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

GEOLOGY OF THE ELLIOTT KNOB, DEERFIELD, CRAIGSVILLE, AND AUGUSTA SPRINGS QUADRANGLES, VIRGINIA

SAMUEL J. KOZAK

REPORT OF INVESTIGATIONS 21

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

CHARLOTTESVILLE, VIRGINIA
1970

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

GEOLOGY OF THE ELLIOTT KNOB, DEERFIELD, CRAIGSVILLE, AND AUGUSTA SPRINGS QUADRANGLES, VIRGINIA

SAMUEL J. KOZAK

REPORT OF INVESTIGATIONS 21

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

CHARLOTTESVILLE, VIRGINIA
1970

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF PURCHASES AND SUPPLY
RICHMOND
1970

Kozak, S. J., 1970, Geology of the Elliott Knob, Deerfield, Craigsville, and Augusta Springs quadrangles, Virginia: Virginia Division of Mineral Resources Rept. Inv. 21, 23 p.

DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT

Richmond, Virginia

MARVIN M. SUTHERLAND, *Director*

CHARLES A. CHRISTOPHERSEN, *Deputy Director*

A. S. RACHAL, JR., *Executive Assistant*

BOARD

CARLISLE H. HUMELSINE, Williamsburg, *Chairman*
ANDREW A. FARLEY, Danville, *Vice-Chairman*
MAJOR T. BENTON, Suffolk
JOSEPH C. CARTER, JR., Richmond
FRANK E. DICKERSON, Virginia Beach
CLAUDE A. JESSUP, Charlottesville
W. MARTIN JOHNSON, Lynchburg
WILLIAM H. KING, Burkeville
GEORGE C. MCGHEE, Middleburg
ERNEST L. SMITH, Grundy
JOHN S. THORNTON, Culpeper
ARCHIE L. WENRICH, Hopewell

CONTENTS

ILLUSTRATIONS

TABLES

GEOLOGY OF THE ELLIOTT KNOB, DEERFIELD, CRAIGSVILLE, AND AUGUSTA SPRINGS QUADRANGLES, VIRGINIA

By

SAMUEL J. KOZAK[1]

ABSTRACT

The Elliott Knob, Deerfield, Craigsville, and Augusta Springs quadrangles include an area of 235.1 square miles in parts of Augusta, Bath, Highland, and Rockbridge counties in west-central Virginia. They lie entirely within the Valley and Ridge physiographic province. Bedrock in the area is sedimentary and ranges in age from Early Cambrian to Mississippian; the total thickness probably exceeds 20,000 feet. Cambrian and Ordovician limestones, dolomites, and shales occur southeast of Little North Mountain. Rocks of Silurian, Devonian, and Mississippian age occur to the northwest.

Geologic structures in the area have northeasterly strikes, and the intensity of deformation appears to decrease to the northwest. The North Mountain fault traverses the area between Newport and Shemariah Church. Northwest of Little North Mountain relatively open folds dominate the structural style, and, in addition to numerous smaller folds, the McClung syncline, the Deerfield anticline, and the Elliott Knob syncline have been mapped. Deformation occurred in post-Mississippian time, and possibly earlier.

Mineral resources in the area include limestones and dolomites; clay, shale, and related materials; silica sand; and iron ore. Devonian carbonate rocks and shales have been used in the production of both portland and masonry cement near Fordwick. Shales in the Brallier Formation have been utilized for the manufacture of brick in the vicinity of North Mountain.

INTRODUCTION

The Elliott Knob (Plate 1), Deerfield (Plate 2), Craigsville (Plate 3), and Augusta Springs (Plate 4) quadrangles include a combined area of 235.1 square miles in parts of Augusta, Bath, Highland, and Rockbridge counties in west-central Virginia. They are bounded by 79° 15′ and 79° 30′ W. longitude and 38° 00′ and 38° 15′ N. latitude (Figure 1).

[1]Department of Geology, Washington and Lee University, Lexington, Virginia.

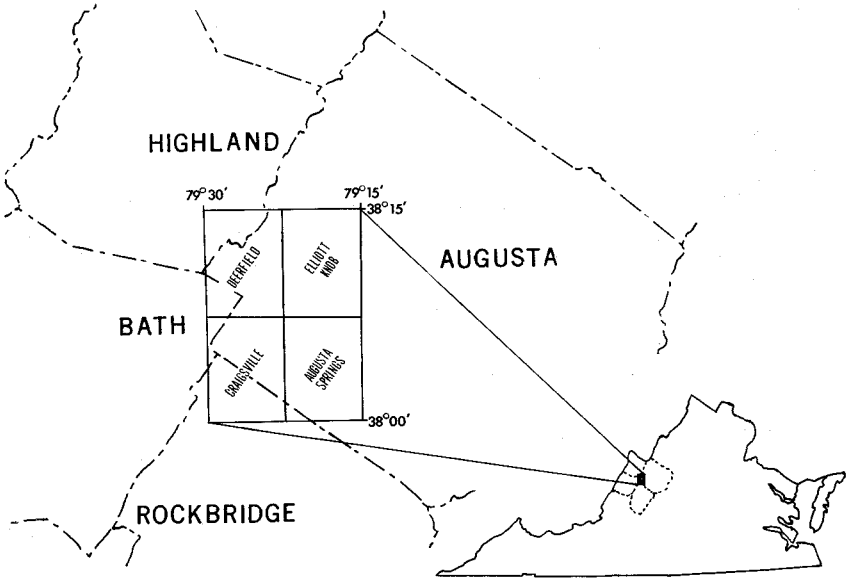


Figure 1. Index map showing locations of the Elliott Knob, Deerfield, Craigsville, and Augusta Springs quadrangles.

Major roads traversing the quadrangles include State Road 602 along Walker Creek; State Highway 252 along Moffatts Creek to the southeast of Little North Mountain; State Road 601 along Estaline Valley between Brown Ridge and Little North Mountain; U. S. Highway 42 along the southeast side of Great North Mountain; State Road 629 in Deerfield Valley along the southeast edge of Shenandoah Mountain; and State Road 600 from Deerfield south along the southeast edge of Walker Mountain, Sideling Hill, and Mill Mountain. All are more or less parallel to the geologic structure. A few roads are transverse to the structural and topographic trend in the area; these include State Road 682 across Little North Mountain from McKinley to Estaline, State Road 614, State Road 687, State Road 688, and Hite Hollow Road across Great North Mountain.

The Chesapeake and Ohio Railway extends across the area parallel to U. S. Highway 42, from south of Bells Valley (Plate 3) to Buffalo Gap just east of the Elliott Knob quadrangle. The largest community in the area is Craigsville (Plate 3). Other communities include Deerfield (Plate 2), Augusta Springs, Fordwick, Newport, and McKinley (Plate 4).

The area included by this report is within the Valley and Ridge province (Fenneman, 1938). The southeastern one-third of the Au-

gusta Springs quadrangle (Plate 4), lies within the Great Valley of Virginia. Topography in this part of the area consists of gently rounded to conical hills and a few northeast-southwest trending ridges. Hilltop elevations range, in general, between 2100 feet and 2200 feet above sea level; relief is about 400 feet. Drainage is to the James River via Walker Creek and Moffatts Creek in the southwest and to the Shenandoah River via Middle Creek in the northeast; the drainage pattern is dendritic. Northwest of Little North Mountain topographic features are linear, trending northeast-southwest, and mountains and valleys are underlain by anticlines, synclines, and monoclines. Drainage in this part of the area is to the southwest via the Calfpasture River and its tributaries to the Maury and James rivers. On the western flank of Shenandoah Mountain in the northwestern part of the Deerfield quadrangle (Plate 2), drainage is to the James River via the Cowpasture River. The drainage pattern is mainly rectangular, becoming dendritic in the upper reaches of smaller tributaries. The maximum elevation in the area is at Elliott Knob (Plate 1), which is 4463 feet above sea level. The minimum elevation is approximately 1420 feet where the Calfpasture River leaves the Craigsville quadrangle (Plate 3). Total relief is about 3040 feet. Maximum and minimum elevation and total relief for each quadrangle are as follows:

Quadrangle	Maximum Elevation in feet	Minimum Elevation in feet	Total Relief in feet
Elliott Knob	4463	1700 ± 20	2763 ± 20
Deerfield	3700 ± 20	1580 ± 20	2120 ± 40
Craigsville	3095	1420 ± 20	1675 ± 20
Augusta Springs	3300 ± 20	1700 ± 20	1600 ± 40

The earliest detailed geologic map of the area was prepared by Darton (1894). The area was later included on a geologic map of the Appalachian Valley (Butts, 1933). Published geologic maps are available for the adjoining Churchville and Greenville 7.5-minute quadrangles on the east (Rader, 1967), the Lexington 15-minute quadrangle to the south (Bick, 1960), and the Williamsville 15-minute quadrangle to the west (Bick, 1962). Butts (1940) reported on some aspects of the structure and stratigraphy of the area, and Edmundson (1958) presented a number of measured stratigraphic sections located within the area mapped.

