COMMONWEALTH OF VIRGINIA

DEPARTMENT OF CONSERVATION
AND ECONOMIC DEVELOPMENT

DIVISION OF MINERAL RESOURCES

GEOLOGY OF THE STAUNTON, CHURCHVILLE, GREENVILLE, AND STUARTS DRAFT QUADRANGLES, VIRGINIA

EUGENE K. RADER

REPORT OF INVESTIGATIONS 12

VIRGINIA DIVISION OF MINERAL RESOURCES

James L. Calver
Commissioner of Mineral Resources and State Geologist

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Richmond
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DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT

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GEOLOGY OF THE STAUNTON, CHURCHVILLE, GREENVILLE, AND STUARTS DRAFT QUADRANGLES, VIRGINIA

By

EUGENE K. RADER

ABSTRACT

The Staunton, Churchville, Greenville, and Stuarts Draft quadrangles are located in the central part of Augusta County, west-central Virginia. Bedrock in the area ranges in age from Middle Cambrian to Late Devonian, but consists principally of Cambrian and Ordovician rocks. Most of the rocks are sedimentary and have a total thickness of approximately 20,000 feet. Igneous rocks in the area (dikes, plugs, and sills) are of four general compositions: diabase, nepheline syenite, teschenite-syenite, and teschenite-picrite. Generally the dikes are poorly exposed and are less than 50 feet thick.

Structurally, the eastern part of the area has folds and minor thrust faults in the Massanutten synclinorium. Northwest of the synclinorium, the Pulaski-Staunton fault transects the area in a northeasterly direction. This thrust fault is folded conformably with the Middlebrook anticline and a branch of the Long Glade syncline. Roughly parallel to, and northwest of, the Pulaski-Staunton fault is another thrust fault, the North Mountain fault, which is on the southeast side of Little North Mountain. Little North Mountain consists of overturned steeply dipping Silurian and Devonian rocks. Northwest of Little North Mountain is a portion of a broad syncline containing Upper Devonian rocks.

The mineral resources in the area consist of limestone, dolomite, shale, bauxite, and iron oxide. Limestone and dolomite used as crushed stone and agricultural stone are quarried from rocks of Cambrian and Ordovician ages. Shales of the Edinburg and Brallier formations and some residual clays have been tested for potential use in the manufacture of brick and ceramic products. Bauxite has been produced from residuum west of Greenville. Iron oxide has been produced from the lower portion of the Beekmantown Formation. Adequate domestic water supplies can be obtained in most areas, and abundant water supplies may occur in the vicinity of South River.

INTRODUCTION

The Staunton (Plate 1), Churchville (Plate 2), Greenville (Plate 3), and Stuarts Draft (Plate 4) quadrangles are located in central Augusta

County and have a combined area of 234.86 square miles. They are bounded by 79° and 79° 15′ W. longitude and 38° and 38° 15′ N. latitude (Figure 1). The quadrangles lie entirely within the Valley and Ridge physiographic province. The region between the Blue Ridge and Little North Mountain is commonly referred to as the Shenandoah Valley or the Great Valley of Virginia. Topographically the area is characterized by gently sloping hills, a few conical-shaped hills, and low narrow ridges. The maximum and minimum elevations and total relief in each quadrangle are as follows:

Quadrangle	*Maximum Elevation in Feet*	*Minimum Elevation in Feet*	*Total Relief in Feet*
Staunton	1940	1200	740
Churchville	3111	1360	1751
Greenville	2120	1500	620
Stuarts Draft	1951	1260	691

The earliest "detailed" geologic map of the Staunton area was the Staunton folio (Darton, 1894). The "Geologic Map of the Appalachian Valley of Virginia with Explanatory Text" (Butts, 1933) and the "Geology of the Appalachian Valley of Virginia" (Butts, 1940-41) are useful references. The "Geologic Map of Virginia" (Virginia Division of Mineral Resources, 1963) illustrates the general regional geology. Theses by Browning (1951), Caskie (1951), Fara (1957), Patterson (1958), and Fitzgerald (1966) were utilized. The field investigation was begun in July 1964 and completed in August 1966.

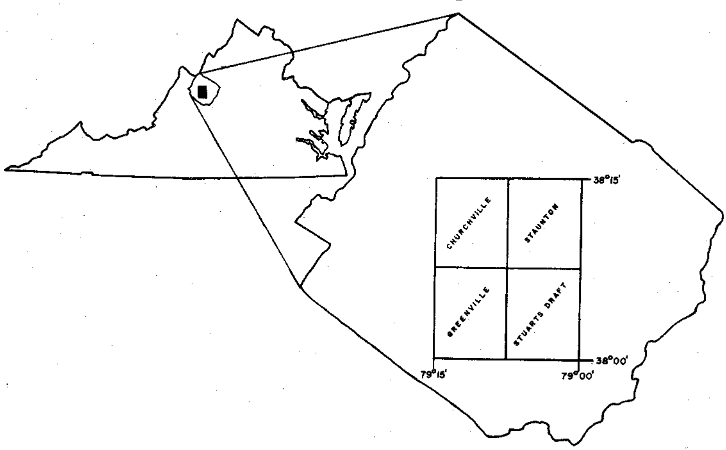

Figure 1. Index map showing locations of the Staunton, Churchville, Greenville, and Stuarts Draft quadrangles. Augusta County.

Numbers preceded by "R" in parentheses (R-3051) correspond to sample localities on Plates 1-4; those preceded by "F" (F-693) correspond to fossil localities on Plates 1-3. These samples and fossils are on file in the repository of the Virginia Division of Mineral Resources where they are available for examination.

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, both in the field and in discussion. Thanks are also due Drs. W. B. Brent and S. J. Kozak for the time they spent with the writer in the field and for the numerous discussions that contributed to a better understanding of the stratigraphy and structure of the area. Discussions with Drs. W. R. Johnson and Charles Milton have provided the basis for the descriptions and locations of the alkalic igneous rocks. Special thanks are due Mr. T. M. Gathright for the photographic illustrations in this report.

STRATIGRAPHY

The rock strata cropping out in the area are divided into 23 formations and 17 mappable units on the bases of lithologic character and fossils. The oldest rock exposed is the Rome Formation of Cambrian age and the youngest is the Hampshire Formation of Devonian age. The age, lithologic character, and formation thickness are listed in Table 1. The area southeast of Little North Mountain is underlain by folded and faulted Cambrian and Ordovician dolomites, limestones, shales, and subordinate sandstones. Little North Mountain is underlain by steeply inclined Ordovician, Silurian, and Devonian sandstones, shales, and limestones. West of Little North Mountain the Devonian shales and sandstones are folded.

CAMBRIAN SYSTEM

Rome Formation

The Rome Formation was named by Hayes (1891, p. 143) from exposures near Rome, Georgia. It is a heterogeneous formation of red, green, and yellow shale and medium- to dark-gray, fine-grained dolomitic limestone (R-3051). Exposures are present 0.5 mile east of Cockran Spring and in a roadcut along State Road 603, 1.1 miles northwest of its junction with State Highway 252 (Plate 3). A deep well has penetrated the Rome beneath the terrace gravel near South River just south of the Stuarts Draft quadrangle. As the upper contact is not exposed, the thickness was not determined, but the portion present southeast of Cockran Spring is estimated to be greater than 1000 feet.

Table 1.—Geologic formations in the Staunton, Churchville, Greenville, and Stuarts Draft quadrangles.

Age	*Name*	*Map Symbol*	*Character*	*Thickness in Feet*
Quaternary(?)	Alluvium Terrace gravel	Qal Qg	Sand and clay. Sandstone gravels with unconsolidated sand and clay.	50 to 160
Jurassic-Cretaceous	Alkalic intrusive rocks	Kd	Dikes and plugs of alkalic composition.	
Triassic	Diabase intrusive rocks	₹d	Diabase dikes.	
Devonian	Hampshire Formation	Dhs	Chiefly chocolate-brown sandstone, shale, and mudrock.	700±
	Chemung Formation	Dch	Gray to green sandstone, shale, and conglomerate; fossiliferous.	3000±
	Brallier Formation	Db	Greenish-gray, stiff, micaceous shale and thin-bedded sandstone; sparsely fossiliferous.	2200±
	Millboro Shale—Needmore Formation	Dmn	Millboro Shale—fissile black shale, weathers light gray or pinkish. Needmore Formation—olive-green shale and argillaceous limestone.	700
	Oriskany Sandstone	DS	Coarse-grained, rusty-brown sandstone with calcareous cement; fossiliferous.	0-25
	Licking Creek Limestone	DS	Medium- to dark-gray cherty and sandy limestone; fossiliferous.	40-120
	Healing Springs Sandstone	DS	Coarse-grained, rusty-brown friable sandstone.	0-15
	Coeymans Limestone	DS	Coarse-grained, crinoidal limestone.	0-10

Age	*Name*	*Map Symbol*	*Character*	*Thickness in Feet*
Devonian-Silurian	Keyser Formation	DS	Medium-gray, fine-grained, nodular limestone, some shale and sandy beds; fossiliferous.	30-100
Silurian	Tonoloway Formation	DS	Gray, thin-bedded, argillaceous limestone.	80
	Keefer Sandstone	Ske	White to gray, fine-grained sandstone.	40-80
	Cacapon Formation	Sca	Red sandstone and red and green shale.	200-250
	Tuscarora Formation	Stu	White to gray, fine-grained, quartz sandstone; some quartz-pebble conglomerate.	0-200
Ordovician	Martinsburg Formation	Omb	Shale, calcareous, silty; some greenish sandstone, fossiliferous near Little North Mountain.	2000+
	Edinburg Formation	Oe	Dense, black, argillaceous limestone; black shale and dark-gray, nodular-weathering limestone.	1200
	Lincolnshire Formation	Ol	Medium-grained, dark-gray, cherty limestone.	75-225
	New Market Limestone	On	Dove-gray, compact, high-calcium limestone.	0-200
	Beekmantown Formation	Ob	Thick-bedded, light-gray, fine-grained dolomite; some medium-gray limestone; abundant chert.	1800-2000
	Chepultepec Formation	Och	Dark-gray to black limestone; some thin beds of dolomite; nodular black chert.	300-400

Age	*Name*	*Map Symbol*	*Character*	*Thickness in Feet*
Cambrian	Conococheague Formation	€co	Laminated gray limestone, thick-bedded dolomite, and thin sandstone beds.	2200-2500
	Elbrook Formation	€e	Thin- to thick-bedded limestone and dolomite; shaly dolomite.	2000+
	Rome Formation	€r	Green-weathering dolomite, red and green shale, and siltstone.	1000+

Elbrook Formation

Stose (1906, p. 209) named the Elbrook from exposures at Elbrook, Franklin County, Pennsylvania. The formation consists of two somewhat distinct lithologies. One is composed of thick-bedded, medium- to dark-gray, medium- to fine-grained dolomite and limestone that weather light gray and white (R-3050); some of the limestone contains algal biostromes that have been partly dolomitized (Figure 2). The other consists of thin-bedded, light- to medium-gray, fine- to medium-grained, argillaceous dolomite and limestone, that weather to slabby or shaly plates. One of the more distinctive features of the Elbrook is the punky yellow coating that covers the weathered surface of some of the dolomite. In the upper half of the Elbrook there are thin, relatively pure, tannish limestones. About 2 miles west of Greenville the formation crops out along Roaring Run that is approximately parallel to State Road 662 between its junctions with State Roads 604 and 673 (Plate 3), and in a quarry (Plate 3, No. 23) 0.5 mile southwest of the junction of State Roads 662 and 673. It also crops out along State Highway 254 from about 0.4 mile northwest of West View to its junction with State Road 876; algal masses are in the eastern portion of the exposures (Plate 2). The top of the Elbrook is picked above the first occurrence of yellowish-weathering shaly dolomite and below the lowest sandstone and dolomite sequence of the Conococheague. The only evidence of fossils found in the area are the algal masses and fossil fragments (trilobites and brachiopods ?). The Elbrook Formation is of Cambrian age.

Figure 2. Algal structures in the upper part of the Elbrook Formation along State Highway 254, 100 yards east of bridge across Middle River (Plate 2).

Conococheague Formation

The Conococheague was named by Stose (1908, p. 701) from Conococheague Creek, Franklin County, Pennsylvania. The formation approximately parallels State Highway 340 trending west-southwest from Stuarts Draft to Greenville. Another series of outcrops trend northeastward from Greenville to the northeast corner of the Staunton quadrangle. Other exposures occur in the southwest portion of the Greenville quadrangle and trend northward through Churchville.

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 (R-3073, R-3079, R-3080). Lenticular beds of intraformational conglomerate are common in the formation. Minor amounts of black oolitic chert and black dense chert are present throughout the formation. The thicker sandstones (5 to 10 feet) are in the lower 700 to 800 feet of the formation where it is up to 2500 feet thick.

Dolomite and dolomitic sandstone are well exposed along State Road 612 for a distance of 0.6 mile east of Quicks Mill (Plate 1);

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Dolomite and dolomitic sandstone are well exposed along State Road 612 for a distance of 0.6 mile east of Quicks Mill (Plate 1);

about 1.5 miles north-northeast of West View limestone and dolomitic limestone are present along State Road 720 for a distance of 0.4 mile west from the bridge over Middle River (Plate 2). The topography of the Conococheague is characterized by linear ridges of sandstone, the longest of which is 4 miles. Generally the ridges with greatest relief are near the base of the formation. This part of the formation has been described as the Big Spring Station member in Pennsylvania and Frederick County, Virginia (Wilson, 1952). In the Staunton area are large, almost completely dolomitized and partially silicified, algal masses (Figure 3). The Conococheage Formation is Cambrian in age.

