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

GEOLOGY OF THE STRASBURG AND TOMS BROOK QUADRANGLES, VIRGINIA

EUGENE K. RADER AND
THOMAS H. BIGGS

REPORT OF INVESTIGATIONS 45

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

CHARLOTTESVILLE, VIRGINIA
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CONTENTS

	PAGE
Abstract	1
Introduction	2
Stratigraphy	4
Cambrian System	8
Waynesboro (Rome) Formation	8
Elbrook Formation	8
Conococheague Formation	9
Ordovician System	11
Stonehenge Formation	11
Rockdale Run Formation	12
New Market Limestone	15
Lincolnshire Formation	17
Edinburg Formation	19
Oranda Formation	21
Martinsburg Formation	21
Oswego Formation	24
Juniata Formation	25
Silurian System	25
Massanutten Sandstone	25
Tuscarora Formation	28
Rose Hill Formation	29
Keefer Formation	30
Lower Devonian and Upper Silurian rocks	30
McKenzie Formation	30
Bloomsburg Formation	31
Wills Creek Formation	31
Tonoloway Formation	33
Keyser Formation	33
Devonian System	33
Helderberg limestones	33
New Creek Limestone	34
New Scotland limestone	34
Ridgeley Sandstone	34
Needmore Formation	35
Tioga Bentonite	36
Marcellus Shale	36
Mahantango Formation	38
Quaternary System	38

PAGE

Talus deposits 39
Terrace deposits 40
Alluvium 40
Peridotite dike 42
Structure 45
Massanutten mountain range 45
Martinsburg Formation belt 47
Carbonate lowland 48
Little North Mountain 48
Economic geology 49
Industrial limestone and dolomite 49
High-calcium limestone 53
Impure limestone 53
Crushed and broken stone 55
High-silica sand 55
Sand and gravel 56
Clay, shale, and related materials 56
Iron and manganese 56
Hydrogeology, by Richard H. DeKay 59
Clastic rocks 60
Clastic-carbonate rocks 63
Carbonate rocks 67
Formation protection 70
Environmental geology 71
Unit 1 72
Unit 2 73
Unit 3 74
Unit 4 74
Unit 5 75
Unit 6 75
Unit 7 77
Unit 8 77
Unit 9 78

PAGE

Unit 10 79
Unit 11 80
Unit 12 80
Rockfalls and landslides 81
Fill 81
Karst areas 81
References 83
Appendix I: Stratigraphic section 86
Appendix II: Road log 88
Appendix III: Soils 94
General index 99
Index of fossil names 104

ILLUSTRATIONS

PLATE — PAGE

1. Geologic map of the Strasburg quadrangle, Virginia ..... In pocket
2. Geologic map of the Toms Brook quadrangle, Virginia ..... In pocket
3. Geologic factors affecting land modification, Strasburg quadrangle, Virginia ..... In pocket
4. Geologic factors affecting land modification, Toms Brook quadrangle, Virginia ..... In pocket

FIGURE

1. Index map 2
2. Topographic areas 3
3. Sandstone in the lower Conococheague Formation 10
4. Dolomite and chert in the Rockdale Run Formation 13
5. Collapse breccia in the Rockdale Run Formation 14
6. Lincolnshire-New Market contact 16
7. Photomicrograph of pelsparite of the New Market Limestone 17
8. Edinburg-Lincolnshire contact 18
9. Black chert in the Lincolnshire Formation 19
10. Cobbly limestone of the Edinburg Formation 20
11. Photomicrograph of sandstone and siltstone of the Martinsburg Formation 23
12. Quartzite of the lower Massanutten Sandstone 26
13. Sandstone and shale of the upper Massanutten Sandstone 27
14. Photomicrograph of quartzite of the upper Massanutten Sandstone 28
15. Photomicrograph of biosparite of the Wills Creek Formation 32
16. Photomicrograph of sandstone of the Ridgeley Sandstone 35

FIGURE PAGE

17. Black fissile shale of the Marcellus Shale 37
18. Limestone concretion 37
19. Talus deposit 39
20. Magnetic profiles 43
21. Analyses of soil samples 44
22. Small fold in the Massanutten Sandstone 46
23. Small fold in the Martinsburg Formation 47

TABLES

PAGE

1. Geologic formations in the Strasburg and Toms Brook quadrangles 4
2. Chemical requirements for uses of limestone and dolomite 50
3. Chemical composition of carbonate rocks from selected localities in the Strasburg and Toms Brook quadrangles 51
4. Physical test data of coarse aggregate from potential sources 54
5. Potential uses of clay and shale materials from the Strasburg and Toms Brook quadrangles 57
6. Composite record of reported-depth and estimated-yield data for 102 water wells in clastic rocks 62
7. Composite of the most commonly reported total-depth and estimated-yield ranges for 177 water wells in eight geologic formations 64
8. Composite record of reported-depth and estimated-yield data for 24 wells in clastic-carbonate rocks 66
9. Composite record of reported-depth and estimated-yield data for 51 water wells in carbonate rocks 68

GEOLOGY OF THE STRASBURG AND TOMS BROOK QUADRANGLES, VIRGINIA

By

Eugene K. Rader and Thomas H. Biggs

ABSTRACT

The Strasburg and Toms Brook 7.5-minute quadrangles are located in Shenandoah and Warren counties, northern Virginia, in the Valley and Ridge physiographic province. The bedrock ranges in age from Early Cambrian (Waynesboro Formation) through Middle Devonian (Mahantango Formation). The Paleozoic rocks are assigned to 28 formations and 23 mappable units. Additionally, Cenozoic sediments consisting of terrace deposits, talus deposits, alluvial fans, and flood-plain deposits are mapped. Also, one peridotite dike of unknown age is mapped.

The major structural features consist of the Massanutten synclinorium and North Mountain fault. East of Massanutten Mountain the bedrock has a steep dip and locally the east limbs of synclines and west limbs of anticlines are overturned. The North Mountain fault has an easterly dip. Four large detached footwall slices are exposed along the North Mountain fault. The major fold axes trend to the northeast along the general strike of the formational outcrops. The strongest joint direction is N. 40° W. Two generations of southeastward-dipping cleavage pervade the less competent rock units.

Impure and high-calcium limestone and crushed and broken stone are produced. Iron and manganese ores have been mined in the past. Limestone, dolomite, sandstone, and shale are available as raw materials for many purposes.

Although the geologic formations present have little primary permeability, secondary permeability in the form of fractures and solution openings are sufficiently well developed to contain small to moderate supplies of ground water in most portions of the two quadrangles. Wells in the clastic rocks are the shallowest and have the fewest failures, and wells in the carbonate rocks have the greatest range in depth and yield. Rock units that contain both lithologies furnish the smallest quantities of water from wells of moderate depths.

Data for land-use decisions is provided by environmental geology information obtained from geological characteristics such as lithology, slope stability, erodibility, rockfall areas, and sinkholes. Reference to soils and land-use potential is made.

INTRODUCTION

The Strasburg (Plate 1) and Toms Brook (Plate 2) 7.5-minute quadrangles are located in Warren and Shenandoah counties, northern Virginia (Figure 1). They have an area of about 58 square miles (150 sq km) each and are bounded by 78°15′ and 78°30′ west longitudes and 30°52′30″ and 39°00′ north

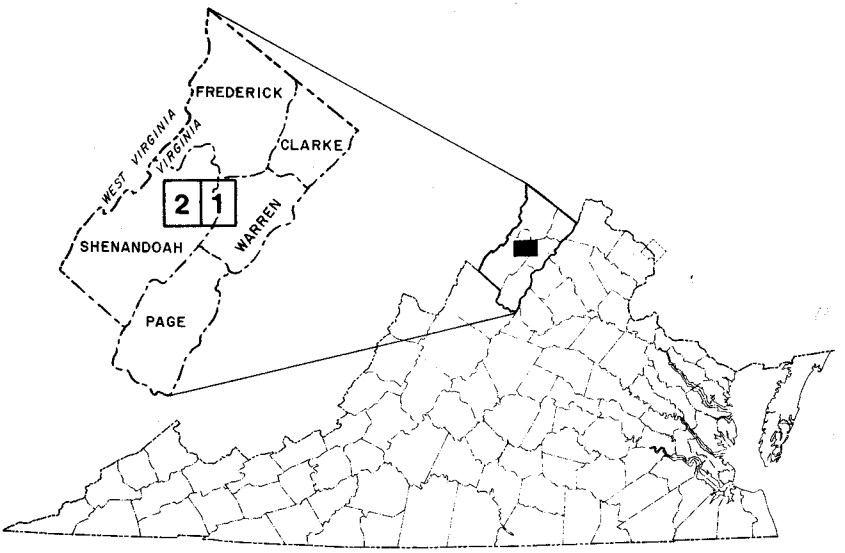
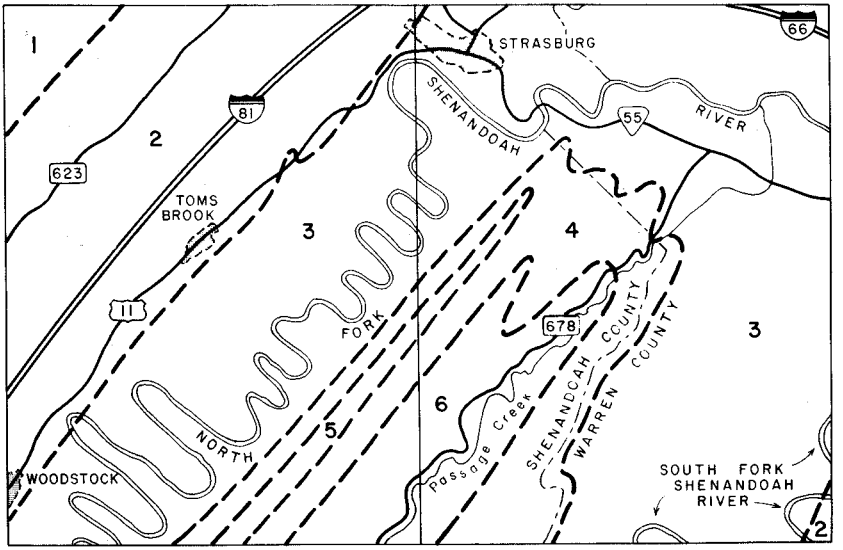


Figure 1. Index map showing location of the Strasburg (1) and Toms Brook (2) quadrangles, Virginia.

latitudes. The quadrangles are in the Valley and Ridge physiographic province and have six distinctive topographic areas. In the northwest corner of the Toms Brook quadrangle (Figure 2, Area 1) the topography is dominated by a narrow linear ridge. Sreams flow northwesterly and southeasterly normal to the ridge trend. Upper slopes are concave and steep. Lower slopes are mostly convex and gentle. Area 2 is a broad northeastward-trending belt in the Toms Brook quadrangle and in the southeast corner of the Strasburg quadrangle. The western portion of Area 2 is dominated by northeastward-trending linear ridges with convex slopes. Stream valleys are generally straight and relatively wide. A broad, horseshoe-shaped area that encloses the Massanutten mountain range has deeply dissected linear and arcuate hills and V-shaped valleys (Figure 2, Area 3). Included in Area 3 are the meanders of the North and South



Figures 2. Topographic areas in the Strasburg and Toms Brook quadrangles.

forks of the Shenandoah River and associated wide flood plains, terraces, and cutoff meanders. The famous Seven Bends of the North Fork are in this area and have been described by Hack and Young (1959). The Massanutten mountain range is a group of deeply dissected linear ridges joined by a dissected arcuate ridge on the north (Figure 2, Area 4). Within Area 4 are two valleys labeled 5 and 6. Area 5, the westernmost valley (Little Fort Valley), is a northeastward-trending, cigar-shaped valley. Fort Valley, the easternmost valley, is a dissected valley with linear and arcuate hills (Figure 2, Area 6). Elevations range from less than 480 feet (146 m) on the North and South forks of the Shenandoah River at the east edge of the map to 2,393 feet (729 m) at Meneka Peak (Plate 1).

Access to the area is by Interstate Highways 66 and 81, U. S. Highway 11, State Highway 55, and numerous State Roads. Railroad service is provided by the Baltimore and Ohio Railway, the Norfolk and Western Railway, and Southern Railway.

The "Geologic Map of the Appalachian Valley of Virginia with Explanatory Text" (Butts, 1933), the "Geology of the Appalachian Valley in Virginia" (Butts, 1940-41), and the "Geologic Map of Virginia" (Virginia Division of Mineral Resources, 1963) provided useful regional geologic data. In-

formation related to industrial limestones and dolomites was obtained from Edmundson (1945). Geomorphic data was obtained from Hack (1965) and Hack and Young (1959). Published measured sections are listed in Webb and Nunan (1972, p. 148-154, 176-179). Field maps of the Strasburg 15-minute quadrangle, prepared by R. S. Edmundson and C. Thornton, were of great assistance. The field investigation was begun in September 1974 and completed in May 1975.

