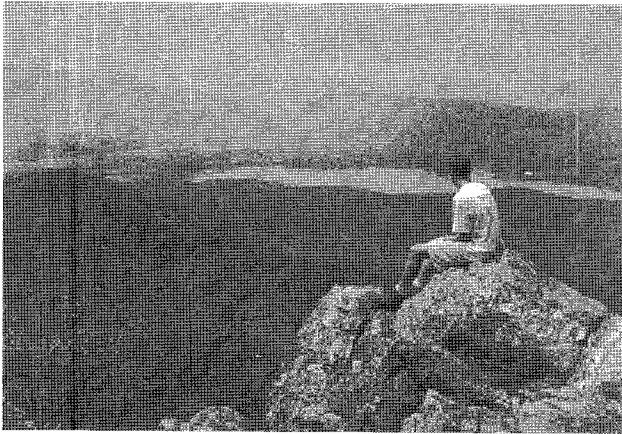


Figure 37a. Easily seen from Lake Meriweather, Viewing Rock on the west flank of Little North Mountain commands an excellent vantage of the Goshen Wildlife Management Area and Camp Meriweather.

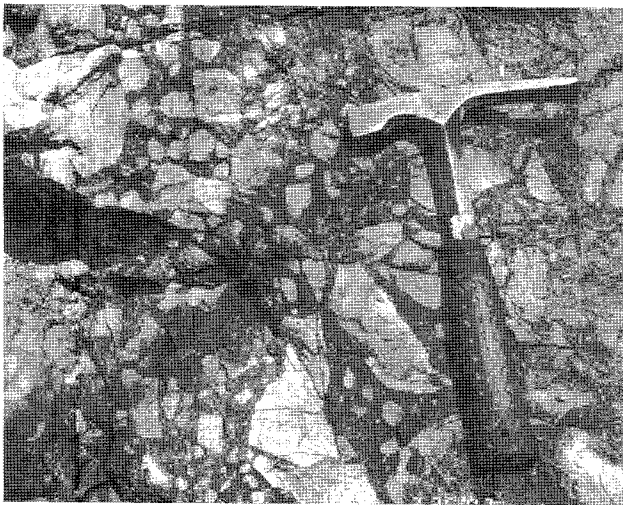


Figure 37b. Viewing Rock is a brecciated Silurian sandstone. The angular clasts attest to the brittle nature of faulted competent rock.

The Knob Mountain anticline is a broad, symmetric anticline where it enters Rockbridge County from the north. Its southern terminus is in the Goshen Wildlife Management Area where part of its east flank is on the footwall of a southeast-dipping thrust fault. To the south, the axial plane is also terminated by a folded thrust. In Bells Valley, a minor backthrust is noted in the Silurian rocks of the anticline's core.

The Mill Mountain anticline is an eastern

extension of the Deerfield anticlinorium of Butts (1940) and exposes Silurian and Devonian rocks. The crest of Mill Mountain marks the political boundary between Rockbridge and Bath counties and only the east limb of the anticline is exposed in Rockbridge County. Part of the eastern flank of the anticline is faulted by a minor strike-slip fault just west of Rockbridge Alum Springs.

The Short Hills syncline is asymmetric to the west and its southeast limb is locally truncated by a southeast-dipping thrust.

ECONOMIC GEOLOGY

Rockbridge County contains a wide variety of rock types, resulting in a great number of mineral resources. These resources have been used in the past, are currently being developed, or have the potential of becoming important in the future. The Virginia Division of Mineral Resources maintains a list of active and abandoned mines in the county. This information is available from the Division through the Mineral Resources of Virginia program (MRV).