Fieldwork for this report was carried out during parts of the summers of 1963 through 1968, supported by the Virginia Division of Mineral Resources. Support from the Division and the cooperation of

the residents of the area mapped are here acknowledged. Special thanks are expressed to E. W. Spencer, O. S. McGuire, E. K. Rader, and H. Webb for time spent in the field and in discussion.

STRATIGRAPHY

The outcropping Paleozoic sedimentary rocks are divided into 23 previously defined formations, and these have been combined to form 17 mappable units that range in age from Cambrian to Mississippian. In addition, Quaternary alluvium has been mapped. The ages, thickness, and character of these units are summarized on Table 1.

Table 1.—Geologic formations in the Elliott Knob, Deerfield, Craigsville, and Augusta Springs quadrangles.

Age	Name	Character	Approximate thickness in feet
Quaternary	Alluvium	Unconsolidated clays, sands, and gravels.	?
Mississippian	Pocono Formation	Gray to brownish, thick-bedded, coarse-grained sandstones and conglomerates.	300+
Devonian	Hampshire Formation	Reddish-brown sandstones and shales.	2200
	Chemung Formation	Green to greenish-gray sandstones and shales and quartz-pebble conglomerates; fossiliferous.	3600
	Brallier Formation	Greenish-gray, thin-bedded, micaceous siltstones and shales; dimpled bedding surfaces.	2400
	Millboro Shale	Black, fissile shale that weathers light-gray, pink, or buff; scattered limestone concretions.	1000
	Needmore Formation	Olive-green shale.	

Age	Name	Character	Approximate thickness in feet
Devonian	Oriskany Sandstone	Light- to medium-gray, coarse-grained sandstone; locally conglomeratic and fossiliferous.	20
	Licking Creek Limestone	Medium- to dark blue-gray, medium-bedded, fine- to medium-grained, fossiliferous, cherty limestone.	125
	New Scotland Formation	Medium- to dark-gray, medium- to coarse-grained, sandy, fossiliferous, cherty limestone.	25
	New Creek Limestone	Light- to medium-gray and pink, medium- to coarse-grained, crinoidal limestone.	46
	Keyser Formation	Medium- to dark-gray, medium- to coarse-grained, fossiliferous limestones in upper part; medium- to dark-gray, fine- to medium-grained limestones and light-gray, calcareous sandstones in lower part.	230
	Tonoloway Formation	Dark-gray, fine-grained, thin-bedded limestones; mud cracks are present locally.	135
Silurian	Keefer Sandstone	White, fine- to medium-grained, friable sandstone that is locally conglomeratic.	300
	Cacapon Formation	Red and green shales and sandstones.	300
	Tuscarora Formation	White to light-gray, fine- to medium-grained quartzitic sandstones.	200

Age	Name	Character	Approximate thickness in feet
Ordovician	Martinsburg Formation	Light- to medium-gray, fine-grained limestone; light-gray to olive-drab shales; and fine- to medium-grained, olive-drab sandstones. Map unit includes greenish-gray, fine- to medium-grained, dense sandstone at the top (Oswego Sandstone?).	?
	Edinburg Formation	Black, fine-grained, thin-bedded limestones alternating with black, calcareous shales (Liberty Hall); medium- to dark-gray, medium-grained, cobbly limestones (Lantz Mills). Botetourt Member (at base)—medium- to coarse-grained, medium- to dark-gray, fossiliferous limestone; locally stained red.	?
	Lincolnshire Formation	Medium- to dark-gray, medium-grained, nodular limestone and shale with black chert. White to light-gray, coarse-grained, fossiliferous limestone (Murat).	400
	New Market Limestone	Dove-gray, aphanitic, limestone.	0-100
	Beekmantown Formation	Light-gray, fine-grained, thick-bedded dolomite with locally abundant chert; aphanitic light-gray limestones near the top.	?
	Chepultepec Formation	Not exposed.	
	Conococheague Formation	Medium-gray, thin- to medium-bedded limestone and dolomite; vermiculoid-weathering argillaceous and silty beds present.	?

Age	Name	Character	Approximate thickness in feet
Cambrian	Elbrook Formation	Light- to dark-gray, fine- to medium-grained limestones and dolomites.	?
	Rome Formation	Red, purple, green, and gray shales and medium- to dark-gray dolomite and limestone.	?

CAMBRIAN SYSTEM

Rome Formation

The Rome Formation is a heterogeneous unit composed of red, purple, green, and gray shales and mottled medium- to dark-gray, somewhat arenaceous, fine-grained dolomite and limestones (R-3866). Exposures of the Rome Formation are confined to a northeast-southwest trending belt in the southeast part of the Augusta Springs quadrangle (Plate 4). Well-exposed portions of the formation are present along State Road 920 approximately 0.4 mile northeast of Newport, and along an unnamed tributary on the northwest side of Moffatts Creek approximately 1.3 miles northeast of Newport along State Highway 252 (Plate 4). In this area, the North Mountain fault forms the lower boundary of the Rome Formation; it is in contact with the Beekmantown Formation that is on the footwall side of the fault. The upper contact is conformable with the overlying Elbrook Formation. The width of the outcrop belt ranges from 1800 to 3400 feet. Dips within the Rome are all to the southeast but differ greatly in magnitude.

Elbrook Formation

The Elbrook Formation occurs in a northeast-southwest trending belt in the southeast part of the Augusta Springs quadrangle (Plate 4). The outcrop belt is about 7600 feet wide, but no reliable estimate of thickness can be made because of the variation of structural attitudes within the formation. The Elbrook Formation is composed of very fine-grained to medium-grained, light- to dark-gray limestones and dolomites (R-3867). Bedding ranges from massive units several feet thick to thinly laminated, somewhat irregular, argillaceous beds characterized by a

platy fracture parallel to bedding. A few thin beds of very fine-grained white limestone and dolomite (R-3868) are present. Elbrook lithologies are exposed in the area between State Road 726 and Otts Creek (Plate 4). The base of the Elbrook was mapped above the highest prominent shale beds.

Conococheague Formation

The Conococheague Formation is present along State Road 726 in the extreme southeast portion of the Augusta Springs quadrangle (Plate 4). The Conococheague is composed of thin- to medium-bedded, medium-gray limestones and dolomites. Thin irregular, light brownish-yellow, argillaceous and silty laminae stand out on weathered surfaces and give outcrops a vermicular appearance. Sandstone beds (5 to 10 feet thick) have been reported in the Conococheague in adjacent quadrangles where the total thickness is present (Rader, 1967, p. 7), but these were not observed in the area covered by this report. The upper contact is not present; therefore no determination of thickness could be made.

ORDOVICIAN SYSTEM

Beekmantown Formation

The Beekmantown Formation is exposed in a northeast-southwest trending belt in the southeast quarter of the Augusta Springs quadrangle (Plate 4). It forms the footwall of the North Mountain fault. The principal lithology in the Beekmantown is a light-gray to blue-gray, thick-bedded, fine-grained dolomite (R-3869). This lithology is exposed in the fields adjacent to State Road 682, approximately 0.75 mile southeast of McKinley, and extends to the southeast for approximately 0.6 mile (Plate 4). Buff to light reddish-brown chert occurs as irregular masses and as more or less bedded units throughout the formation. Dense, aphanitic, light-gray limestones and fine- to medium-grained, medium- to dark-gray limestones occur in the upper parts of the formation. A fairly well exposed section of interbedded limestones and dolomites is present along State Road 602 and in the bed of Walker Creek, approximately 0.2 mile southwest of the junction of State Road 602 and the westward extension of State Road 682 (Plate 4). In many places well-developed sets of fractures perpendicular to bedding planes in the dolomites have developed a characteristic reticulated pattern on bedding surfaces. The Beekmantown disconformably underlies the New Market Limestone. For mapping purposes the top of the

Beekmantown Formation was placed at the top of the highest prominent dolomite bed. The base of the Beekmantown is not present in the area mapped because the formation is cut by the North Mountain fault.

New Market Limestone

The New Market Limestone disconformably overlies the Beekmantown and is composed primarily of aphanitic to very fine-grained, light-gray to light brownish-gray, massively bedded limestone (R-3870). Small crystals of clear calcite about 1 mm in diameter impart a "birds-eye" appearance which is characteristic of the unit. Black chert nodules and thin, fine-grained dolomite beds are present locally. Exposures of the New Market Limestone are confined to the belt between the North Mountain fault and Little North Mountain (Plate 4). An excellent exposure is present in the creekbed along State Road 602 approximately 0.8 mile southwest of the junction of State Roads 682 and 602 near McKinley; approximately 100 feet of section was measured at this locality. Farther south the New Market appears to thin, and at the southern boundary of the Augusta Springs quadrangle (Plate 4) it is absent.

