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

GEOLOGY OF THE STOKESVILLE AND PARNASSUS QUADRANGLES, VIRGINIA

EUGENE K. RADER

REPORT OF INVESTIGATIONS 19

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

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CONTENTS

	Page
Abstract	1
Introduction	1
Stratigraphy	3
Cambrian System	3
Elbrook Formation	3
Conococheague Formation	6
Ordovician System	8
Chepultepec Formation	8
Beekmantown Formation	8
New Market Limestone	9
Lincolnshire Formation	9
Edinburg Formation	10
Martinsburg Formation	10
Oswego Sandstone	11
Juniata Formation	11
Silurian System	11
Tuscarora Formation	11
Cacapon Formation	11
Keefer Sandstone	12
Upper Silurian-Lower Devonian rocks	12
Bloomsburg Formation	12
Tonoloway Formation	12
Keyser Formation	13
Coeymans Limestone	13
Healing Springs Sandstone	13
Licking Creek Limestone	13
Oriskany Sandstone	14
Devonian System	14
Needmore Formation	14
Millboro Shale	14
Brallier Formation	14
Chemung Formation	15
Hampshire Formation	15
Mississippian System	15
Pocono Formation	15
Mesozoic igneous rocks	16
Quaternary System	17
Structure	18
Pulaski-Staunton fault	18
Long Glade syncline	18

PAGE

North Mountain fault and associated structures 18
West Mountain syncline 21
Mineral resources 21
Industrial limestone and dolomite 21
Cement materials 22
Shale 22
Sand and gravel 23
Iron ore 24
References 25
Index 27

ILLUSTRATIONS

PLATE — PAGE

1. Geologic map of the Stokesville quadrangle, Virginia.. In pocket
2. Geologic map of the Parnassus quadrangle, Virginia.. In pocket

FIGURE

1. Index map showing location of the Stokesville and Parnassus quadrangles 2
2. Algal structures in the upper part of the Elbrook Formation .. 7
3. Resistant graywackes in the Pocono Formation at North River Gap 16
4. Flood plain along North River 17
5. Thrust fault at the south end of Buck Hill 19
6. North Mountain fault 20
7. Isolated block of Tuscarora quartzite 20

TABLES

PAGE

1. Geologic formations in the Stokesville and Parnassus quadrangles 4
2. Potential uses of clay materials from the Stokesville quadrangle 23

GEOLOGY OF THE STOKESVILLE AND PARNASSUS QUADRANGLES, VIRGINIA

By

EUGENE K. RADER[1]

ABSTRACT

The Stokesville and Parnassus quadrangles are located in the north-central part of Augusta County, west-central Virginia. Bedrock in the area ranges in age from Middle Cambrian to Early Mississippian, but consists principally of Cambrian, Ordovician, and Devonian units. Most of the rocks are sedimentary and have a total stratigraphic thickness of approximately 17,000 feet. Igneous rocks in the area (dikes, plugs, and sills) are of two general compositions, nepheline syenite and teschenite. Generally the dikes are poorly exposed and are less than 50 feet thick.

The Pulaski-Staunton fault transects the southeast part of the area in a northeasterly direction. Northwest of the Pulaski-Staunton fault, on the southeast side of Little North Mountain, is the North Mountain fault. Between these faults, Cambrian and Ordovician formations are folded into a major overturned syncline (Long Glade syncline) and several minor anticlines and synclines. Little North Mountain consists of overturned, steeply dipping Silurian and Devonian rocks. Another thrust fault parallels Little North Mountain on the northwest slope. Northwest of Little North Mountain is the broad West Mountain syncline.

Mineral resources in the area consist of limestone, dolomite, shale, iron ore, sand, and gravel. Limestone and dolomite have been quarried from rocks of Cambrian and Ordovician age for the production of crushed stone and agricultural stone. Shales from the Millboro, Brallier, and Hampshire formations have been tested for potential use in the manufacture of brick and lightweight aggregate. Iron ore has been produced from the lower portion of the Beekmantown Formation. Sand may be obtained from the Tuscarora, Keefer, and Oriskany formations and from the alluvium along North River and Jennings Branch.

INTRODUCTION

The Stokesville (Plate 1) and Parnassus (Plate 2) quadrangles are located mainly in north-central Augusta County and have an area of 117 square miles; the northeast portion of the Parnassus quadrangle is

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in Rockingham County. They are bounded by 79° and 79° 15′ W. longitude and 38°15′ and 38°22′30″ N. latitude (Figure 1). The quadrangles are within the Valley and Ridge physiographic province. The area east of Little North Mountain, commonly referred to as the Shenandoah Valley, has topography characterized by gently sloping hills and low, narrow ridges. West of Little North Mountain the slopes are steep and the general elevation much higher. The maximum and minimum elevations and total relief for each quadrangle are:

	Maximum Elevation in Feet	Minimum Elevation in Feet	Total Relief in Feet
Stokesville	3450	1440	2010
Parnassus	1740	1200	540

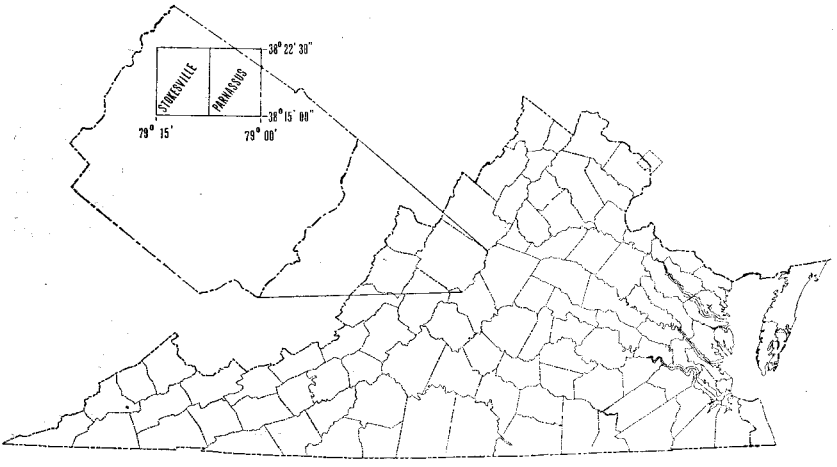

Figure 1. Index map showing location of the Stokesville and Parnassus quadrangles, Augusta County.

The earliest "detailed" geologic map of the area was the Staunton folio (Darton, 1894). Investigations by Butts (1933, 1940-41) included the area of this report. Brent (1960, Pl. 1) mapped a small portion of the northeast corner of the Parnassus quadrangle, and geologic studies of portions of the area were made by Fara (1957), Patterson (1958), and Fitzgerald (1966). The field investigation was begun in March 1967 and completed in November 1968.

Numbers preceded by "R" in parentheses (R-3624) correspond to sample localities on Plates 1 and 2; those preceded by "F" (F-821) correspond to localities on Plate 2 where fossil specimens were collected. These samples and fossils are on file in the repository of the Virginia

Division of Mineral Resources where they are available for examination. Localities where typical fossils may be seen are indicated on Plates 1 and 2. The writer wishes to thank Dr. James L. Calver, Commissioner of Mineral Resources and State Geologist, and other staff members of the Virginia Division of Mineral Resources for their aid in the preparation of this report.

STRATIGRAPHY

The rock strata cropping out in the area are divided into 26 formations that form 17 mappable units on the bases of lithologic character and fossils. The total stratigraphic thickness is approximately 17,000 feet. The oldest rock exposed is the Elbrook Formation of Middle Cambrian age, and the youngest is the Pocono Formation of Early Mississippian age (Table 1). Southeast of the North Mountain fault, the area is underlain by folded Cambrian and Ordovician dolomites, limestones, and sandstones. Little North Mountain is underlain by steeply inclined Ordovician, Silurian, and Devonian sandstones, shales, and limestones. West of Little North Mountain the Devonian and Mississippian shales and sandstones are folded in a broad syncline.

CAMBRIAN SYSTEM

Elbrook Formation

The Elbrook Formation, a heterogeneous unit composed of dolomite and limestone, is exposed along and southeast of the leading edge of the North Mountain and Pulaski-Staunton thrust sheets. The dolomite is fine to medium grained, medium to dark gray, thin bedded, and argillaceous. This lithology is dominant in the formation and is easily recognized by the punky yellow coating on weathered surfaces and the slabby or shaly plates that develop during weathering. Limestones in the Elbrook (R-3624) are fine grained, dark gray to black, and weather light gray. Some of the limestone, particularly near the top, consists of algal biostromes that have been partly dolomitized (Figure 2). In areas where the formation is well exposed, the upper 300 to 400 feet (dominantly algal biostromes) of the Elbrook probably could be mapped as a separate formation. West of Stover, along State Road 737 and in adjacent fields (Plate 1), the Elbrook is exposed in a series of folds that illustrate the incompetent nature of the formation.

Table 1.—Geologic formations in the Stokesville and Parnassus quadrangles.