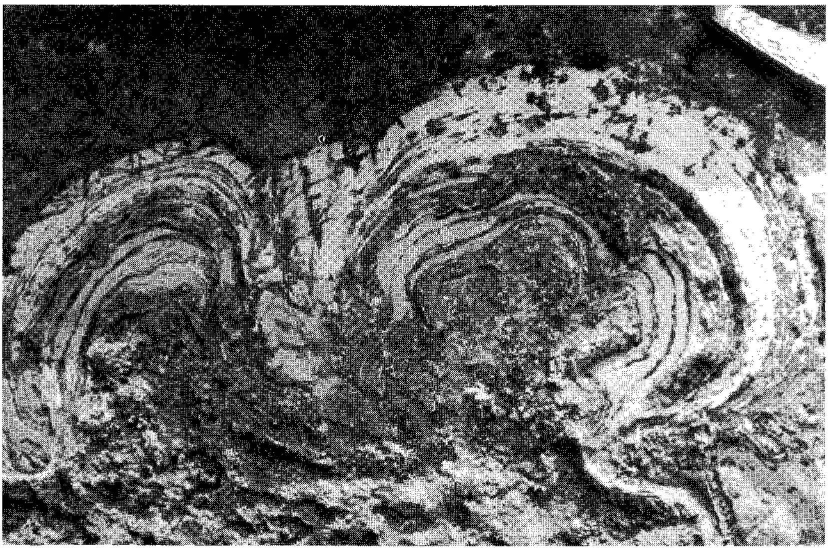
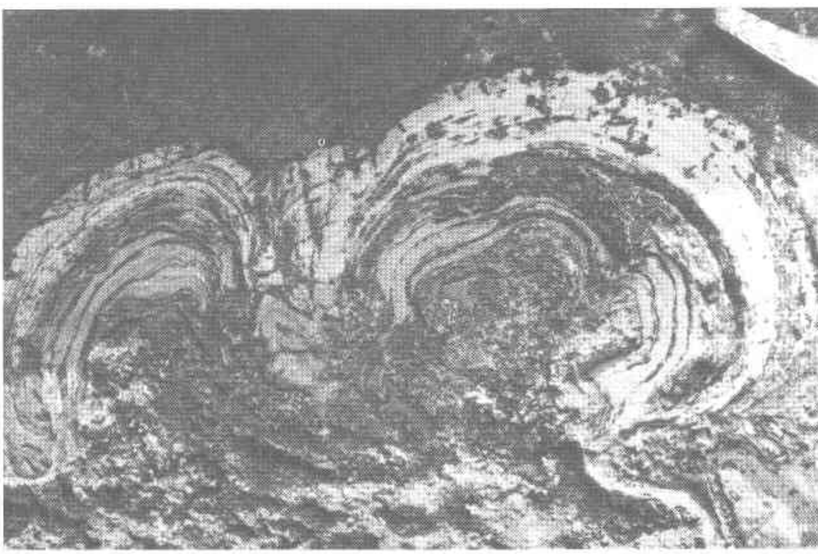


Figure 3. Algal structures in the lower part of the Conococheague Formation east of Back Creek at the end of State Road 712 (Plate 3).

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 Chepultepec is dominantly a fine-grained, blue-black limestone with nodules of black chert along bedding planes and masses about 1.5 miles north-northeast of West View limestone and dolomitic limestone are present along State Road 720 for a distance of 0.4 mile west from the bridge over Middle River (Plate 2). The topography of the Conococheague is characterized by linear ridges of sandstone, the longest of which is 4 miles. Generally the ridges with greatest relief are near the base of the formation. This part of the formation has been described as the Big Spring Station member in Pennsylvania and Frederick County, Virginia (Wilson, 1952). In the Staunton area are large, almost completely dolomitized and partially silicified, algal masses (Figure 3). The Conococheage Formation is Cambrian in age.



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The Chepultepec generally occurs beneath the valleys between ridges consisting of Conococheague sandstone and conical hills of Beekmantown chert. The lower contact is placed about halfway up these ridges and the upper contact below the first thick-bedded dolomite. The contact with the overlying Beekmantown Formation is gradational and is poorly exposed throughout the area. The formation is 300 to 400 feet thick. Small curved cephalopods are relatively common in the middle member; brachiopods occur throughout the formation (Sando, 1958; Wood, 1962). It is of Ordovician age.

Beekmantown Formation

The Beekmantown was named by Clarke and Schuchert (1899, p. 874-878) for a locality in New York. The formation has several lithologies: (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. The chiefly dolomitic Beekmantown Formation is well exposed about 2.25 miles south of Middlebrook along a "field traverse" 0.3 mile northeast of and parallel to State Road 674, beginning at a sharp turn in the road 0.3 mile northeast of the junction of State Roads 670 and 674 (Plate 3); in four quarries on the eastern city limits of Staunton just north and northeast of U. S. Highway 250 (Plate 1, Nos. 6-9); and along State Road 728 about 0.5 mile west of Franks Mill for a distance of 2.2 miles. Chert is abundant as large lenticular masses in the lower portion of the formation and forms large conical hills. Weathered surfaces of the dolomite and dolomitic limestone are extremely fluted and in many exposures a cross-hatched pattern is formed.

The lower contact is placed at the base of the first thick dolomite that overlies the black limestone of the Chepultepec. The upper contact is unconformable with the overlying New Market and in three areas is unconformable with the overlying Lincolnshire. The thickness ranges from 1800 to 2000 feet. Most of the fossils found in the Staunton area are gastropods. They are particularly abundant on the hill south of Greenville (F-693) and 0.4 mile east of the junction of State Roads 670 and 674 west of Greenville. The Beekmantown Formation is of Ordovician age.

New Market Limestone

The New Market Limestone was named by Cooper and Cooper (1946, p. 71-72) from the Madden quarry near New Market, Virginia. The New Market is a thick-bedded dove-gray, fine-grained limestone with a few 2- to 3-inch-thick dolomite beds near the base. Complete sections of the limestone occur northeast of Mint Spring about 500 feet northeast of the junction of U. S. Highway 11 and State Road 654 (Plate 4); in four quarries on the eastern city limits of Staunton just north and northeast of U. S. Highway 250 (Plate 1, Nos. 6-9); at the Bowling quarry northwest of Verona along State Road 781, 0.2 mile from its intersection with U. S. Highway 11 (Plate 1); northwest of Staunton, just southeast of the junction of U. S. Highway 250 and State Road 612 (Plate 1); and about 0.5 mile west of Franks Mill in a quarry just north of State Road 728 (Plate 1, No. 1). The locality northwest of Staunton on U. S. Highway 250 has about 2 feet of reddish mudstone at the base of the section, and the locality northeast of Mint Spring contains a basal conglomerate. The formation generally occurs on the steep side of hills where it is overlain by the cherty Lincolnshire. Southeast of Staunton at De Jarnette State Sanatorium and along State Road 612, the New Market is truncated at an unconformity. The thickness ranges from 0 to 200 feet. Large gastropods and small tetracorals are present in the New Market at the abandoned Bowling quarry north of Verona.

Lincolnshire Formation

The Lincolnshire limestone was named by Cooper and Prouty (1943, p. 863) from an abandoned quarry near Lincolnshire Creek, Tazewell County, Virginia. The Lincolnshire is equivalent to the Lenoir in northern Virginia (Butts, 1940). The Murat limestone (Campbell, 1905) was named for Murat, Rockbridge County, Virginia. It is essentially the unit that Butts (1933, 1940) mapped and described as Holston north of Roanoke.

The Lincolnshire is composed of dark-gray, medium-grained, cherty limestone. The chert is black and generally occurs along bedding planes. The formation is characterized by the blocky chert and mottled beds of limestone. The Murat is a light pinkish-gray, coarse-grained, biohermal or biostromal limestone. The lithology of the formation is well exposed near Staunton, just southeast of the junction of U. S. Highway 250 and State Road 612 (Plate 1) and in four quarries on the eastern city limits of Staunton just north and northeast of U. S. Highway 250 (Plate 1, Nos. 6-9). The Murat limestone is well exposed 0.4 mile south of Barterbrook in a roadcut along State Road 608 (Plate 4). The cherty portion of the Lincolnshire normally underlies ridges of low relief. Along U. S. Highways 11 and Alternate 11 between Staunton and Verona the ridges are well developed. Where the Murat limestone is dominant, the formation is expressed topographically as a valley. The thickness averages about 130 feet. The unit contains abundant silicified trilobites, brachiopods, ostracodes, and bryozoans. The most distinctive fossil is *Dinorthis atavoides,* a brachiopod.

Edinburg Formation

The Edinburg was named by Cooper and Cooper (1946, p. 78) from exposures near Edinburg, Shenandoah County, Virginia. It is equivalent to the Whitesburg, Athens, and Chambersburg of Butts (1940). Within the Edinburg Formation an estimated maximum thickness of 25 feet of dark-gray to brownish-gray, medium- to coarse-grained, iron oxide stained limestone is representative of the Botetourt Member. It occurs only in the Staunton area as float; no exposures were observed. The Liberty Hall facies is composed of black fine-grained argillaceous limestone and shale and pink-weathering shales (R-1633, R-1664, R-3061); it occurs in the Massanutten and Long Glade synclines. In these areas the limestone has been subjected to much intraformational folding and faulting and may be recognized in part by the abundance of white calcite and dolomite fracture fillings. The Lantz Mills facies is well developed west of the North Mountain fault as a cobbly- or nodular-weathering, medium-grained, dark-gray to black limestone (R-3077). The Liberty Hall facies occurs in Staunton along U. S. Highway 11 from northeast of its intersection with State Highway 254 to the city limits (Plate 1) and along U. S. Highway 250 in the Peyton area. The Lantz Mills facies crops out about 2 miles due west of Sugarloaf, westward along State Road 713 from its junction with State Road 876 (Plate 3). The thickness of the formation is estimated to be about 1200 feet.

The basal shales of the Liberty Hall facies near Staunton contain abundant graptolite species which are part of the *Nemograptus gracilis* fauna of the Normanskill Shale in New York. 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. The Edinburg probably correlates with the Chambersburg of Pennsylvania and the various limestone formations between the Lincolnshire and the Trenton of southwestern Virginia.

Martinsburg Formation

The Martinsburg was named by Geiger and Keith (1891, p. 161) from outcrops in the vicinity of Martinsburg, West Virginia. The Martinsburg Formation differs lithologically in outcrops east of Staunton from those along the east slope of Little North Mountain. East of Staunton the Martinsburg is composed of interbedded buff- to brown-weathering, gray to olive, stiff shale and medium- to coarse-grained gray sandstone (R-3045). The individual sandstone beds rarely exceed 2 feet in thickness, although probably 50 to 60 percent of the formation is sandstone. On the east slope of Little North Mountain and in the adjoining lowland, the Martinsburg is a yellow-weathering, gray, calcarous shale with sandstone near the top (R-3074, R-3075). The sandstone is medium grained, light gray, and iron oxide flecked (R-3076). This sandstone at Buffalo Gap resembles the Oswego Formation. Outcrops are present from Peyton to a location 0.7 mile east of Christians Creek (Plates 1, 4) and along the Chesapeake and Ohio Railway for a distance of about 0.2 mile beginning at a location 0.4 mile from the railway intersection with State Road 705 at Christian (Plate 2). The lower contact is extremely difficult to determine, and the base is arbitrarily mapped above the uppermost black shaly limestone of the Edinburg. Along Little North Mountain the base is mapped above the uppermost cobbly limestone of the Lantz Mills facies of the Edinburg. The upper contact in the west is placed at the base of the first white to gray quartzite of the Tuscarora. The thickness of the Martinsburg is about 2000 feet.

Orthorhynchula sp. was found at Buffalo Gap and northwest of Camp Shenandoah. Along State Road 705 and near the Jonesboro Cemetery south of Christian, the trilobite *Cryptolithus* sp., several species of brachiopods, and the ostracode *Pseudorakverella altalirata* are present (F-690).

SILURIAN SYSTEM

In the area of study only the Churchville quadrangle (Plate 2) contains rocks of Silurian and Devonian ages. These are present in the northwest portion in the vicinity of Little North Mountain.

Tuscarora Formation

The Tuscarora Formation was named by Darton and Taff (1896, p. 2). The Tuscarora is a tough, white to light-gray, fine- to medium-grained, sandstone and quartzite (R-3082) (Figure 4). A few beds of conglomerate have been observed, and thin shale beds are common near the base. The formation crops out along State Highway 42 and the Chesapeake and Ohio Railway in Buffalo Gap (Plate 2). The lower contact is placed at the top of the uppermost gray sandstone of the Martinsburg Formation, and the upper contact is placed at the lowermost "red bed" of the Cacapon Formation. The Tuscarora Formation has a maximum thickness of 200 feet. It is of Silurian age.

Figure 4. Massive overturned beds of Tuscarora quartzite along Chesapeake and Ohio Railway, south side of Buffalo Gap (Plate 2).

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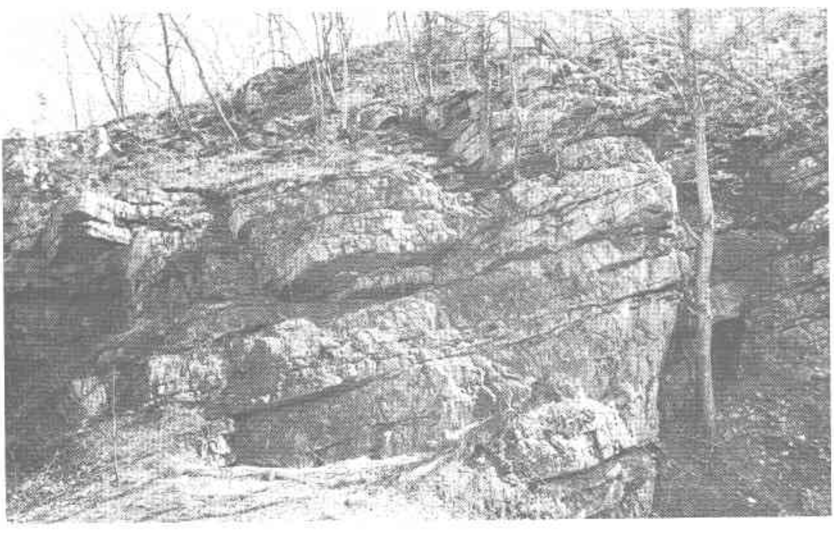

Figure 4. Massive overturned beds of Tuscarora quartzite along Chesapeake and Ohio Railway, south side of Buffalo Gap (Plate 2).