Three quarries are presently active in the county. Rockbridge Stone Products, Inc. (formerly Lone Jack quarry) is located just north of Glasgow at the northwestern base of Sallings Mountain. At this quarry, quartzite from the Antietam Formation (Figure 38) and shale, limestone, and dolostone from the Waynesboro Formation are extracted primarily for aggregate (Gooch, Wood, and Parrott, 1960). The Charles W. Barger and Son quarry, situated in Edinburg Formation limestone, produces aggregate from an operation just east of Lexington on U.S. Highway 60 (Figure 39). Haley, Chisholm, and Morris, Inc. operates a shale pit east of Glasgow for fill material.

Many of the Cambrian-Ordovician carbonate formations in the county have the potential to produce aggregate, agricultural lime, dimension stone, sand for glassware, and metallurgical flux. Nine quarries, all within the Great Valley carbonates, were developed in the County to produce aggregate for construction of Interstate Highway 81 in the 1960s and Interstate Highway 64 in the 1970s.

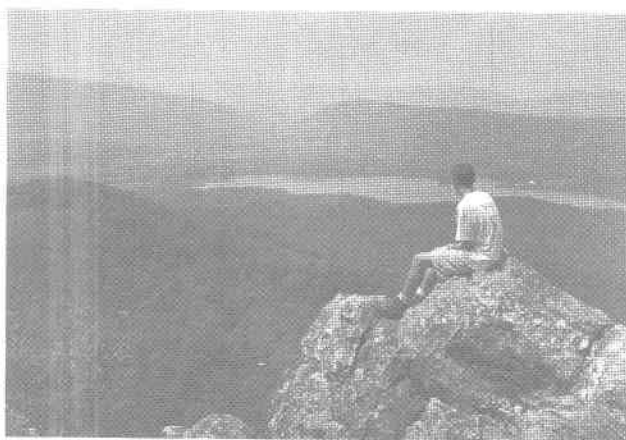


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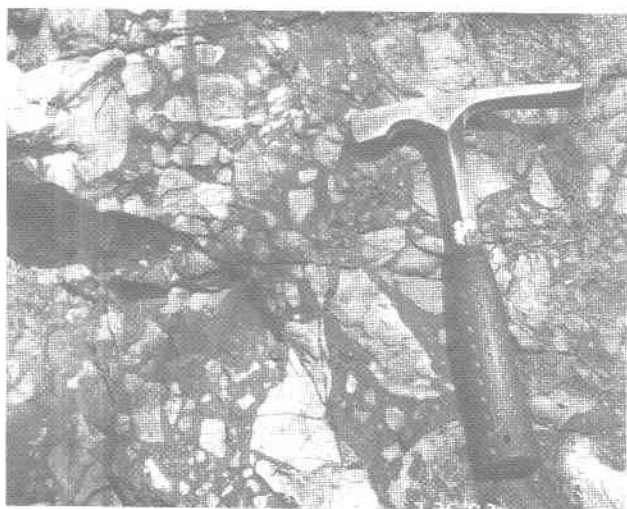


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Travertine deposits were mined for agricultural lime and cement near Marlbrook and Riverside (Sweet and Hubbard, 1990). Natural cement (argillaceous magnesian limestone) was formerly quarried from the Shady Dolomite near Balcony Falls in the late 1800s (Fontaine, 1883; Watson, 1907).

Quartzite, used for metallurgical flux and non-polishing aggregate, is found primarily in the Antietam and Tuscarora formations. These formations contain abundant quantities of potential resources on the Blue Ridge, Sallings Mountain, Miller Mountain, Brady Hill, the Short Hills, Green Mountain, and several places on Little North Mountain (Sweet, 1981). Sandstone for glass sand, ground silica, foundry sand, and construction purposes was extracted from the Keefer Sandstone near Goshen (Lowry, 1954).

Residuum from some Cambrian, Ordovician, and Devonian formations is suitable for the manufacture of structural clay products, especially brick. Clay material was formerly obtained at sites near Lexington, Glasgow, Buena Vista, Goshen, and near Natural Bridge. Calver and others (1964) and Sweet (1982) report evaluation data on clay and shale samples collected throughout the county.