AGE	NAME	Map Symbol	CHARACTER	Approximate Thickness (feet)
Quaternary	Alluvium	Qal	Sand and clay; sandstone gravels with unconsolidated sand and clay.	0–140
Jurassic-Cretaceous	Alkalic intrusive rocks	d	Dikes and plugs of alkalic composition.	
Mississippian	Pocono Formation	Mpo	White to gray, medium-grained sandstone; quartz-pebble conglomerate; buff to black shale; minor thin coal beds; plant fossils in shale and coal.	700
Devonian	Hampshire Formation	Dhs	Chiefly chocolate-brown sandstone, shale, and mudrock.	2200
	Chemung Formation	Dch	Gray to green sandstone, shale, and conglomerate; fossiliferous.	2500
	Brallier Formation	Db	Greenish-gray, stiff, micaceous shale and thin-bedded sandstone; sparsely fossiliferous.	2000
	Millboro Shale-Needmore Formation	Dmn	Millboro Shale—fissile black shale, weathers light gray or pinkish. Needmore Formation—olive-green shale, fossiliferous.	700
	Oriskany Sandstone	DS	Coarse-grained, rusty-brown sandstone with calcareous cement; fossiliferous.	0–20
	Licking Creek Limestone		Light- to medium-gray, cherty and sandy limestone; fossiliferous.	75

Table 1.—Geologic formations in the Stokesville and Parnassus quadrangles.—Continued

AGE	NAME	Map Symbol	CHARACTER	Approximate Thickness (feet)
Devonian	Healing Springs Sandstone	DS	Coarse-grained, rusty-brown, friable sandstone.	5
	Coeymans Limestone		Coarse-grained, crinoidal limestone.	10
	Keyser Formation		Medium-gray, fine-grained, nodular limestone; some shale and sandy beds; fossiliferous.	70
Silurian	Tonoloway Formation		Gray, thin-bedded, argillaceous limestone.	80
	Bloomsburg Formation		Red shale and sandy mudrock.	40
	Keefer Sandstone-Cacapon Formation	Scl	Keefer Sandstone—white to gray, fine-grained sandstone. Cacapon Formation—red sandstone and red and green shale.	140–160
	Tuscarora Formation	Stu	White to gray, fine-grained, sandstone; some quartz-pebble conglomerate.	0–200
Ordovician	Juniata Formation-Oswego Sandstone	Ojos	Juniata Formation—red shale and mudrock; brown to red sandstone. Oswego Sandstone—greenish-gray sandstone with limonitic specks.	250
	Martinsburg Formation	Omb	Olive-green to gray, calcareous, silty shale; thick-bedded, greenish sandstone locally present at top.	1500
	Edinburg Formation	Oe	Dark-gray, nodular-weathering, fossiliferous limestone; minor black shale.	900

Table 1.—Geologic formations in the Stokesville and Parnassus quadrangles.—Continued

AGE	NAME	Map Symbol	CHARACTER	Approximate Thickness (feet)
Ordovician	Lincolnshire Formation	Ol	Dark-gray, finely crystalline, cherty limestone.	75–150
	New Market Limestone	On	Dove-gray, compact, high-calcium limestone.	50–135
	Beekmantown Formation	Ob	Light-gray, fine-grained, thick-bedded, dolomite; some medium-gray limestone.	1700
	Chepultepec Formation	Och	Bluish-gray to black limestone with black chert; minor fine-grained, medium-gray dolomite.	175–250
Cambrian	Conococheague Formation	Ꞓco	Gray laminated limestone; thick-bedded dolomite; thin sandstone beds.	2200
	Elbrook Formation	Ꞓe	Gray thin- to thick-bedded limestone and dolomite; shaly dolomite.	1000

The top of the Elbrook is above the uppermost occurrence of yellowish-weathering shaly dolomite and algal biostromes. The base of the formation is not exposed in this area. Thickness of that portion of the Elbrook exposed in the area is estimated to be 1000 feet. Fossils found in the Elbrook include algal masses and trilobite and brachiopod fragments.

Conococheague Formation

Outcrops of the Conococheague Formation are in a wide northeastward-trending belt parallel to State Highway 42 from the southern edge of the Stokesville quadrangle (Plate 1) to the northern edge of the Parnassus quadrangle (Plate 2) and in a small belt in the southeast part of the Parnassus quadrangle. The Conococheague is composed of

thin-bedded, medium-gray to bluish-gray limestone and dolomitic limestone and thick-bedded, light- to medium-gray dolomite with minor amounts of coarse-grained dolomite, dolomitic sandstone, and sandy dolomite. Lenticular beds of intraformational conglomerate are common in the formation. Minor amounts of gray to black oolitic chert (R-3625) and black dense chert are present throughout the formation.

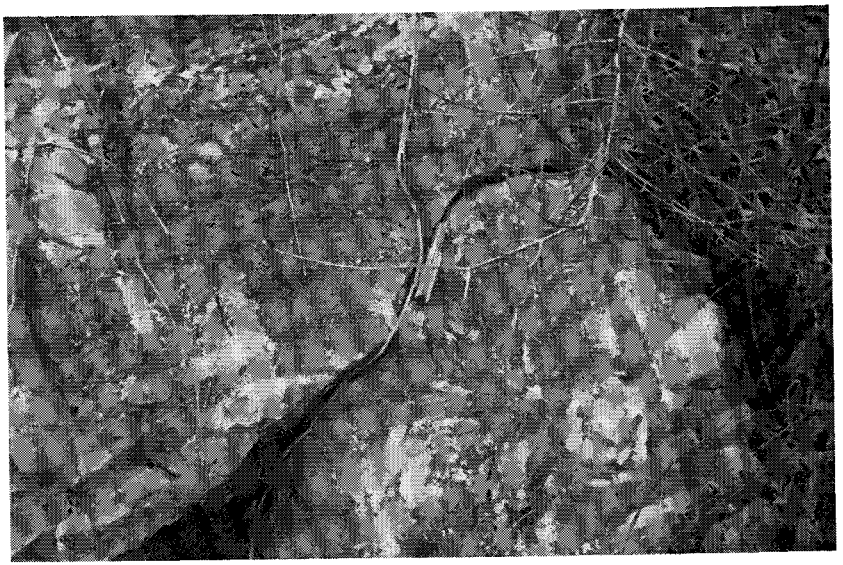

Figure 2. Algal structures in the upper part of the Elbrook Formation along State Road 760, 0.1 mile west of its junction with State Highway 42 (Plate 1).

The thicker dolomitic sandstones (5 to 10 feet) are present only in the lower 700 to 800 feet of the formation. The Conococheague is well exposed from Mt. Solon southward along State Road 731 to Moscow and along State Road 739 east of Parnassus parallel to Moffet Creek (Plate 2). One mile north of Mt. Solon is a notable scenic attraction, Natural Chimneys. These natural features composed of horizontal bedded dolomite and limestone were formed by dissolution of the rock along vertical joints.

The top of the Conococheague is not well exposed in the area of study but is placed below the first siliceous limestone in the overlying Chepultepec. Thickness of the formation is estimated to be 2200 feet. Large, almost completely dolomitized and partially silicified algal masses are present in the Conococheague.

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ORDOVICIAN SYSTEM

Chepultepec Formation

The Chepultepec limestone was named by Ulrich (1911, p. 638). The Chepultepec of this report is equivalent to the Stonehenge of Pennsylvania (Stose, 1908) and Maryland (Sando, 1958) and in part correlates with the Chepultepec of southwestern Virginia and eastern Tennessee. The formation can be divided into three members: (1) a lower limestone (Stoufferstown member of Sando, 1958), (2) a middle cherty fossiliferous limestone, and (3) an upper unit of interbedded limestone and dolomite. The lower limestone member is a dark-gray, fine-grained, dolomitic limestone with siliceous laminae. Butts (1941, p. 87) placed this unit in the Conococheague; however, recent investigations (Wood, 1962) showed that this lower limestone contains a Chepultepec fauna. Small brachiopods (*Finkelnburgia*), rounded algal masses, black chert nodules, and gnarly black chert characterize the blue-black middle limestone member. The upper member is composed of dark-gray, dense limestone and medium-gray, fine-grained dolomite. At a location 0.2 mile due west of the junction of State Roads 733 and 835, recrystalline dolomite abuts the typical fine-grained limestone of the Chepultepec. Several magnetic traverses were made across the recrystalline mass and a small positive anomaly of 100 to 200 gammas was recorded. It is suggested that a dike may be responsible for both the anomaly and the recrystallization. A complete section of Chepultepec is exposed north of State Road 835, 0.2 mile west of its junction with State Road 733 (Fara, 1957, p. 9-10).

The Chepultepec generally occurs in valleys between ridges of Conococheague sandstone and conical hills and ridges of cherty Beekmantown dolomite. The lower contact is placed at the base of the lowest siliceous limestone in the Chepultepec. The upper contact is placed at the base of thick-bedded dolomite with Beekmantown-type gastropods. Small curved cephalopods are present, and brachiopods (*Finkelnburgia*) are relatively common in the middle member and less common in the other members. The formation ranges in thickness from 175 to 250 feet.

Beekmantown Formation

Several lithologies are present in the Beekmantown Formation: (1) light-gray, fine-grained dolomite; (2) dark- to medium-gray, fine-grained dolomite and limestone; (3) dark-gray, coarse-grained recrystalline dolomite; and (4) medium- to light-gray, very fine-grained limestone. Weathered surfaces of the dolomite and dolomitic limestone

are fluted, and in many exposures a cross-hatched pattern has formed. Along State Road 613 from its intersection with State Highway 42 to the junction of State Roads 613 and 754, the Beekmantown is well exposed (Plate 2). Overturned upper Beekmantown is exposed 0.25 mile east of Jennings Gap in the footwall of the North Mountain fault (Plate 1). The lower and middle portions of the formation are well exposed along State Road 754 eastward from its intersection with State Highway 42 (Plate 2). Chert occurs throughout the formation and is abundant in the lower portion.

The lower contact is placed at the base of thick-bedded, gastropod-bearing dolomite overlying the interbedded limestone and dolomite of the upper Chepultepec. The upper contact is probably unconformable with the overlying New Market and is placed at the base of the first thick sequence of dove-gray limestone with no dolomite. The thickness is approximately 1700 feet.