Cacapon Formation

The Cacapon Formation was named by Darton and Taff (1896, p. 2) from Cacapon Mountain, Maryland. The formation is present just northwest of the crest of Little North Mountain. The Cacapon consists of red and green shales, red medium-grained sandstones, red oolitic beds, and ferruginous sandstones (R-3071, R-3072). Thin white to gray, fine-grained sandstones are also present. The formation crops out along State Highway 42 and the Chesapeake and Ohio Railway in Buffalo Gap (Plate 2). *Anoplotheca hemispherica* and *Liocalymene clintoni* are common in some sections (F-692).

Keefer Sandstone

The Keefer Sandstone was named by Stose and Swartz (1912, p. 5) from Keefer Mountain, Pennsylvania. The Keefer (Figure 5) is a gray to rusty-brown, fine- to medium-grained sandstone (R-3083). The sandstone crops out along State Highway 42 and the Chesapeake and Ohio Railway in Buffalo Gap (Plate 2). 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 40 to 80 feet.

Figure 5. Ripple-marked overturned Keefer Sandstone, along Chesapeake and Ohio Railway, south side of Buffalo Gap. Three directions of ripple marks are present on the overturned beds (Plate 2).

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Figure 5. Ripple-marked overturned Keefer Sandstone, along Chesapeake and Ohio Railway, south side of Buffalo Gap. Three directions of ripple marks are present on the overturned beds (Plate 2).

Tonoloway Formation

The Tonoloway was named by Ulrich (1911, p. 128) from Tonoloway Ridge west of Hancock, Maryland. It is a laminated, medium- to dark-gray, fine- to very fine-grained, argillaceous limestone. The lower contact is at the top of the uppermost sandstone of the Keefer, and the upper contact is placed at the base of the first cobbly bed of the Keyser. The formation crops out along the Chesapeake and Ohio Railway in the western portion of Buffalo Gap (Plate 2). The Tonoloway Formation is approximately 80 feet thick. For the purpose of mapping, it has been included with the Upper Silurian-Lower Devonian rocks. The small brachiopod *Camarotoechia* cf. *C. litchfieldensis* and the ostracode *Leperditia* cf. *L. alta* are relatively common in the Tonoloway.

UPPER SILURIAN-LOWER DEVONIAN ROCKS

The Keyser Formation, Coeymans Limestone, Healing Springs Sandstone, Licking Creek Limestone, and Oriskany Sandstone are mapped as one unit. These rocks are undivided either because many occurrences are thin, poorly exposed or discontinuous, or in some places they are absent.

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 three members: (1) a lower limestone, (2) the Clifton Forge sandstone, and (3) an upper limestone. The lower unit is a cobbly-weathering, fine-grained, dark-gray, fossiliferous limestone. The Clifton Forge is a thick-bedded, gray to white, rusty-weathering, medium- to coarse-grained sandstone. The upper unit is a medium- to dark-gray, fine- to coarse-grained, fossiliferous limestone. Crinoidal limestone in the upper part resembles the Coeymans. The formation crops out along the Chesapeake and Ohio Railway in the western portion of Buffalo Gap (Plate 2). The total thickness ranges from 40 to 100 feet. The lower limestone is Silurian age (Bowen, 1963) and contains the "*Chonetes*" *jerseyensis* zone (Swartz, 1929). The Clifton Forge sandstone is unfossiliferous. The upper limestone contains the *Favosites helderbergiae* zone (Swartz, 1929) which is of Devonian age.

DEVONIAN SYSTEM

Coeymans Limestone

The Coeymans Limestone was named by Clarke and Schuchert (1899, p. 874-877) from the town of Coeymans, New York. The Coeymans is a medium- to light-gray and pinkish, coarse-grained, crinoidal limestone (R-3069). The limestone crops out along the Chesapeake and Ohio Railway in the western portion of Buffalo Gap (Plate 2). The lower contact is taken at 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. Crinoid columnals and *Gypidula coeymanensis* were found in the area. The Coeymans Limestone is Devonian in age.

Healing Springs Sandstone

The Healing Springs Sandstone was named by Swartz (1929, p. 41) from an exposure in the gorge through Little Mountain, 3 miles northwest of Healing Springs, Bath County, Virginia. The Healing Springs is a friable, light-gray, medium- to coarse-grained sandstone that weathers to a rusty brown. The sandstone crops out along the Chesapeake and Ohio Railway in the western portion of Buffalo Gap (Plate 2). The contacts of the Healing Springs Sandstone are with the coarse crinoidal limestone of the Coeymans below and the cherty Licking Creek Limestone above. The thickness does not exceed 5 feet. Fragments of "*Spirifer*"-type brachiopods were the only fossils found.

Licking Creek Limestone

The Licking Creek Limestone was named by Swartz (1939, p. 69-70) from exposures along Licking Creek near Warren Point, Pennsylvania. The formation may be divided into two members: (1) a lower member that is medium- to dark-gray, fine-grained, cherty limestone (R-3070) and (2) an upper member that is light- to medium-gray, coarse-grained sandy limestone. Generally fossiliferous chert float is the only indication of the presence of the formation. A nearly complete section is exposed 1.5 miles west of Lone Fountain, 0.1 mile due west of the first knob south of the gap where McKittricks Branch transects Little North Mountain (Plate 2). A more accessible location is in a second gap about 1.2 miles to the northeast which is outside the area studied. It is at the end of the first abandoned farm road to the west of U. S. Highway 250 and south of its junction with State Road 736. The thickness probably does not exceed 75 feet. The chert in the lower member contains abundant brachiopod fragments. It is correlated with the Becraft Limestone (Swartz, 1939; Butts, 1940).

Oriskany Sandstone

The Oriskany was named by Hall (1839, p. 308-309) from Oriskany Falls, New York. It is a friable gray, medium- to coarse-grained, sandstone that is stained with iron oxide on weathered surfaces. The Oriskany is present in patches along the lower northwest slope of Little North Mountain. 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 sandstone is poorly exposed in the area. The thickness rarely exceeds 25 feet and generally is less than 5 feet. *Costispirifer arenosus* was the only fossil identified.

Needmore Formation

The Needmore shale was proposed by Willard (1939, p. 149) for the shale facies of the Onondaga Group of Pennsylvania. The Needmore Formation and the Millboro Shale were mapped as a unit because of poor exposures. The Needmore is poorly exposed in the Churchville quadrangle. However, from a study of isolated shale chips in the soil cover it may be described as a thin-bedded, dark-gray to olive-green shale with a thin black fissile shale near the base and lenses of argillaceous limestone in the upper portion. The lower contact is unconformable and is well defined where exposed as a shale overlying the Oriskany Sandstone. The upper contact is nowhere exposed in the area, but a small topographic low and small springs and seeps occupy a position about 100 feet above the base and below definite Millboro-type shale near the northwest base of Little North Mountain. The thickness does not exceed 100 feet. Fossils are relatively abundant in the Needmore, especially ostracodes and brachiopods. More than 20 species of ostracodes and at least 12 species of brachiopods are present.

Millboro Shale

The Millboro Shale was named by Butts (1940, p. 308) from exposures at Millboro Springs, Bath County, Virginia. The Millboro is a black, fissile shale that weathers to a buff color. The upper contact is taken as the uppermost black shale below the greenish-gray shale of the Brallier. The thickness is approximately 600 feet. The small brachiopod *Orbiculoidea minuta* was the only fossil identified. The Millboro is correlated with the Marcellus and Hamilton of northern Virginia.

Brallier Formation

The Brallier Formation was named by Butts (1918, p. 523-537) from Brallier, Pennsylvania. The Brallier is a subfissile, stiff, green to gray, micaceous, sandy shale, commonly with uneven or dimpled surfaces (R-3068). 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 State Road 688 for about 0.7 mile northwestward from near its junction with State Highway 42 (Plate 2). The Brallier lies in the belt of conical-shaped hills west of Little North Mountain. The lower contact is discussed under the Millboro Shale. The upper contact is taken below the lowermost zone containing large brachiopods of the Chemung type, and below the lowermost thick sandstone if no fossils are present. The approximate thickness is about 2200 feet.

Chemung Formation

The Chemung Formation was named by Hall (1839, p. 322-326) from Chemung Narrows near Elmira, New York. The formation is composed of greenish-gray, medium-grained, arkosic sandstone (R-3067) and olive-green to greenish-gray shale. In addition to the sandstone and shale several thin beds of conglomerate, up to 1 foot thick, are common near the top (R-3066). Also 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. The lower fossiliferous sandstone and shale are exposed along State Road 688, 0.7 mile northwest of its junction with State Highway 42 (Plate 2). A more complete section may be seen on a "field traverse" along the north side of McKittricks Branch beginning at a location about 1.2 miles northwest of Jerusalem Church. The contact with the Hampshire is placed at the top of the uppermost conglomerate and the base of the lowest thick red-bed sequence. The thickness of the Chemung is about 3000 feet. Brachiopods and pelecypods are common in the Chemung (F-691).

Hampshire Formation

The Hampshire Formation was named by Darton (1892, p. 13-18) from Hampshire County, West Virginia. The Hampshire is composed of moderately thick-bedded, chocolate-brown, medium-grained, arkosic and micaceous sandstone (R-3065) and lumpy, red to green mudrock and shale. Outcrops are present along McKittricks Branch beginning at a location about 1.8 miles northwest of Jerusalem Church. The lower contact is discussed with the Chemung. The overlying Pocono Formation does not occur in the Churchville quadrangle; the portion of the Hampshire Formation that is present is estimated to be about 700 feet thick.

MESOZOIC IGNEOUS ROCKS

Numerous dikes and sill-like igneous bodies occur in the area. All but one of these bodies have an alkalic composition. The alkalic rocks are composed of nepheline syenite, teschenite-syenite, and teschenite-picrite. The nepheline syenite is a porphyritic igneous rock characterized by alkalic feldspar and one or more feldspathoids (in this case nepheline). The dikes are generally dark green and weather to a brownish gray. The phenocrysts are lath-shaped crystals of natrolite and square-shaped crystals of analcite. The nepheline syenite is exposed north of the junction of U. S. Highways 11 and Alternate 11 (R-3064) and at other localities on Plate 1 (R-3053, R-3058, R-3059).

Teschenite-syenite is a coarse- to fine-grained igneous rock composed of labradorite, abundant pyroxene and/or hornblende and/or biotite, and analcite. The rock is reddish brown on weathered exposures, and large greenish-black phenocrysts of hornblende are present. Teschenite-syenite (R-3057) is well exposed along State Road 742, 0.5 mile north of its junction with State Road 613 (Plate 1) (Figure 6).

Teschenite-picrite is a dark reddish-brown igneous rock composed almost entirely of pyroxene, amphibole, and olivine with little or no feldspar or feldspathoid. A small sill-like body of teschenite-picrite occurs on the hill east of State Road 742, 0.5 mile north of its junction with State Road 613 (Plate 1).

Figure 6. Teschenite-syenite dike trending northwestward, 0.5 mile north of the junction of State Roads 742 and 613 (Plate 1).

A diabase dike trends northwestward from near the junction of Pine Run and South River (Plate 4) to a point about 1 mile south of Arbor Hill (Plate 3). The mineral composition is labradorite, pyroxene, olivine, serpentine, magnetite, chlorite, and chromite (Campbell and Cole, 1961, p. 71-72). No evidence of wallrock alteration was found in the adjacent rocks. The dike is well exposed along U. S. Highway 11 just north of its junction with State Road 694 (Plate 3); along State Road 658 just south of U. S. Highway 340 (R-3047); and on the hill about 0.4 mile southeast of the junction of State Roads 697 and 693 (R-3049).

QUATERNARY(?) SYSTEM

Alluvium, gravel, and travertine deposits of questionable Quaternary age occur south of Stuarts Draft, along the east front of Little North Mountain, and in most stream flood plains. These deposits, except the travertine along Folly Mills Creek, are unconsolidated sand and gravel. Alluvial materials along the streams are the most common deposits. All of the major streams have flood plains composed of fine- to coarse-grained sand and gravel. Clay layers have been reported by

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Ries and Somers (1920, p. 17, 19, 110) from the area southeast of Stuarts Draft along South River.

Extensive gravel deposits occur south of Stuarts Draft (Plate 4) and east of Little North Mountain (Plate 2). South of Stuarts Draft the gravels are derived from the weathering of the sandstones in the Chilhowee Group. The gravels in this area are highly weathered and crumble to sand when broken with a hammer. They have a thickness in excess of 165 feet as estimated from wells drilled in the terrace gravels south of Stuarts Draft. East of Little North Mountain the gravels are more resistant, being derived from the Tuscarora, Cacapon, Keefer, Brallier, and Chemung formations. These deposits form large gravel and sand fans to the east of gaps in the mountain.

Travertine occurs along Folly Mills Creek along State Road 654, 0.6 mile west of its junction with U. S. Highway 11 (Plate 4). The travertine is porous, tannish, impure calcium carbonate. Plant fragments and leaves are common in the deposit. The thickness could not be determined, but a waterfall and exposures along the creek bank indicate that the thickness is greater than 15 feet (Figure 7).