Lincolnshire Formation

Lithologies mapped as Lincolnshire Formation occur along a northeast-southwest trending belt in the southeast portion of the Augusta Springs quadrangle (Plate 4). Two principal lithologies characterize the formation. One is composed of medium-grained, medium- to dark-gray limestones (R-3871); black chert nodules ranging in length from a few inches to a few feet are locally abundant. Thin, irregular, argillaceous partings impart a nodular appearance to many outcrops. A second characteristic lithology (Murat limestone) is composed of very coarse-grained, light brownish-gray to white limestone (R-3872), in which fossil fragments are abundant and bedding is generally massive. For mapping purposes in this study, medium-grained cherty limestones above the New Market Limestone and below the Botetourt Member of the Edinburg were included in the Lincolnshire Formation. The formation is well exposed along Walker Creek and State Road 602 approximately 0.8 mile southwest of its junction with State Road 682 near McKinley. A thickness of appproximately 400 feet was measured here.

Edinburg Formation

The Edinburg Formation conformably overlies the Lincolnshire Formation. The basal 20 to 30 feet of the Edinburg is composed of medium- to coarse-grained, medium- to dark-gray, fossiliferous limestone (R-3888) that is locally stained red. This unit, the Botetourt Member, is well exposed where it is crossed by State Road 602 approximately 0.9 mile southwest of the junction of State Roads 602 and 682 near McKinley (Plate 4). The principal Edinburg lithology above the Botetourt consists of alternating beds of dense, fine-grained, relatively unfossiliferous, black limestone (R-3873) and black shale (Liberty Hall). Individual limestone and shale beds average about 2 inches in thickness. Some portions of the Edinburg consist of medium-grained, medium- to dark-gray, cobbly limestone (Lantz Mills). The formation is well exposed adjacent to State Road 602 from its intersection with State Road 681 northward for approximately 3 miles. The top of the Edinburg is transitional into lighter colored limestones and shales of the Martinsburg Formation. Internal deformation in the Edinburg makes estimates of its thickness unreliable.

Martinsburg Formation

The Martinsburg Formation occurs along the southeast side of Little North Mountain (Plates 1, 3, 4). It is a lithologically heterogeneous unit that includes fine-grained, light- to medium-gray, thin-bedded limestone; light-gray calcareous shales; olive-brown shales; and fine-grained, olive-brown sandstones. In general there appears to be a change from limestones and calcareous shales at the base to shales and fine-grained sandstones at the top of the formation. The lower contact was placed at the top of the highest medium- to dark-gray limestones of the Edinburg Formation. Overlying the Martinsburg Formation, above 15 feet of fine-grained, rust-flecked sandstones (R-3874) containing the *Orthorhynchula* bed (Butts, 1940), there occurs about 200 feet of dense, fine- to medium-grained feldspathic sandstone (R-3875). Olive to greenish-brown colors predominate in the lower part of this sequence and reddish-grays, at the top. These greenish and reddish unfossiliferous sandstones between the *Orthorhynchula* bed and dense, well-sorted quartz sandstones identified as Tuscarora may represent the Oswego Sandstone. Because of relatively poor exposures along Little North Mountain these units were included in the Martinsburg Formation for purposes of mapping, and the top of the Martinsburg was placed beneath the lowest beds of well-sorted, white quartzitic sandstones and conglomerates identified as Tuscarora. Excellent exposures of the

Orthorhynchula beds and the questionable Oswego Sandstone are present along State Road 682 where it crosses Little North Mountain between McKinley and Estaline (Plate 4).

SILURIAN SYSTEM

Tuscarora Formation

The Tuscarora Formation crops out along State Road 682 near the crest of Little North Mountain (Plate 4). It is composed of dense to weakly cemented and friable, fine- to medium-grained, well-sorted, light-gray to white quartz sandstones (R-3876). Bedding is generally thick to massive and cross bedding is present. Thin conglomeratic lenses with quartz pebbles up to 5mm in diameter occur locally near the base. The base of the formation was placed at the top of the highest greenish-gray, rust-specked sandstone mapped with the Martinsburg Formation. The upper contact was placed beneath the lowest red sandstones identified as Cacapon. The Tuscarora Formation has a maximum thickness of approximately 200 feet.

Cacapon Formation

Outcrops of the Cacapon Formation occur along Little North Mountain and along Big Knob and Byrd Knob immediately to the west of Little North Mountain (Plates 3, 4). The Cacapon Formation is composed of red and greenish-gray shales and brownish-red, purplish-red, greenish-gray, and white, medium-grained sandstones. The darker purplish-red hematitic sandstones (R-3877) characterize the formation, and float of this type can be used as a fairly reliable indication of its presence in covered areas. Bedding ranges from thin to massive, and cross bedding is developed on a small scale. The Cacapon is well exposed along State Road 682 on the crest and northwest slope of Little North Mountain, and where State Road 682 crosses the topographic continuation of Big Knob just northwest of Little North Mountain (Plate 4). Estimated maximum thickness of the Cacapon Formation is between 250 and 300 feet.

Keefer Sandstone

The Keefer Sandstone is a fine- to medium-grained, generally well-sorted, white to light-gray, friable quartzose sandstone (R-3878). Bedding ranges from thin to massive and cross bedding is developed locally. A few thin conglomeratic lenses with subrounded quartz pebbles up to 0.5 inch in diameter are present. The Keefer weathers to white

or very light-gray sand, and many outcrop areas are covered by sands derived from it. Pink, red, and brownish staining aid in distinguishing the Keefer from the Tuscarora; red *Scolithus* tubes, averaging about 0.5 inch in diameter and oriented perpendicular to the bedding, serve to distinguish the Keefer from other sandstones in the area mapped.

Outcrops of Keefer generally form the crest or flanks of anticlinal and monoclinal hills and ridges (Plates 1, 2, 3, 4). Because slopes are generally parallel to bedding surfaces, the Keefer is not well exposed in most areas. However, exposures are present along State Road 682 on the northwest slope of the continuation of Big Knob (Plate 4), and along State Road 614 between Black Oak Hill and Wilson Bridge (Plate 3). The maximum thickness of the formation in this area is estimated to be about 300 feet.

LOWER DEVONIAN AND UPPER SILURIAN ROCKS

Stratigraphic units identified as Tonoloway Formation, Keyser Formation, New Creek Limestone, New Scotland Formation, Licking Creek Limestone, and Oriskany Sandstone were mapped as a single unit, Lower Devonian and Upper Silurian rocks. These formations were combined for mapping purposes because they are thin and, in general, poorly exposed.

Tonoloway Formation

The Tonoloway Formation is composed of thin-bedded, thinly laminated, argillaceous, fine-grained, dark-gray to black limestone (R-3879). Mud cracks are present locally. The base of the Tonoloway is placed at the top of the highest sandstone in the Keefer; the top is placed above the highest dark-gray to black, thin-bedded limestone. The formation is in general poorly exposed in the area covered by this report. Its occurrence topographically below the Keefer Sandstone along the flanks of anticlinal and monoclinal mountains and ridges has resulted in its being covered in many places by sandy material derived from weathered Keefer. A measured thickness of 135 feet is present at Bells Valley (Plate 3) (Swartz, 1929, p. 67).

Keyser Formation

The Keyser Formation conformably overlies the Tonoloway Formation and is predominantly a limestone. Lower parts of the formation are in general somewhat nodular, fine grained, dark gray and fossiliferous, and thin shale partings emphasize the nodular character. Lime-

stones higher in the formation are generally coarser grained, medium to dark gray, medium to thick bedded, and fossiliferous (R-3880). The upper part in many places is a coarse-grained crinoidal limestone nearly identical to the overlying New Creek Limestone. Strata of medium- to thick-bedded, medium- to coarse-grained, white to medium-gray, rather well-sorted calcareous sandstones are present, and these have been interpreted as tongues of the Clifton Forge sandstone (Swartz, 1929, p. 67). Measured sections at Bells Valley (Swartz, 1929, p. 66-67) and Wilson Bridge (Plate 3) include respectively about 134 feet and 230 feet of Keyser, a thickening of nearly 100 feet in approximately 1 mile. The lower part of the Keyser is Silurian in age (Bowen, 1967); the upper part is Devonian (Swartz, 1929).

New Creek Limestone

The New Creek Limestone (Bowen, 1967) conformably overlies the Keyser Formation. In the area of study, it is composed of light- to medium-gray and pink, coarse-grained, massive-bedded, crinoidal limestone (R-3881). It is as much as 46 feet thick. The base of the New Creek is difficult to locate accurately in many outcrops, as it is nearly identical to some portions of the underlying Keyser. *Gypidula coeymanensis* is present in the limestone examined. The New Creek is well exposed along State Roads 601 and 614 near Wilson Bridge (Plate 3) and in most of the quarries near Craigsville and Fordwick (Plates 3, 4).

New Scotland Formation

The New Scotland Formation is composed of thin- to medium-bedded, medium- to dark-gray, medium- to coarse-grained limestones and sandy limestones. Thin beds of poorly exposed, medium-grained, friable sandstones are present locally and may represent tongues of the Healing Springs Sandstone. Ellipsoidal white chert nodules several inches long are present in several areas. In many places where this part of the section is poorly exposed, these resistant chert nodules in the soil are the only evidence that the formation is present. The thickness of the New Scotland is up to about 25 feet. The New Scotland is well exposed along State Road 601 just south of Wilson Bridge (Plate 3) and in the Lehigh Portland Cement Company quarry (Plate 3, No. 6).