New Market Limestone

The New Market is a thick-bedded, dove-gray, cryptocrystalline limestone (R-3626) with a few 2- to 3-inch-thick dolomite beds near the base. The thickness ranges from 50 to 135 feet (Edmundson, 1945, p. 104; Fara, 1957, p. 17, 19). Several species of gastropods and a small tetracoral are present in the New Market. The formation crops out along the east edge of Little North Mountain in a northeastward-trending belt in the footwall of the North Mountain fault (Plate 1) and on both limbs of the Long Glade syncline (Plate 2). The New Market is well exposed in the field south of State Road 646, 0.7 mile east of its junction with State Highway 42. At the junction of State Roads 613 and 754, 0.1 mile west of Long Glade Creek, approximately 130 feet of limestone is exposed. An almost complete section of New Market is exposed 0.8 mile south of the junction of State Roads 753 and 613 (Plate 2). The lower contact is placed at the base of the lowest thick sequence of dove-gray limestone. The upper contact is placed at the base of cherty, dark-gray limestone of the Lincolnshire.

Lincolnshire Formation

The Lincolnshire Formation is a dark-gray, medium- to coarse-grained, silty, cherty limestone. The chert is black and blocky and generally occurs along bedding planes. Exposures of Lincolnshire are present in the same areas where the New Market is well exposed. The Lincolnshire forms linear ridges. Silicified trilobites, brachiopods, ostracodes, and bryozoans are abundant locally. The thickness ranges from 75 to 150 feet.

Edinburg Formation

Two facies of the Edinburg Formation are present in this area, the Liberty Hall and the Lantz Mills (Fara, 1957, p. 16-18). The Liberty Hall facies is composed of black, fine-grained, argillaceous limestone and shale and pink-weathering shale; it occurs on the southeast slope of Little North Mountain and along Long Glade Creek. The overlying Lantz Mills facies is a cobbly- or nodular-weathering, medium-grained, dark-gray to black limestone. Both facies have been subjected to much intraformational folding and faulting and may be recognized in part by the abundance of fractures filled with white calcite and dolomite. Graptolites (F-821), which are common in the Liberty Hall, are present in the west limb of the Long Glade syncline. The alga *Mastopora pyriformis* (Osgood and Fischer, 1960, p. 896-902) is present in both facies, although it is more abundant in the Lantz Mills facies. Brachiopod and gastropod fragments are also abundant. On the southeast slope of Little North Mountain 0.25 mile east of the intersection of U. S. Highway 250 and State Road 736, the Edinburg is well exposed (Plate 1). The formation is exposed along State Roads 753 and 754 between Long Glade Creek and their junctions with State Road 699. The Edinburg is well exposed for a distance of 0.5 mile along State Road 699 northeast of its junction with State Road 613 (Plate 2). The lower contact is placed at the base of the first black shale; the upper contact is at the base of the first thick sequence of greenish-gray, stiff, silty shale. The thickness is estimated to be 900 feet.

Martinsburg Formation

On the east slope of Little North Mountain the Martinsburg Formation consists of yellow-weathering, gray, calcareous shale and dark-gray, fossiliferous limestone with sandstone near the top. The sandstone is medium grained, light gray, and rusty weathering. In the trough of the Long Glade syncline the Martinsburg is mostly a greenish-gray fossiliferous shale with thin siltstones. The lower contact is arbitrarily mapped at the base of the first approximately 4-foot-thick greenish-gray shale; the upper contact is placed at the base of the first gray, limonite-specked sandstone of the Oswego. Fossils present include the trilobite *Cryptolithus* sp. (F-822), the brachiopod *Orthorhynchula* sp., and several unidentified species of brachiopods. The ostracode *Pseudorakverella altalirata* occurs in the lower and middle portions of the formation. The thickness is estimated to be 1500 feet.

Oswego Sandstone

In the area of study, the Oswego Sandstone is exposed only at the south end of Buck Hill. It is a medium-grained, greenish-gray, rusty-weathering rock (R-3527); scattered blebs of limonite are common and clay balls occur in a few layers. This sandstone occurs below poorly exposed reddish beds of the Juniata Formation (with which it has been combined for mapping purposes) and above the more friable sandstones of the upper Martinsburg. The Oswego is generally covered on the southeastern slopes of Little North Mountain and Buck Hill. The thickness of the formation probably does not exceed 150 feet.

Juniata Formation

The Juniata Formation is poorly exposed at the south end of Buck Hill. Its presence is indicated near the crest of Little North Mountain and Buck Hill by the occurrence of red mudrock and shale float. The formation is composed of lumpy red shale and mudrock and red to brown, fine- to medium-grained sandstone. The thickness is estimated to be 100 feet. Because of poor exposures, the Oswego and Juniata are mapped as one unit.

SILURIAN SYSTEM

Tuscarora Formation

The Tuscarora Formation is a tough, white to light-gray, fine- to medium-grained sandstone (R-3627). A few beds of quartz-pebble conglomerate and thin, buff-colored shale are present in the lower 10 feet of the formation. The maximum thickness is 200 feet on Little North Mountain 1 mile north of Jennings Gap. The lower contact is placed at the base of the first white to gray sandstone, and the upper contact is placed at the lowermost "red bed" of the Cacapon Formation.

Cacapon Formation

The Cacapon Formation is present just northwest of the crest of Little North Mountain. It consists of red and green shales; red, medium-grained sandstones; red, oolitic hematite beds; and ferruginous sandstones. Thin, white to gray, fine-grained sandstones are also present. The Cacapon crops out at the southwest end of Buck Hill and in the woods a few hundred feet to the north. No fossils were found in this area; however, the formation is fossiliferous to the south at Buffalo Gap.

The thickness is about 100 feet. Because both the Cacapon and overlying Keefer are thin and poorly exposed in the area of study, they have been mapped as a single unit (Plate 1).

Keefer Sandstone

The Keefer Sandstone is present on the northwest slope of Little North Mountain, and it is well exposed at the south end of Buck Hill. The Keefer is gray to rusty brown and fine to medium grained. The lower contact is placed at the top of the uppermost red or green shale or sandstone of the Cacapon; the upper contact is taken as the top of the uppermost sandstone. The thickness ranges from 20 to 30 feet.

UPPER SILURIAN–LOWER DEVONIAN ROCKS

In the area of study, the Bloomsburg, Tonoloway, and Keyser formations, Coeymans Limestone, Healing Springs Sandstone, Licking Creek Limestone, and Oriskany Sandstone are thin and poorly exposed. Individual units range in thickness from about 5 to 80 feet, and have an aggregate thickness of about 300 feet. For the purpose of mapping, these Upper Silurian-Lower Devonian rocks have been considered as one unit.

Bloomsburg Formation

The only indication of the presence of Bloomsburg Formation in the area is at the south end of Buck Hill. At this locality red mudrock float was found between Keefer sandstone and Tonoloway limestone. The formation is composed of laminated red shale, red mudrock, and brownish-red, fine-grained sandstone and siltstone. The thickness is estimated to be about 50 feet.

Tonoloway Formation

The Tonoloway Formation consists of laminated, medium- to dark-gray, fine- to very fine-grained, argillaceous limestone. The lower contact is at the top of the uppermost "red bed" of the Bloomsburg, and the upper contact is placed at the base of the lowermost cobbly bed of the Keyser. The formation is poorly exposed in Moffett Creek and along State Road 728 at the south end of Buck Hill. The small brachiopod *Camarotoechia* cf. *C. litchfieldensis* and the ostracode *Leperditia* cf. *L. alta* were found on pieces of float. The thickness is about 80 feet.

Keyser Formation

The Keyser Formation was named by Swartz (1913, p. 98-102) from a quarry at Keyser, West Virginia. It can be divided into two members; the lower unit is a cobbly-weathering, fine-grained, dark-gray, fossiliferous limestone, and the upper unit is a medium- to dark-gray, fine- to coarse-grained, fossiliferous limestone. Crinoidal limestone in the upper part resembles the overlying Coeymans. The formation is poorly exposed at the south end of Buck Hill. The thickness is about 70 feet. The lower limestone is Silurian age (Bowen, 1963) and contains the "*Chonetes*" *jerseyensis* zone (Swartz, 1929). The upper limestone contains the *Favosites helderbergiae* zone (Swartz, 1929) which is of Devonian age.

Coeymans Limestone

The Coeymans is a medium- to light-gray and pinkish, coarse-grained, crinoidal limestone. The unit is exposed in the gaps in Little North Mountain south of U. S. Highway 250 and at the south end of Buck Hill. The lower contact is taken at the base of the lowermost thick crinoidal limestone above the dark-gray, fine-grained upper limestone of the Keyser. The upper contact in this area is at the base of the Healing Springs Sandstone. The thickness of the Coeymans does not exceed 10 feet.

Healing Springs Sandstone

The Healing Springs Sandstone is friable, light gray, medium to coarse grained, and weathers to a rusty brown. This formation was identified from float and stratigraphic position of a few scattered outcrops along the northwest slope of Little North Mountain. The thickness is less than 5 feet.

Licking Creek Limestone

The Licking Creek Limestone may be divided into two members: (1) a lower member that is medium- to dark-gray, fine-grained, cherty limestone and (2) an upper member that is light- to medium-gray, coarse-grained, sandy limestone. Fossiliferous chert float is generally the only indication of the presence of the formation. A nearly complete section is exposed along Swoope Run, 0.7 mile south of the junction of U. S. Highway 250 and State Road 736 (Plate 1). The thickness probably is less than 75 feet. In the lower member the chert contains abundant brachiopod fragments.