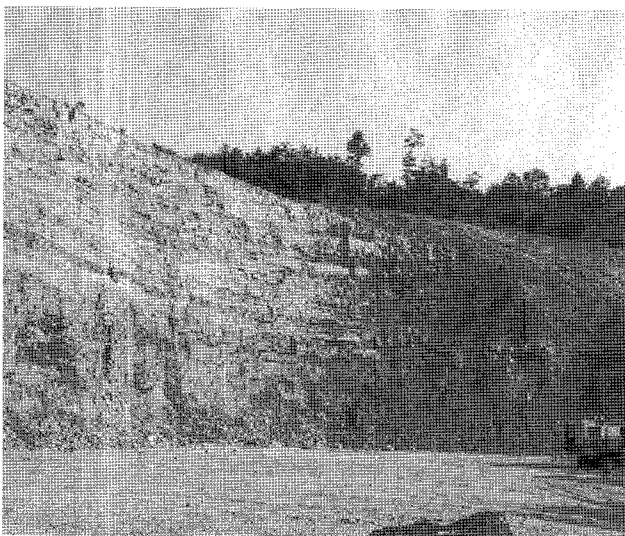


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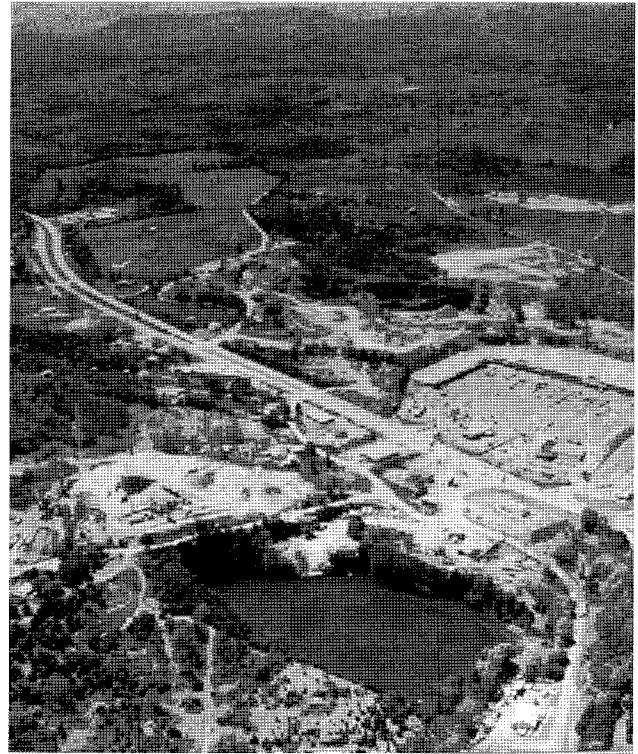


Figure 39. Barger and Sons quarry east of Lexington. This operation reclaimed part of the quarry to a suitable condition to have a shopping center built.

Iron was mined near Buena Vista, Midvale, and Vesuvius during the late 1800s from the Waynesboro Formation (Fontaine, 1883, and McCreath, 1883). Fontaine reported that these ores had been worked since the Revolutionary War. Iron was produced also from Ridgeley ore deposits along Brushy, Mill, Bratton, Knob, and Little North mountains (Figure 40). Manganese ore has also been mined near Goshen and along the west slope of the Blue Ridge (Stose and others, 1919). In the Irish Creek area, tin was produced from a series of openings during the late 1800s to early 1900s (Luttrell, 1966). This deposit also contains varying amounts of lead, zinc, and gold (Sweet and others, 1989; Good, 1991).