Licking Creek Limestone

The Licking Creek Limestone is composed of medium-bedded, generally fine- to medium-grained, medium- to dark bluish-gray limestone (R-3882). Nodules and irregular stringers of black chert are

prominent in most sections, and thin shaly beds and sandy limestone are present locally. Brachiopods are locally abundant. The Licking Creek is well exposed along State Road 601 approximately 1000 feet south of Wilson Bridge (Plate 3) and in most of the quarries near Fordwick and Craigsville (Plates 3,4). The maximum thickness of the Licking Creek Limestone in the area of this report is about 125 feet. The well-defined upper contact is placed at the top of the highest limestone unit overlain by sandstones of the Oriskany.

Oriskany Sandstone

The Oriskany Sandstone is composed of massively bedded, light- to medium-gray, well-sorted, medium- to coarse-grained sandstone (R-3883). In places it contains thin conglomeratic lenses with ellipsoidal quartz pebbles up to 0.5 inch in diameter. It is cemented by calcite, at least in part, and upon weathering becomes very friable; yellowish-brown to gray-brown iron oxide stains are common on weathered surfaces. Large spirifer-type brachiopods are present in some places. The Oriskany is well exposed along U. S. Highway 42 from Lebanon Church southwestward for approximately 0.7 mile (Plate 3). Thickness of the Oriskany is generally less than 20 feet. It is overlain by green to olive shales of the Needmore Formation.

DEVONIAN SYSTEM

Needmore Formation and Millboro Shale

The Needmore Formation was included with the Millboro Shale for mapping purposes in the area of study. It is composed of poorly bedded, subfissile, greenish to olive shales. Exposures are poor, and in most cases only green to olive shale chips in the soil indicate its presence. Needmore lithologies are exposed at Bells Valley and along U. S. Highway 42 in the vicinity of Lebanon Church, approximately 1.5 miles north of Bells Valley (Plate 3).

The Millboro Shale is composed of fissile, black to dark-gray shale that weathers to light gray, pink, or buff. Calcareous beds and nodules are present locally. The lower contact with the Needmore Formation is not exposed in the area. The upper contact with the Brallier shale, although poorly exposed, appears to be transitional, with alternating Brallier and Millboro lithologies. For mapping purposes, the upper contact was placed at the top of the highest prominent black shale bed. The Millboro Shale is fairly well exposed along Shillings Trail approximately 1.2 miles north of Mt. Elliott Springs (Plate 1). The thickness of the Millboro Shale in the area is estimated to be 800 to 1000 feet.

Brallier Formation

The Brallier Formation conformably overlies the Millboro Shale and underlies the Chemung Formation. It is composed of light-gray, brown, or olive-drab micaceous subfissile shales, siltstones, and sandstones. Dimpled bedding surfaces are common. Thin beds of Millboro-type black shales are present near the base. Beds are generally only a few inches thick, but in the upper part of the unit they reach a thickness of several feet. Brallier lithologies are fairly well exposed on the southeast slope of Great North Mountain along an unnumbered, unpaved road that extends westward from Hite Hollow Road (Plate 4). The Brallier Formation is gradational with the overlying Chemung Formation through a zone of approximately 200 feet in which sandstone beds become thicker and more abundant and the interbedded finer grained units lose their fissility. For mapping purposes the top of the Brallier Formation was placed below the lowest occurrence of Chemung-type faunal assemblages. In the absence of fossils, the base was placed beneath the lowest sandstone bed 3 or more feet thick. The Brallier Formation has a thickness of about 2400 feet in this area.

Chemung Formation

A sequence of clastic rocks including sandstones, conglomerates, shales, and mudstones, and containing a marine fossil assemblage characterized by large brachiopods and pelecypods, was mapped as the Chemung Formation. Sandstones are medium to coarse grained, thick bedded, and commonly cross bedded. They range in color from light yellowish-brown to brownish-green (R-3884) and bluish-gray with some chocolate-brown to brownish-red beds in the upper few hundred feet of the formation. Finer grained units are generally subfissile and lumpy with greenish and gray-green colors at the base, and interbedded with red shales and mudstones near the top of the formation. Conglomerate beds are from a few inches to over 1 foot thick, and are composed of white to gray ellipsoidal quartz pebbles 0.25 to 1 inch in diameter in a matrix of greenish to medium gray-brown sandstone (R-3885). The Chemung Formation is well exposed along State Road 688 in the vicinity of Dry Branch Gap (Plate 1) and along an unnumbered, unpaved road that extends from its junction with State Road 629 northwestward across Shenandoah Mountain (Plate 2).

The contact with the overlying Hampshire Formation is transitional. The Chemung Formation occurs along Shenandoah Mountain (Plate 2) and along Great North Mountain (Plates 1, 2, 3, 4). Its maximum thickness is estimated to be about 3600 feet. Its minimum thickness

in the area is estimated to be approximately 1880 feet along the southeast flank of Great North Mountain between Chapin and Falls Hollow (Plate 1).

Hampshire Formation

The Hampshire Formation occurs along the flanks of Great North Mountain and is fairly well exposed along the jeep trail from U. S. Highway 42 to the fire lookout tower on Elliott Knob (Plate 1). It consists of fine- to coarse-grained micaceous and arkosic sandstones and lumpy mudstones. Bedding is thick and cross bedding is prominent. Colors range from medium red to brownish red (R-3886) through grayish green to grays and browns. Conglomerate lenses similar to those in the Chemung are present, but are relatively rare. The contact with the underlying Chemung Formation is transitional through a few hundred feet, with interbedded greenish Chemung-type sandstones and mudstones and reddish-brown Hampshire-type sandstones and mudstones. In several places assemblages of large Chemung-type fossils occur in "Chemung-type" lithologies stratigraphically above thick sequences of red and brown "Hampshire-type" lithologies. The base of the Hampshire was placed above the uppermost beds containing Chemung-type fossil assemblages. The thickness of the Hampshire Formation is estimated to be approximately 2200 feet.

MISSISSIPPIAN SYSTEM

Pocono Formation

The Pocono Formation occurs along Great North Mountain in the vicinity of Elliott Knob (Plate 1). It is composed of thick-bedded, coarse-grained, gray to brownish sandstones (R-3887) and conglomerates; cross bedding is present. The lower contact is poorly exposed along the slopes of Elliott Knob, and for mapping purposes was placed above the highest significant occurrences of red and green sandstones of the Hampshire Formation. The upper contact is not present in the area of this report.

QUATERNARY (?) SYSTEM

Nearly all river valleys are veneered by unconsolidated clays, sands, and gravels of questionable Quaternary age. Extensive deposits of this material occur along the Calfpasture River south of Deerfield and in Deerfield Valley (Plate 2).

STRUCTURE

Deformation of the rocks in the area of this report occurred in post-Mississippian time, and possibly earlier. The intensity of deformation appears to decrease from southeast to northwest across a northeast-southwest trending system of faults and folds. Major structures, recognized and named earlier (Butts, 1940), which traverse the area include (from southeast to northwest) the North Mountain fault, the Elliott Knob syncline, the Deerfield anticline, and the McClung syncline. Numerous smaller folds parallel these larger structures.

The North Mountain fault (Butts, 1940, p. 452) crosses the southeast portion of the Augusta Springs quadrangle (Plate 4). Extending northeastward from Newport, it crosses State Road 677 approximately 0.5 mile southeast of Shemariah Church. Along its trace in the Augusta Springs quadrangle, the Beekmantown Formation forms the footwall, and the Rome Formation forms the hanging wall. Locally, outcrops of Beekmantown near the fault are intensely fractured.

The Elliott Knob syncline (Butts, 1940, p. 454) extends from the southwest portion of the Craigsville quadrangle (Plate 3) northeastward for approximately 22 miles to the northeast portion of the Elliott Knob quadrangle (Plate 1). The Pocono Formation, the youngest Paleozoic sedimentary unit mapped in the area of this report, is present within this syncline in the vicinity of Elliott Knob. The syncline is relatively open, although locally the Brallier and Chemung formations become vertical or overturned, as can be seen along State Road 688 about 2.5 miles northeast of North Mountain (Plate 1). The Tuscarora, Cacapon, and Keefer formations crop out along Little North Mountain. Attitudes of the beds along Little North Mountain range from moderate normal westerly dips to inverted ones east of Mt. Elliott Springs. Faults are present from the vicinity of Pond Gap (Plate 4) to the area just southeast of Chapin (Plate 1). Northwest of Little North Mountain there are a number of small anticlines in which the Keefer Sandstone is exposed; the two most prominent ones are Knob Mountain-Black Oak Hill and Brown Ridge.