Oriskany Sandstone

The Oriskany is a friable, gray, medium- to coarse-grained sandstone (R-3628) that is stained with iron oxide on weathered surfaces. It occurs in isolated areas along the lower northwest slope of Little North Mountain. A well-exposed section is present at the south end of Buck Hill. The lower contact is placed at the top of the uppermost sandy limestone of the Licking Creek. The upper contact is unconformable with the olive-green shale of the Needmore Formation. The thickness rarely exceeds 20 feet and generally is less than 5 feet. *Costispirifer arenosus* was identified.

DEVONIAN SYSTEM

Needmore Formation

The Needmore Formation and the Millboro Shale were mapped as a unit because of poor exposures. The Needmore at the south end of Buck Hill is a thin-bedded, dark-gray to olive-green shale with thin black fissile shale near the base and lenses of argillaceous limestone in the upper portion. The unconformable lower contact is well defined where exposed as a shale overlying the Oriskany Sandstone. The upper contact is nowhere exposed in the area. A small topographic low and small springs and seeps located about 100 feet above the base of the Needmore and below definite Millboro-type shale near the northwest base of Little North Mountain probably represent the position of the Tioga metabentonite. The thickness of the Needmore is less than 100 feet. Fossils are relatively abundant in the Needmore; more than 20 species of ostracodes and at least 12 species of brachiopods are present.

Millboro Shale

The Millboro Shale is black, fissile, and weathers to a buff color. Concretions ranging from 1 inch to 3 feet in diameter are present, especially 0.5 mile southwest of the junction of State Roads 728 and 730 (R-3629). The upper contact is taken at the uppermost black shale below the greenish-gray shale of the Brallier. The thickness is estimated to be 600 feet; however, intraformational folding and faulting are present. The small brachiopod *Orbiculoidea minuta* was identified.

Brallier Formation

The Brallier Formation consists of subfissile, stiff, green to gray, micaceous, sandy shale (R-3630), commonly with uneven or dimpled surfaces. Interbedded with the shale are layers, up to 6 inches thick,

of greenish-gray, very fine-grained, blocky sandstone. Exposures of the formation occur along the lower slopes of Lookout and Crawford mountains. The lower contact is at the base of greenish-gray shale above black Millboro Shale. The upper contact is taken below the lowermost zone containing large Chemung-type brachiopods, and below the lowermost thick sandstone if no fossils are present. The approximate thickness is 2000 feet.

Chemung Formation

The Chemung Formation is composed of greenish-gray, medium-grained, arkosic sandstone and olive-green to greenish-gray shale. In addition to the sandstone and shale, thin beds of conglomerate (R-3631), up to 1 foot thick, are common; red and chocolate-brown shales are common in the upper portion of the unit. The lower contact is placed at the base of the lowermost 3-foot-thick sandstone of the Chemung or below the lowermost zone containing large Chemung-type brachiopods. The contact with the overlying Hampshire is placed at the base of the lowest thick red bed sequence. Fossiliferous sandstones and shales in the Chemung are exposed along U. S. Highway 250, 0.8 mile west of Whites Store (Plate 1). A more complete section may be seen along Leading Ridge Road west of Todd Lake (Plate 1). The thickness is about 2500 feet.

Hampshire Formation

The Hampshire Formation is composed of moderately thick-bedded, chocolate-brown, medium-grained, arkosic and micaceous sandstone and lumpy red to green mudrock and shale. Along the Forest Service road west of North River Gap (Plate 1), the Hampshire is well exposed (Fara, 1957, p. 27). The lower contact is placed at the base of the lowest thick red bed sequence. The upper contact is placed above the uppermost red beds and below the thick sandstones of the Pocono. The thickness is about 2200 feet.

MISSISSIPPIAN SYSTEM

Pocono Formation

The Pocono Formation is composed of fine-grained, medium- to light-gray, argillaceous sandstone (graywacke) (R-3632); olive-green to dark-gray shale; and thin, carbonaceous shales (R-3633) (Figure 3). Thin beds of low-grade coal have been described as occurring in the Pocono west of North River Gap (Howell, 1925). The lower contact

is placed at the base of thick sandstones above Hampshire red beds. The upper portion is not exposed. The formation is well exposed in North River Gap and along the Forest Service road near Camp Flather. Portions of the formation present are estimated to be up to 700 feet thick. Plant fossils occur in the carbonaceous shales.

Figure 3. Resistant graywackes in the Pocono Formation at North River Gap along State Road 718 (Plate 1).

MESOZOIC IGNEOUS ROCKS

Forty-one dikes, sills, or plugs of alkalic composition have been mapped in the area. The rocks are of two general types, nepheline-natrolite syenite and teschenite. The nepheline syenite is a porphyritic igneous rock characterized by alkalic feldspar and one or more feldspathoids. The dikes are generally dark green and weather to a brownish gray (R-3636). The phenocrysts are lath-shaped crystals of natrolite and square-shaped crystals of analcime. Nepheline syenite is well exposed at the following localities: south of Stribling Springs, in the field south of the junction of State Roads 730 and 728 (R-3635) (Plate 1); across State Road 764 and in the adjacent field to the west 1 mile north of its junction with State Road 730 (Plate 1); and at the hilltop 0.3 mile south of Centerville along State Road 699 (Plate 2).

Teschenite in the area is a coarse- to fine-grained igneous rock composed of calcic plagioclase, abundant euhedral brown biotite

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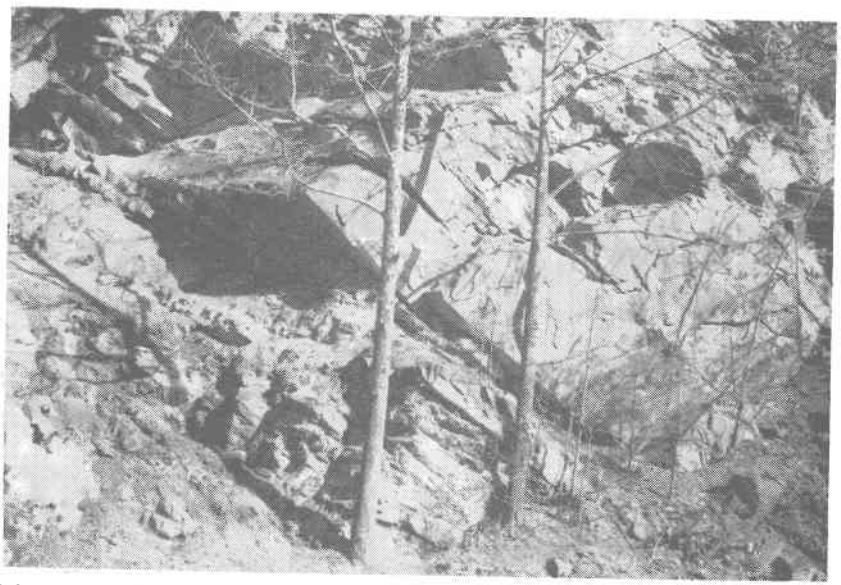

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and/or hornblende, and, rarely, altered olivine, titaniferous pyroxene, and apatite. Analcime is fairly abundant and occurs as glassy or milky crystals in vugs. Wollastonite and garnet, variety andradite, (R-3634) have been formed as a result of contact metamorphism (R. W. Johnson, Jr. and Charles Milton, personal communication).

These rocks form a portion of an alkalic complex that adjoins a basalt-andesite complex to the west in Highland County, Virginia, and Pendleton County, West Virginia. The intrusion of these bodies is considered to be related tectonically to the major local structures of the Appalachian Valley, the Massanutten synclinorium and the Pulaski-Staunton and North Mountain faults.

QUATERNARY SYSTEM

Alluvium and gravel of possible Quaternary age occur east of North River Gap and in most stream flood plains (Figure 4). Alluvial materials along the streams are composed of unconsolidated fine to coarse sands and gravel. Extensive areas of gravel occur east of North River Gap and east of Jennings Gap where the gravels have been derived from the Tuscarora, Keefer, Brallier, Chemung, and Hampshire formations. At North River Gap much of the gravel is derived from the Pocono Formation. Because of the dissolution of the carbonate rocks in the overthrust block of the North Mountain fault, the area east of North River Gap acted as a trap for the gravels. Fara (1957) reported that the gravel may exceed 140 feet in thickness near Castle Hill.

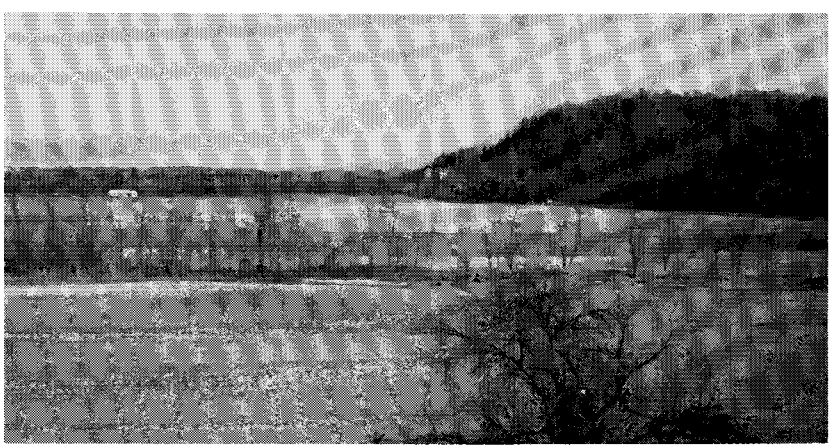

Figure 4. Flood plain along North River. View is northward from a point 0.5 mile northwest of Mt. Solon (Plate 2).