Penick (1994) compiled a comprehensive list of mineral occurrences of the county including rockbridgeite, discovered in and named for Rockbridge County. Titaniferous sandstone occurs near Buena Vista in the Unicoi Formation

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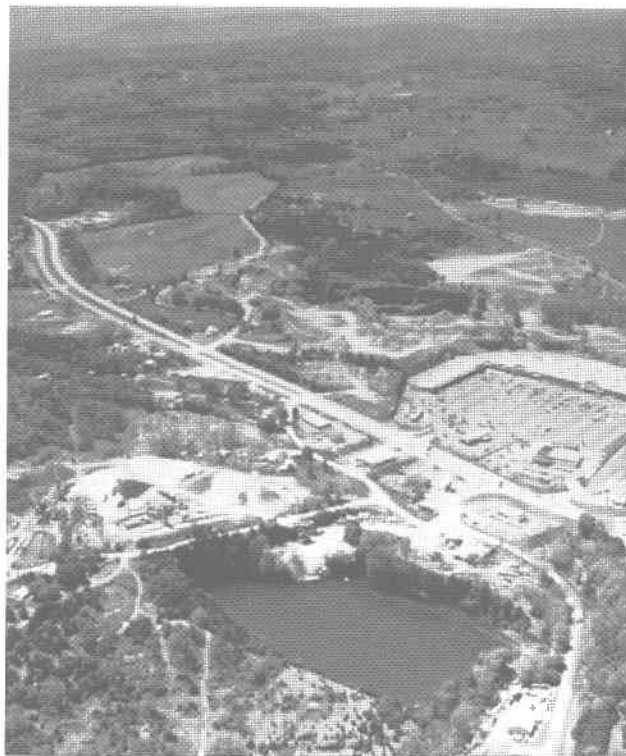


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Figure 40. Several 1800-era iron mines occur along the eastern flank of the Brushy Mountain anticline. They were crudely dug, following the lenticular nature of the ore deposits. These and other nearby mines supplied raw ore to Longdale and other nearby furnaces where pig iron was refined from the ore. This iron was then supplied to forges to make tools and other iron-goods.

(Bloomer and De Witt, 1941, Pegau, 1956). Barite has been prospected for in the county (Edmundson, 1938). Red ocher, used as a paint pigment, is reported near Fairfield (Hotchkiss, 1883) and bauxitic clay has been located along Chalk Mine Run (Warren and others, 1965). Gravel, with a potential as aggregate and ornamental stone, is present in the flood plains of the Maury, James, and South rivers.