The writers wish to acknowledge the assistance given by R. S. Edmundson and J. M. Dennison which has contributed to a clearer understanding of the stratigraphy and structure of the area. R. A. Bailey of the U. S. Geological Survey provided a sample, thin sections, and photographs of the peridotite dike.

Numbers preceeded by "R" in parentheses (R-6135) correspond to sample localities; those preceeded by "F" (F-907) correspond to fossil localities (Plates 1, 2). These samples and fossils are on file in the repository of the Virginia Division of Mineral Resources where they are available for examination.

STRATIGRAPHY

The rock strata cropping out in the area are divided into 28 formations and 23 mappable units on the bases of lithologic character and fossils. The oldest rock exposed is the Waynesboro (Rome) Formation of Lower Cambrian age and the youngest is the Mahantango Formation of Middle Devonian age (Table 1).

Table 1.—Geologic formations in the Strasburg and Toms Brook quadrangles.

Age	Name	Character	Thickness in feet (meters)
Quaternary	Alluvium	Flood-plain deposits of brown, fine-grained quartz sand, silt, and minor clay and gravel.	3-25 (1-8)
		Alluvial-fan deposits of pebbles, cobbles, and boulders of sandstone, quartzite, and conglomerate in a sand matrix.	10-30 (3-9)
	Terrace deposits	Pebbles and cobbles of sandstone, quartzite, and conglomerate in a matrix of sand, silt, and clay.	0-25± (0-8±)
	Talus deposits	Loose, angular accumulations of cobbles and boulders on steep slopes.	3-20 (3-9)

Age	Name	Character	Thickness in feet (meters)
?	Peridotite dike	Chloritized mica periodotite.	
Devonian	Mahantango Formation	Greenish-gray, silty shale, siltstone, and very fine-grained sandstone; fossiliferous.	900+ (274+)
	Marcellus Shale	Dark-gray to black, fissile shale; limestone concretion layer near middle.	350-400 (107-122)
	Tioga Bentonite	Gray silty shale and siltstone and biotite-bearing, calcareous tuffs.	80-100 (24-30)
	Needmore Formation	Greenish-gray, silty shale and siltstone; fossiliferous.	100-450± (30-137±)
	Ridgeley Sandstone	White to gray, coarse-grained, calcareous sandstone; sandy limestone; fossiliferous.	5-100 (2-30)
	New Scotland limestone	Dark-gray, silty limestone; gray to white, blocky chert; medium- to coarse-grained limestone; fossiliferous.	10-40 (3-12)
	New Creek Limestone	Gray, coarse-grained, crinoidal limestone.	6-8 (9)
	Keyser Formation	Gray, fine- to medium-grained limestone; and coarse-grained crinoidal limestone; thin, brown sandstone; fossiliferous.	75± (23±)
Silurian	Tonoloway Formation	Dark-gray, laminated, argillaceous limestone with thin, yellow-weathering shale partings; fossiliferous.	50-100 (15-30)
	Wills Creek Formation	Greenish-gray, calcareous silty shale; brown-weathering, gray calcareous, sandy siltstone; gray, fossiliferous limestone; thin maroon shale; fossiliferous.	60-150 (18-46)
	Bloomsburg Formation	Maroon, ferruginous sandstone, siltstone, shale, and mudstone; gray sandstone; carbonaceous shale; fossiliferous.	100-400 (30-122)
	McKenzie Formation	Yellowish-brown shale.	0-75 (0-23)

Age	Name		Character	Thickness in feet (meters)
Silurian	Keefer Formation	Sandstone	Gray to white, cross-bedded quartzite.	60-70 (18-21)
	Rose Hill Formation		Yellowish-brown, brittle, sandy shale; gray, fine- to medium-grained sandstone.	650± (198±)
	Tuscarora Formation		Thick-bedded, white quartzite with a basal conglomerate; minor red, green, and purple shale common locally.	300± (91±)
		Massanutten	Massive, white to gray, conglomeratic sandstone and quartzite; reddish-brown in upper part.	700-1200 (213-365)
Ordovician	Juniata Formation		White, chocolate, and red sandstone; red shale.	450-500 (137-152)
	Oswego Formation		Greenish-gray, brown-weathering, fine-grained sandstone; tan shale; conglomerate.	
	Martinsburg Formation		Black shale and limestone; interbedded greenish shale and lithic sandstone; brown lithic sandstone; fossiliferous.	3,200± (975±)
	Oranda Formation		Gray to brownish-gray siltstone; black silty shale; calcareous mudstone; cobbly weathering limestone; tan to brown metabentonites; fossiliferous.	50-60 (15-18)
	Edinburg Formation		*St. Luke Member:* Gray, medium- to coarse-grained limestone and dove-gray, micritic limestone. *Lantz Mills:* Cobbly weathering, dark-gray to black, fine-grained, argillaceous limestone. *Liberty Hall:* Black, fine-grained to aphanic, shaly limestone and black shale.	450-550 (137-168)
	Lincolnshire Formation		Dark-gray, medium-grained limestone; locally, black and dark-gray, blocky chert; thin beds of light-gray, coarse-grained bioclastic limestone; fossiliferous.	25-170 (8-52)

Age	Name	Character	Thickness in feet (meters)
Ordovician	New Market Limestone	Bluish- to dove-gray, micritic limestone (upper part). Carbonate-pebble, -cobble, and -boulder conglomerate and impure limestone (lower part).	40-162 (12-49)
	Rockdale Run Formation	Light- to dark-gray, fine-grained dolomite; bluish-gray limestone, mottled dolomitic limestone; coarse-grained recrystalline dolomite; black nodular and bedded chert; rusty gnarly chert; fossiliferous.	2,127 (648)
	Stonehenge Formation	Black to dark-gray, thick-bedded limestone; bioclastic limestone; dolomite; dolomitic limestone; minor dark-gray to black chert; fossiliferous *Stoufferstown Member:* dark-gray limestone with crinkly siliceous laminae; fossiliferous.	400-450 (122-137)
Cambrian	Conococheague Formation	Bluish-gray, fine-grained, laminated limestone; light-gray, fine-grained dolomite; calcareous sandstone. *Big Spring Station Member:* rusty-weathering, calcareous quartz sandstone; bluish-gray, laminated limestone; light-gray dolomite; intraformational conglomerate.	2,500± (762±)
	Elbrook Formation	Bluish-gray, algal limestone and yellow-weathering, laminated dolomite (upper part). Bluish-gray limestone; greenish-gray, argillaceous dolomite; light-gray dolomite (middle part). Light-gray dolomite, minor limestone; maroon and yellow shale near middle (lower part).	2,200± (671±)
	Waynesboro (Rome) Formation	Maroon and yellow shale and siltstone; minor gray dolomite and rusty-weathering sandstone.	200± (61±) (incomplete)

Southeast of Little North Mountain to about U. S. Highway 11 (Plate 2) and in the southeast corner of Plate 1 the area is underlain by Cambrian and Ordovician limestone, dolomite, and shale. Between the carbonates and the Massanutten mountain range the Ordovician lithic sandstones and shales are intensely folded. Little North Mountain and the Massanutten mountain range are underlain by Silurian and Devonian sandstone, shale, red beds, and minor limestone.

Surficial sediments of Cenozoic age consist of four mapping units: flood-plain deposits, alluvial fans, terrace deposits, and talus deposits.

CAMBRIAN SYSTEM

WAYNESBORO (ROME) FORMATION

A narrow belt of the Waynesboro (Rome) Formation is exposed along the North Mountain fault in the north-central portion of the Toms Brook quadrangle (Plate 2) northwest of State Road 623. The outcrops extend for about 0.4 mile (0.6 km) along a northeasterly strike with a southeasterly dip. The rocks are cut by steep southeastward-dipping fracture cleavage. The upper contact is placed at the top of the youngest maroon shale overlain by argillaceous dolomite and dolomitic shale of the Elbrook. The unit is composed of maroon and yellow shale and siltstone with minor gray, fine- to medium-grained, thick-bedded dolomite and thin-bedded, rusty-weathering sandstone. The thickness is about 200 feet (61 m).

ELBROOK FORMATION

The Elbrook Formation is exposed in a northeastward-trending belt east and west of State Road 623 from Saumsville on the southwest to the center of the northern boundary of the map (Plate 2). Northwest of the junction of State Roads 652 and 658 for 0.5 mile (0.8 km) the upper portion of the formation is well exposed. The upper few hundred feet of the formation is exposed northeast of the farmhouse 0.6 mile (1.0 km) south-southwest of the junction of State Roads 601 and 623. The remainder of the formation is exposed along Toms Brook east and west of State Road 623; in the fields north of State Road 658; and along farm roads northwest of State Road 623, 0.4 (0.6 km) and 1.1 miles (1.8 km) northeast of Mt. Olive. The

lower contact is faulted except near the north edge of the map where the maroon shale of the Waynesboro conformably underlies the argillaceous dolomite of the Elbrook. The upper contact is mapped as the youngest silty, dolomitic, dark-gray, rusty-weathering shale below typical Conococheague sandstone.

The lower approximately 500 feet (152 m) is composed of medium- to light-gray, thick-bedded, fine-grained dolomite with minor bluish-gray, thin-bedded limestone and greenish-gray, platy-weathering dolomite. Near the middle of this lower unit is a thin, 10- to 15-foot- (3- to 5-m-) thick, maroon and yellow shale (R-6166). The bulk of the formation is included in the middle unit which is approximately 1,400 feet (427 m) thick. Bluish-gray, thin-bedded, fine-grained limestone (R-6174); greenish-gray, argillaceous dolomite (R-6180); and light-gray, fine-grained dolomite comprise the rocks of the unit. The upper 300 feet (91 m) of the formation is a distinctive interbedded sequence of yellow- to buff-weathering, gray, laminated dolomite, dolomitic shale, and bluish-gray, algal limestone.

A thickness of 2,200 feet (671 m) is estimated from the map and this agrees with estimates by Butts and Edmundson (1966, p. 17) and Rader and Biggs (1975, p. 18). Algae were the only fossils found.

CONOCOCHEAGUE FORMATION

West of State Road 623 along the headwaters of Toms Brook a faulted slice of Conococheague is exposed in a northeastward-trending belt for 1.5 miles (2.4 km, Plate 2). The main belt of Conococheague trends northeasterly from south of Saumsville to the north-central boundary of the map (Plate 2) and is folded in numerous small folds. Good exposures of the formation occur along Jordon Run east and southwest of State Road 642 and along State Road 653 and Toms Brook. Numerous folds are well exposed along Snapps Run and State Road 646 and along State Road 601. The lower sandstones are best exposed along State Road 652, 0.3 mile (0.5 km) northeast of the junction of State Roads 652 and 658. The upper sandstones are well exposed along Jordon Run, 1,000 to 2,000 feet (305-610 m) east of the junction of State Roads 652 and 642. The basal contact is described with the Elbrook Formation. The upper contact is mapped at the top of the youngest bluish-gray, fine-grained limestone below the dark-gray limestone with siliceous laminae of the Stoufferstown member of the Stonehenge Formation.

The lower 300 feet (91 m) of the Conococheague has been named the Big Spring Station Member by Wilson (1952). It is composed of rusty-weathering, coarse-grained, calcareous, quartz sandstone (Figure 3) ; bluish-gray, fine-grained, laminated

Figure 3. Thin-bedded, calcareous, quartz sandstone in the lower Conococheague Formation (Big Spring Station Member) along State Road 655, 300 feet (91 m) east of the junction of State Roads 652 and 655 (Plate 2).

limestone; minor light-gray, fine-grained dolomite; dark-gray, dolomitic limestone; and intraformational conglomerate. The conglomerate beds contain flat, plate-like limestone clasts in a fine- to medium-grained limestone matrix with algae, oolites, and quartz grains. The sandstone beds are rarely more than 10 feet (3 m) thick but seem to be concentrated at distinct stratigraphic levels. The linear ridges near the base and higher in the Conococheague are the result of the sandstones. These sandstone concentrations are shown in Plate 4. Above the Big Spring is a unit about 1,000 feet (305 m) thick composed of bluish-gray, fine-grained, laminated limestone with about 10 percent light-gray, fine-grained dolomite. Much of the limestone contains siliceous laminae which stand out in low relief. Dark-gray, ribbon-banded limestone and edgewise conglomerate are

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common. A second unit with abundant sandstone beds, about 900 feet (274 m) thick, overlies the laminated limestone. Lithologically the unit is composed of rusty-weathering, coarse-grained, calcareous, quartz sandstone (R-6178); laminated, bluish-gray, fine-grained limestone (R-6173); and less than 10 percent light-gray, fine-grained dolomite and dolomitic limestone (R-6177). The upper 300 feet (91 m) of the formation is composed of laminated, bluish-gray, fine-grained limestone with scattered oolitic beds and a few edgewise conglomerates. Dolomite beds are rare in the upper 300 feet (91 m) of the Conococheague. The total thickness of the Conococheague is estimated to be 2,500 feet (762 m).