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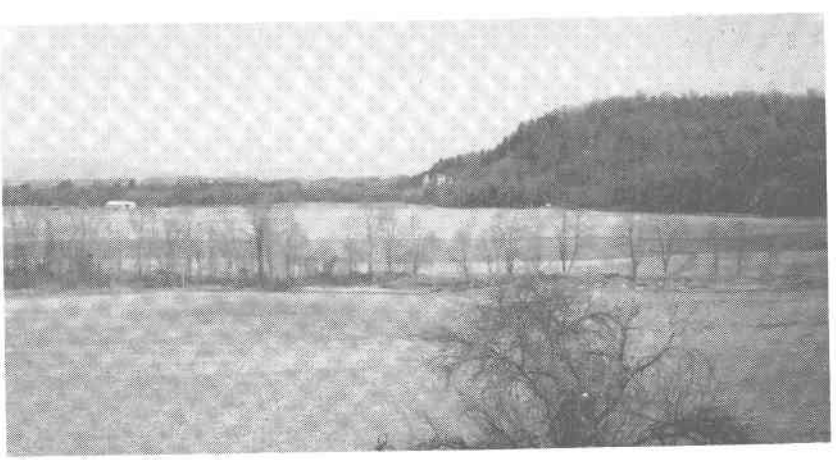

Figure 4. Flood plain along North River. View is northward from a point 0.5 mile northwest of Mt. Solon (Plate 2).

STRUCTURE

The sedimentary rocks are folded in northeastward-trending synclines and anticlines. Minor folding, also trending northeastward in the Elbrook, Conococheague, Brallier, and Chemung, is present. The folds and faults are described in order of their geographic occurrence from east to west.

PULASKI-STAUNTON FAULT

The Pulaski-Staunton fault trends northeastward across the southeast portion of the Parnassus quadrangle (Plate 2). Southeast of the fault, the Elbrook and Conococheague formations are folded into a broad syncline and an anticline. The Elbrook Formation forms the hanging wall of the fault and the Beekmantown, New Market, Lincolnshire, and Edinburg formations locally form the footwall. The fault zone is a silicified dolomite and chert breccia. The angular fragments are generally rectangular in shape and range up to 2 inches in length.

LONG GLADE SYNCLINE

Extending northeastward from Spring Hill to Centerville and parallel to Glade Valley, is the Long Glade syncline. The southeast limb of this syncline has been overridden by the Pulaski-Staunton fault causing it to be overturned to the northwest. The axial portion is occupied by the Martinsburg Formation, and cherty limestone ridges of the Lincolnshire Formation outline the structure.

NORTH MOUNTAIN FAULT AND ASSOCIATED STRUCTURES

From a point about 10 miles northwest of Lexington, Virginia, the North Mountain fault has been traced northeastward approximately 160 miles to the Bear Pond Mountains, Washington County, Maryland. The fault extends across the Stokesville quadrangle (Plate 1) from southwest to northeast a distance of 10 miles. Butts (1933, 1940, p. 452-453) presented the first "detailed" map and discussion of Little North Mountain in central Augusta County. Fara (1957) and Fitzgerald (1966) studied the geology of the mountain in the Stokesville area.

Giles (1927, p. 53) considered the structure of Little North Mountain in northern Virginia to be a faulted monocline of overturned beds with steep southeasterly dips. He believed the major fault was continuous on the west side of the mountain and that faults on the east side were distributive from it. Most later reports have indicated

that the major fault is on the east side of the mountain and has dips to the southeast which are generally less than 20 degrees. Butts and Edmundson (1966, p. 79) and Fitzgerald (1966) indicated that the major fault, although on the east side of the mountain, has branches on the west side and that gaps in the mountain may result from the intersection of these faults.

Field evidence in the Stribling Springs area (Plate 1) indicates that the major fault is on the east side of Little North Mountain and that at least in this area there is a continuous fault on the west side of the mountain in the Millboro Formation (Figure 5). Intersection of the North Mountain fault and faults on the west side of the mountain, along with some stratigraphic thinning, probably caused all of the gaps in the area of study except the one at Stribling Springs. In general, the closer these faults are, the lower the elevation of the mountain. The faults are merged at a location 0.9 mile south of the junction of State Roads 730 and 747 (Figure 6). At the north end of the hill about 1 mile southeast of Stokesville (Plate 1), the faults merge, and elevations along the trend of the mountain are quite low for a distance of 15 miles to the northeast. About 1 mile southeast of Stokesville, just northeast of the junction of State Roads 730 and 747, separate blocks of Licking Creek limestone and Tuscarora quartzite are exposed between the two faults (Figure 7).

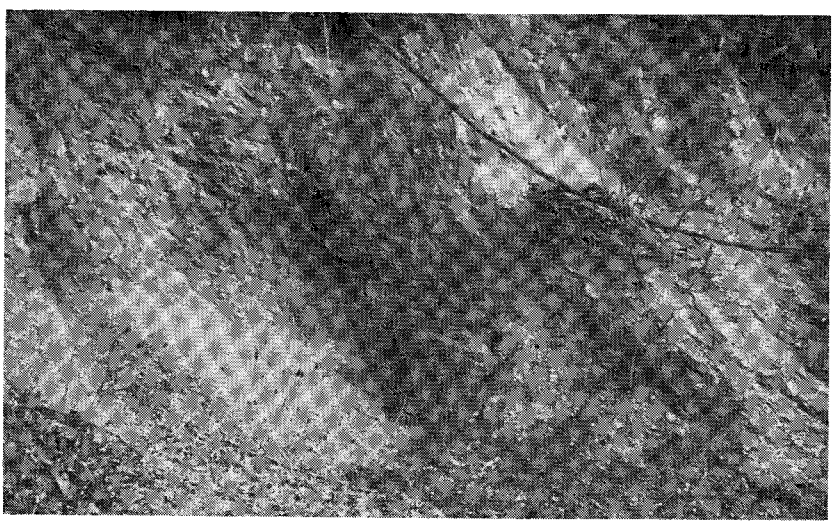

Figure 5. Thrust fault at the south end of Buck Hill, 0.3 mile east of the junction of State Roads 728 and 730 (Plate 1). The fault zone is located entirely within the overturned Millboro Shale.

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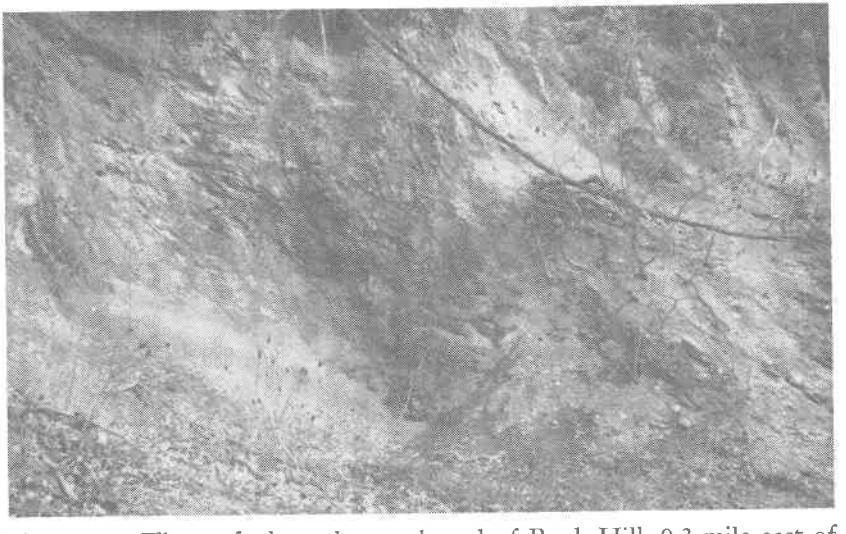

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Figure 6. North Mountain fault 0.9 mile south of the junction of State Roads 730 and 747 (Plate 1). In this area, the fault that is continuous on the west side of Little North Mountain is merged with the North Mountain fault. Elbrook Formation (on the right) has been thrust over Millboro Shale; the hammer is on the fault trace.

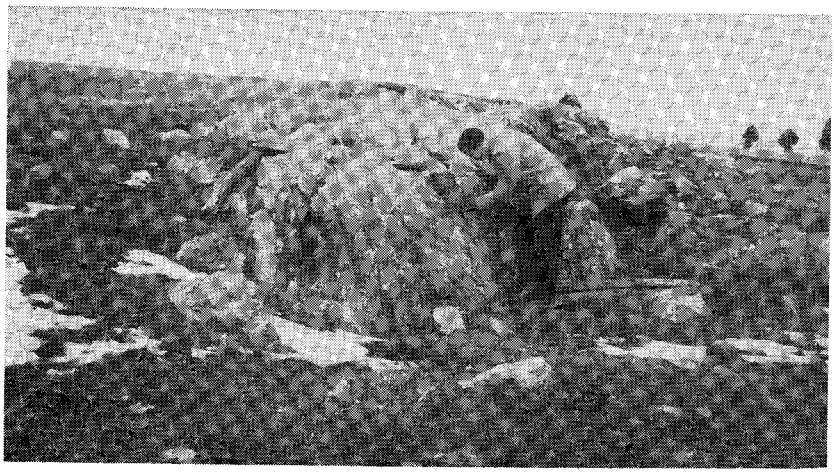

Figure 7. Isolated block of Tuscarora quartzite 0.2 mile northeast of the junction of State Roads 730 and 747 (Plate 1). Here the Tuscarora is situated between the North Mountain fault and another thrust fault to the west.