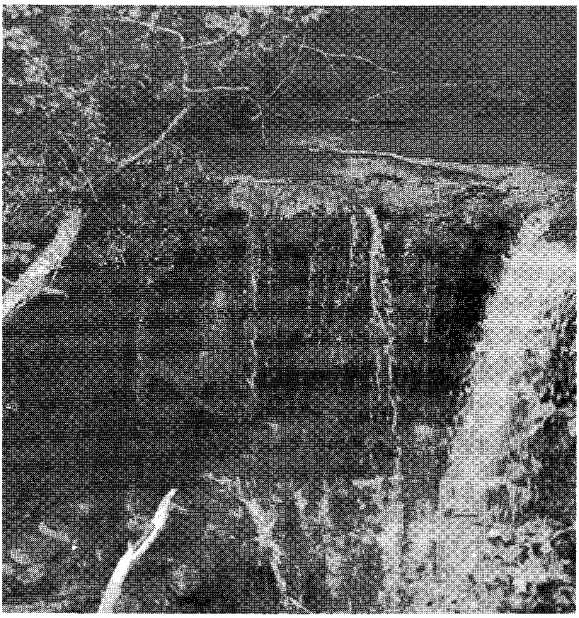

Figure 7. Falls on Folly Mills Creek, 100 yards south of Folly Mills (Plate 4); water flows over travertine mass.

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STRUCTURE

During late Paleozoic time or possibly continuing throughout most of the Paleozoic, the area was subjected to deforming forces. Sedimentary rocks were inclined at moderate and steep angles to the almost horizontal position in which they had been deposited. These rocks are folded in a series of northeastward-trending anticlines and synclines that are divided into the Massanutten synclinorium on the east (Plates 1, 4), the Middlebrook anticline from the southwest portion (Plate 3) to the northeast portion (Plate 1), and the Long Glade syncline on the west (Plates 1-3). There are two major zones in which the strata are broken: the Pulaski-Staunton fault between the Massanutten synclinorium and the Middlebrook anticline, and the North Mountain fault west of the Long Glade syncline. The folds and faults are described in order of their geographic occurrence from east to west.

MASSANUTTEN SYNCLINORIUM

The major fold structure of the Shenandoah Valley is the Massanutten synclinorium. This synclinal complex is bounded by the Blue Ridge (not in area mapped) on the east and the Pulaski-Staunton fault on the west. Shales and sandstones of the Martinsburg Formation are the youngest rocks in the trough of the synclinorium west of longitude 79°. The axis trends about N. 40°E., and the axes of minor anticlinal and synclinal structures on the east flank are about N. 70° E. and N. 50° E. They have been tightly compressed, and faults with displacements of less than 200 feet, slip cleavage, and folds are present.

The folds on the flanks of the synclinorium are best reflected in the outcrop pattern of the Conococheague and Lincolnshire limestones. In the vicinity of White Hill, north of Mint Spring on U. S. Highway 11, and north of the junction of U. S. Highways 250 and 11, the folds are well defined. Northeast of the junction of U. S. Highways 11 and 340 the rocks are broken by the Fairfield fault. The sandstones of the Conococheague clearly reflect the minor folding near Mint Spring and southwest of Staunton (Plates 1, 3, 4).

BRECCIA NEAR FOLLY MILLS

Just east of Folly Mills along State Road 654, approximately 1000 feet of breccia is exposed in the roadcut. The contact between the Conococheague and the overlying Chepultepec Formation is masked for about 1 mile by nearly the entire length of the northeastward-trending breccia. The dip of these formations ranges from 70° to 85°. A much smaller pod of breccia, 300 by 800 feet, occurs within the Conococheague Formation and is located about 0.1 mile to the north. At the west end of the roadcut, milled fragments of carbonate rock are cemented by fine-grained calcite; slickensided surfaces are present. About 30 feet east of this material are fragments of limestone and dolomite in a matrix of claystone. East of the claystone, and making up more than three-fourths of the outcrops in the roadcut, is a collapse breccia composed of angular fragments and blocks of carbonate rock cemented by white dolomite (Figure 8). A possible sequence of events leading to the development of the collapse breccia is that of fault movement, dissolution of adjacent carbonate rock, and development of a cavern, followed by loosening, dissolution, and collapse of fragments and blocks from the unsupported cavern roof, and finally cementation of the fragments and blocks by dolomite.

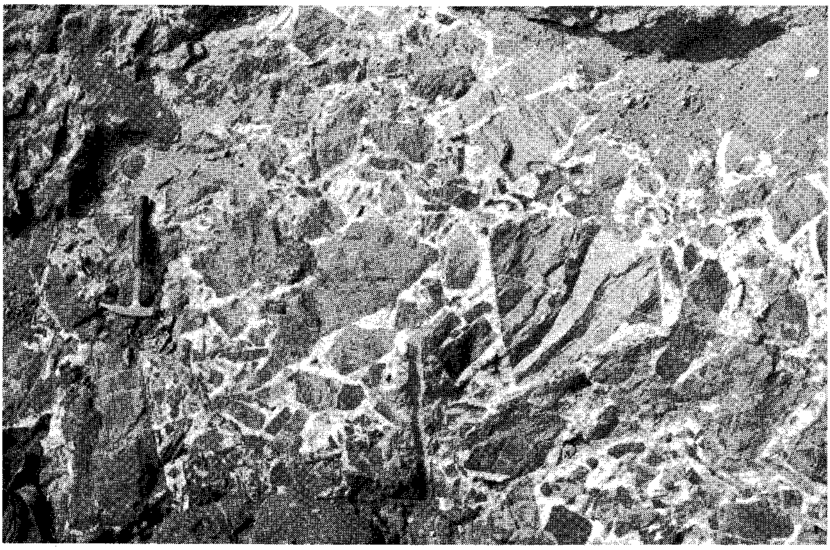
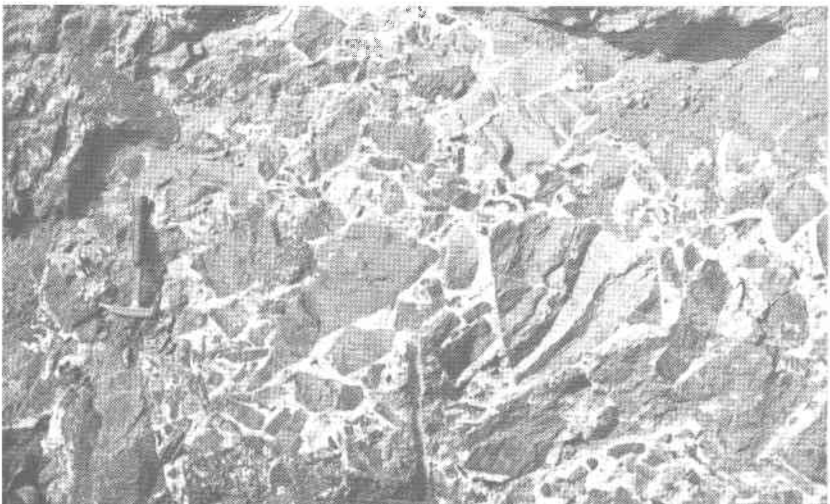


Figure 8. Collapse breccia composed of limestone and dolomite of the Conococheague and Chepultepec formations along State Road 654 about 100 yards east of Folly Mills (Plate 4).

PULASKI-STAUNTON FAULT

The Pulaski-Staunton fault trends northeastward from an area about 2.5 miles west of Greenville (Plate 3) through Oak Grove Church (Plate 4), Gypsy Hill Park in Staunton (Plate 1) to Quicks Mill. North of Quicks Mill it makes a loop to the northwest and from there trends southwestward to Huckleberry Hill. It makes another loop to the smaller pod of breccia, 300 by 800 feet, occurs within the Conococheague Formation and is located about 0.1 mile to the north. At the west end of the roadcut, milled fragments of carbonate rock are cemented by fine-grained calcite; slickensided surfaces are present. About 30 feet east of this material are fragments of limestone and dolomite in a matrix of claystone. East of the claystone, and making up more than three-fourths of the outcrops in the roadcut, is a collapse breccia composed of angular fragments and blocks of carbonate rock cemented by white dolomite (Figure 8). A possible sequence of events leading to the development of the collapse breccia is that of fault movement, dissolution of adjacent carbonate rock, and development of a cavern, followed by loosening, dissolution, and collapse of fragments and blocks from the unsupported cavern roof, and finally cementation of the fragments and blocks by dolomite.



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Large masses of breccia and "crush conglomerate" are associated with the Pulaski-Staunton fault. The distribution of these breccia masses is depicted on Plates 1, 3, and 4. Three well-exposed localities are: along U. S. Highway 250 across from the west end of Gypsy Hill Park (Figure 9) in Staunton (Plate 1), southeast of Arbor Hill along State Road 697 about 0.3 mile east of its junction with State Road 693 (Plate 3), and west of Greenville along State Road 674 about 1.1 miles southeast of its junction with State Road 670 (Plate 3).

Figure 9. Upper megabreccia in the Pulaski-Staunton fault along U. S. Highway 250, across from Gypsy Hill Park in Staunton (Plate 1).

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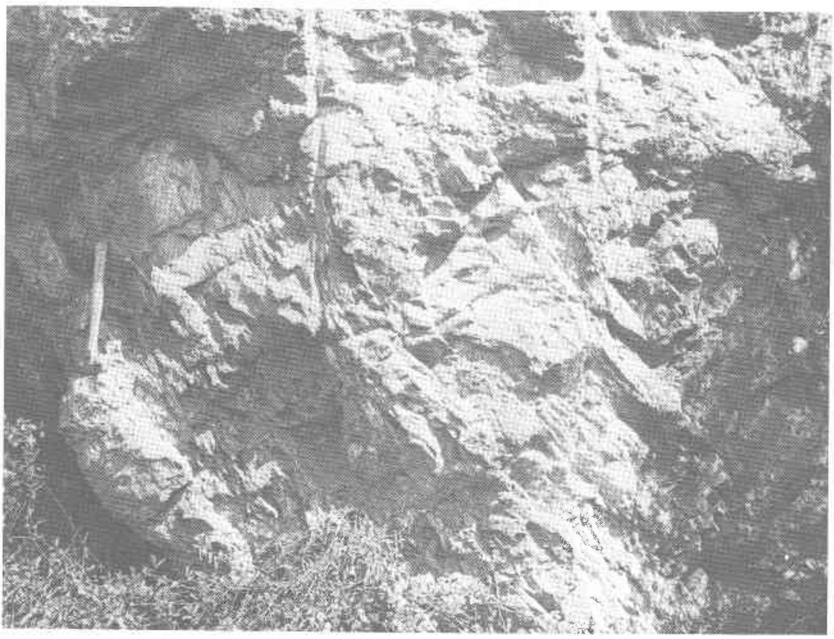

Figure 9. Upper megabreccia in the Pulaski-Staunton fault along U. S. Highway 250, across from Gypsy Hill Park in Staunton (Plate 1).

The largest area of exposed breccia is west of Greenville where the outcrop width is greater than 4000 feet. In areas where limestone and dolomite are present in both the hanging wall and footwall, the breccia can be divided into three zones: a lower megabreccia composed of blocks of Elbrook, Beekmantown, New Market, and Lincolnshire limestone and dolomite surrounded by crush conglomerate; a middle zone of crush conglomerate (Figure 10) composed of fragments of Elbrook, Beekmantown, New Market and Lincolnshire rocks (R-3052, R-3060, R-3062); and an upper megabreccia composed of fractured blocks of Elbrook limestone and dolomite surrounded by crush conglomerate.

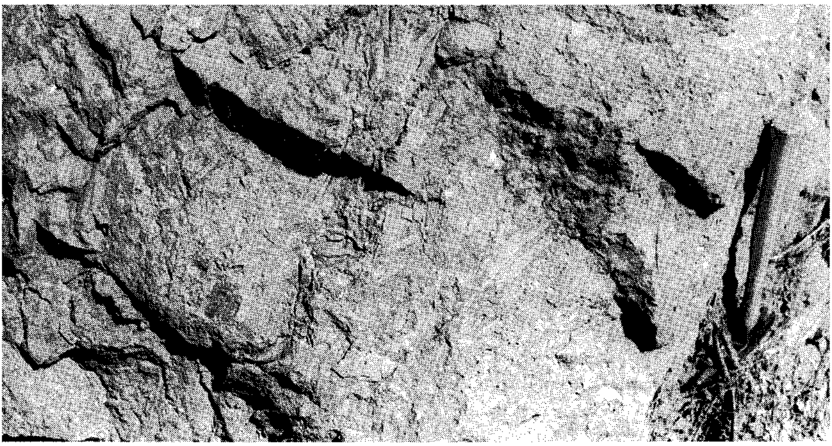

Figure 10. Crush conglomerate in the Pulaski-Staunton fault along State Road 687 about 0.3 mile east of the junction with State Road 693 (Plate 3).

Breccias similar to those described above occur along the Pulaski and Max Meadows faults in Montgomery and Pulaski counties (Cooper, 1961, p. 86). There is some evidence to support the connection of the Pulaski and Staunton fault zones, (Bick, 1960; Edmundson, 1958).

MIDDLEBROOK ANTICLINE

Northeastward from Middlebrook through Arbor Hill (Plate 3) a gently curving anticlinal trace extends to a location near Thackers Hollow (Plate 1) in the northeast portion of the area studied. This anticlinal structure is referred to as the Middlebrook anticline and is so designated from the town of the same name. The Elbrook Formation is the oldest unit exposed in the anticline and the Lincolnshire, the

The largest area of exposed breccia is west of Greenville where the outcrop width is greater than 4000 feet. In areas where limestone and dolomite are present in both the hanging wall and footwall, the breccia can be divided into three zones: a lower megabreccia composed of blocks of Elbrook, Beekmantown, New Market, and Lincolnshire limestone and dolomite surrounded by crush conglomerate; a middle zone of crush conglomerate (Figure 10) composed of fragments of Elbrook, Beekmantown, New Market and Lincolnshire rocks (R-3052, R-3060, R-3062); and an upper megabreccia composed of fractured blocks of Elbrook limestone and dolomite surrounded by crush conglomerate.