ORDOVICIAN SYSTEM

STONEHENGE FORMATION

The Stonehenge Formation may be divided into two units in the mapped area. Sando (1958) named the lower unit the Stoufferstown Member. The upper unit, which comprises the bulk of the formation, is unnamed. The Stonehenge is exposed in a synclinal belt extending from Pughs Run to Harrisville, in a small syncline 1 mile (1.6 km) northeast of Harrisville, and in a northeastward-trending belt extending from Pughs Run to the north boundary of the map (Plate 2). The best exposures of the Stoufferstown Member are along Tumbling Run and near the two farm ponds south of the junction of State Roads 642 and 657. The upper unit is well exposed along Pughs Run west of State Road 642, in the fields north of the junction of State Roads 642 and 662, along State Road 653 and Toms Brook, along Tumbling Run, and in abandoned quarry number 17. The lower contact is discussed with the Conococheague. The upper contact is mapped at the top of the youngest black limestone overlain by a thin bed of recrystalline dolomite of the Rockdale Run Formation.

The Stoufferstown Member is a thin- to thick-bedded, fine- to medium-grained, dark-gray limestone (R-6172). Crinkly siliceous or silty laminae are abundant and are the most distinctive feature of this member. The laminae weather grayish orange, yellowish brown, and yellowish orange and range in thickness from 1 to 25 mm. Dark-gray, fine-grained dolomite comprises less than 5 percent of the member. Lenticular beds of intraformational conglomerate and scattered oolites are common.

The Stoufferstown commonly forms a low topographic bench along the slope of the linear ridges on the Conococheague. Butts (1940-41) and Butts and Edmundson (1966) mapped the Stoufferstown as part of the Conococheague. Sando (1958) and Wood (1962), however, indicate that the Ordovician boundary is at the base of the Stoufferstown.

The unit above the Stoufferstown Member consists of black to dark-gray, aphanic to fine-grained, thick-bedded limestone (R-5903) with scattered beds and channel fill of dark- to medium-gray, bioclastic limestone. Medium- to dark-gray, fine-grained dolomite and dolomitic limestone comprise about 10 percent of the upper member. A few thin beds of light-gray, fine-grained dolomite occur just below the contact with the Rockdale Run. Nodules of dark-gray to black chert are locally common.

The total thickness of the Stonehenge ranges from 400 to 450 feet (122-137 m). According to Wood (1962) the Stoufferstown Member thins from 80 feet (24 m) northwest of Oranda (north of the Toms Brook 7.5-minute quadrangle) to 53 feet (16 m) near Mt. Jackson (southwest of the Toms Brook 7.5-minute quadrangle). Fossils, such as *Finkelnburgia* (brachiopod), *Eccyliomphalus* (gastropod), and small curved cephalopods (Unklesbay and Young, 1956), are common but not obvious upon casual examination of an outcrop.

ROCKDALE RUN FORMATION

The Rockdale Run Formation is exposed in a broad belt extending southwesterly from Strasburg Junction to Woodstock (Plates 1, 2) as a western lithofacies, adjacent to the South Fork of the Shenandoah River as an eastern lithofacies (Plate 1), and in fault slices adjacent to the North Mountain fault (Plate 2). The western lithofacies of the formation is best exposed along State Road 601 and Tumbling Run in the vicinity of Fishers Hill and along Snapps Run, Toms Brook, and Pughs Run. Near the South Fork of the Shenandoah River in the extreme southeast corner of Plate 1 along the Norfolk and Western Railway a section that is typical of the eastern Rockdale Run lithofacies is exposed. Along the North Mountain fault sheared dolomite of the Rockdale Run is exposed in several fault slices (Plate 2).

Locally, a 4- to 8-foot- (1- to 2-m-) thick bed of recrystalline dolomite (R-5905) serves as a marker for the base of the forma-

tion. Below the dolomite is the black to dark-gray, fine-grained limestone of the Stonehenge Formation and above is the interbedded gray limestone and dolomite of the Rockdale Run. The upper contact with the New Market is unconformable and is locally marked by a basal conglomerate in the New Market. Where the conglomerate is absent the contact of the dolomite of the Rockdale Run and the dove-gray micrite of the New Market is easily located.

The eastern lithofacies of the Rockdale Run, present in the southeast corner of Plate 1, is composed of interbedded light-gray, yellow-weathering, fine-grained dolomite and bluish-gray, fine-grained limestone. Dolomitic, bluish- to medium-gray, fine-grained limestone and mottled, light- and dark-gray, fine- to medium-grained, locally dolomitic, limestone are present. A comparison of the formation to the northeast (Rader and Biggs, 1975; Edmundson, 1945, p. 167) and to the southwest (Edmundson, 1945, p. 167-169) indicates a southwesterly increase in dolomite in the upper several hundred feet of the formation.

Figure 4. Recrystalline dolomite (light gray bed with white blebs of dolomite to left of hammer); bedded, black, calcareous, fossiliferous chert (black bed under hammer); and fine-grained dolomite (light bed above hammer) in the Rockdale Run Formation along State Road 601, 100 feet (30 m) east of junction of State Roads 601 and 757 (Plate 2.)

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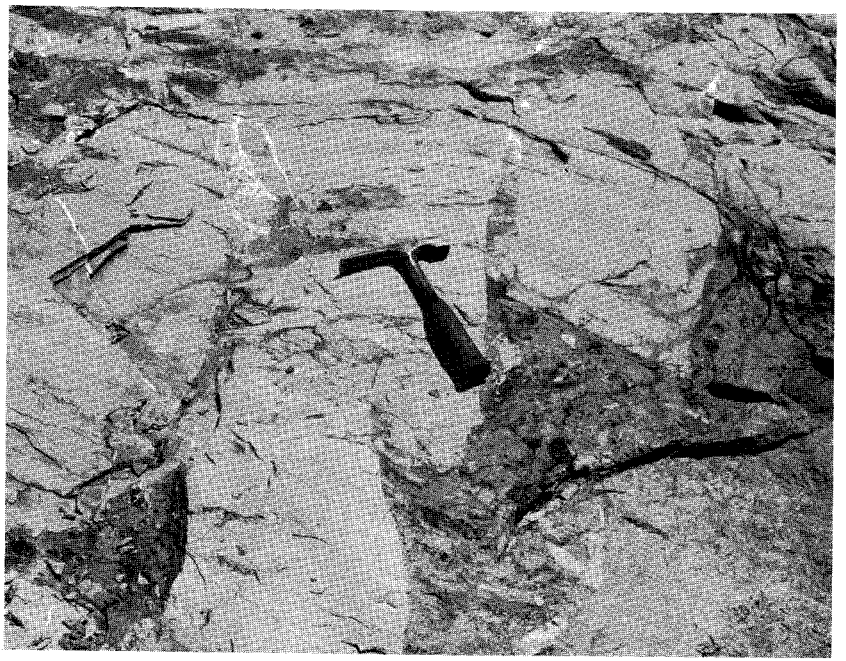
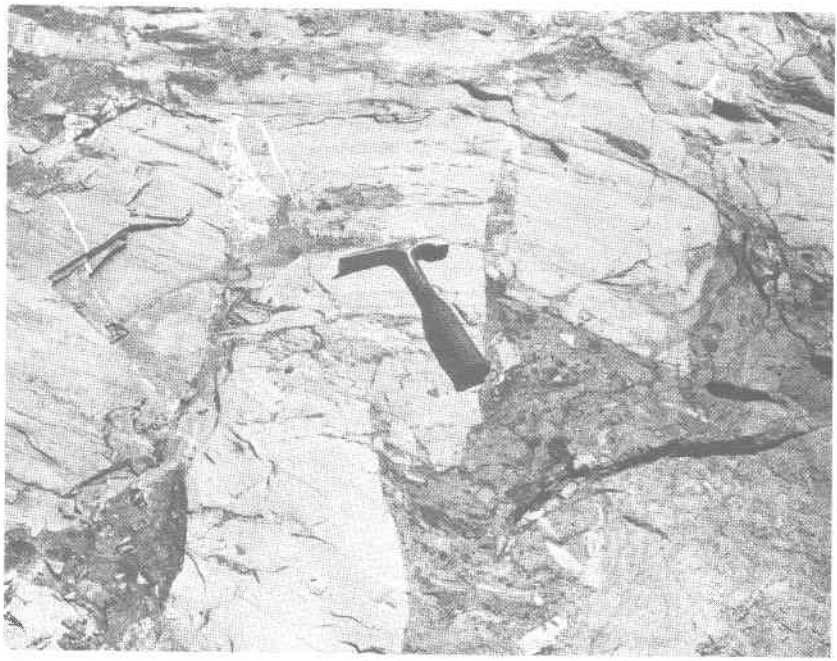


Figure 5. Collapse breccia in the Rockdale Run Formation in Tumbling Run at Fishers Hill (P. O.) (Plate 2). Light-colored blocks are bluish-gray limestone and the dark material is argillaceous dolomite. Note black chert nodules below hammer.

The western lithofacies is composed of thin- to thick-bedded, light- to dark-gray, fine-grained dolomite (R-6170) interbedded with bluish-gray, fine-grained limestone. The amount of limestone increases toward the base of the section and along strike to the southwest. Thin beds of recrystalline dolomite with white blebs of dolomite, black nodular and bedded chert (R-6171, Figure 4), and gnarly, massive rusty-weathering chert with limonite (R-6168) are locally common. In Tumbling Run at Fishers Hill (P. O.) a breccia (R-6179), interpreted as a collapse feature, is exposed (Figure 5). The angular clasts range in size from 1 inch (2.5 cm) to 6 feet (2 m) in a recrystalline dolomite matrix (R-6181, R-6182, R-6183). The clasts are composed of laminated, argillaceous, fine-grained, tan to light-gray dolomite and bluish-gray, fine-grained limestone. Black nodular chert is common. Round Hill (Plate 2), an isolated conical-shaped hill, is composed of chert. The chert, being more resistant to weathering processes, has remained as a topographic high whereas the more soluble carbonate rock was removed.



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Fossil fragments are common in limestone beds; however, identifiable fossils are rare. The thickness of the Rockdale Run is 2,127 feet (648 m) along Pughs Run (Edmundson, 1945, p. 66).

NEW MARKET LIMESTONE

East of Massanutten Mountain the New Market Limestone is exposed in a northeastward-trending belt near the southeast corner of the map (Plate 1). West of Massanutten synclinorium and south of Round Hill the limestone is exposed in a narrow northeastward-trending belt east of and parallel to U. S. Highway 11. North of Round Hill the outcrop belt is west of U. S. Highway 11 (Plates 1, 2). The New Market also occurs along the North Mountain fault where it is mapped with the Lincolnshire and Edinburg formations. A good exposure of the eastern belt occurs east of the Norfolk and Western Railway along the South Fork of the Shenandoah River (Plate 1). Excellent exposures occur along Pughs Run (Edmundson, 1945, p. 49, geologic section 22), in the Riverton Corporation quarry at Toms Brook (active quarry number 16), along Tumbling Run (Cooper and Cooper, 1946, p. 96, sec. 20), and in the abandoned quarries (numbers 1, 9, 10, 11, 12, 13) north of Tumbling Run (Edmundson, 1945, p. 45-48, geologic sections 17, 18, 19, 20; Plates 1, 2).

The lower contact is described with the Rockdale Run Formation. The upper contact, which is exposed along State Road 601 east of Fishers Hill, is marked by dark-gray, coarse- to medium-grained, locally cherty limestone of the Lincolnshire overlying dove-gray, compact limestone of the New Market (Figure 6).

The New Market can be separated into an upper high-calcium limestone and a lower impure limestone and conglomerate. The lower unit is composed of a carbonate-pebble, -cobble, and -boulder conglomerate. Angular clasts are limestone, dolomite, and chert in a sparry calcite matrix. The thickness of the conglomerate varies from a few inches to 5 feet (2 m). Overlying the conglomerate is a series of thin-bedded, argillaceous, gray, fine-grained to aphanic limestones; the thickness varies from a few inches to about 20 feet (6 m). Along Tumbling Run where State Road 601 crosses the contact and in active quarry number 16 are the best localities to see the lower unit.