If deformation began as early as Martinsburg time, as suggested by Brower (1961, p. 81), and was relatively continuous throughout the

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If deformation began as early as Martinsburg time, as suggested by Brower (1961, p. 81), and was relatively continuous throughout the

remainder of Paleozoic time, local thinning or even absence of units could easily be explained by nondeposition or localized erosion. Some units, principally the Tuscarora, Cacapon, and Keefer, become thinner along strike in the vicinity of the gaps. These areas of thinning resulted in zones of weakness and also placed the incompetent Millboro shale closer to the axial plane of the overturned anticline along which the major break occurred.

WEST MOUNTAIN SYNCLINE

The West Mountain syncline extends from Hankey Mountain to Grindstone Mountain in a northeasterly direction. The Hampshire Formation occupies the axial portion to the west and the Pocono, to the north. The beds dip steeply to the west or are slightly overturned on the southeast limb of the syncline in the Lookout Mountain area. From just south of North River Gap to the northern edge of the area, the beds are overturned and dip to the southeast. The overturned limb (that consists chiefly of Pocono) forms a narrow ridge known as Narrow Back Mountain.

MINERAL RESOURCES

INDUSTRIAL LIMESTONE AND DOLOMITE

That portion of the area adjoining and southeast of the North Mountain fault is underlain, for the most part, by limestones and dolomites that may be suitable for various industrial uses. Edmundson (1945) discussed the distribution of carbonate rocks in the area of study and included chemical analyses. The upper part of the Beekmantown Formation and the New Market Limestone contain high-calcium limestone (over 95 percent calcium carbonate). The thickness of the New Market averages 60 feet, although it is greater than 130 feet at the junction of State Roads 613 and 754 (Plate 2). The upper part of the Beekmantown contains 100 to 200 feet of high-calcium limestone; however, dolomites or impure limestones are interbedded with the high-calcium limestone. The thickest belt of high-calcium limestone occurs west of Long Glade Creek (Plate 2). An abandoned quarry in the New Market is located 0.3 mile S. 25°E. of the junction of U. S. Highway 250 and State Road 736 (Plate 1). High-calcium limestone may be used as flux and agricultural stone and in the manufacture of dye, fertilizer, glass, lime, paper, portland cement, mineral feeds, and a variety of other industrial and chemical products, as well as for the more common crushed-stone uses.

Impure limestone (low in magnesium carbonate and containing more than 5 percent noncarbonate material) occurs in, excluding those formations that have abundant dolomite, the Edinburg, Chepultepec, and Lincolnshire formations. The Edinburg occurs on the east slopes of Little North Mountain and Buck Hill (Plate 1); it is also present in the west limb of the Long Glade syncline from Spring Hill north-northeastward through the area west of Centerville and in the east limb from Spring Hill northeastward through the vicinity of Roman (Plate 2). The thickness ranges from 200 to 900 feet. The Chepultepec, which averages 200 feet in thickness, crops out in a northeastward-trending belt across the Parnassus quadrangle (Plate 2). These impure limestones may be useful in the manufacture of cement and in the production of agricultural limestone and crushed stone.

The two thickest carbonate formations in the area are included in a third group composed of limestone (less than 10 percent magnesium carbonate), magnesian limestone (10 to 30 percent magnesium carbonate), and dolomite (calcium-magnesium carbonate). These formations are the Elbrook and Conococheague. Their distribution is shown on Plates 1 and 2. These rocks may be used for the production of agricultural stone and crushed stone and other purposes.

CEMENT MATERIALS

Raw materials suitable for the production of portland cement may be available in the area. Portland cement is manufactured by combining a finely ground mixture of rock materials, commonly limestone and shale or clay, and heating it in a kiln at about 2700° F (Barton, 1965). The bulk composition of the mixture approximates the following: calcium carbonate, 75 percent; magnesium carbonate, 4 percent; silica, 14 percent; alumina, 5 percent; iron oxide, 1 percent; and impurities that may contain sulfur and alkalies, 1 percent. In the area of study, the upper part of the Beekmantown, New Market, and Lincolnshire formations contain limestones, and the Edinburg, Martinsburg, and Millboro formations have shales that may be suitable for the production of portland cement.

SHALE

Formations that are predominantly shale occur in approximately 30 percent of the area mapped. These formations are the Edinburg, Martinsburg, Needmore, Millboro, Brallier, Chemung, and Hampshire. Materials from three localities in the area have been evaluated (Calver and others, 1964); the potential uses of these raw materials are compiled in Table 2.

Table 2.—Potential uses of clay materials from the Stokesville quadrangle (data compiled from Calver and others, 1964).

Repository No.	*Location*	*Formation*	*Sample Interval*	*Potential Use*
R-1614	Roadcut, 1.5 miles northeast of Stokesville, on the northwest side of State Road 764 approximately 0.1 mile west of the intersection with State Road 758.	Brallier	Composite sample across 120 feet of shale	Brick, quarry or patio tile, and lightweight aggregate
R-1615	Roadcut, 2.7 miles northwest of Parnassus, just southwest of the intersection of State Roads 730 and 761.	Millboro	Composite sample across 50 feet of shale	Lightweight aggregate
R-1616	Roadcut on the southwest side of State Road 730 approximately 0.1 mile west of the intersection with State Road 763 in Stokesville.	Hampshire	Composite sample across 114 feet of shale	Common brick

SAND AND GRAVEL

East of North River Gap (Plate 1) there are large quantities of gravel with lesser amounts of sand. This material is more than 100 feet thick east of the North Mountain fault. Gravel and sand are also present east of Jennings Gap (Plate 1).

Four formations that consist mainly of sandstone are present in the area, the Tuscarora, Keefer, Oriskany, and Pocono. The Tuscarora crops out along Little North Mountain, where, because of its resistance to erosion, it is the ridge maker. The Keefer crops out along the northwest slope of Little North Mountain; however, it is very thin in this area. The Oriskany sandstone is poorly exposed along the northwest base of Little North Mountain where blocks of friable iron oxide-stained sandstone are present. The thickness is less than 25 feet. The Pocono is present on Narrow Back and Lookout mountains.

IRON ORE

Iron oxide has been mined from the lower part of the Beekmantown Formation on the Old Ore Banks Farm east of State Highway 42 just north of its junction with State Road 613. It has been estimated that several thousand tons of ore were removed (Patterson, 1958). The iron oxide occurs in a decalcified chert and appears to be of relatively high grade; however, it is doubtful that sufficient quantities of material are present to be of economic importance.

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INDEX

PAGE

Algal structures 3, 6, 7, 8
Alkalic dikes 4, 16
Alluvium 4, 17
Appalachian Valley 17

Beekmantown Formation 6, 8, 9, 18, 21, 22, 24
Bloomsburg Formation 5, 12
Brachiopods 8, 9, 10, 12, 13, 14, 15
Brallier Formation 4, 14, 17, 22, 23
Bryozoans 9
Buck Hill 11, 12, 13, 14, 19, 22

Cacapon Formation 5, 11, 12, 21
Camarotoechia cf. *C. litchfieldensis* 12
Camp Flather 16
Castle Hill 17
Cement materials 22
Centerville 16, 18, 22
Cephalopods 8
Chemung Formation 4, 15, 17, 22
Chepultepec Formation 6, 8, 9, 22
  Stoufferstown member 8
"*Chonetes*" *jerseyensis zone* 13
Clay balls 11
Clay materials 23
Coal 15
Coeymans Limestone 5, 13
Concretions 14
Conococheague Formation 6, 7, 8, 18, 22
Contact metamorphism 17
Costispirifer arenosus 14
Crawford Mountain 15
Crinoidal limestone 5, 13
Cryptolithus sp. 10

Edinburg Formation 5, 10, 18, 22
  Lantz Mills facies 10
  Liberty Hall facies 10

Elbrook Formation 3, 6, 7, 18, 20, 22

PAGE

Favosites helderbergiae zone 13
Finkelnburgia 8
Fossils 2, 3, 4, 6, 10

Gastropods 8, 9
Glade Valley 18
Graptolites 10
Gravel 17, 23
Grindstone Mountain 21

Hampshire Formation 4, 15, 16, 17, 21, 22, 23
Hankey Mountain 21
Healing Springs Sandstone 5, 13
High-calcium limestone 6, 21

Industrial limestone and dolomite 21
Intraformational conglomerate 7
Iron ore 24

Jennings Gap 9, 11, 17, 23
Juniata Formation 5, 11

Keefer Sandstone 5, 12, 17, 21, 23
Keyser Formation 5, 12, 13

Leperditia cf. *L. alta* 12
Licking Creek Limestone 4, 13, 14, 19
Lightweight aggregate 23
Lincolnshire Formation 5, 9, 18, 22
Little North Mountain... 3, 9, 10, 11, 12, 13, 14, 18, 19, 20, 22, 23
Long Glade Creek 9, 10, 21
Long Glade syncline 9, 10, 18, 22
Lookout Mountain 15, 21, 23

Magnetic traverses 8
Martinsburg Formation 5, 10, 11, 18, 22
Massanutten synclinorium 17
Mastopora pyriformis 10
Mesozoic igneous rocks 16
Millboro Shale 4, 14, 15, 19, 20, 21, 22, 23
Moffet Creek 7, 12