Northwest of the Elliott Knob syncline is the Deerfield anticline (Butts, 1940, p. 454). Northeast of Deerfield, the anticline is topographically inconspicuous (Plates 1, 2) in an area of relatively nonresistant Millboro and Brallier shales. Southwest of Deerfield (Plates 2, 3) the Keefer Sandstone and Silurian-Devonian limestones and sandstones are exposed in the Deerfield anticline along Walker Mountain. Smaller anticlines are present along Mill Mountain and Sideling Hill to

the southeast (Plate 3) and Brushy Ridge to the northwest (Plate 2). The main structure has a northeasterly plunge of about 15 degrees.

Northwest of the Deerfield anticline the Brallier and Chemung formations have been folded into a large open syncline, the axial trace of which is subparallel to the crest of Shenandoah Mountain (Plate 2). This structure has been named the McClung syncline (Butts, 1940, p. 455).

ECONOMIC GEOLOGY

INDUSTRIAL LIMESTONE AND DOLOMITE

Within the area of this report, three principal areas are underlain by limestones and dolomites. These include the following: Devonian limestones along the flanks of Walker Mountain, Mill Mountain, and Sideling Hill (Plates 2, 3); Devonian limestones along the flanks of Brown Ridge, Black Oak Hill, and Knob Mountain (Plates 3, 4); and Cambrian and Ordovician limestones and dolomites in the southeast portion of the Augusta Springs quadrangle (Plate 4).

The Devonian and Ordovician limestones and dolomites were described by Edmundson (1958); "high-calcium" limestones occur in all three areas. For more detailed information, interested readers are referred to the report by Edmundson (1958) which also contains a section on the uses of limestones and dolomites.

CEMENT MATERIALS

During the time fieldwork was being conducted for this report, the Lehigh Portland Cement Company was quarrying Devonian carbonate rocks and shales in the vicinity of Fordwick (Plate 3, Nos. 5, 6, 10) for use in the manufacture of cement. Both portland and masonry cement were produced at the plant near Fordwick. This operation is presently inactive.

CLAY, SHALE, AND RELATED MATERIALS

Analyses of six samples of potentially useful clay, shale, and related materials from the area were presented by Calver, Smith, and Le Van (1964). Five of these are from Augusta County, and one is from Rockbridge County. Potential uses of these materials are listed in Table 2. Shales in the Brallier Formation have been utilized by North Mountain Brick of Virginia near North Mountain (Plate 1, No. 2) for the manufacture of brick.

Table 2.—Potential uses of clay materials from the Elliott Knob, Craigsville, and Augusta Springs quadrangles (data compiled from Calver, Smith, and Le Van, 1964).

Repository Number	Location	Sampled Interval	Potential Use
R-1	Exposure east of the crest of Little North Mountain and south of State Road 682, about 1.7 miles west of McKinley (Plate 4)	Composite sample from 4 feet of clay in outcrop and auger hole	Decorative brick and tile
R-38, R-39	Inactive quarry of North Mountain Brick of Virginia located on the east side of State Highway 42 at North Mountain (Plate 1)	Representative sample of 25 feet of weathered shale (R-38) and sample across 130 feet of unweathered shale and siltstone (R-39)	Brick, tile, and probably sintered aggregate
R-1624	Roadcut on the north side of State Road 683 approximately 0.5 mile northwest of the junction with State Road 684, 2 miles southwest of Fordwick (Plate 3)	Sample across 110 feet of shale and siltstone	Common brick
R-1625	Roadcut on the north side of State Road 682 about 1.1 miles west of the junction with State Road 602 (Plate 4)	Sample across 35 feet of shale and siltstone	Common brick and tile
R-1665	Roadcut on the northwest side of State Highway 42 about 1.4 miles northeast of the junction with State Road 614 in Bells Valley (Plate 3)	Sample across 18 feet of shale	Common brick and tile and lightweight aggregate

SILICA SAND

Although there are no operations presently producing silica sand within the area covered by this report, three sandstone units, the Tuscarora, Keefer, and Oriskany, have been mined for silica sand elsewhere in the Valley and Ridge province. The most promising of these in the area mapped is the Keefer Sandstone along the northwest slope of Little North Mountain (Plate 4), where it is highly weathered. Samples of these formations from other locations within the State have been described and analyzed (Lowry, 1954; Carter, 1968, p. 352-353).

IRON ORE

Iron ore was locally mined before 1894 at several places along the western slope of Little North Mountain, and furnaces were located at Ferrol, Pond Gap, and Estaline (Darton, 1894; Watson, 1907, p. 436). These workings were in the Monterey sandstone (Darton, 1894), later referred to as the Oriskany ores. Little evidence of these early workings is still present; exposures along the northwest slope of Little North Mountain are poor, and no outcrops of iron ore were observed. The Oriskany Sandstone, where better exposed farther west, does not contain mineralization.

REFERENCES

Bick, K. F., 1960, Geology of the Lexington quadrangle, Virginia: Virginia Division of Mineral Resources Rept. Inv. 1, 40 p.

_____ 1962, Geology of the Williamsville quadrangle, Virginia: Virginia Division of Mineral Resources Rept. Inv. 2, 40 p.

Bowen, Z. P., 1967, Brachiopoda of the Keyser Limestone (Siluro-Devonian), Maryland and adjacent areas: Geol. Soc. America Mem. 102, 103 p.

Butts, Charles, 1933, Geologic map of the Appalachian Valley of Virginia with explanatory text: Virginia Geol. Survey Bull. 42, 56 p.

_____ 1940-41, Geology of the Appalachian Valley in Virginia: Virginia Geol. Survey Bull. 52, pt. 1 (geologic text), 568 p., pt. 2 (fossil plates), 271 p.

Calver, J. L., Smith, C. E., and Le Van, D. C., 1964, Analyses of clay, shale and related materials—west-central counties: Virginia Division of Mineral Resources, Mineral Resources Rept. 5, 230 p.

Carter, W. D., 1968, Silica, *in* Mineral resources of the Appalachian region: U. S. Geol. Survey Prof. Paper 580, p. 337-354.

Darton, N. H., 1894, Description of the Staunton sheet (Virginia-West Virginia): U. S. Geol. Survey Geol. Atlas, Folio 14.

Edmundson, R. S., 1958, Industrial limestones and dolomites in Virginia: James River district west of the Blue Ridge: Virginia Division of Mineral Resources Bull. 73, 137 p.

Fenneman, N. M., 1938, Physiography of Eastern United States: New York, McGraw-Hill Book Co., Inc., 714 p.

Lowry, W. D., 1954, Silica sand resources of western Virginia: Virginia Polytech. Inst. Bull., vol. 47, no. 12 (Eng. Expt. Sta. Ser. No. 96), 63 p.

Rader, E. K., 1967, Geology of the Staunton, Churchville, Greenville, and Stuarts Draft quadrangles, Virginia: Virginia Division of Mineral Resources Rept. Inv. 12, 43 p.

Swartz, F. M., 1929, The Helderberg group in parts of West Virginia and Virginia: U. S. Geol. Survey Prof. Paper 158-C, p. 27-75.

Watson, T. L., 1907, The mineral resources of Virginia: Lynchburg, Virginia, J. P. Bell Co., 618 p.

INDEX

PAGE

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

REPORT OF INVESTIGATIONS 21
PLATE 1

GEOLOGIC MAP OF THE ELLIOTT KNOB QUADRANGLE, VIRGINIA

Geology by Samuel J. Kozak

EXPLANATION

CENOZOIC — QUATERNARY

Qal — Alluvium
Unconsolidated clays, sands, and gravels.

MISSISSIPPIAN

Mpo — Pocono Formation
Gray to brownish, thick-bedded, coarse-grained sandstones and conglomerates.

Dhs — Hampshire Formation
Reddish-brown sandstones and shales.

DEVONIAN

Dch — Chemung Formation
Green and greenish-gray sandstones and shales and quartz-pebble conglomerates; fossiliferous.

Db — Brallier Formation
Greenish-gray, thin-bedded, micaceous siltstones and shales; dimpled bedding surfaces.

Dmn — Millboro Shale and Needmore Formation
Millboro: black fissile shale that weathers light gray, pink, or buff; scattered limestone concretions. Needmore: olive-green shale.

PALEOZOIC

DS — Lower Devonian and Upper Silurian Rocks
Oriskany Sandstone: light- to medium-gray, coarse-grained sandstone; locally conglomeratic and fossiliferous. Licking Creek Limestone: medium to dark blue-gray, medium-bedded, fine- to medium-grained, fossiliferous, cherty limestone. New Scotland Formation: medium- to dark-gray, medium- to coarse-grained, sandy, fossiliferous, cherty limestone. New Creek Limestone: light- to medium-gray and pink, medium- to coarse-grained, crinoidal limestone. Keyser Formation: medium- to dark-gray, medium- to coarse-grained, fossiliferous limestones in upper part; medium- to dark-gray, fine- to medium-grained limestones and light-gray, calcareous sandstones in lower part. Tonoloway Formation: dark-gray, fine-grained, thin-bedded limestones.