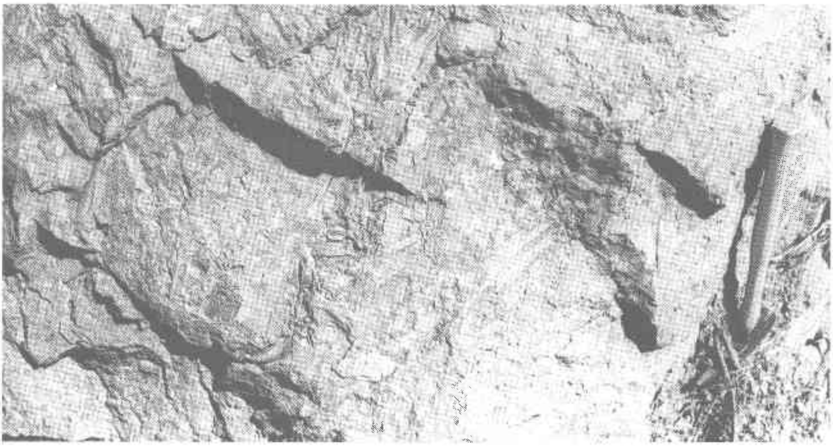

Figure 10. Crush conglomerate in the Pulaski-Staunton fault along State Road 687 about 0.3 mile east of the junction with State Road 693 (Plate 3).

Breccias similar to those described above occur along the Pulaski and Max Meadows faults in Montgomery and Pulaski counties (Cooper, 1961, p. 86). There is some evidence to support the connection of the Pulaski and Staunton fault zones, (Bick, 1960; Edmundson, 1958).

MIDDLEBROOK ANTICLINE

Northeastward from Middlebrook through Arbor Hill (Plate 3) a gently curving anticlinal trace extends to a location near Thackers Hollow (Plate 1) in the northeast portion of the area studied. This anticlinal structure is referred to as the Middlebrook anticline and is so designated from the town of the same name. The Elbrook Formation is the oldest unit exposed in the anticline and the Lincolnshire, the youngest. The east flank is bounded principally by the Pulaski-Staunton fault, and the west flank is adjacent to the Long Glade syncline. Northwest of Verona the Middlebrook anticline has a gentle plunge to the northeast. Included in this anticlinal structure are rocks of the overthrust block of the Pulaski-Staunton fault; the rocks above and below the fault plane are incorporated in the same fold.

LONG GLADE SYNCLINE

The axial trace of the Long Glade syncline extends from the north-central portion of the Staunton quadrangle (Plate 1) through a location about 0.5 mile east of Franks Mill, through Hebron (Plate 2) and Sugarloaf (Plate 3) to a location about 1 mile northwest of Middlebrook. The general trend of the syncline is approximately N. 55° E. The Conococheague Formation is the oldest unit exposed and the Edinburg, the youngest. At Hebron the syncline has a noticeable northeasterly plunge as indicated by the broad outcrop of the Beekmantown Formation. In the area between Middle River and State Road 740 and north of Huckleberry Hill the Long Glade syncline branches into a northeastward-trending subsidiary syncline that may terminate near the Middlebrook anticline about 1 mile north of Thackers Hollow. An intervening structure between the main and branch synclines is an overturned anticline; the oldest rock exposed is the Beekmantown Formation. Tectonically, a portion of the upper plate of the Pulaski-Staunton fault has been superposed and folded with rocks forming the subsidiary syncline. The oldest rocks in the fault plate are part of the Elbrook Formation and the youngest, part of the overlying Conococheague Formation. The west limb of the Long Glade syncline, just north of Franks Mill, is cut by three minor transverse faults that have strikes ranging from about N. 35° W. to N. 60° W. (Plate 1). The maximum offset is about 0.2 mile. Silicified breccia occurs along these faults (R-3054 to R-3056) (Figure 11).

NORTH MOUNTAIN FAULT AND ASSOCIATED STRUCTURES

Little North Mountain, the western boundary of the Shenandoah Valley, extends northeastward from Rockbridge County to Frederick County, Virginia. Approximately 6.5 miles of the ridge crosses the northwestern portion of the Churchville quadrangle (Plate 2.) The elevation of the crest ranges from 1060 feet north of McKittricks Branch to 2697 feet south of Buffalo Gap (Figure 12).

Figure 11. Silicified breccia in transverse fault north of Franks Mill at the junction of State Roads 732 and 733 (Plate 1).

Figure 12. Buffalo Gap (viewed from the east). The south side of the gap is 170 feet higher than the north side due to the steeper dip and a general thinning of the Tuscarora Formation to the north (Plate 2).

The structure and stratigraphy of Little North Mountain have been the subject of numerous detailed reports, three of which contain discussions of the mountain in the Churchville quadrangle (Darton, 1894; Butts, 1940; Fitzgerald, 1966). Structurally, Little North Mountain is interpreted as a faulted overturned anticline with steep southeasterly dips, which is bounded on the east by the North Mountain fault and on the west by a broad syncline (Butts and Edmundson, 1939, 1966; Brent,

Figure 11. Silicified breccia in transverse fault north of Franks Mill at the junction of State Roads 732 and 733 (Plate 1).

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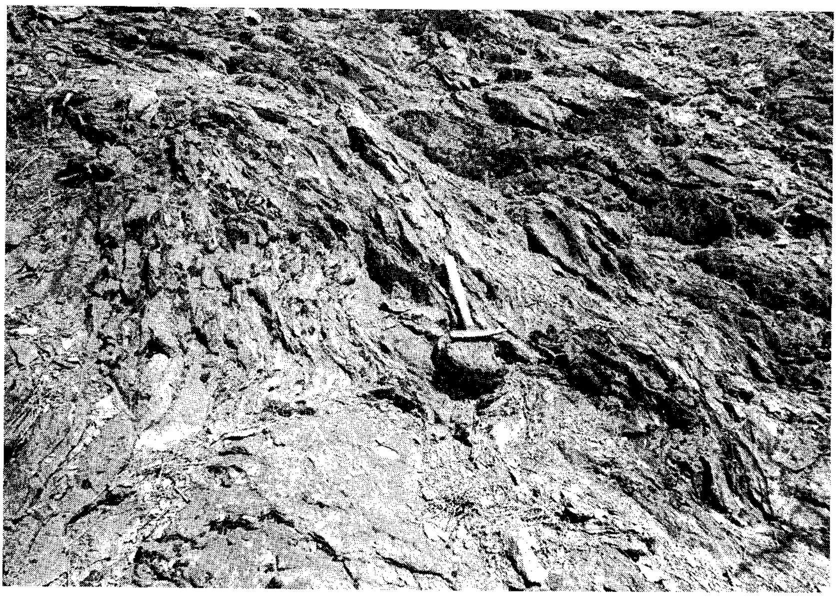

Figure 13. Deformed Edinburg Formation in the footwall of the North Mountain fault, 1.5 miles west of Lone Fountain (Plate 2).

Little North Mountain has at least three minor transverse faults. In several places north of Buffalo Gap a minor fault parallel to the North Mountain fault has caused the Martinsburg Formation to be thrust over the Tuscarora and part of the Cacapon. The only evidence of a fault west of the ridge crest is at Buffalo Gap where part of the Cayuga Group is absent; however, such absence may represent only partial deposition of the group. South of Buffalo Gap the overturned Keefer is folded into a tight overturned anticline and syncline (Figure 14). On the southeast slope of Little North Mountain west of Camp Shenandoah the overturned Tuscarora Formation is folded into an anticline (Plate 2, Section C-C′).

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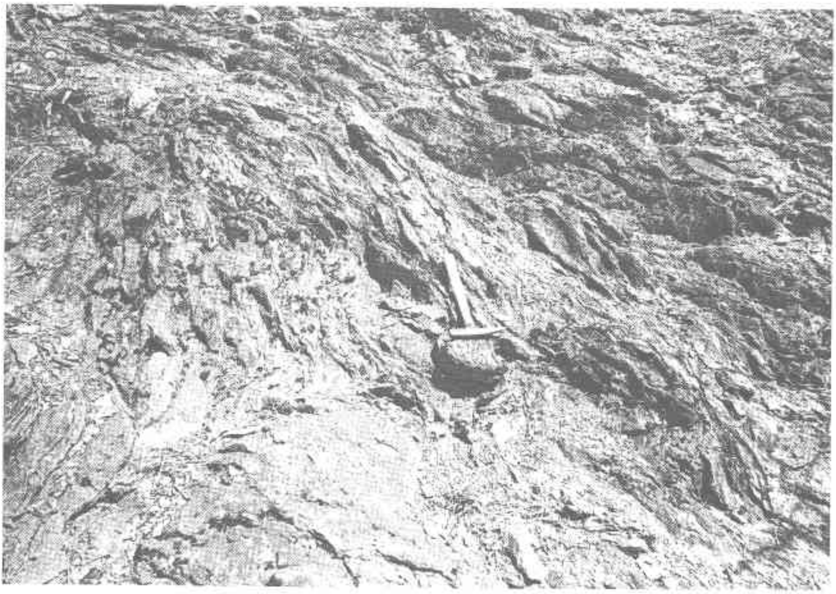

Figure 13. Deformed Edinburg Formation in the footwall of the North Mountain fault, 1.5 miles west of Lone Fountain (Plate 2).

Little North Mountain has at least three minor transverse faults. In several places north of Buffalo Gap a minor fault parallel to the North Mountain fault has caused the Martinsburg Formation to be thrust over the Tuscarora and part of the Cacapon. The only evidence of a fault west of the ridge crest is at Buffalo Gap where part of the Cayuga Group is absent; however, such absence may represent only partial deposition of the group. South of Buffalo Gap the overturned Keefer is folded into a tight overturned anticline and syncline (Figure 14). On the southeast slope of Little North Mountain west of Camp Shenandoah the overturned Tuscarora Formation is folded into an anticline (Plate 2, Section C-C′).

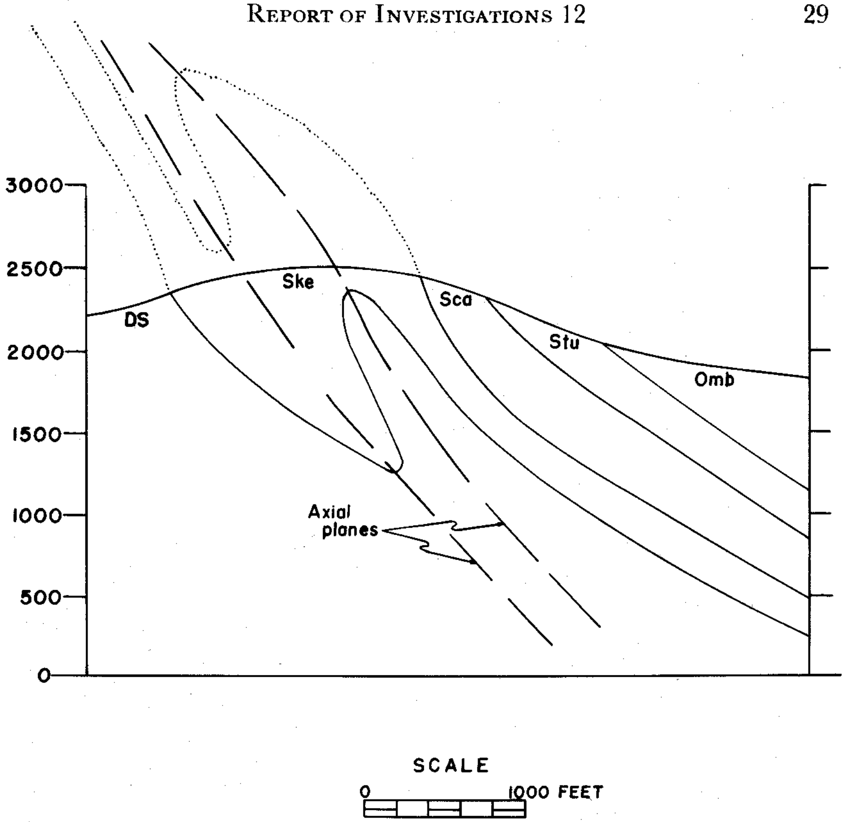

Figure 14. Cross-section showing structural configuration of the Keefer Sandstone, 0.9 mile southwest of Buffalo Gap (Plate 2). Symbols are: DS, Lower Devonian-Upper Silurian, undivided; Ske, Keefer Sandstone; Sca, Cacapon Formation; Stu, Tuscarora Formation; and Omb, Martinsburg Formation.

MINERAL RESOURCES

GROUND WATER

Records are available for 145 water wells located within the area studied and may be examined at the Virginia Division of Mineral Resources in Charlottesville. Examination of these records reveals the close relationship between ground-water conditions and the geologic environment in which they occur. The following are pertinent facts regarding these wells: most wells have been drilled to obtain only the small quantities of water needed for domestic or farm use; the majority of wells are less than 300 feet deep and are 5 and 6 inches in diameter; reported yields do not reflect aquifer capacity because too few adequate pump tests have been conducted; although the principal aquifers are reported to occur in the first 300 feet below ground level, too few deep wells have been drilled to evaluate the aquifer potential at greater depths; thick gravel and alluvial deposits along South River may yield industrial quantities of water from relatively shallow, large-diameter wells; quantities of water for public and industrial use are available from wells drilled at selected hydrogeologic sites; and topographic location and surface drainage are important factors relating to productivity of wells.

Table 2.—Depth and average reported yield of 145 wells relative to initial formation drilled.

Formation	*Depth (feet)*	*Number of Drilled Wells*	*Average Yield (gallons/minute)*
Elbrook	0-100	3	18
	100-200	9	14
	200-300	4	15
	over 300	4	3
Conococheague	0-100	10	11
	100-200	18	12
	200-300	9	61
	over 300	10	53
Chepultepec	0-100	2	2
	100-200	1	9
	200-300	1	10
Beekmantown	0-100	6	27
	100-200	21	23
	200-300	11	12
	over 300	16	21
Lincolnshire	0-100	1	20
	100-200	3	9
	200-300	1	10
Edinburg	100-200	3	6
	200-300	2	5
	over 300	4	12
Martinsburg	100-200	4	10
	200-300	1	5
	over 300	1	22

Analyses of water samples collected from several wells in the area studied indicate that the chemical quality of ground water is generally indicative of the rock formation from which it was obtained. Waters obtained from limestone aquifers have a range in total hardness values from about 140 ppm (parts per million) to 355 ppm and pH values from 7.0 to 7.7. In examining the compilation of well data two facts are important in the use of Table 2: several water-bearing zones are encountered in many wells, and therefore the total depth is not always indicative of the depth at which the water occurs; and the ground-water potential of a formation is difficult to evaluate where only a few wells have been drilled.