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GEOLOGIC MAP OF ROCKBRIDGE COUNTY, VIRGINIA

Gerald P. Wilkes, Edgar W. Spencer, Nick H. Evans, and Elizabeth V. M. Campbell

2007

Simplified map showing
major structural features

UNIT DESCRIPTIONS

- BRECCIA**
Angular fragments of quartzite and granite conglomerate. Fragments can be several inches in size and the matrix may contain iron staining.
- ALLUVIUM**
Unconsolidated clay, sand, and gravel.
- ANCIENT LANDSLIDE**
Large, steep rock block slide.
- PERIDOTITE**
Ultramafic stock-like mass of weathered olivine-mica kinkherite.
- FOREKNOS FORMATION**
Sandstone and shale, green and greenish-gray, fossiliferous in places (most notably large rounded stems), and minor quartz-pebble conglomerate. Less than 1000 feet exposed in the county.
- BEALLIER FORMATION**
Siltstone, shale, and thin sandstone, olive-gray, micaceous, sparsely fossiliferous. 1500 to 2200 feet thick.
- MILLBORO SHALE AND NEEDMORE FORMATION UNDIVIDED**
Millboro shale, black, shale, near the base is an interval of thin limestone beds, dark gray, spongy (Pencil Member). Toga interval: gray silty shale, limestone beds, and black shale near base. Needmore shale, olive-gray, coarsely weathered, fossiliferous. Composite thickness 800 to 1200 feet.
- UNCONFORMITY**
- DEVONIAN AND SILURIAN ROCKS UNDIVIDED**
Ridgeley Sandstone: sandstone, medium-gray, calcareously cemented, fine- to coarse-grained, fossiliferous, most notably "Starrier" Halberberg Group, including Licking Creek Limestone: limestone, medium-gray, argillaceous, with white chert. Hauling Spring Sandstone: sandstone, medium-grained, calcareously cemented, cross-bedded. New Creek Limestone: limestone, gray to pink, coarse-grained, crinoidal. Keyser Formation: limestone, coarse-grained, nodular, argillaceous. Clifton Forge Sandstone Member of the Keyser: quartzite, silty, ledge-former, typically cherty. Tangleway Limestone: limestone, dark gray, fine-grained, thin-bedded. Composite thickness of Devonian-Silurian unit is from 825 to 840 feet.
- CAYUGA GROUP AND KEYSER SANDSTONE**
Cayuga Group includes Willa Creek Formation: shale, silty, yellow-weathering. Williamsport Sandstone: sandstone, indurated, greenish-gray, with minor silty beds. Keyser Formation: sandstone, calcareous, cross-bedded, interbedded with limestone, very thick-bedded, knobby-weathering, dark gray. Keifer Sandstone: sandstone, argillaceous in places, white to light-gray, very thick-bedded, bearing a coarse-grained, massive ledge-former. Composite thickness of the Cayuga and Keifer is 1500 to 450 feet.
- ROSE HILL FORMATION**
Sandstone, maroon, medium-grained, lenticular, well-indurated, and red, green, and gray shale and siltstone. 200 to 320 feet thick.
- TUSCARORA FORMATION**
Sandstone, white to light gray, ledge-forming, quartzite, medium- to coarse-grained, with quartz-pebble conglomerate ("pebbly beams") in lower half of unit. 50 to 200 feet thick.
- UNCONFORMITY**
- JUNIATA FORMATION**
Sandstone, shale, and sandstone, and to olive-gray, 0 to 300 feet thick.
- MARTINSBURG FORMATION**
Upper: sandstone, siltstone, and shale, light- to medium-gray, distinctive Ortho-rychthoid zone near top of unit. Sandstone, fine-grained, thin-bedded. Lower: limestone, argillaceous, light-gray, very thick- to thin-bedded. Up to 1500 feet thick.
- EDINBURG FORMATION**
Collingwood Limestone: limestone, coarse-grained, fossiliferous. Liberty Hall facies: limestone, black to dark-gray, argillaceous, interbedded with thin black shale. Late Mills facies: limestone, black, thick-bedded, medium- to coarse-grained, nodular weathering. Bottom Member: limestone, reddish-weathering, massive, fossiliferous. 800 to 1225 feet thick.
- LINCOLNSHIRE LIMESTONE AND NEW MARKET LIMESTONE**
Lincolnsire Limestone: limestone, dark gray to olive-gray, fine-grained, with bedded black chert. Market facies: limestone, light-gray, coarse-grained, fossiliferous, very thick-bedded. New Market Limestone: limestone, spongy, light-gray, very thick- to medium-bedded. 100 to 425 feet thick.
- UNCONFORMITY**
- BECKMANTOWN FORMATION**
Dolomite, light- to medium-gray, medium- to very thick-bedded, fine-grained, the limestone "butterfly chert" lining on weathered surfaces, black bedded, beds of white massive chert near top of unit, with some interbeds of limestone, light- to medium-gray. This unit has been effluvia west of the Staunton fault. 200 to 300 feet thick.
- STONEMEN LIMESTONE**
Limestone, dark gray to black, fine-grained, with black chert along bedding. 200 to 300 feet thick.
- CONOCOCHAGUS FORMATION**
Limestone, medium-gray, thin- to very thick-bedded, fine-grained, with lesser amounts of light-gray, fine- to medium-grained dolomite, and calcareously cemented, fine- to medium-grained sandstone. Silty laminae stand out in relief on weathered surfaces. 2000 to 2200 feet thick.
- ELBROOK FORMATION**
Dolomite and limestone, thin-bedded, fine- to medium-grained with pink and green shale. 1225 to 2200 feet thick.
- WAYNESBORO FORMATION**
Shale, maroon, green, and gray, interbedded with limestone, fine-grained, medium-gray, minor black chert nodules, and dolomite, light- to dark-gray, fine- to coarse-grained, calcareous. Approximately 1200 feet thick.
- SHADY DOLomite**
Dolomite, dark gray; very thick-bedded, impure, white-weathering with minor limestone beds. 1000 to 1500 feet thick.
- CHILHOWEE GROUP**
(Includes Antietam, Harper, and Ellettsburg Formations.)
- ANTETAM FORMATION**
Quartzite and sandstone, ledge-former, fine- to medium-grained, cross-laminated, medium- to very thick-bedded, silty cemented and welded in some beds, abundant phyllite associated with the thicker beds, minor quartz-pebble conglomerates. Approximately 500 feet thick.
- HARPER FORMATION**
Sandstone and quartzite, gray, fine- to medium-grained, in part ferruginous, gray to olive gray phyllite and sandy phyllite with interbedded limestone (C2b). Approximately 1500 feet thick. Snowden Member: quartzite (C2b).
- UNICO FORMATION**
Sandstone and quartzite with phyllite, tuffaceous phyllite, conglomerate, and minor basalt. Quartz pebble conglomerate and micaceous sandstone, greenish gray sandy phyllite and micaceous sandstone, basal conglomerate composed of calcareous rounded quartz and flat shale chert in a matrix of sand-stained quartz and lithic grains (C2c). 200 to 400 feet thick including a persistent quartzite and lithic arenite (C2c).
- CATOCIN FORMATION**
Metachert, purple and green tuffaceous phyllite, and metasedimentary rocks.
- BLUE RIDGE BASEMENT COMPLEX**
- GRANITE**
Includes medium-gray, fine- to medium-grained anorthogranite, granitic, leucocratic, biotite granite (G2), and hornblende-bearing light greenish-gray, coarse- to very-coarse grained, and leucocratic (G2b).
- CHARNOCKITE**
Includes light to dark grayish-green, coarse- to very coarse-grained, massive to weakly foliated pyroxene-bearing granite to granodiorite. It may have porphyritic (Y2c), or leucocratic (Y2b) textures.
- GRANULITE**
Includes pyroxene granulite (Y2g): medium- to dark-granitic-gray, fine- to coarse-grained, aggregation horrel, and leucocratic granulite (Y2g) greenish-gray, medium-grained, banded, quartzoid/diaphanous gneiss.