The upper unit is the high-calcium quarry stone of the Shenandoah Valley. This unit is composed of compact, thick-

Figure 6. Lincolnshire-New Market contact along State Road 601 0.3 mile (0.5 km) west of the junction of U. S. Highway 11 and State Road 601 (Plate 2). Hammer end of hammer is on the contact between the dove-gray micrite of the New Market and medium-grained Lincolnshire limestone.

bedded, bluish- to dove-gray micritic limestone (R-6135) that breaks with a distinct conchoidal fracture and weathers with a chalklike coating. Small, clear, rhomboid-shaped crystals of calcite are common, giving the limestone a bird's-eye appearance. Interbedded locally with the micritic limestone is a coarse-grained, gray, fossiliferous limestone (pelsparite, R-6136) (Figure 7). Bryozoan, ostracode, brachiopod, and gastropod fragments and pellets with a micrite rim comprise the framework grains. The cement is sparry calcite. The pelsparite comprises only a very minor portion of the upper unit. Generally, the upper unit contains 97 to 98 percent calcium carbonate (see Economic Geology section for chemical analyses). The thickness of the upper unit varies from 30 to 130 feet (9 to 40 m).

Because of the unconformable relationship with the Rockdale Run, the thickness of the New Market is highly variable. At the Powhatan Lime Company quarry (Plate 2, abandoned quarry number 1) the formation is 162 feet (49 m) thick. It thins

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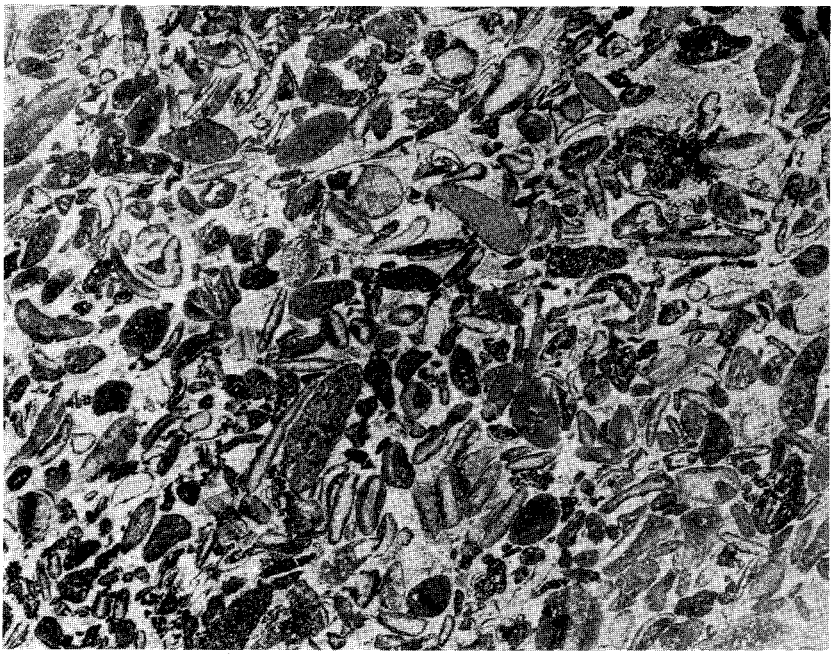
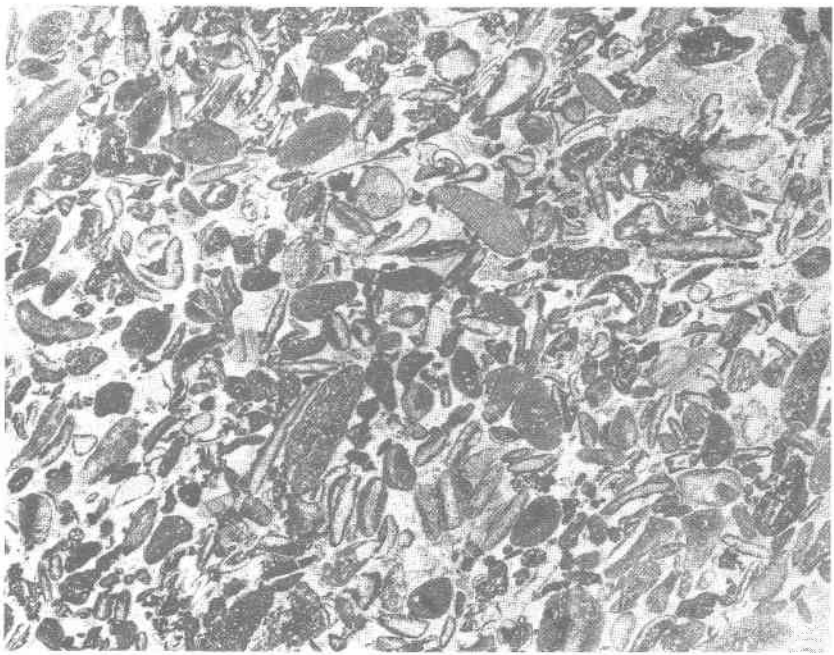


Figure 7. Photomicrograph of pelsparite (R-6136) of the New Market Limestone along Norfolk and Western Railway 0.2 mile (0.3 km) north of the south boundary of Plate 1; dark pellets partially recrystallized in sparry calcite; crossed nicols; approximately 8X.

southwestward to 56 feet (17 m) at Tumbling Run and then thickens to 80 feet (24 m) at Toms Brook (Plate 2, active quarry number 16). Southwest of Toms Brook the New Market thins to 66 feet (20 m) along Pughs Run and to about 40 feet (12 m) at Woodstock (Edmundson, 1945, p. 49). *Tetradium syringoporoides,* a coral, is the most common fossil. An ostracode, probably *Leperditia fabulites,* has been found in the Tumbling Run section.

LINCOLNSHIRE FORMATION

The distribution and well-exposed sections of the Lincolnshire Formation are the same as those discussed with the New Market. The lower contact with the New Market is placed at the top of the youngest dove-gray, micritic limestone and below the oldest dark-gray, medium- to coarse-grained limestone of the Lincolnshire. The Lincolnshire is overlain by black, cobbly or argillaceous limestone and the top of the Lincolnshire is mapped as the base of either of the above lithologies (Figure 8).



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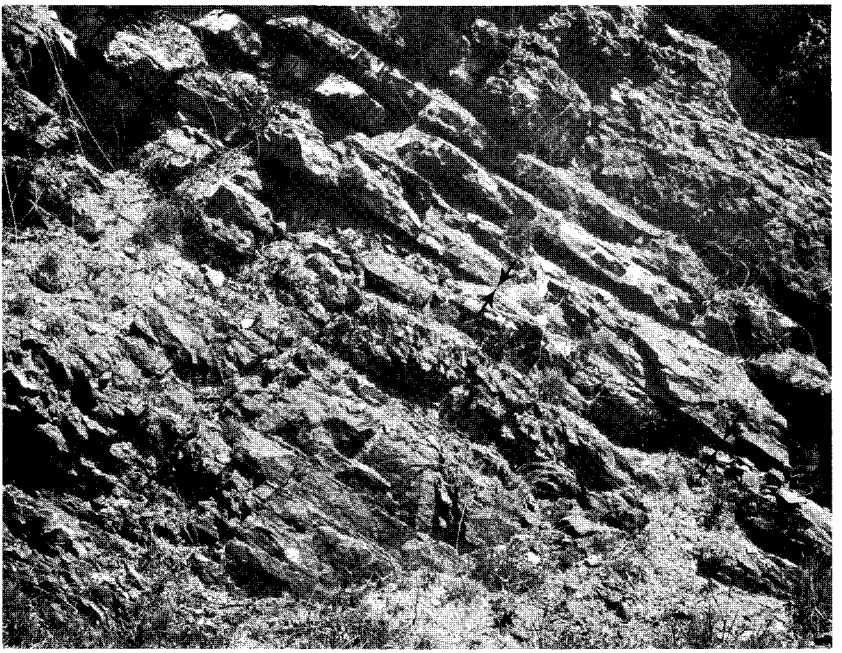

Figure 8. Edinburg-Lincolnshire contact along State Road 601 about 0.3 mile (0.5 km) west of junction of U. S. Highway 11 and State Road 601 (Plate 2). Contact is inclined from upper left to lower right between the black arrows.

The principal lithology of the formation is dark-gray, medium- to coarse-grained limestone (R-5904). Black chert nodules and stringers are common (R-6176) (Figure 9). Minor thin-bedded, platy, dark-gray limestone is locally present. Coarse-grained, noncherty, light-gray, bioclastic limestone is locally present and may qualify as a high-calcium limestone (Edmundson, 1945, p. 46). The thickness in the eastern outcrop belt varies from 25 to 100 feet (8-30 m); in the western belt the thickness varies from 60 to 170 feet (18 to 52 m).

Fossils are common to abundant in the Lincolnshire, including ramose bryozoans, gastropods, ostracodes, trilobites *(Homotelus, Calliops,* F-904), brachiopods *(Sowerbyites, Multicostella, Dinorthis),* and algae *(Girvanella). Girvanella* locally may comprise 75 percent of the rock. Evitt (1947, 1950, 1951) and Whittington and Evitt (1954) have described the trilobites from the Lincolnshire near Strasburg. Ostracodes of the formation have been described by Kraft (1962).

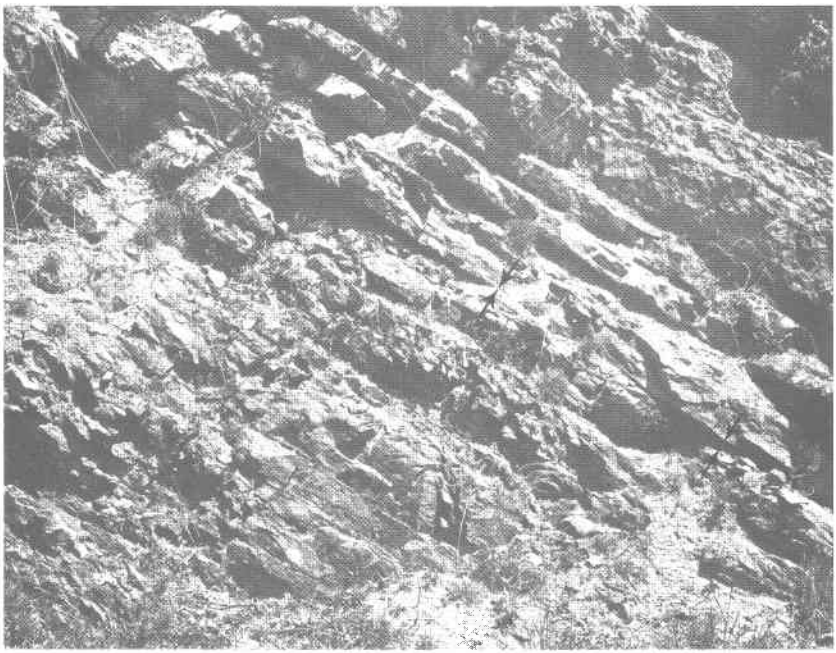

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Figure 9. Black chert in the Lincolnshire Formation along State Road 601, 0.3 mile (0.5 km) west of the junction of U. S. Highway 11 and State Road 601 (Plate 2). Knife in right center of photograph is 2 inches (5 cm).

EDINBURG FORMATION

The distribution of the Edinburg Formation is the same as that given for the New Market and Lincolnshire formations except for a folded area north of Strasburg (Plates 1, 2). The lower Edinburg is exposed in an eastern belt along the Norfolk and Western Railway along the South Fork of the Shenandoah River (Plate 1). Two excellent exposures in the western belt occur along Tumbling Run (State Road 601) and Pughs Run (State Road 663). The St. Luke Member is exposed 0.35 mile (0.56 km) north of BM 748 on U. S. Highway 11 south of Fishers Hill and along State Highway 55, 0.45 mile (0.72 km) northwest of the junction of U. S. Highway 11 and State Highway 55. The lower contact is discussed with the Lincolnshire. The top of the Edinburg is placed at the base of the Oranda calcareous siltstone which overlies dark, medium- to coarse-grained limestones of the St. Luke Member.