Although the presence of water may be partially dependent upon rock type, the amount of topographic relief and abundance of fractures are in many cases more important in determining its availability. The data in Table 2 are retabulated in Table 3 to illustrate the relationship between the depth and yield of the 145 wells.

Table 3.—Relationship between depth and yield of wells (consolidated from Table 2).

		Yield	
Depth (feet)	*Number of Drilled Wells*	*Range (gallons/minute)*	*Average (gallons/minute)*
0-100	22	1-100	17
100-200	60	< 1-175	16
200-300	27	1-284	22
300-400	16	< 1- 30	7
400-500	8	< 1-215	56
over 500	12	1-140	25

INDUSTRIAL LIMESTONE AND DOLOMITE

The four quadrangles discussed in this report are underlain, for the most part, by carbonate rocks of various types. Large quantities of limestone and dolomite are present which meet the qualifications for many industrial uses. Edmundson (1945, 1958) discussed the distribution of the carbonate rocks in Augusta County and included chemical analyses; the interested reader is referred to these reports for details.

The carbonate rocks in the area may be divided into three major groups based on chemical composition: (1) high-calcium limestone, (2) impure limestone, and (3) limestone, magnesian limestone, and dolomite. Three formations contain high-calcium limestone (over 95 percent calcium carbonate): the upper part of the Beekmantown Formation, the New Market Limestone, and the Murat limestone of the Lincolnshire Formation. The thickness of the New Market averages 30 feet, although in some areas it may be absent, and north of White Hill the thickness may be as much as 200 feet. North of White Hill and south of Barterbrook (Plate 4), the Murat limestone is about 160 feet thick. West of the Pulaski-Staunton fault the Lincolnshire contains more than 5 percent chert. The upper part of the Beekmantown contains 100 to 300 feet of high-calcium limestone; however, dolomites or impure limestones are interbedded with the high-calcium limestone in most sections. The principal deposits of high-calcium limestone occur in a narrow belt that parallels U. S. Highway 11 from Verona to near Greenville and from there trends northeastward toward Barterbrook (Plates 1, 4). High-calcium limestones may be used as flux and agricultural stone and in the manufacture of dye, fertilizers, 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 (more than 5 percent noncarbonate material) occurs in, excluding those formations which have abundant dolomite, the Chepultepec, the Lincolnshire, and the Edinburg formations. The Chepultepec is present in all four quadrangles. It outlines the Massanutten and Long Glade synclines and the Middlebrook anticline. The average thickness is 350 feet. The Lincolnshire and Edinburg have the same distribution as the high-calcium limestones. These limestones may be useful in the manufacture of cement, hydraulic lime, and explosives and in the production of agricultural limestone and crushed stone.

The three 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, Conococheague, and Beekmantown. Their distribution is shown on Plates 1-4. These rocks may be used for the production of agricultural stone and crushed stone.

Most of the carbonate rock quarried in the area is used for highway construction (Plate 1, Nos. 2, 6, 7, 9; Plate 3, No. 23). Two quarries grind lime for agricultural uses (Plate 1, Nos. 6, 9). The other quarries indicated on the maps are abandoned but were used as sources of aggregate for highway construction.

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 burning 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. Magnesium carbonate occurs in some limestones, but is not a necessary component.

Some of the limestones and shales in the four-quadrangle area are potential sources of raw material. 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.

CLAY, SHALE, AND RELATED MATERIALS

A portion of an early report on the clay and shale resources of Virginia west of the Blue Ridge contained detailed physical data on 12 samples (Ries and Somers, 1920). Eleven of the samples were residual clays derived from the dissolution of Cambrian and Ordovician carbonates. One sample was flood-plain clay. Seven of the samples were from the Stuarts Draft area and may be suitable for use in the manufacture of brick or tile. The other five were from Staunton, and, except for one sample that contains residual Beekmantown chert, the clay may be useful in the manufacture of brick. A recent report (Calver and others, 1964) contains evaluation data on materials from five localities in the area. The potential uses of three of these raw materials are compiled in Table 4.

Table 4.—Potential uses of clay materials from Staunton, Churchville, and Greenville quadrangles (data compiled from Calver and others, 1964).

Repository No.	*Location*	*Formation*	*Sample Interval*	*Potential Use*
R-1622	North side of State Road 688 about 0.6 mile northwest of the intersection with State Highway 42 at Buffalo Gap (Plate 2).	Brallier	Composite sample across 75 feet of shale	Common brick and tile
R-1626	Abandoned clay pit, 2.6 miles south of Middlebrook, on the west side of State Road 670 about 0.2 mile south of the intersection with State Road 674 (Plate 3).	Residual clay	Composite sample representing all clays exposed in pit	Super-duty refractories and colored ceramic ware
R-1664	Roadcut, on the eastern city limits of Staunton, on the northwest side of U. S. Highway 11 about 0.7 mile northeast of the intersection of U. S. Highways 11 and 250 (Plate 1).	Edinburg	Composite sample across 105 feet of shale	Common red brick and lightweight aggregate

Bauxite was mined west of State Road 670, 0.2 mile southwest of its junction with State Road 674 (Allen mine, Plate 3, No. 21) by Republic Mining and Manufacturing Company and on the hill southeast of the same junction (Harris mine, Plate 3, No. 22) (Warren and others, 1965, p. 10). Operation of the pits began in 1941 and continued intermittently through 1946. There is no evidence of an extensive deposit. The pit west of State Road 670 is now filled with water.

SAND AND GRAVEL

Three sandstone formations are present in the area, the Tuscarora, Keefer, and Oriskany. Sand is also associated with the Blue Ridge terrace south of Stuarts Draft. Large quantities of gravel are present along the east front of Little North Mountain.

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. Samples have been described and analyzed from these formations at other localities in the State (Lowry, 1954). The Oriskany Sandstone is poorly exposed along the northwest base of Little North Mountain. Iron oxide stained sandstones and friable blocks were found where the Oriskany is present. Generally the thickness is less than 25 feet. Analyses of the Oriskany are reported by Lowry (1954).

South of Stuarts Draft the terrace developed along the west front of the Blue Ridge contains large quantities of sand and gravel. This material is more than 165 feet thick in several places. Just south of the area, sand is being produced from the terrace. The gravel is friable to a considerable depth, and a small crusher would be sufficient to reduce the material to sand size.

IRON ORE

Several old iron-ore pits are present along Little North Mountain a short distance north and south of Buffalo Gap (Plate 2). It is believed that they were worked right after the Civil War, possibly to supply ore for a furnace in the Craigsville or Augusta Springs area. An iron-ore mine in the lower Beekmantown (Plate 3, No. 24) was operated near the end of the nineteenth century. The main shaft was about 25 feet deep and had several drifts. Ore rocks found near the opening appear to be of a weathered high-grade material, but no extensive surficial deposits were found.

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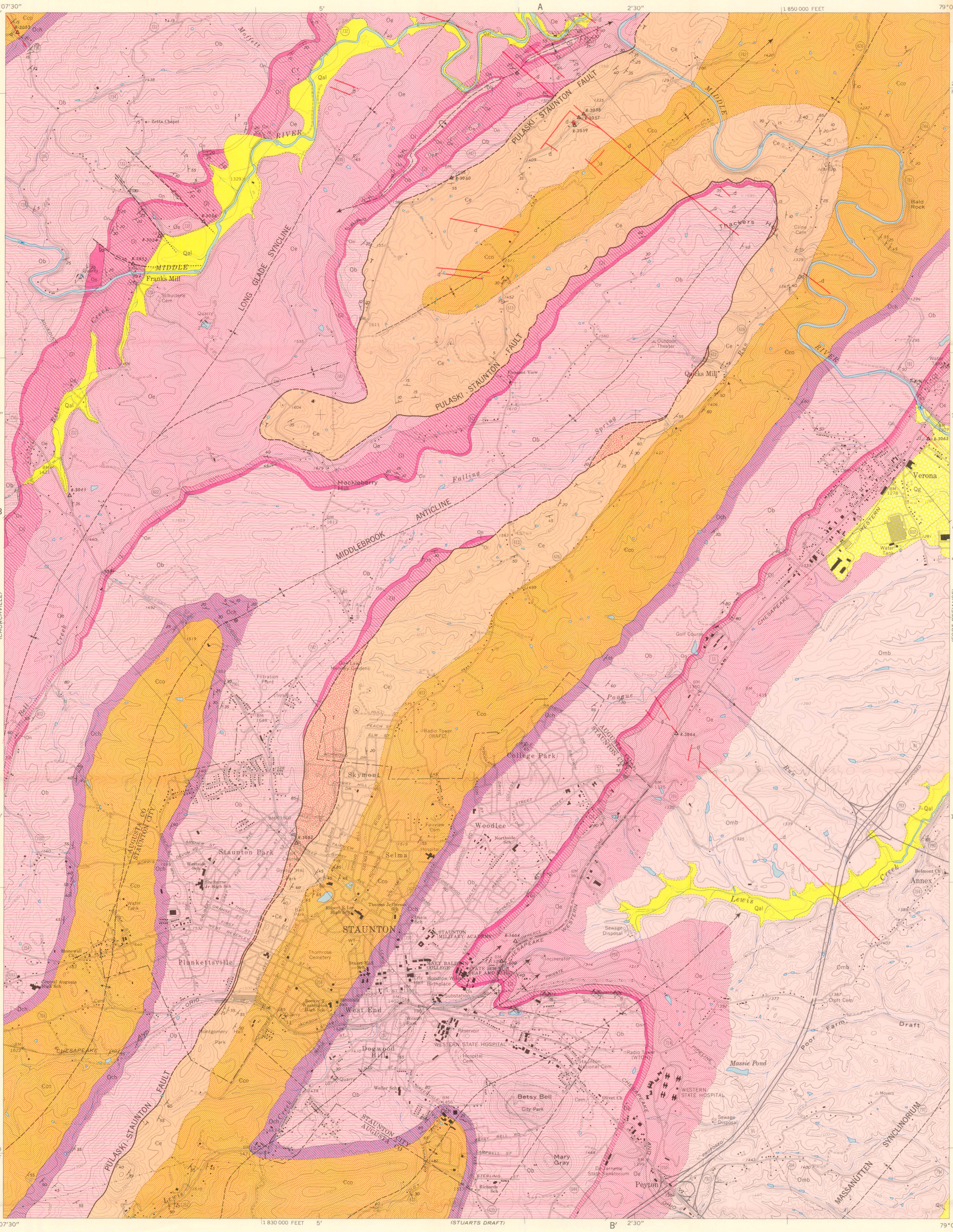
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES
James L. Calver
Commissioner of Mineral Resources and State Geologist



Base From U.S. Geological Survey 1964, Staunton Quadrangle, 7½-Minute Series

Williams & Heintz Map Corporation
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GEOLOGIC MAP OF THE STAUNTON QUADRANGLE, VIRGINIA

Geology by Eugene K. Rader

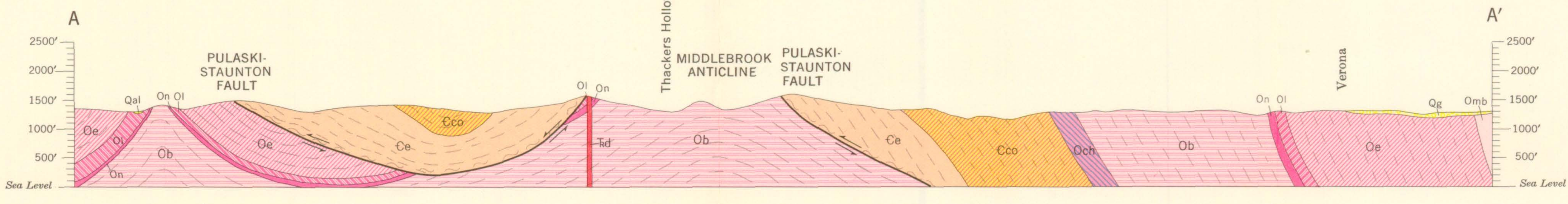
1964 MAGNETIC DECLINATION

SCALE 1:24 000

CONTOUR INTERVAL 40 FEET

QUADRANGLE LOCATION

1967



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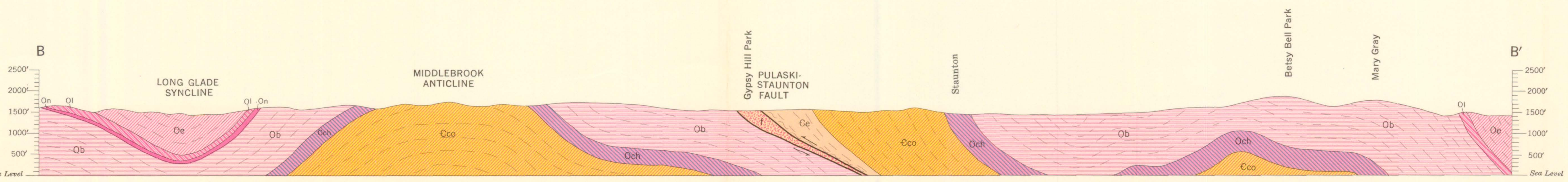


EXPLANATION

CENOZOIC — QUATERNARY

- Qal — Alluvium
- Qg — Terrace gravel

MESOZOIC

- d — Alkalic dike
  Nepheline syenite, teschenite-syenite, and teschenite-picrite.