PAGE

Moscow 7
Mt. Solon 7, 17

Narrow Back Mountain 21, 23
Natural Chimneys 7
Needmore Formation 4, 14, 22
Nepheline syenite 16
New Market Limestone 6, 9, 18, 21, 22
North Mountain fault 3, 9, 17, 18, 19, 20, 21, 23
North River 17
North River Gap 15, 16, 17, 21, 23

Oolitic chert 7
Oolitic hematite 11
Orbiculoidea minuta 14
Oriskany Sandstone 4, 14, 23
Orthorhynchula sp. 10
Ostracodes 9, 10, 12, 14
Oswego Sandstone 5, 10, 11

Parnassus 7
Parnassus quadrangle 1, 2, 4, 5, 6, 18, 22
Plant fossils 16
Portland cement 22
Pocono Formation 3, 4, 15, 16, 17, 21, 23
Pseudorakverella altalirata 10
Pulaski-Staunton fault 3, 17, 18

"Red bed" 12, 15, 16
Roman 22

Sand and gravel 17, 23
Shale 22
Shenandoah Valley 2
Spring Hill 18, 22
Stokesville 19, 23
Stokesville quadrangle 1, 2, 4, 5, 6, 18, 23
Stover 3
Stribling Springs 16, 19
Swoope Run 13

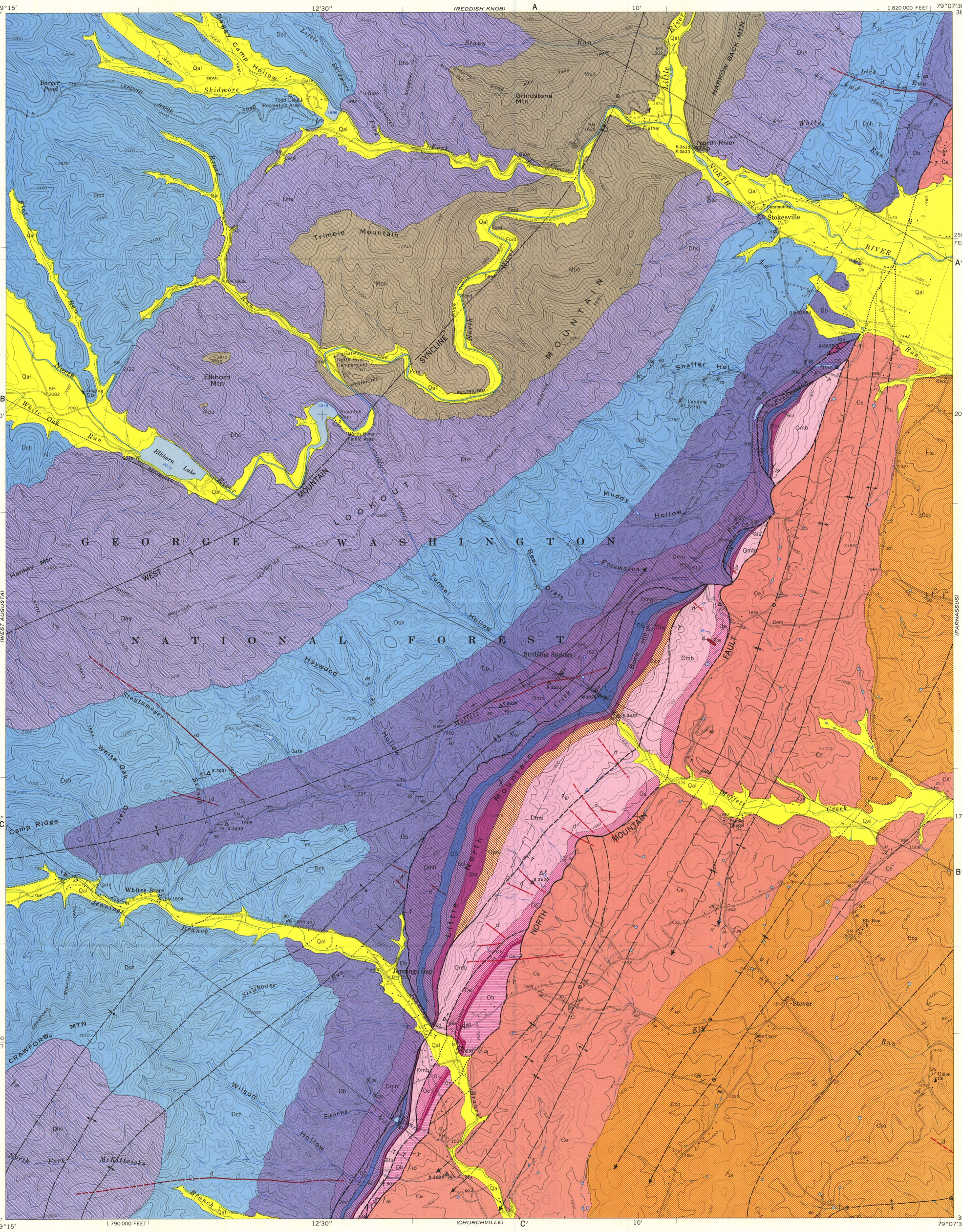
PAGE

Teschenite 16
Tetracoral 9
Tioga metabentonite 14
Todd Lake 15
Tonoloway Formation 5, 12
Trilobites 9, 10
Tuscarora Formation 5, 11, 17, 19, 20, 21, 23

Valley and Ridge province 2

West Mountain syncline 21
Whites Store 15

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



EXPLANATION

MESOZOIC CENOZOIC

QUATERNARY

Qal — Alluvium

d — Alkalic dike
Nepheline syenite or teschenite-syenite.

PALEOZOIC

MISSISSIPPIAN

Mpo — Pocono Formation
White to gray, medium-grained sandstone; buff to black, fissile shale; thin coal beds.

DEVONIAN

Dhs — Hampshire Formation
Chocolate-brown to red shale, sandstone, and mudrock.

Dch — Chemung Formation
Chiefly greenish-gray shale and sandstone with thin conglomerates and some red shale.

Db — Brallier Formation
Greenish to brown, micaceous shale with thin intercalated layers of gray, fine-grained sandstone.

Dmn — Millboro Shale-Needmore Formation
Millboro: black fissile shale. Needmore: olive-green shale with gray argillaceous limestone.

DS — Lower Devonian-Upper Silurian rocks
Oriskany Sandstone: gray coarse-grained, argillaceous sandstone, stained with iron oxide; Licking Creek Limestone: light- to medium-gray cherty and sandy limestone; Healing Springs Sandstone: light-gray coarse-grained sandstone, stained with iron oxide; Coeymans Limestone: medium- to light-gray, coarse-grained, crinoidal limestone; Keyser Formation: medium-gray, fine-grained limestone; Tonoloway Formation: medium- to dark-gray, thin-bedded argillaceous limestone; and Bloomsburg Formation: red shale and sandy mudrock.

SILURIAN

Scl — Keefer Sandstone-Cacapon Formation
Keefer: white to gray, fine-grained sandstone. Cacapon: red sandstone and red and green shales.

Stu — Tuscarora Formation
Gray to white, thick-bedded sandstone with a few beds of conglomerate.

ORDOVICIAN

Ojos — Juniata Formation-Oswego Sandstone
Juniata: red shale and mudrock and brown to red sandstone. Oswego: greenish-gray sandstone with limonitic specks.

Omb — Martinsburg Formation
Olive-green to gray, subfissile shale with argillaceous sandstone in upper portion.

Oe — Edinburg Formation
Dark-gray to black, argillaceous limestone; black fissile shale; and cobbly, coarse-grained, fossiliferous limestone.

Ol — Lincolnshire Formation
Dark-gray, finely crystalline limestone with nodules and stringers of black chert.

On — New Market Limestone
Dove-gray, compact, thick-bedded limestone.

Ob — Beekmantown Formation
Light- to dark-gray, fine-grained limestone; light-gray, fine-grained dolomite; and dark-gray, coarse-grained recrystalline dolomite.

CAMBRIAN

Ꞓco — Conococheague Formation
Bluish-gray limestone and light-gray dolomite with interbedded thin sandstone.

Ꞓe — Elbrook Formation
Thin-bedded, argillaceous limestone and gray, fine-grained dolomite that commonly weathers to iron oxide stained slabs and thin plates.

CONTACTS

exposed
approximate
covered

FOLDS

Anticline—trace of axial plane and direction of plunge of axis.
Syncline—trace of axial plane and direction of plunge of axis.
Overturned syncline—trace of axial plane.