In this area the bulk of the Edinburg is composed of two principal lithologies to which Cooper and Cooper (1946, p. 78-86)

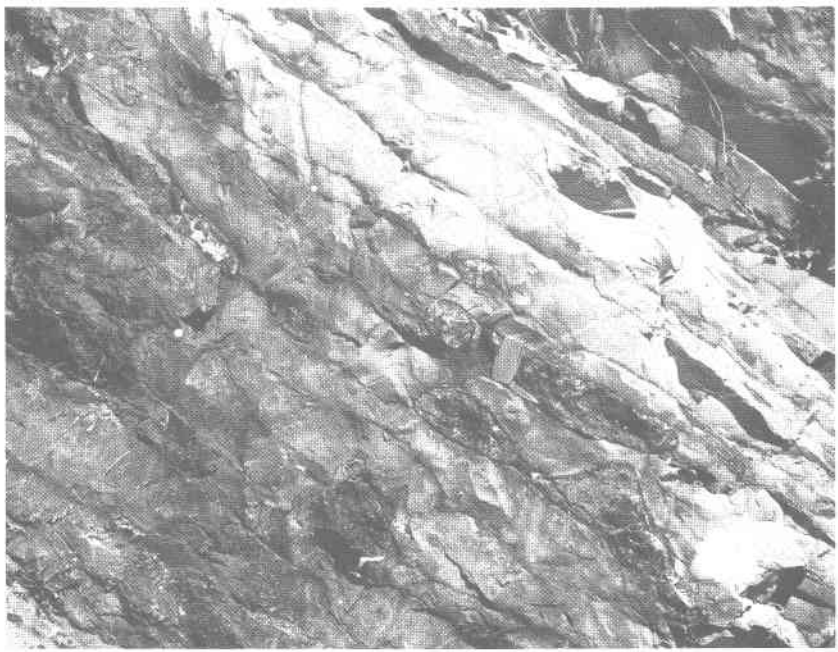

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Figure 10. Cobbly limestone and thin black shale of the Edinburg Formation along State Road 601, 0.2 mile (0.3 km) west of the junction of U. S. Highway 11 and State Road 601 (Plate 2).

beds of black, fine-grained to aphanic, shaly limestone and black shale. The Liberty Hall is the principal lithology in the eastern belt. In the Tumbling Run section several metabentonite beds are exposed (R-6175). These beds are interpreted to be altered volcanic ash falls.

The upper 50 to 75 feet (15-23 m) of the Edinburg in the western belt is composed of medium- to dark-gray, medium- to coarse-grained limestone (R-6159) and several thin beds of dove-gray micritic limestones. Cooper and Cooper (1946, p. 81) applied the name St. Luke Member to this unit. Small sinkholes are common in the St. Luke and serve as a distinctive marker where outcrops are sparse.

Cooper and Cooper (1946, p. 95) report a thickness of 530 feet (162 m) for the Edinburg along Tumbling Run. Thicknesses scaled from the map indicate a variation of 450 to 550 feet (137-168 m). Fossils are common to abundant locally. The

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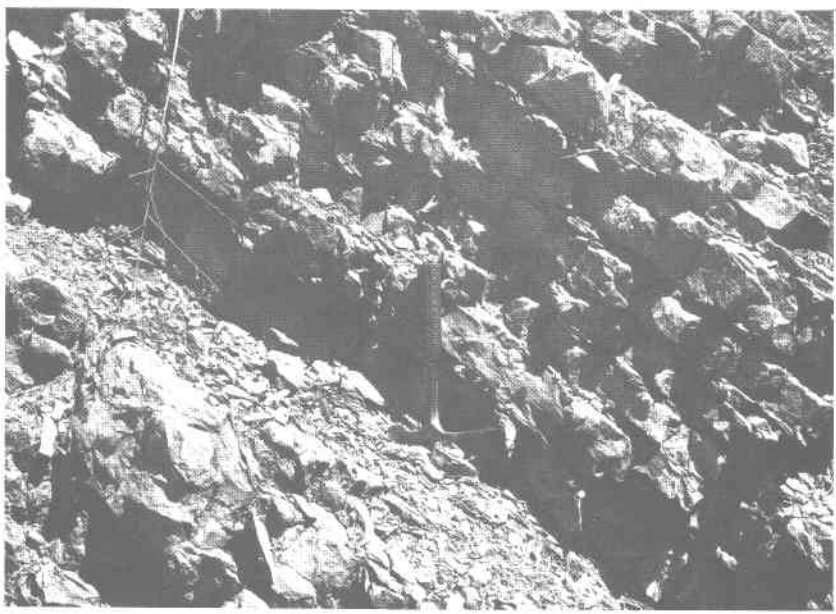

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Lantz Mills is abundantly fossiliferous, the Liberty Hall less so, and the St. Luke sparsely fossiliferous. The forms most useful for identification of the Edinburg are *Echinosphaerites aurantium* (cystoid), *Mastopora pyriformis* (algae), and species of *Resserella, Christiania,* and *Sowerbyella* (brachiopods). Ostracodes of the Edinburg have been described by Kraft (1962).

ORANDA FORMATION

The type locality of the Oranda Formation is along State Highway 55, 0.45 mile (0.72 km) north of its junction with U. S. Highway 11 (Plate 1, R-6160) (Cooper and Cooper, 1946, p. 86-89). The formation, generally poorly exposed, crops out in a very narrow, northeastward-trending belt extending from Woodstock on the southwest to Strasburg on the northeast (Plates 1, 2). Other than the type locality there are good exposures of the Oranda (1) 0.35 mile (0.56 km) northeast of BM 748 along U. S. Highway 11 and (2) southeast of State Road 664 0.25 mile (0.40 km) southeast of the junction of U. S. Highway 11 and State Road 664. East of the Massanutten synclinorium calcareous siltstone similar to the Oranda is interbedded with the upper 50 to 75 feet (15-23 m) of the Edinburg Formation.

The lower contact is discussed with the Edinburg. The upper contact is placed at the top of the youngest black siltstone overlain by black argillaceous limestone and calcareous shale of the Martinsburg Formation.

The Oranda is composed of gray to brownish-gray calcareous siltstone; black, silty shale; dark-gray, calcareous mudstone; cobbly weathering, gray, fossiliferous and argillaceous limestone (R-6160) ; and tan to brown metabentonites. One of the thicker metabentonites has a thin silicified zone at the base (R-6161). The silicified zone is highly fossiliferous, containing trilobites, bryozoans, brachiopods, and cephalopods (F-905, F-907). Cooper and Cooper (1946, p. 87-88) give a thickness of 56 feet (17 m) for the Oranda. The thickness ranges between 50 and 60 feet (15-18 m) in the area.

MARTINSBURG FORMATION

The Martinsburg Formation occupies a broad belt extending in a horseshoe shape around the north end of the mountainous portion of the Massanutten synclinorium (Plates 1, 2). Good

exposures of the lower part occur along Tumbling Run and U. S. Highway 11 near BM 539 (Plate 2). Typical flysch deposits may be seen along the farm road on the southwest side of Rittenour Ridge (Plate 2) and along State Road 615, 0.1 mile (0.16 km) southeast of the junction of State Roads 618 and 615 (Plate 1). The upper fossiliferous marine sandstone unit is exposed along State Road 678 at Blue Hole and along the trail northeast of Signal Knob. A broad northeastward-trending belt occurs on the east flank of Little North Mountain. There are no good exposures of this belt within the mapped area; however along State Road 600 about 1 mile (1.6 km) west of the west boundary of Plate 2, on the Woodstock 7.5-minute quadrangle, a good Martinsburg section is exposed (Young and Rader, 1974).

The lower contact in the main outcrop belt is discussed with the Oranda. The upper contact with the Massanutten Sandstone in the Massanutten synclinorium is unconformable (John M. Dennison, personal communication). The contact is placed at the top of a medium-grained, brown, unfossiliferous sandstone that underlies the white sandstones and conglomerates of the Massanutten Sandstone. In the Little North Mountain belt the Martinsburg is in fault contact with the Cambrian Elbrook or Waynesboro formations and various Lower and Middle Ordovician formations. The contact with the overlying Oswego Formation is conformable and terminates above a medium-grained, brown sandstone.

The Martinsburg of the Massanutten synclinorium may be divided into three lithologic units (in ascending order): black shale and limestone, sandstone and shale, and sandstone. The lower unit consists of 200 to 250 feet (61-76 m) of black, aphanic, argillaceous limestone (R-6167); black, calcareous shale; and thin, tan metabentonites. Associated with the metabentonites are 0.5- to 3-inch- (1.3-7.6-cm-) thick beds and lenses of coarse-grained, gray resinous calcite (Bailey and Young, 1956). Carroll (1959) described zircon from metabentonites along U. S. Highway 11 south of Tumbling Run. An age of 353 million years was obtained by Jaffe (Carroll, 1959). The bulk of the formation in the Massanutten synclinorium is a typical flysch sequence (unit 2) of alternating shale and sandstone. The shale is olive green, brown, and greenish gray and silty in units ranging from 1 inch to 5 feet (2.5 cm-1.5 m) thick. The lithic sandstone is olive green to gray, rusty weathering

and fine to medium grained (R-6139). Thin-section (R-5907, R-6133, R-6134, R-6138) examination reveals quartz (monocrystalline), chlorite, sericite, calcite, dolomite, chert, limonite, and rock fragments (siltstone, polycrystalline quartz and chert) (Figure 11). The framework grains are subangular to subrounded. Graded bedding, flute casts, and load casts are common. Because of complex structure and the lack of marker beds, the thickness of this unit is estimated at more than 2,800 feet (835 m). Overlying the flysch sequence is a sandstone (unit 3)

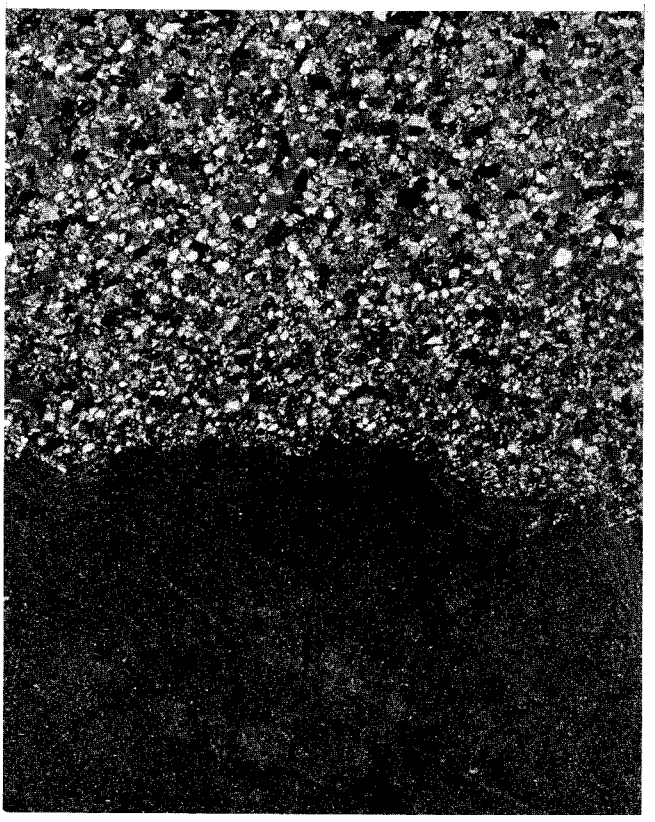

Figure 11. Photomicrograph of sandstone and siltstone (R-5907) from the flysch sequence of the Martinsburg Formation at the junction of State Roads 618 and 673, 0.25 mile (0.40 km) southwest of Otterburn School (Plate 1); the siltstone (lower part of picture) represents the top of a turbidite unit and the sandstone (upper part of picture) the base of a younger turbidite unit; crossed nicols; approximately 8X.

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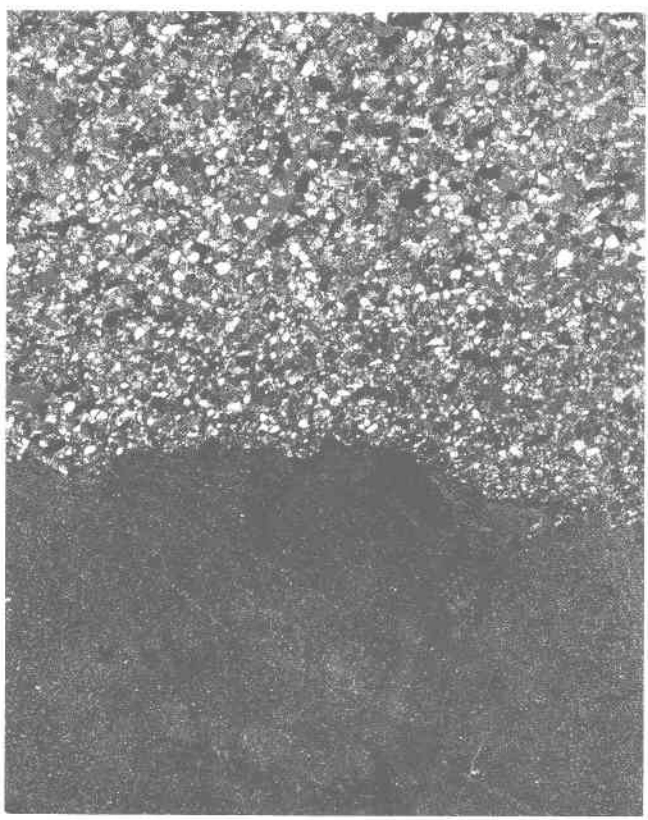

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about 170 feet (51 m) thick. The lithic sandstone is brown, medium grained, rusty weathering and the lower 100 feet (30 m) is fossilferous. The upper 70 feet (21 m) is a medium- to coarse-grained, brown, rusty-weathering, cross-bedded, unfossiliferous sandstone. This sandstone was presumed to be nonmarine by Secrist and Evitt (1943). The total thickness of the Martinsburg is estimated to be more than 3,200 feet (975 m).