PALEOZOIC — ORDOVICIAN

- Omb — Martinsburg Formation
  Olive-green to gray, subfissile shale and fine-grained, thin-bedded sandstone.
- Oe — Edinburg Formation
  Dark-gray to black, argillaceous limestone and black, fissile, graptolitic shale.
- 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 nodules; lower part contains siliceous laminae that are exposed in relief on weathered surfaces.

PALEOZOIC — 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.

- f — Breccia
  f, *fault breccia, large blocks of dolomite, limestone, and shaly dolomite with crush conglomerate.*

CONTACTS

exposed
approximate
covered

FOLDS

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

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

Overturned anticline—approximate trace of axial plane and direction of plunge of axis

FAULTS

THRUST

exposed
approximate
covered
T overthrust side

TRANSVERSE

approximate
covered

Arrows indicate relative movement

ATTITUDE OF ROCKS

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

QUARRIES

ACTIVE QUARRY
2. Augusta Stone Corporation
6. State Lime Quarry No. 1
8. Valley Stone Company
9. Belmont Trap Rock Company

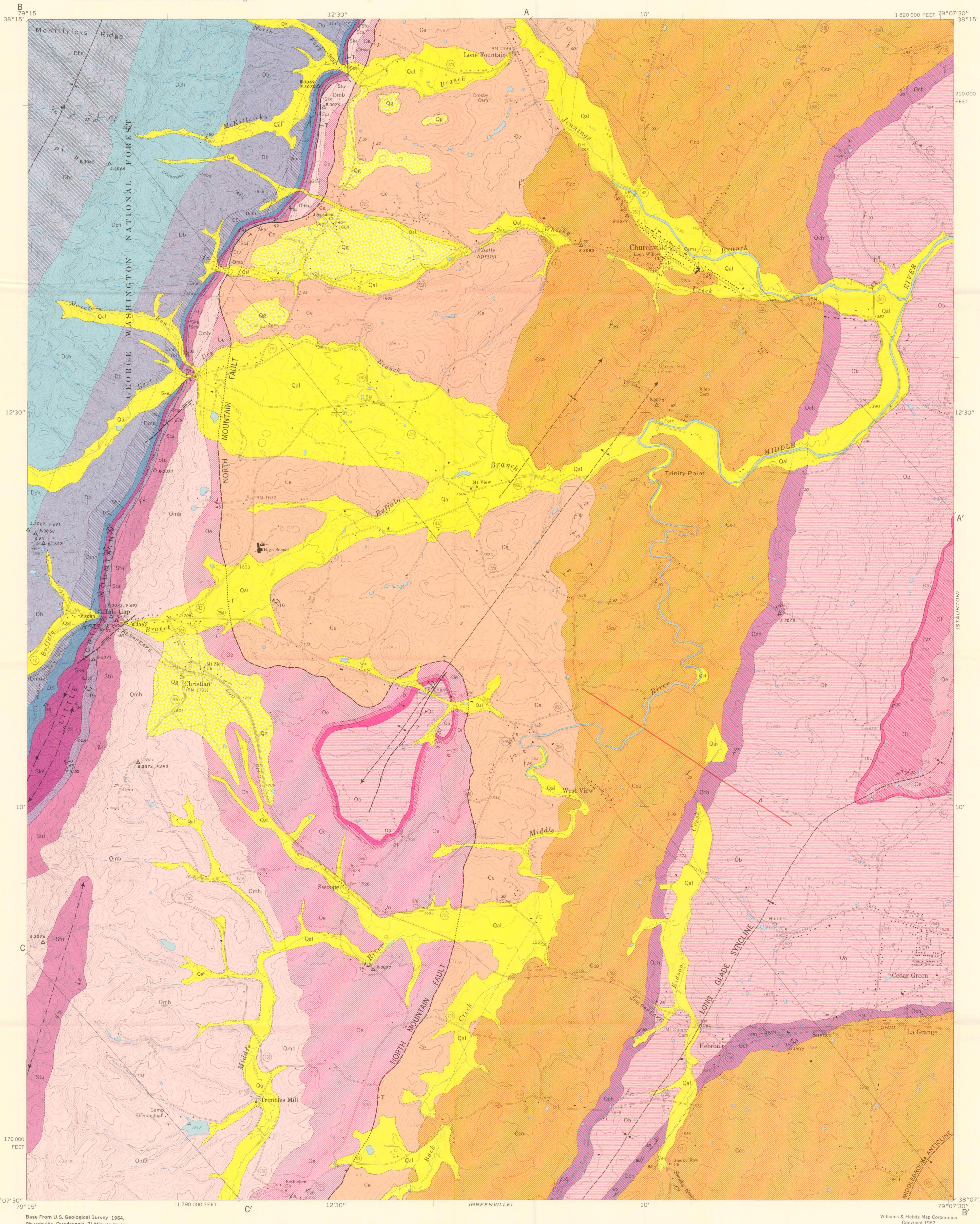
ABANDONED QUARRY
1. Augusta Stone Corporation
3. Crushed-stone quarry
4. Bowling quarry
5. Crushed-stone quarry
7. Crushed-stone quarry
10. Crushed-stone quarry
11. Crushed-stone quarry
12. Crushed-stone quarry

SAMPLE LOCATIONS

R-3055 Locations of samples representative of various lithologies mapped.

F-600 Locations of fossils collected.

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



Base From U.S. Geological Survey 1964, Churchville Quadrangle, 7½-Minute Series

Williams & Heintz Map Corporation
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GEOLOGIC MAP OF THE CHURCHVILLE QUADRANGLE, VIRGINIA

Geology by Eugene K. Rader

1964 MAGNETIC DECLINATION

SCALE 1:24 000

CONTOUR INTERVAL 40 FEET

QUADRANGLE LOCATION

1967

EXPLANATION

CENOZOIC — QUATERNARY

Qal — Alluvium

Qg — Terrace gravel

MESOZOIC

d — Alkalic dike
Nepheline syenite, teschenite-syenite, and teschenite-picrite.

PALEOZOIC

DEVONIAN

Dhs — Hampshire Formation
Chiefly red shale, mudrock, and sandstone.

Dch — Chemung Formation
Chiefly gray shale and sandstone with thin conglomerates and a few red zones.

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.

SILURIAN-DEVONIAN

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: gray to white, medium- to coarse-grained limestone with sandstone near the middle; and Tonoloway Formation: medium- to dark-gray, thin-bedded, argillaceous limestone.

SILURIAN

Ske — Keefer Sandstone
Gray, medium- to thick-bedded sandstone.

Sca — Cacapon Formation
Red and green shales, gray sandstone, and ferruginous quartzite.

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

ORDOVICIAN

Omb — Martinsburg Formation
Olive-green to gray, subfissile shale with argillaceous sandstone at top.

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 nodules; lower part contains siliceous laminae that are exposed in relief on weathered surfaces.

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—approximate trace of axial plane and direction of plunge of axis
Syncline—approximate trace of axial plane and direction of plunge of axis
Axial trace of minor fold on overturned limb of larger fold and direction of plunge of axis.

FAULTS

THRUST

exposed
approximate
covered
T overthrust side

TRANSVERSE

approximate
covered
Arrows indicate relative movement

ATTITUDE OF ROCKS

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

QUARRIES AND MINES

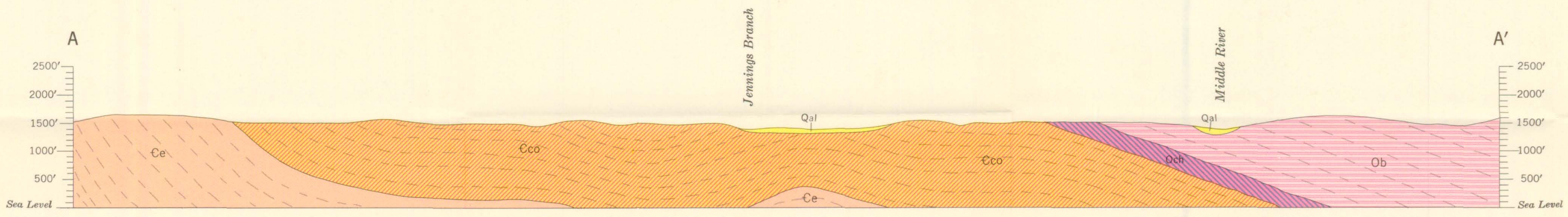
ABANDONED QUARRY OR MINE

13. Iron-ore mine
14. Iron-ore mine
15. Iron-ore mine
16. Crushed-stone quarry
17. Crushed-stone quarry
18. Crushed-stone quarry
19. Lime quarry

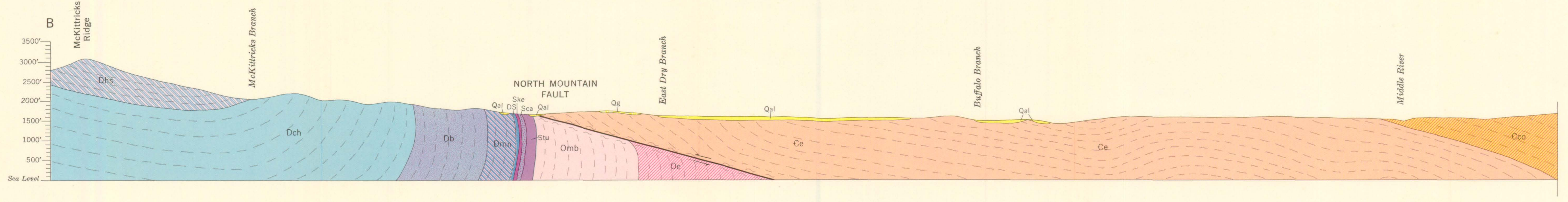
SAMPLE LOCATIONS

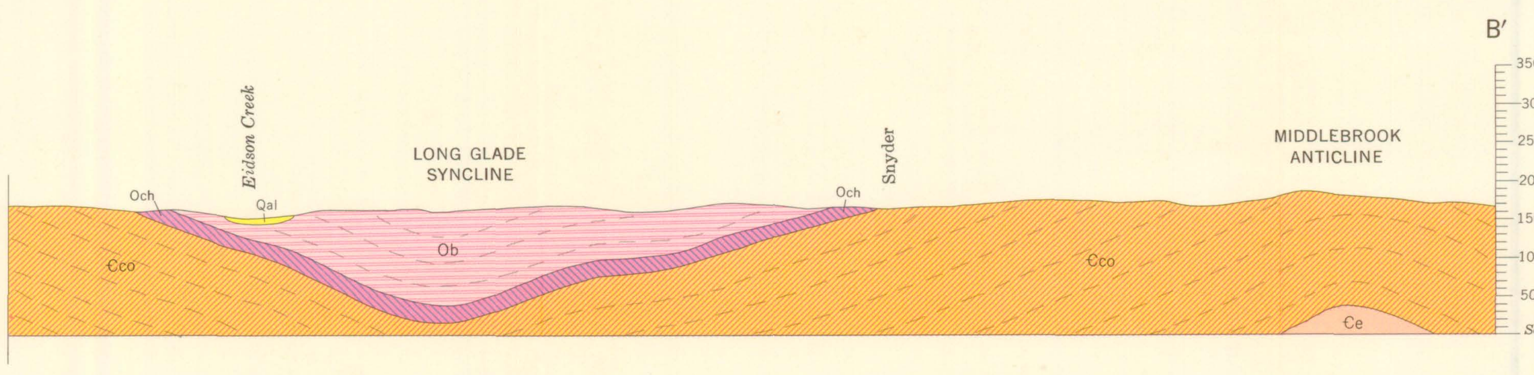
R-3065 Locations of samples representative of various lithologies mapped.

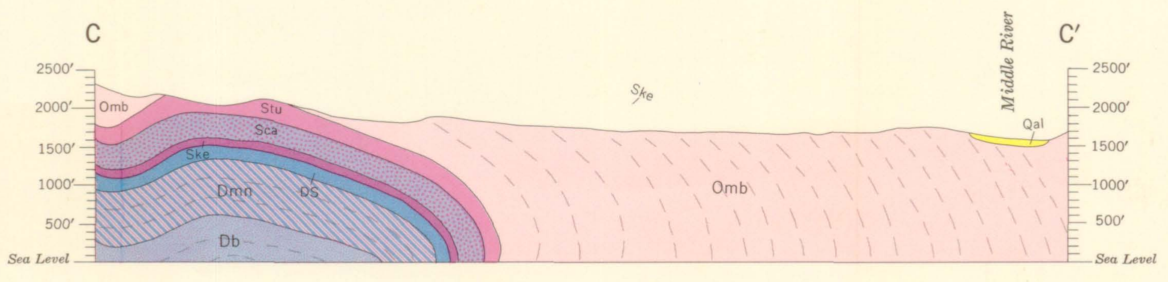
F-690 Locations of fossils collected.