SILURIAN

Ske — Keefer Sandstone
White, fine- to medium-grained, friable sandstone that is locally conglomeratic.

Sca — Cacapon Formation
Red and green shales and sandstones.

Stu — Tuscarora Formation
White to light-gray, fine- to medium-grained quartzitic sandstones.

ORDOVICIAN

Omb — Martinsburg Formation
Light- to medium-gray, fine-grained limestone; light-gray to olive-drab shales; and fine- to medium-grained olive-drab sandstones. Map unit includes greenish-gray, fine- to medium-grained, dense sandstone at the top (Oswego Sandstone?).

CONTACTS

exposed
approximate
covered or inferred

FOLDS

Syncline—trace of axial plane
Anticline—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
NORMAL OR REVERSE

approximate
covered or inferred
U — upthrown side
D — downthrown side

ATTITUDE OF ROCKS

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

QUARRIES

Abandoned quarry
1. Shale and siltstone
2. North Mountain Brick of Virginia quarry (shale)

SAMPLE LOCATIONS

R-3885 — Representative samples of lithologies mapped or raw materials that have potential use in the ceramic industry.

Base from U.S. Geological Survey 1969, Elliott Knob Quadrangle, 7½-Minute Series

1967 MAGNETIC DECLINATION

SCALE 1:24 000

CONTOUR INTERVAL 40 FEET

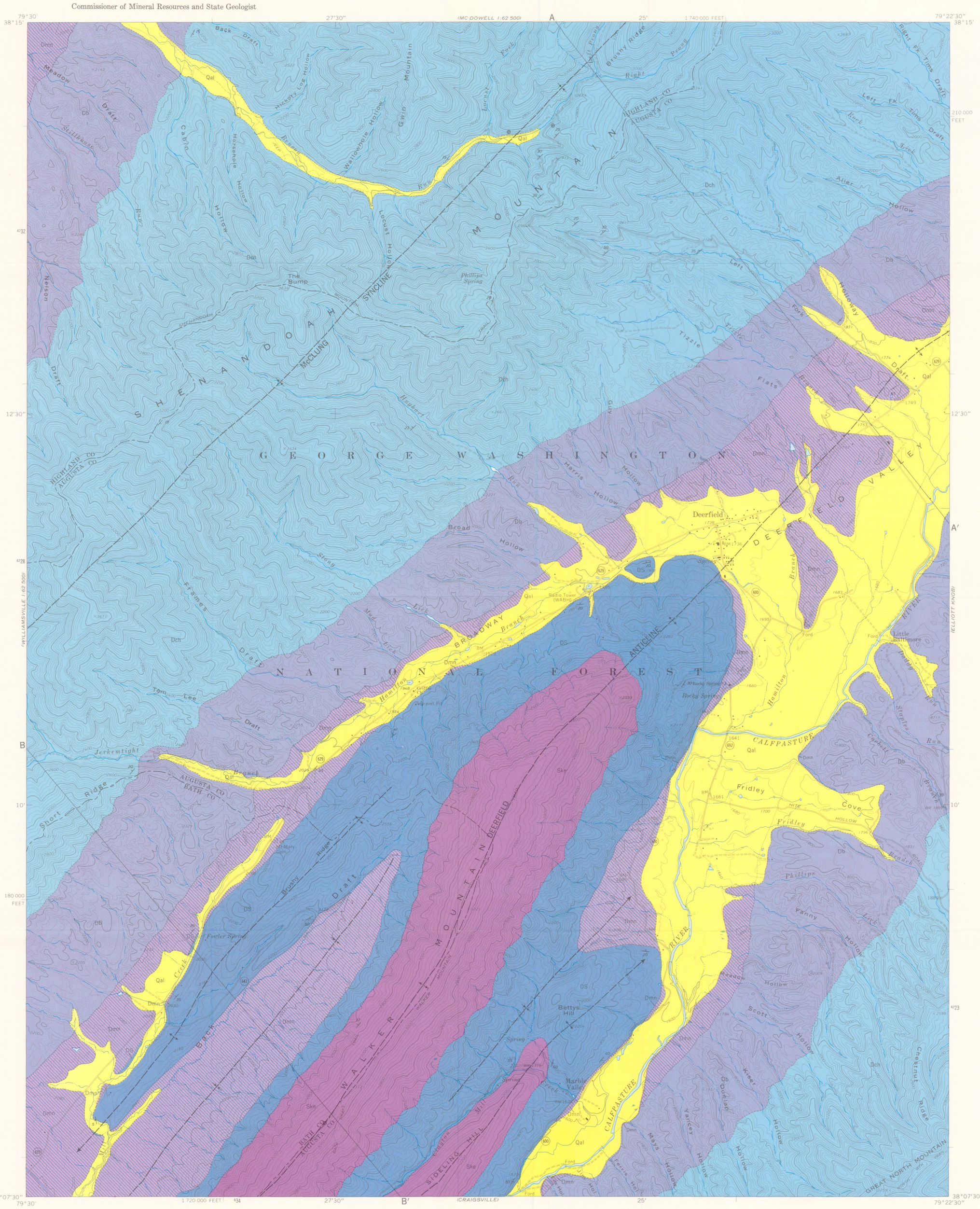
1970

VIRGINIA
QUADRANGLE LOCATION

Interpretive cross sections with 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

REPORT OF INVESTIGATIONS 21
PLATE 2



EXPLANATION

CENOZOIC — QUATERNARY

Qal — Alluvium
Unconsolidated clays, sands, and gravels.

PALEOZOIC — DEVONIAN

Dch — Chemung Formation
Green and greenish-gray sandstones and shales and quartz-pebble conglomerates; fossiliferous.

Db — Brallier Formation
Greenish-gray, thin-bedded, micaceous siltstones and shales; dimpled bedding surfaces.

Dmn — Millboro Shale and Needmore Formation
Millboro: black fissile shale that weathers light gray, pink, or buff; scattered limestone concretions. Needmore: olive-green shale.

DS — Lower Devonian and Upper Silurian Rocks
Oriskany Sandstone: light- to medium-gray, coarse-grained sandstone; locally conglomeratic and fossiliferous. Licking Creek Limestone: medium to dark blue-gray, medium-bedded, fine- to medium-grained, fossiliferous, cherty limestone. New Scotland Formation: medium- to dark-gray, medium- to coarse-grained, sandy, fossiliferous, cherty limestone. New Creek Limestone: light- to medium-gray and pink, medium- to coarse-grained, crinoidal limestone. Keyser Formation: medium- to dark-gray, medium- to coarse-grained, fossiliferous limestones in upper part; medium- to dark-gray, fine- to medium-grained limestones and light-gray, calcareous sandstones in lower part. Tonoloway Formation: dark-gray, fine-grained, thin-bedded limestones.

Ske — Keefer Sandstone
White, fine- to medium-grained, friable sandstone that is locally conglomeratic.

In cross sections only

SILURIAN

Sca — Cacapon Formation

Stu — Tuscarora Formation

ORDOVICIAN

Omb — Martinsburg Formation

Oe — Edinburg Formation

CONTACTS

exposed
approximate
covered or inferred

FOLDS

Anticline—trace of axial plane a direction of plunge of axis
Syncline—trace of axial plane direction of plunge of axis