The lower unit is moderately fossiliferous containing trilobites *(Cryptolithus* and *Isotelus)*, gastropods *(Sinuites)*, and graptolites. The flysch sequence is sparsely fossiliferous containing trilobites, bryozoans, gastropods, and brachiopods. Along Passage Creek at Blue Hole, Secrist and Evitt (1943) described a Maysville age fauna above the flysch sequence which they called the Passage Creek faunal zone. Included in this zone are graptolites, bryozoans, brachiopods, pelecypods, gastropods, cephalopods, and trilobites.

Along Little North Mountain the Martinsburg is composed of interbedded gray shale, siltstone, and very fine-grained sandstone. These rocks represent distal turbidites related to the flysch sequence described in the Massanutten synclinorium. An accurate determination of thickness could not be made. Fossils are mostly fragmental; however, an ostracode *(Pseudrakverella altalirata)* and several brachiopod species were found.

OSWEGO FORMATION

Along Little North Mountain between the Martinsburg and the Tuscarora formations there is a sequence of greenish-gray, conglomeratic sandstones (Oswego) with red beds (Juniata) near the middle. This sequence is best exposed about 0.9 mile (1.4 km) to the southwest of the west boundary of Plate 2 on State Road 600 (Young and Rader, 1974, Plate 1). To the east in the Massanutten synclinorium distinct lithologies assignable to the Oswego and Juniata are not present.

The lower contact is described with the Martinsburg Formation. The upper contact is gradational with greenish-gray Oswego sandstone and white Tuscarora sandstone being interbedded through a thickness of about 50 feet (15.2 m).

Because of their *intertonguing* relationship and the amount of debris covering the southeast slope of Little North Mountain, the Oswego and Juniata formations are mapped as a single unit on Plate 2. The combined thickness is approximately 450 to 500 feet (137 to 152 m).

Based on exposures in the Woodstock quadrangle and scattered pieces of float, the Oswego is predominantly a fine-grained, brown-weathering, greenish-gray sandstone flecked with limonite grains. The medium to thick beds of sandstone are locally separated by thin tan shale. Lenticular beds of conglomerate are present. The pebbles, up to 2 inches (5 cm) in diameter, are composed of white quartz, gray chert, and siltstone. Typical Oswego lithologies occur below and above red beds of the Juniata in a conformable stratigraphic sequence.

JUNIATA FORMATION

Within the Oswego Formation there are about 50 feet (18 m) of red to chocolate beds similar to the lower Juniata exposed 1 mile (2 km) southwest of Tibbet Knob (Young and Rader, 1974, p. 20 and Plate 2). The sandstones are white, red, and chocolate; cross-bedded; and fine to medium grained. Bedding thicknesses range from 2 inches (5 cm) to about 2 feet (1 m). Deposition appears to have been cyclic with each cycle beginning with cross-bedded sandstone and ending with a thin bed (2 to 6 inches or 5 to 15 cm thick) of medium-grained sandstone with red clay galls.

SILURIAN SYSTEM

MASSANUTTEN SANDSTONE

The Massanutten Sandstone forms the northeastward-trending mountains of the Massanutten synclinorium in the southeastern portion of Plate 2 and the western portion of Plate 1. Good exposures are present along the crest of Massanutten Mountain and Little Crease Mountain (Plate 1), and Green and Three Top mountains (Plates 1, 2). Along State Road 678 beginning at Blue Hole and continuing 1.1 miles (1.8 km) to the south the Massanutten is well exposed. Additional good exposures are found along the Signal Knob and Bear Wallow trails (Plate 1) and in Mine Run, Duncan, and Mudhole gaps (Plate 2).

Placement of the lower contact is discussed with the Martinsburg. The upper contact is generally covered by talus or fan debris. For mapping purposes the contact is placed at the first break in slope below the highest Massanutten ledge and above the lowest Bloomsburg outcrop.

The lower portion of the Massanutten Sandstone is com-

Figure 12. Quartzite of the lower Massanutten Sandstone along State Road 678 at Blue Hole (Plate 1).

posed of cross-bedded, medium-grained, white quartz sandstone and quartzite that is locally conglomeratic (R-6146) (Figure 12). The rounded quartz clasts range from 4 to 6 mm in longest dimension. Framework grains range from 0.5 to 1 mm and are subangular to angular. Quartz cement comprises less than 10 percent of the rock. The interlocking grain boundaries indicate that the grains have been pressure-welded. Thin, black, organic-appearing shales are locally present. Fracture surfaces are stained a rusty brown. The thickness of this unit varies from about 400 feet (122 m) on Three Top Mountain to about 700 feet (213 m) at Blue Hole.

The upper 300 to 500 feet (91-152 m) of the formation is basically thin-bedded sandstone with reddish-brown shale (Figure 13). The bulk of the sandstone unit is a brownish-gray, quartz sandstone (R-6164) composed of quartz grains (0.5-1 mm) with about 10 percent clay or fine-grained mica matrix and about 10 percent chert cement. The subangular to subrounded grains are partially pressure-welded. Secondary hematite is present and gives the rock a reddish-weathering color.

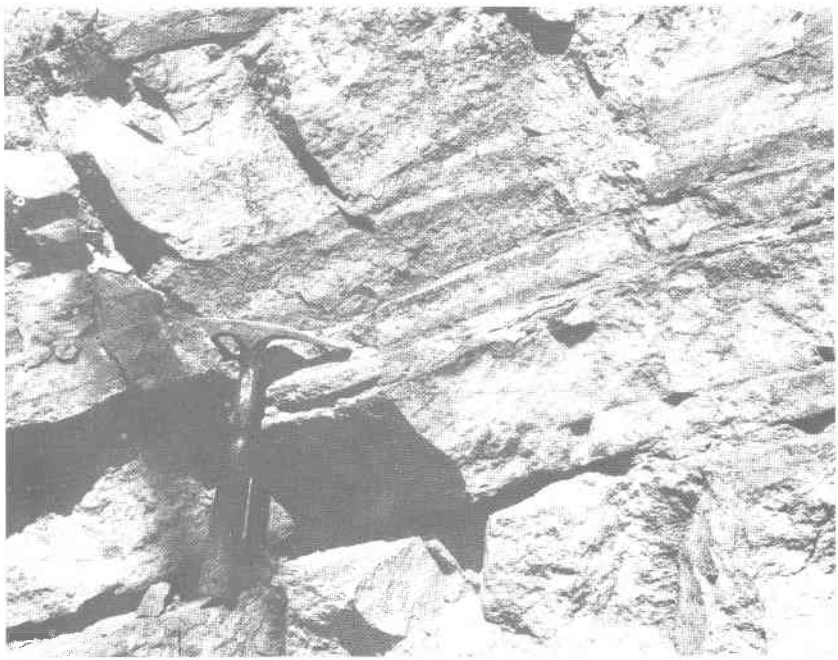

Figure 12. Quartzite of the lower Massanutten Sandstone along State Road 678 at Blue Hole (Plate 1).

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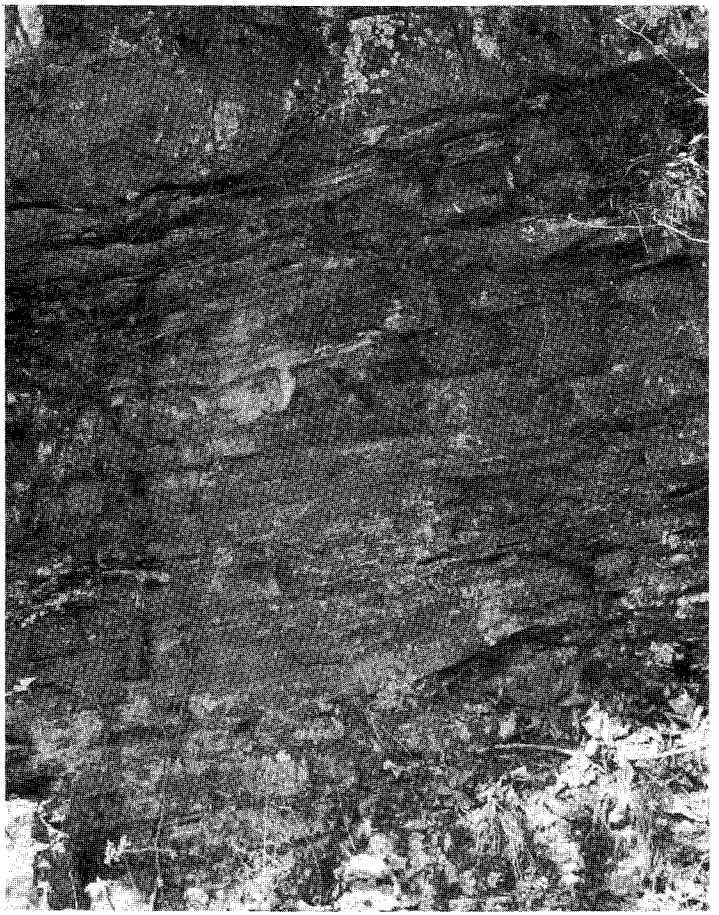
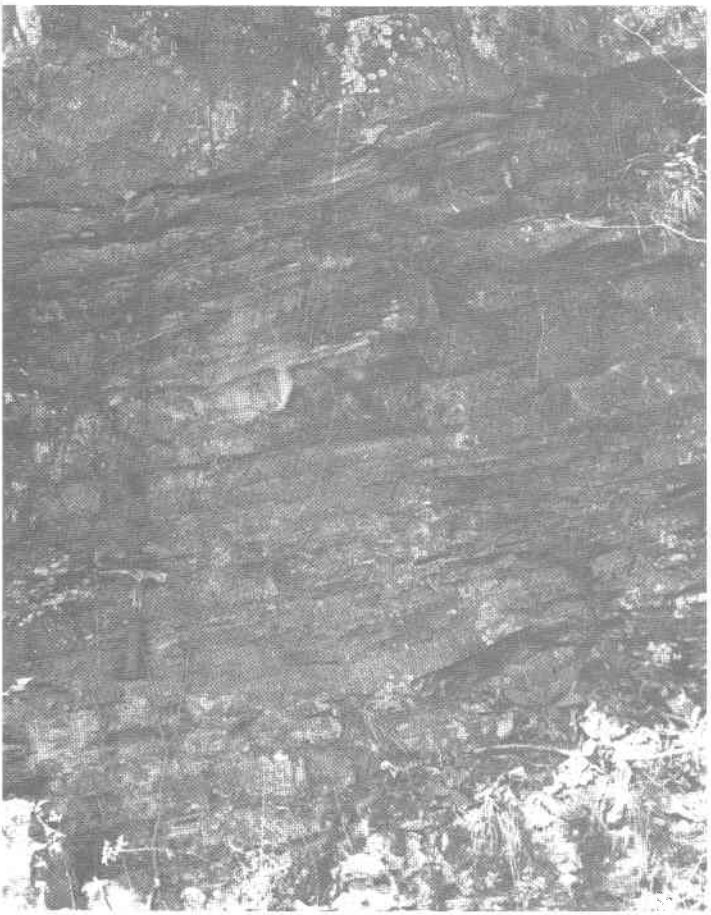


Figure 13. Sandstone and arenaceous shale of the upper Massanutten Sandstone along State Road 678, 0.8 mile (1.3 km) southwest of Blue Hole (Plate 1.)

The thin-bedded rocks may be classified as either very argillaceous sandstone or very sandy shale. They are reddish brown and contain abundant black carbonaceous flakes. Near the top of this unit the sandstones are cleaner. Pressure-welded framework grains (0.5-1 mm) comprise about 99 percent of the rock with only about 1 percent chert cement and a trace of hematite (R-6140) (Figure 14).