Index of geologic mapping

MAP SYMBOLS

For all contact, fault, and fold symbols, question marks are added where identity or existence may be questionable. For geologic observation symbols, observation sites are centered on the strike bar or at the intersection point of multiple symbols.

- Geologic Observations**
/ Strike and dip of inclined beds
/ Strike and dip of overturned beds
/ Strike of vertical beds
/ Horizontal beds
/ Indicated foliation - Showing strike and dip
/ Vertical foliation - Showing strike
/ Breccia
- Mineral Resources**
X Prospect (sh-shale, ls-limestone, bs-black shale)
X Mine or quarry
X Abandoned mine or quarry
X Sand and gravel pit
X Inactive sand and gravel pit
- Contacts**
/ Observed or approximate
/ Inferred
/ Contorted
- Fault Contacts**
/ Normal - 11° upthrown block, D - downthrown block
/ Strike-slip - arrows show relative motion
/ Shear zone
- Folds and Axis**
(Arrows indicate direction of plunge where appropriate)
/ Anticline
/ Syncline
- Location of Cross-sections**
/ A-A'
/ B-B'

SCALE 1:50,000

Base map derived from the 1993 US Geological Survey
Rockbridge County North and Rockbridge County South topographic maps, 1:50,000.
Projection: UTM17 NAD 83
Grid: 5,000-meter UTM zone 17 NAD 83

UTM grid convergence (GN)
and 2007 magnetic declination (MN)
at center of map

Change in magnetic declination is 0° 1' W per year

Diagram is approximate