ATTITUDE OF ROCKS

25 — Strike and dip of beds
Strike of vertical beds
Horizontal beds

Base from U.S. Geological Survey 1969,
Deerfield Quadrangle, 7½-Minute Series

GEOLOGIC MAP OF THE DEERFIELD QUADRANGLE, VIRGINIA

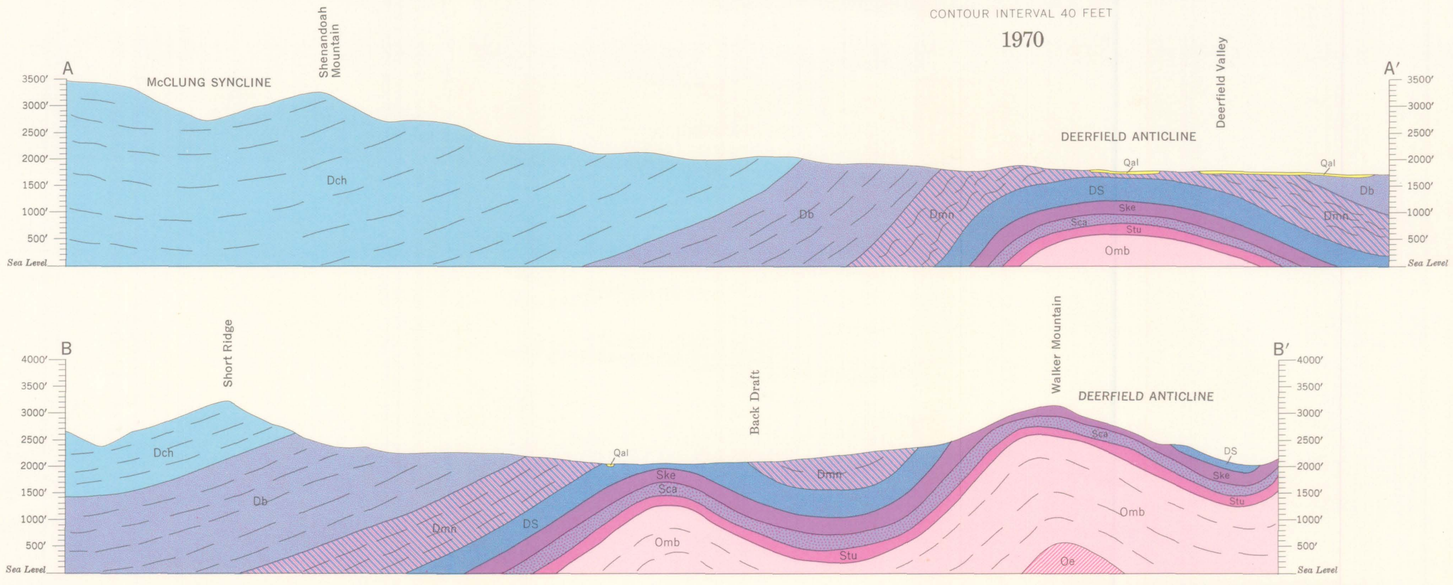
Geology by Samuel J. Kozak

4½° Magnetic North — True North
1967 MAGNETIC DECLINATION

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

1970

VIRGINIA
QUADRANGLE LOCATION



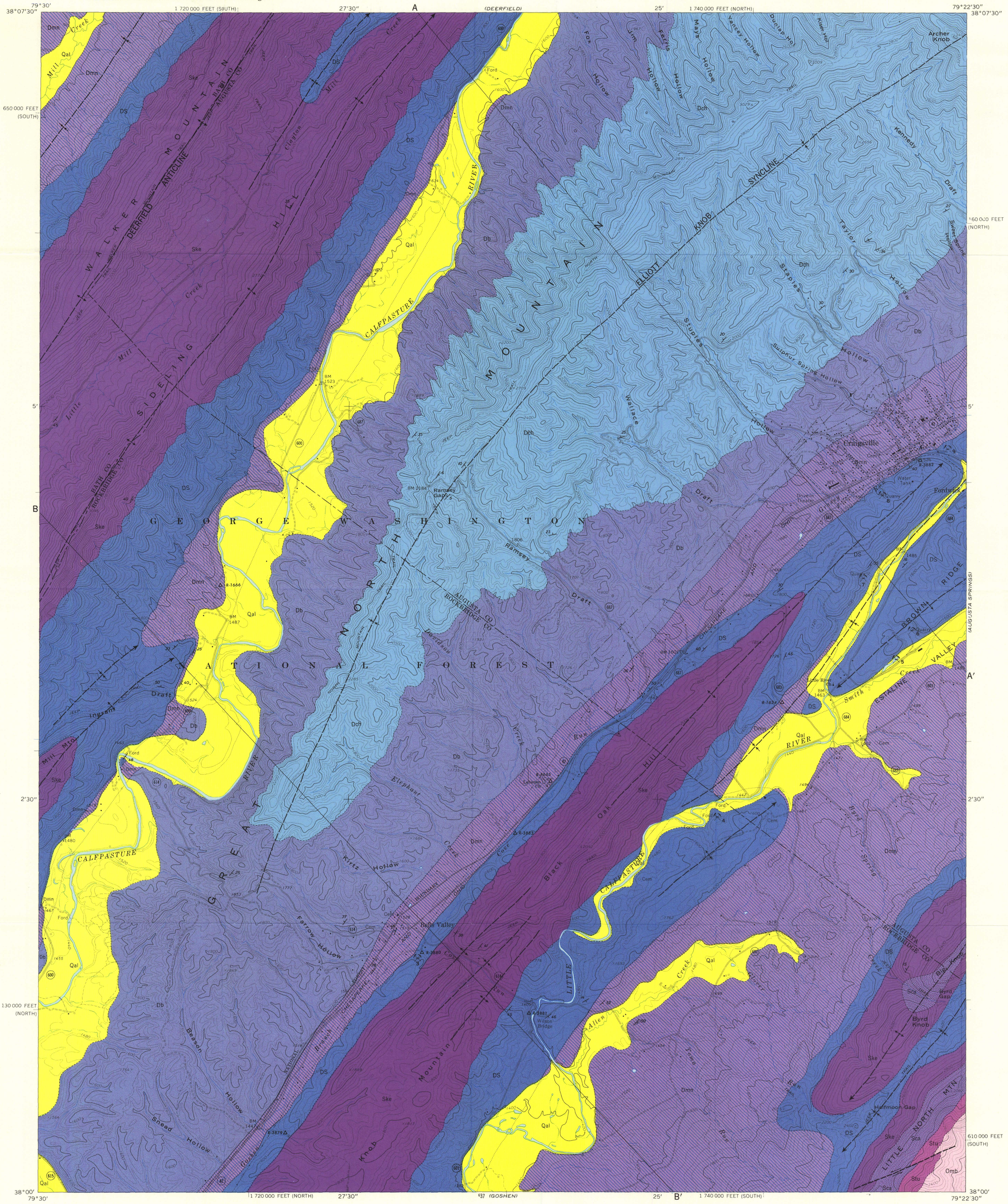
Interpretive cross sections
with no vertical exaggeration

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

REPORT OF INVESTIGATIONS 21
PLATE 3

GEOLOGIC MAP OF THE CRAIGSVILLE QUADRANGLE, VIRGINIA

Geology by Samuel J. Kozak



EXPLANATION

CENOZOIC

Qal — Alluvium
Unconsolidated clays, sands, and gravels. — QUATERNARY

Dch — Chemung Formation
Green and greenish-gray sandstones and shales and quartz-pebble conglomerates; fossiliferous.

Db — Brallier Formation
Greenish-gray, thin-bedded, micaceous siltstones and shales; dimpled bedding surfaces.

Dmn — Millboro Shale and Needmore Formation
Millboro: black fissile shale that weathers light gray, pink, or buff; scattered limestone concretions. Needmore: olive-green shale. — DEVONIAN

DS — Lower Devonian and Upper Silurian Rocks
Oriskany Sandstone: light- to medium-gray, coarse-grained sandstone; locally conglomeratic and fossiliferous. Licking Creek Limestone: medium to dark blue-gray, medium-bedded, fine- to medium-grained, fossiliferous, cherty limestone. New Scotland Formation: medium- to dark-gray, medium- to coarse-grained, sandy, fossiliferous, cherty limestone. New Creek Limestone: light- to medium-gray and pink, medium- to coarse-grained, crinoidal limestone. Keyser Formation: medium- to dark-gray, medium- to coarse-grained, fossiliferous limestones in upper part; medium- to dark-gray, fine- to medium-grained limestones and light-gray, calcareous sandstones in lower part. Tonoloway Formation: dark-gray, fine-grained, thin-bedded limestones.

PALEOZOIC

Ske — Keefer Sandstone
White, fine- to medium-grained, friable sandstone that is locally conglomeratic. — SILURIAN

Sca — Cacapon Formation
Red and green shales and sandstones.

Stu — Tuscarora Formation
White to light-gray, fine- to medium-grained quartzitic sandstones.

Omb — Martinsburg Formation
Light- to medium-gray, fine-grained limestone; light-gray to olive-drab shales; and fine- to medium-grained olive-drab sandstones. Map unit includes greenish-gray, fine- to medium-grained, dense sandstone at the top (Oswego Sandstone?). — ORDOVICIAN

IN CROSS SECTION ONLY

Oe — Edinburg Formation

CONTACTS

- exposed
- approximate
- covered or inferred

FOLDS

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

FAULTS
TRANSVERSE

- approximate
Arrows indicate inferred movement

ATTITUDE OF ROCKS

- 25 — Strike and dip of beds
- Strike of vertical beds
- Horizontal beds

QUARRIES

3 — Abandoned quarry

3. Limestone quarry
4. Limestone quarry
5. Lehigh Portland Cement Company quarry
6. Lehigh Portland Cement Company quarry (limestone)
7. Limestone quarry
8. Limestone quarry
9. Limestone quarry

SAMPLE LOCATIONS

△ R-3880 — Representative samples of lithologies mapped or raw materials that have potential use in the ceramic industry.