Along Three Top Mountain the Massanutten has a minimum thickness of 700 feet (213 m). The thickest section is along Passage Creek southwest of Blue Hole where the section is approximately 1,200 feet (365 m) thick. However, there is some



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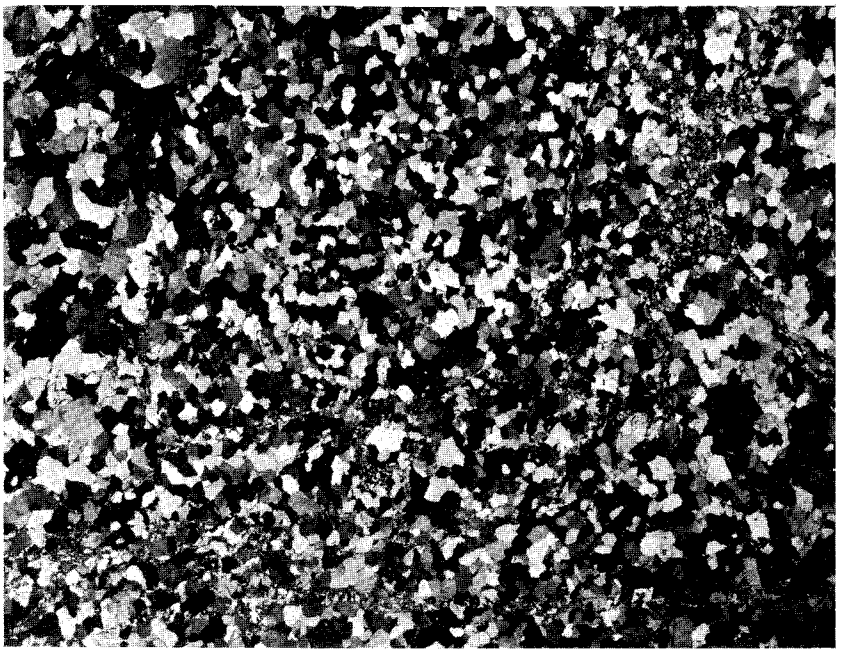
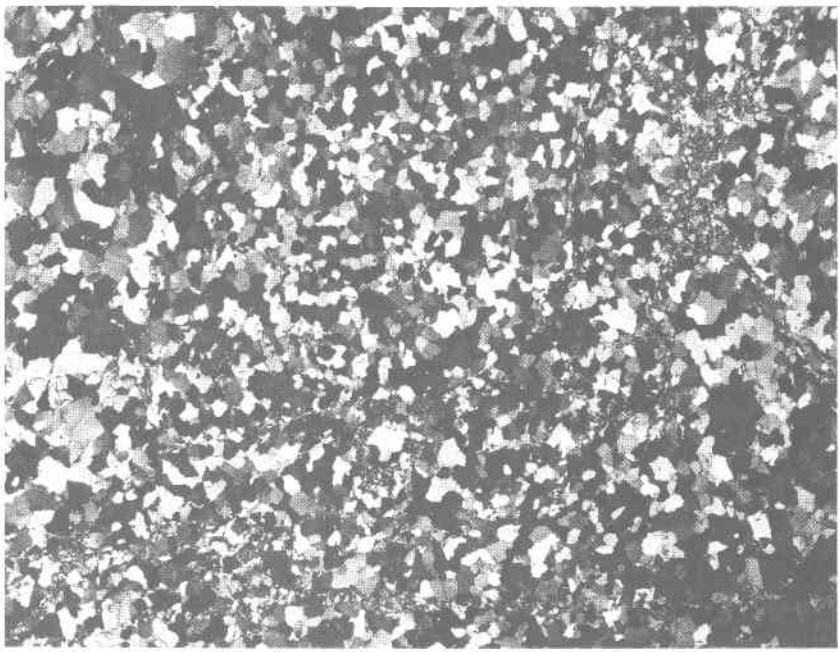


Figure 14. Photomicrograph of quartzite (R-6140) of the upper Massanutten Sandstone along Passage Creek 1.1 miles (1.8 km) southwest of Blue Hole on State Road 678 and 300 feet (91 m) south of road (Plate 1); crossed nicols; approximately 8X.

evidence that the section may be structurally overthickened. *Skolithos* cf. *S. verticalis* and *Arthrophycus alleghaniensis* (trace fossils) are sparse in the Massanutten. Pratt and others (1975) have reported neamatophytes (plants) from 13 horizons southwest of Blue Hole in the lower Massanutten. These plants are probably the oldest land plants reported to date (Pratt and others, 1975). In the upper unit a questionable plant fossil and abundant carbon flecks were found (F-906). The lower unit is roughly equivalent to the Tuscarora of Little North Mountain and the upper unit is roughly equivalent to the Rose Hill and Keefer formations of Little North Mountain.

TUSCARORA FORMATION

Along the crest of Little North Mountain and down each flank for a short distance ledges of the Tuscarora Formation are exposed (Plate 2). The best areas to examine the formation are at the Fetzer triangulation station (Plate 2) and along



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TUSCARORA FORMATION

Along the crest of Little North Mountain and down each flank for a short distance ledges of the Tuscarora Formation are exposed (Plate 2). The best areas to examine the formation are at the Fetzer triangulation station (Plate 2) and along

State Road 600 in Fetzer Gap on the adjoining Woodstock quadrangle (Young and Rader, 1974, Plate 1).

The lower contact is not exposed in the mapped area but to the southwest in the Woodstock quadrangle the contact is gradational with greenish-gray Oswego sandstone and white Tuscarora sandstone interbedded through a thickness of about 50 feet (15 m). The upper contact is placed at the top of the youngest white sandstone ledge which is overlain by brownish-gray sandstone and shale of the Rose Hill.

Based on observations along Little North Mountain in the mapped area and to the southwest (Young and Rader, 1974) the Tuscarora has two phases, a lower conglomeratic phase and an upper quartzitic phase. The conglomeratic phase is composed of subrounded to rounded quartz grains (0.5-1 mm) with rounded quartz clasts (4 mm-1 cm). The cement is quartz; however, pressure-welding is common. The lower phase grades upward into the quartzitic phase. This upper phase is composed of white to gray quartzite. Framework grains are subrounded to rounded quartz that are cemented by quartz or are pressure-welded. Thin red, green, and purple shales are common to the southwest (Young and Rader, 1974) but were not observed in the present mapped area (Plate 2). The thickness of the formation is estimated to be 300 feet (91 m). *Skolithos* cf. *S. verticalis,* a trace fossil, was the only fossil found.

ROSE HILL FORMATION

Along the west slope of Little North Mountain the Rose Hill and Keefer formations were mapped together because of poor exposures (Plate 2). The only outcrops are small and scattered along the upper west slope of Little North Mountain. The lower contact is discussed with the Tuscarora. The upper contact is placed at the first break in slope above red Bloomsburg outcrops or float.

The description of the Rose Hill Formation is based on observations in the mapped area and in the adjoining Woodstock and Wolf Gap quadrangles (Young and Rader, 1974, Plates 1, 2). The Rose Hill consists of sandy shales and thin- to medium-bedded sandstones. The shales are brittle, yellowish brown, and sandy; the sandstones are fine to medium grained and gray to brownish gray. Red sandstone float has been found scattered near the top of the unit. The thickness is estimated to be 650 feet (198 m).

KEEFER FORMATION

The Keefer Formation consists of gray to white, cross-bedded quartzite. Thin green and purple shales are reported to the southwest (Young and Rader, 1974) but were not observed in this area. The thickness is estimated to be 60 to 70 feet (18-21 m).

LOWER DEVONIAN AND UPPER SILURIAN ROCKS

West of Little North Mountain the Bloomsburg, Wills Creek, Tonoloway, and Keyser formations are combined as a single map unit, *Lower Devonian and Upper Silurian rocks;* the New Creek and New Scotland formations are combined as a single unit, *Helderberg limestones;* and the Ridgeley Sandstone is mapped as a separate unit. In the Massanutten synclinorium the McKenzie and Bloomsburg are mapped as one unit; the Wills Creek, Tonoloway, Keyser, and Helderberg are combined as a single map unit, *Lower Devonian and Upper Silurian rocks;* and the Ridgeley Sandstone is mapped as a separate unit.

MCKENZIE FORMATION

The McKenzie Formation is exposed in a drainage ditch 1.2 miles (2.1 km) south of Blue Hole along State Road 678. This is the only known exposure in the Massanutten synclinorium. At the scale of 1:24,000 the McKenzie is too thin to map and is included with the Bloomsburg. In the western belt (Little North Mountain) the interval where the McKenzie should occur is entirely covered; however, to the west in the Woodstock and Wolf Gap quadrangles about 75 feet (23 m) of McKenzie is present. Along Little North Mountain the McKenzie is mapped with the Rose Hill and Keefer. The McKenzie occurs in the slope break between the Massanutten Sandstone and the Bloomsburg. Lithologically, the formation is a yellowish-brown shale (R-6157) composed of muscovite (55 percent), quartz (40 percent), and illite (5 percent) with surface stains of iron and manganese. About 0.6 mile (1.0 km) north-northwest of BM 747 at Elizabeth Furnace Recreation Area near the junction of two small streams the Bloomsburg red beds rest directly on the Massanutten Sandstone. It is believed that the McKenzie is a lateral marine equivalent of the deltaic Bloomsburg. The thickness ranges from 0 to 75 feet (0-23 m).

BLOOMSBURG FORMATION

In the Massanutten synclinorium the Bloomsburg Formation is mapped with the McKenzie while west of Little North Mountain the Bloomsburg is mapped in the *Lower Devonian-Upper Silurian* unit due to sparse outcrops. The formation occurs in Little Fort Valley on the slopes of Three Top and Green mountains, and in Fort Valley along the slopes of Green, Massanutten, and Little Crease mountains (Plates 1, 2). The best exposure of the Bloomsburg is 1.2 miles (2.1 km) south of Blue Hole along Passage Creek. At this locality the formation is somewhat thinner than is typical. The lower contact is described with the Massanutten, Tuscarora, and McKenzie formations. The upper contact is placed at the top of the youngest red beds below greenish-gray silty shale of the Wills Creek.

The Bloomsburg is composed of sandstone, siltstone (R-6148), mudstone, and shale. Ferruginous sandstone (R-6145) composed of rounded to subrounded quartz grains cemented by hematite comprise the bulk of the formation. Numerous prospect pits have been dug in this unit. Maroon and green mottled mudstones (R-6144) are commonly blocky jointed. This jointing has controlled the green mottling, which is linear and roughly perpendicular to the bedding. Thin red and yellow shale units are common throughout the formation but are thicker near the base. Below the lowest sandstone along Passage Creek there is an 8- to 10-inch (20- to 25-cm) thick, black carbonaceous shale unit containing plant fossils (R-6151, F-908). Interbedded with all lithologies in the middle portion of the formation are white to gray quartzites and quartz sandstones. These beds range from 2 to 8 feet (1-2 m) thick. In the Massanutten synclinorium the Bloomsburg is estimated to be 400 feet (122 m) thick.