No Vertical Exaggeration







COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES
James L. Calver
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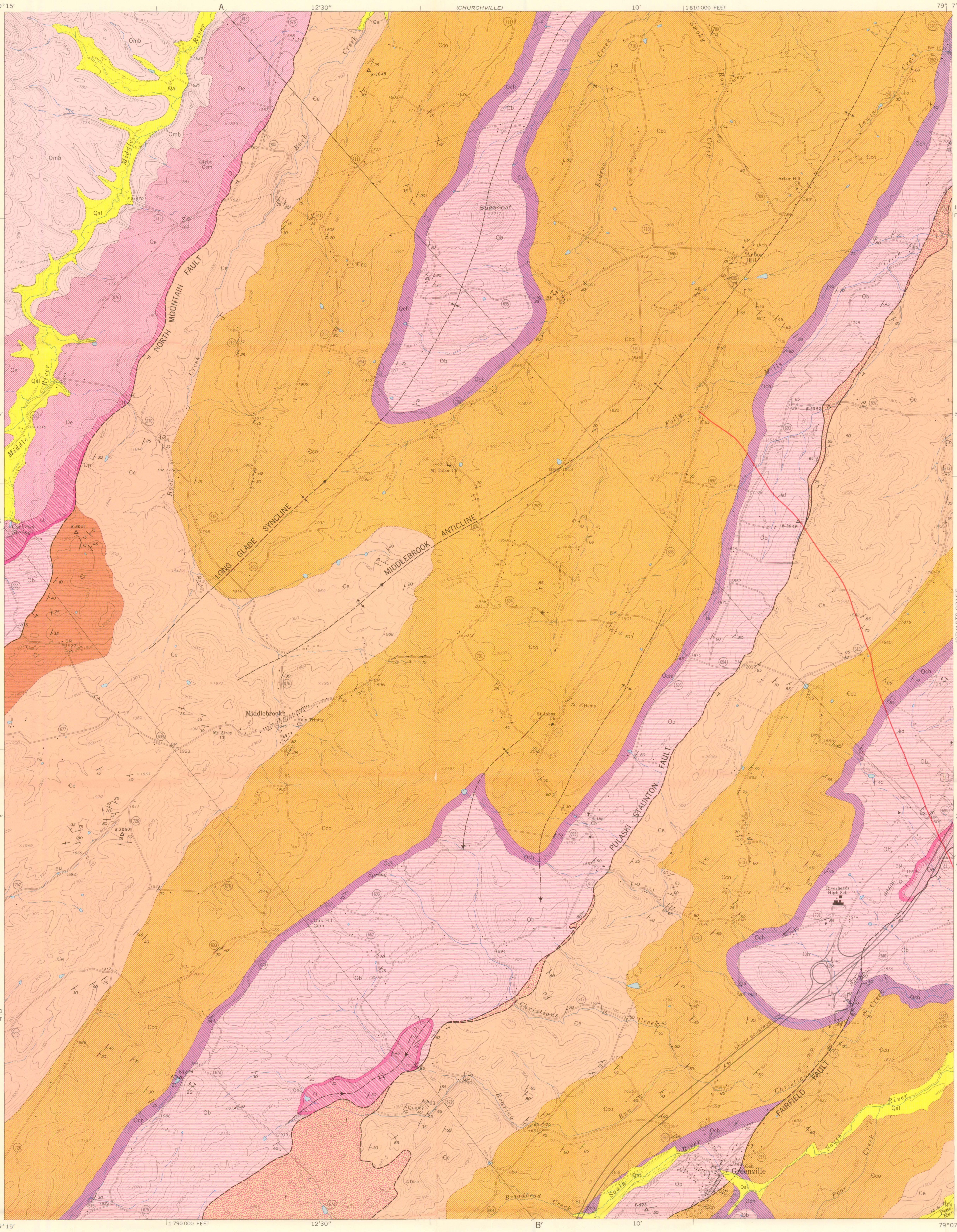
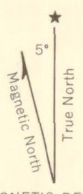


Base From U.S. Geological Survey 1964, Greenville Quadrangle, 7½-Minute Series

GEOLOGIC MAP OF THE GREENVILLE QUADRANGLE, VIRGINIA

Geology by Eugene K. Rader



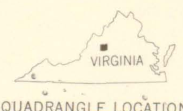
1964 MAGNETIC DECLINATION

SCALE 1:24 000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

CONTOUR INTERVAL 40 FEET



QUADRANGLE LOCATION

1967

EXPLANATION

MESOZOIC CENOZOIC — TRIASSIC QUATERNARY

Qal Alluvium

Ɽd Diabase dike

PALEOZOIC — ORDOVICIAN

Omb Martinsburg Formation
Olive-green to gray, subfissile shale with argillaceous sandstone at top.

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 recrystalline dolomite.

Och Chepultepec Formation
Bluish-gray to black limestone with black chert nodules; lower part contains siliceous laminae that are exposed in relief on weathered surfaces.

PALEOZOIC — 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.

Ꞓr Rome Formation
Red and green shale and greenish-gray, fine-grained dolomite.

f Breccia
, fault breccia, large blocks of dolomite, limestone, and shaly dolomite with crush conglomerate.

CONTACTS

exposed

approximate

covered

FOLDS

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

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

Overturned syncline—approximate trace of axial plane and direction of plunge of axis

FAULTS
THRUST

exposed

approximate

covered

T overthrust side

ATTITUDE OF ROCKS

45 Strike and dip of beds

50 Strike and dip of overturned beds

Strike of vertical beds

⊕ Horizontal beds

QUARRIES AND MINES

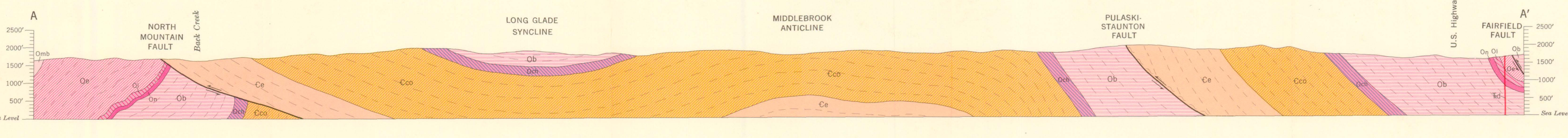
ACTIVE QUARRY
23. Augusta Stone Corporation

ABANDONED QUARRIES AND MINES
20. Crushed-stone quarry
21. Allen mine (bauxite)
22. Harris mine (bauxite)
24. Iron-ore mine

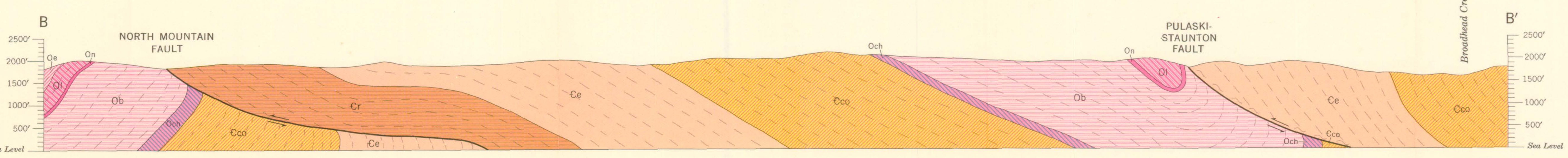
SAMPLE LOCATIONS

△ R-3050 Locations of samples representative of various lithologies mapped.

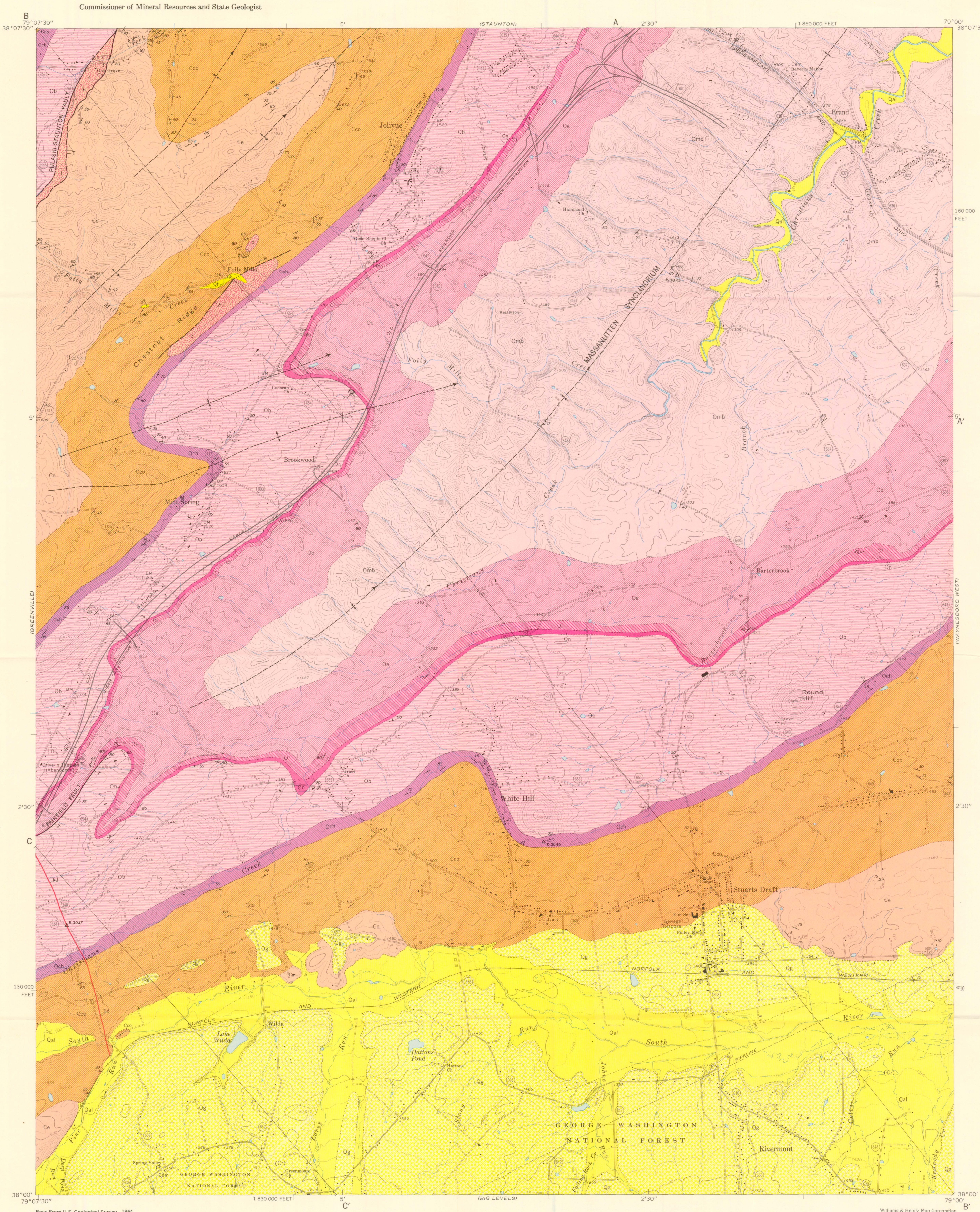
△ F-693 Locations of fossils collected.



No Vertical Exaggeration



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



EXPLANATION

CENOZOIC — QUATERNARY

- Qal — Alluvium
- Qg — Terrace gravel
- Qt — Travertine

MESOZOIC — TRIASSIC

- Ꞧd — Diabase dike

PALEOZOIC — ORDOVICIAN

- Omb — **Martinsburg Formation**
  Olive-green to gray, subfissile shale and fine-grained, thin-bedded sandstone.
- Oe — **Edinburg Formation**
  Dark-gray to black, argillaceous limestone and black fissile shale.
- 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 recrystalline dolomite.
- Och — **Chepultepec Formation**
  Bluish-gray to black limestone with black chert nodules; lower part contains siliceous laminae that are exposed in relief on weathered surfaces.

PALEOZOIC — 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.
- (Ꞓr) — **Rome Formation**
  Red and green shale and greenish-gray, fine-grained dolomite, (covered by alluvium, Qal, *and terrace gravel,* Qg*).*

f, c — **Breccia**
f, *fault breccia, large blocks of dolomite, limestone, and shaly dolomite with crush conglomerate;* c, *collapse breccia, blocks of dolomite and limestone cemented by white dolomite.*

CONTACTS

- exposed
- approximate
- covered

FOLDS

- Anticline—approximate trace of axial plane and direction of plunge of axis
- Syncline—approximate trace of axial plane and direction of plunge of axis

FAULTS
THRUST

- exposed
- approximate
- covered
- T overthrust side

ATTITUDE OF ROCKS

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

QUARRY

ABANDONED QUARRY
25. Lime quarry

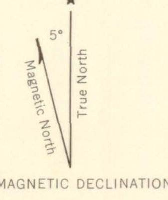
SAMPLE LOCATIONS

R-3045 Locations of samples representative of various lithologies mapped.

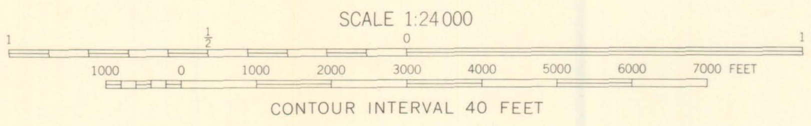
Base From U.S. Geological Survey 1964,
Stuarts Draft Quadrangle, 7½-Minute Series

GEOLOGIC MAP OF THE STUARTS DRAFT QUADRANGLE, VIRGINIA

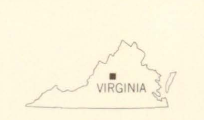
Geology by Eugene K. Rader



1964 MAGNETIC DECLINATION

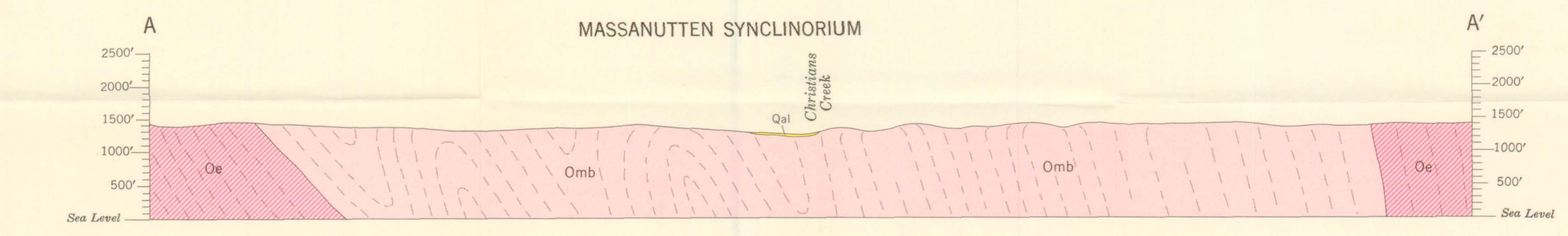


CONTOUR INTERVAL 40 FEET



QUADRANGLE LOCATION

1967



No Vertical Exaggeration