Base from U.S. Geological Survey 1969,
Craigsville Quadrangle, 7½-Minute Series

4½° Magnetic North — True North
1967 MAGNETIC DECLINATION

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

VIRGINIA
QUADRANGLE LOCATION

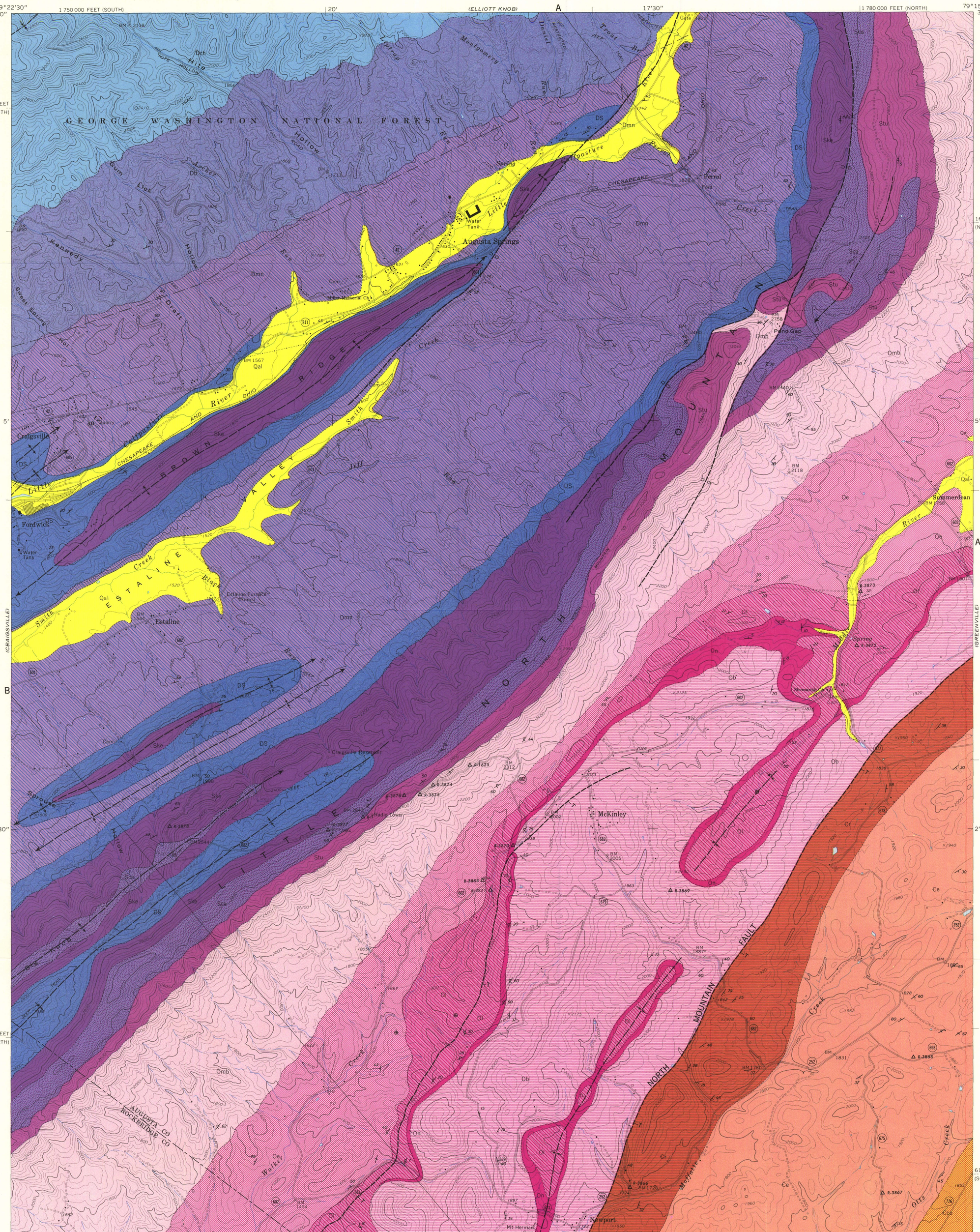
1970

Interpretive cross sections
with 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

GEOLOGIC MAP OF THE AUGUSTA SPRINGS QUADRANGLE, VIRGINIA

Geology by Samuel J. Kozak



EXPLANATION

CENOZOIC

QUATERNARY

Qal — Alluvium
Unconsolidated clays, sands, and gravels.

DEVONIAN

Dch — Chemung Formation
Green and greenish-gray sandstones and shales and quartz-pebble conglomerates; fossiliferous.

Db — Brallier Formation
Greenish-gray, thin-bedded, micaceous siltstones and shales; dimpled bedding surfaces.

Dmn — Millboro Shale and Needmore Formation
Millboro: black fissile shale that weathers light gray, pink, or buff; scattered limestone concretions. Needmore: olive-green shale.

DS — Lower Devonian and Upper Silurian Rocks
Oriskany Sandstone: light- to medium-gray, coarse-grained sandstone; locally conglomeratic and fossiliferous. Licking Creek Limestone: medium to dark blue-gray, medium-bedded, fine- to medium-grained, fossiliferous, cherty limestone. New Scotland Formation: medium- to dark-gray, medium- to coarse-grained, sandy, fossiliferous, cherty limestone. New Creek Limestone: light- to medium-gray and pink, medium- to coarse-grained, crinoidal limestone. Keyser Formation: medium- to dark-gray, medium- to coarse-grained, fossiliferous limestones in upper part; medium- to dark-gray, fine- to medium-grained limestones and light-gray, calcareous sandstones in lower part. Tonoloway Formation: dark-gray, fine-grained, thin-bedded limestones.

SILURIAN

Ske — Keefer Sandstone
White, fine- to medium-grained, friable sandstone that is locally conglomeratic.

Sca — Cacapon Formation
Red and green shales and sandstones.

Stu — Tuscarora Formation
White to light-gray, fine- to medium-grained quartzitic sandstones.

PALEOZOIC

ORDOVICIAN

Omb — Martinsburg Formation
Light- to medium-gray, fine-grained limestone; light-gray to olive-drab shales; and fine- to medium-grained olive-drab sandstones. Map unit includes greenish-gray, fine- to medium-grained, dense sandstone at the top (Oswego Sandstone?).

Oe — Edinburg Formation
Black, fine-grained, thin-bedded limestones alternating with black, calcareous shales (Liberty Hall); medium- to dark-gray, medium-grained, cobbly limestones (Lantz Mills). Botetourt Member (at base)—medium- to coarse-grained, medium- to dark-gray, fossiliferous limestone; locally stained red.

Ol — Lincolnshire Formation
Medium- to dark-gray, medium-grained, nodular limestone and shale with black chert. White to light-gray, coarse-grained, fossiliferous limestone (Murat).

On — New Market Limestone
Dove-gray, aphanitic, limestone.

Ob — Beekmantown Formation
Light-gray, fine-grained, thick-bedded dolomite with locally abundant chert; aphanitic light-gray limestones present near the top.

CAMBRIAN

Cce — Conococheague Formation
Medium-gray, thin- to medium-bedded limestone and dolomite; vermiculoid-weathering argillaceous and silty beds present.

Ce — Elbrook Formation
Light- to dark-gray, fine- to medium-grained limestones and dolomites.

Cr — Rome Formation
Red, purple, green, and gray shales and medium- to dark-gray dolomite and limestone.

CONTACTS

- exposed
- approximate
- covered or inferred

FOLDS

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

NORMAL OR REVERSE
- approximate
- U — upthrown side
- D — downthrown side

ATTITUDE OF ROCKS

- 25 — Strike and dip of beds
- 85 — Strike and dip of overturned beds
- Strike of vertical beds
- Horizontal beds

QUARRY

10 — Abandoned quarry
10. Lehigh Portland Cement Company quarry (shale)

SAMPLE LOCATIONS

△ R-3867 — Representative samples of lithologies mapped or raw materials that have potential use in the ceramic industry.

Base from U.S. Geological Survey 1969,
Augusta Springs Quadrangle, 7½-Minute Series

4½° Magnetic North — True North

1967 MAGNETIC DECLINATION

SCALE 1:24 000

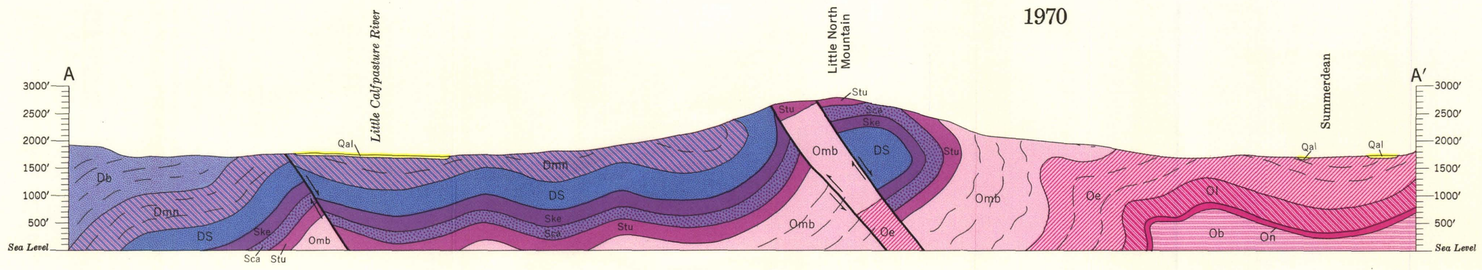
1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 KILOMETER

CONTOUR INTERVAL 40 FEET

1970

VIRGINIA

QUADRANGLE LOCATION



Interpretive cross sections
with no vertical exaggeration