FAULTS

THRUST
exposed
approximate
covered
T overthrust side

ATTITUDE OF ROCKS

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

QUARRY AND PROSPECT

ABANDONED QUARRY
1. Crushed stone

PROSPECT
1. Iron ore

SAMPLE LOCATIONS

R-3624 Location and repository number of sampled lithology.
F Fossil locality

Base from U. S. Geological Survey, 1967
Stokesville Quadrangle 7½ Minute Series

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GEOLOGIC MAP OF THE STOKESVILLE QUADRANGLE, VIRGINIA

Geology by Eugene K. Rader

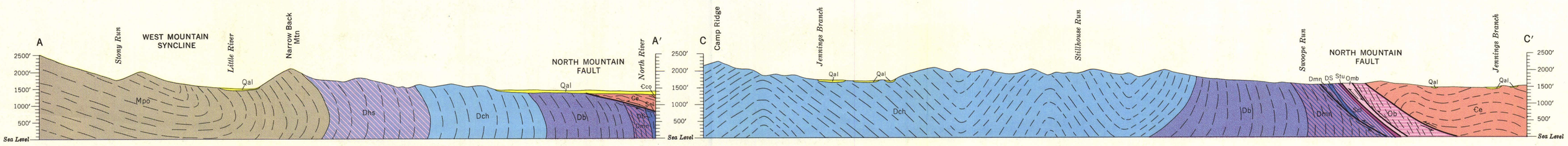
1967 MAGNETIC DECLINATION

SCALE 1:24 000

CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 20-FOOT CONTOURS

1969

QUADRANGLE LOCATION



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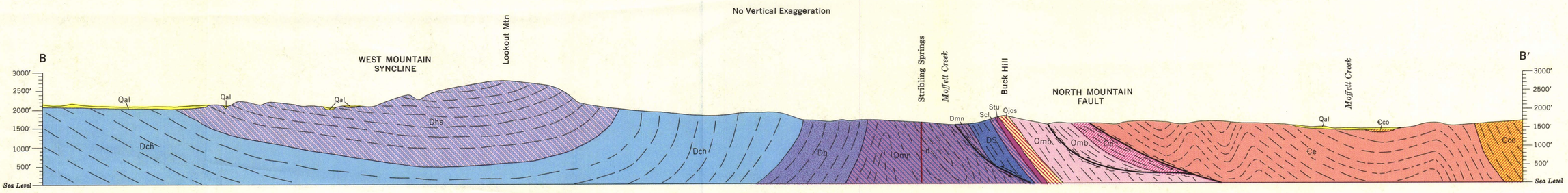

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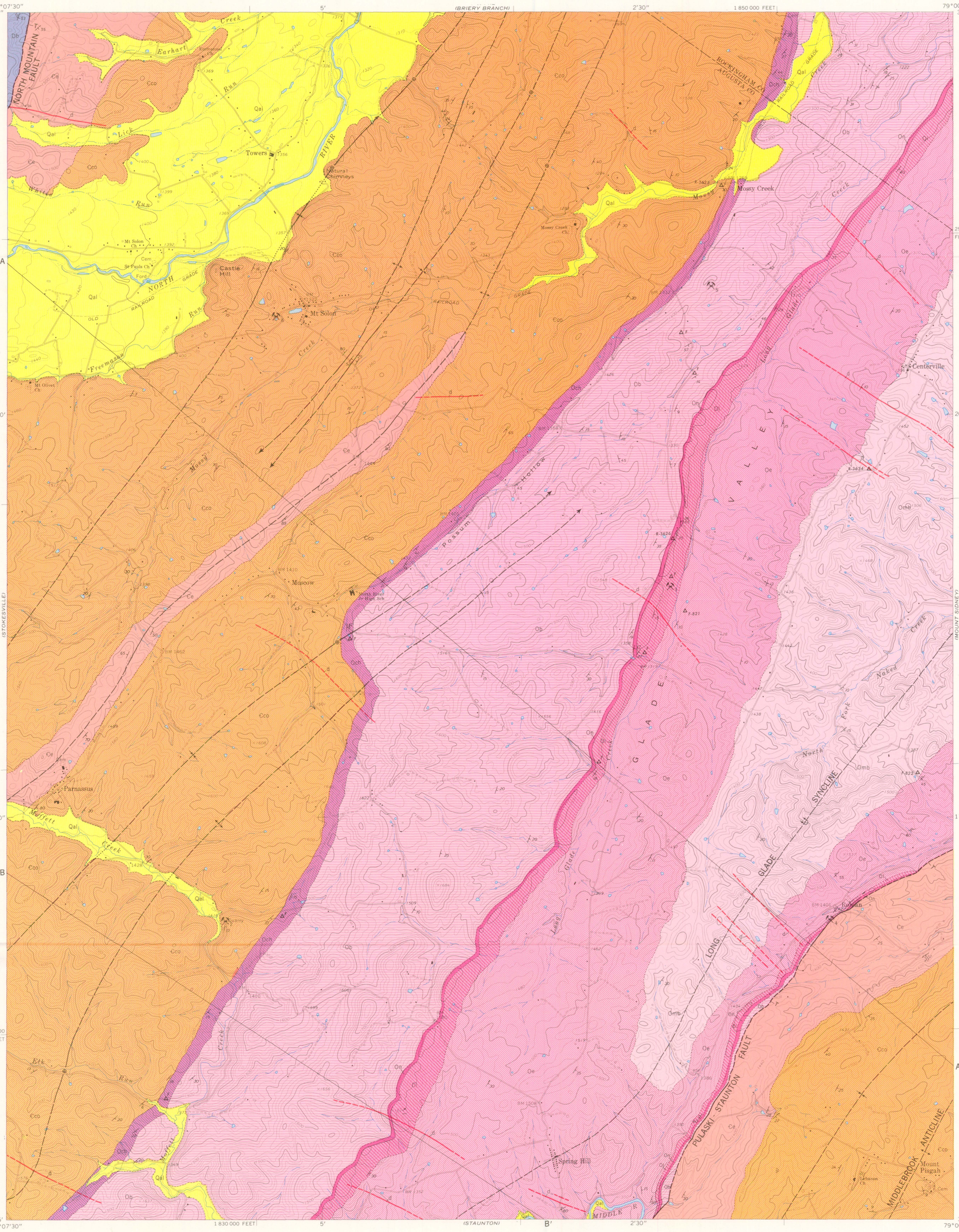

Base from U. S. Geological Survey, 1967
Parnassus Quadrangle 7½ Minute Series

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GEOLOGIC MAP OF THE PARNASSUS QUADRANGLE, VIRGINIA

Geology by Eugene K. Rader

1969

EXPLANATION

QUATERNARY

Qal — Alluvium

MESOZOIC CENOZOIC

d — Alkalic dike
Nepheline syenite or teschenite-syenite.

DEVONIAN

Db — Brallier Formation
Greenish to brown, micaceous shale with thin intercalated layers of gray, fine-grained sandstone.

ORDOVICIAN

Omb — Martinsburg Formation
Olive-green to gray, subfissile shale with argillaceous sandstone in upper portion.

Oe — Edinburg Formation
Dark-gray to black, argillaceous limestone; black fissile shale; and cobbly, coarse-grained, fossiliferous limestone.

Ol — Lincolnshire Formation
Dark-gray, finely crystalline limestone with nodules and stringers of black chert.

On — New Market Limestone
Dove-gray, compact, thick-bedded limestone.

Ob — Beekmantown Formation
Light- to dark-gray, fine-grained limestone; light-gray, fine-grained dolomite; and dark-gray, coarse-grained recrystalline dolomite.

Och — Chepultepec Formation
Bluish-gray to black limestone with black chert; minor medium-gray, fine-grained dolomite.

CAMBRIAN

Ꞓco — Conococheague Formation
Bluish-gray limestone and light-gray dolomite with interbedded thin sandstone.

Ꞓe — Elbrook Formation
Thin-bedded, argillaceous limestone and gray, fine-grained dolomite that commonly weathers to iron oxide stained slabs and thin plates.

PALEOZOIC

CONTACTS

- exposed
- approximate
- covered

FOLDS

- Anticline—trace of axial plane and direction of plunge of axis.
- Syncline—trace of axial plane and direction of plunge of axis.
- Overturned syncline—trace of axial plane

FAULTS

THRUST

- exposed
- approximate
- covered
- T overthrust side

ATTITUDE OF ROCKS

- 45 Strike and dip of beds
- 50 Strike and dip of overturned beds
- Horizontal beds

QUARRIES

ABANDONED QUARRY

2. Crushed stone
3. Crushed stone and lime
4. Lime
5. Ore Bank mine
6. Crushed stone and lime

SAMPLE LOCATIONS

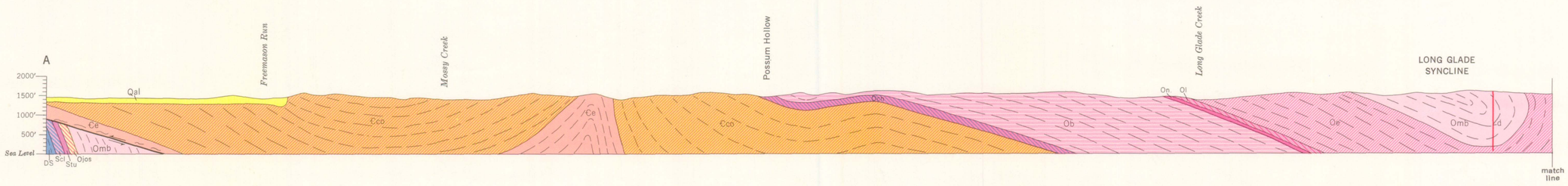
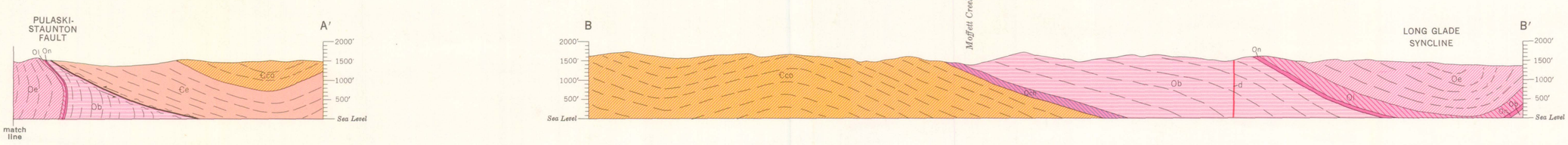
- R-3625 Location and repository number of sampled lithology.
- F-822 Location and repository number of fossils collected
- F Fossil locality

1967 MAGNETIC DECLINATION

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS

QUADRANGLE LOCATION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