WILLS CREEK FORMATION

The outcrop pattern of the Wills Creek Formation is the same as that outlined for the Bloomsburg. The best exposures of the Wills Creek are 1.4 miles (2.3 km) south of Blue Hole in the hollow north of State Road 678 (Plate 1). The lower contact is described with the Bloomsburg. The upper contact with the Tonoloway is gradational and not exposed. The dominant lithologies are greenish-gray, calcareous, silty shale and brown-weathering, gray, calcareous, sandy siltstone (R-6141) with quartz, hematite, limonite, and chert grains. Thin maroon

shale is locally present near the base. Interbedded with the shales and siltstones are limestones. The most common limestone (biosparite) is a gray and red rock composed of sparry calcite, fossil fragments (bryozoans and brachiopods) with micrite rims, quartz, chert, and red siltstone grains, and secondary hematite (R-6142) (Figure 15). Limestone (intrasparite) com-

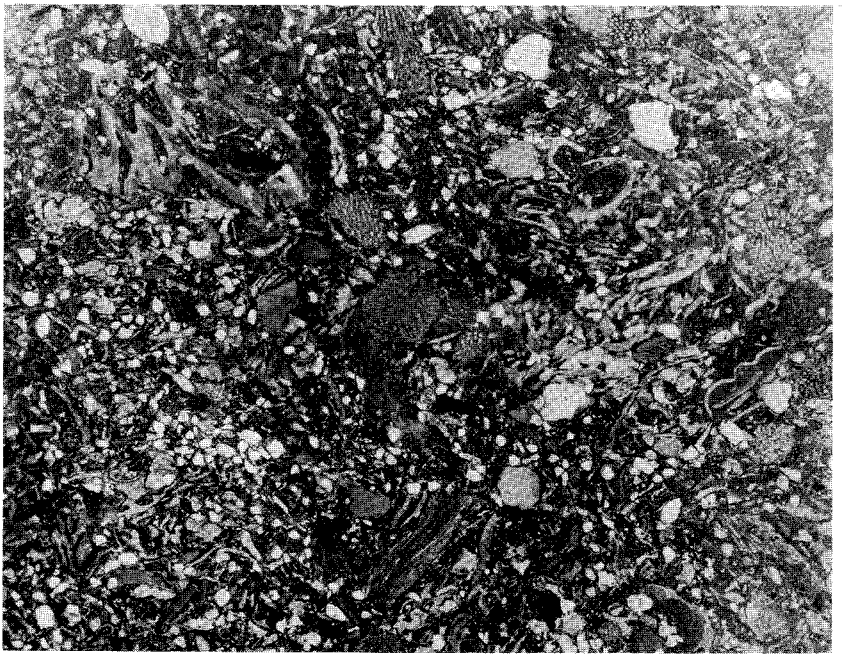

Figure 15. Photomicrograph of biosparite (R-6142) of the Wills Creek Formation 1.9 miles (3.1 km) southwest of Blue Hole and 400 feet (122 m) west of State Road 678 (Plate 1). Note abundant bryozoan (cellular features) and brachiopod (curved features) fragments, crossed nicols; approximately 8X.

posed of sparry calcite with abundant floating grains of quartz (monocrystalline and polycrystalline) and chert is common (R-6143). Thin greenish-gray micrite beds are also present.

The thickness of the Wills Creek in Fort Valley is about 150 feet (46 m). West of Little North Mountain the thickness is about 60 feet (18 m). Brachiopods are the most common megafossil. In thin section bryozoans and ostracodes were identified.

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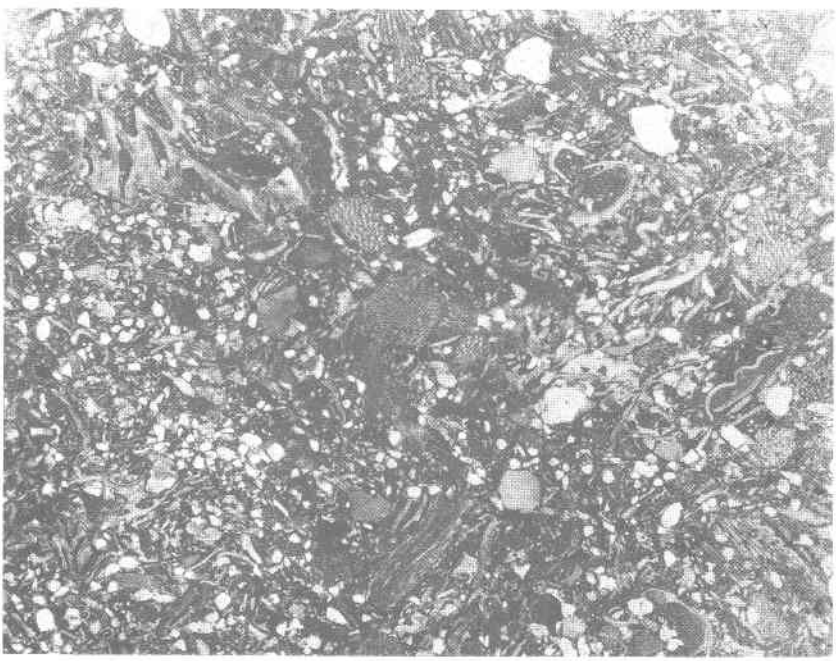

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TONOLOWAY FORMATION

The distribution of the Tonoloway Formation is the same as that given for the Bloomsburg. In the hollow north of the Signal Knob trail west of State Road 678 folded Tonoloway limestone is exposed (Plate 1). The contacts of the Tonoloway are not exposed in the mapped area. The formation consists of thin-bedded, medium- to dark-gray, laminated, fossiliferous, argillaceous limestone with thin, yellow-weathering shale partings. The thickness does not exceed 50 feet (15 m) in Fort Valley but it may be as much as 100 feet (30 m) west of Little North Mountain. An ostracode belonging to the genus *Leperditia* was the only fossil found.

KEYSER FORMATION

The Keyser Formation has the same distribution as the Bloomsburg Formation. Exposures are generally poor. The best exposure is south of State Road 678 along Passage Creek 1.3 miles (2.1 km) south of Blue Hole (Plate 1). The upper and lower contacts with the Tonoloway and Helderberg limestones are not exposed but are presumed to be gradational. In both the Massanutten synclinorium and west of Little North Mountain the bulk of the Keyser is a medium-bedded, gray, fine- to medium-grained limestone (R-6153). Locally the limestone is silty. The formation is partly cherty west of Little North Mountain. Coarse-grained, crinoidal limestone (R-6154) beds, 1 to 5 inches (3-13 cm) thick, resembling the New Creek and thin, very fine-grained, brown to gray, calcareous sandstone beds are interlayered with the Keyser in the eastern belt. Tonoloway-like lithology is present as thin interbeds in the western belt. The thickness of the Keyser is estimated to be 75 feet (23 m). Brachiopods are common. *Leptostrophia bipartita* (F-903) was identified along Passage Creek.

DEVONIAN SYSTEM

HELDERBERG LIMESTONES

West of Little North Mountain the Helderberg limestones may be divided into the cherty New Scotland limestone and the crinoidal New Creek Limestone. Along State Road 600 in the adjoining Woodstock quadrangle sections of Helderberg limestones are exposed (Young and Rader, 1974, Plate 1). In the

Massanutten synclinorium the subdivisions of the Helderberg limestones are not recognized. A good section of the Helderberg may be seen in the first hollow southwest of BM 757 and west of State Road 678 (Plate 1).

New Creek Limestone

The New Creek as a recognizable formation is not present in the Massanutten synclinorium. West of Little North Mountain the interval is entirely covered. Along and northeast of State Road 600 in the adjoining Woodstock quadrangle 6 to 8 feet (about 2 m) of gray, coarse-grained crinoidal limestone is sparsely exposed between the finer-grained Keyser and the cherty New Scotland (Young and Rader, 1974).

New Scotland Limestone

The New Scotland is a dark-gray, fine- to medium-grained, cobbly weathering, cherty, silty limestone (R-6158). Massive white to gray chert layers interbedded with medium- to coarse-grained limestone are the typical lithologies in the western belt. In the Massanutten synclinorium thin, coarse-grained crinoidal limestone is interbedded with cherty, silty limestone. Contacts with the underlying and overlying units are not exposed. The thickness is estimated to be 10 to 40 feet (3-12 m). Several species of brachiopods are present.

RIDGELEY SANDSTONE

The Ridgeley occurs in a narrow belt along the northwest flank of Little North Mountain. Outcrops are small and sparse. A good section is exposed along State Road 600 on the adjoining Woodstock quadrangle (Young and Rader, 1974, Plate 1). In the Massanutten synclinorium area a sandstone occurs between the Helderberg limestones and the Needmore Formation in belts outlining Little Fort and Fort valleys. On a lithologic basis this sandstone is correlated with the Ridgeley of the western part of the Valley and Ridge province. The best exposures are found at Powells Fort Camp and along the Forest Service road southwest of the camp in Little Fort Valley. At the junction of State Roads 771 and 773 and to the north there is a low ridge formed by the sandstone.

In the eastern area (Plates 1, 2) the sandstone is coarse grained, white to gray, rusty weathering and devoid of fossils (R-5906) (Figure 16). Near the top of the Ridgeley in this

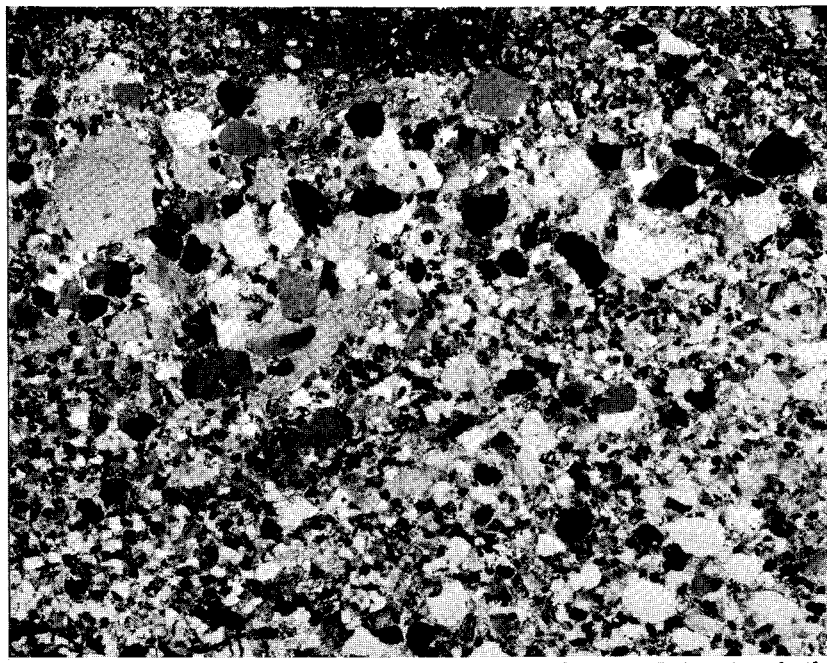
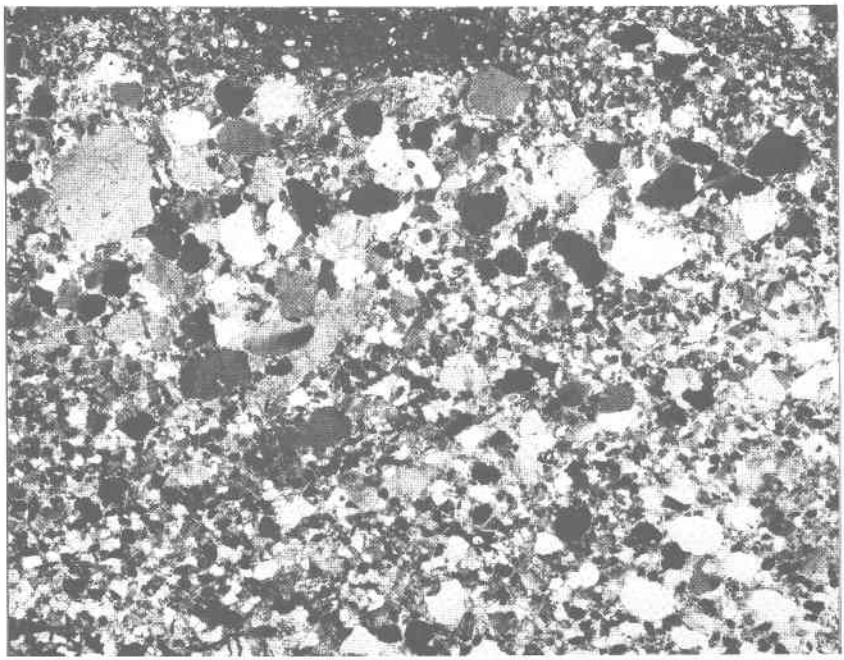


Figure 16. Photomicrograph of calcareous sandstone (R-5906) of the Ridgeley Sandstone along Mine Run 0.15 mile (0.24 km) southwest of junction of State Roads 771 and 758 (Plate 2); crossed nicols; approximately 8X.

area gray, coarse-grained, sandy, cherty limestone containing brachiopod fragments is present. The thickness of the eastern Ridgeley ranges from 5 to 40 feet (2-12 m). West of Little North Mountain the Ridgeley is a medium- to thick-bedded, white to brown, fossiliferous, calcareous sandstone that is locally conglomeratic. The thickness in this belt ranges from 50 to 100 feet (15-30 m).

NEEDMORE FORMATION

The Needmore Formation occurs along the lower northwest slope of Little North Mountain in fault contact with the Marcellus. Outcrops are sparse but small ones occur on the sides of hollows especially in the hollow 1.3 miles (2.1 km) north-northwest of the Fetzer triangulation station (Plate 2). In Little Fort Valley the Needmore occupies the trough of a syncline. Fossiliferous outcrops occur near the cabins at Powells Fort Camp and at some of the abandoned prospect pits (numbers 19, 20). In Fort Valley the Needmore has the same distribution



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as the Ridgeley Sandstone. The most complete section is 1 mile (2 km) south-southeast of Seven Fountains along State Road 758 on the adjoining Rileyville quadrangle.

Based on a study of the ostracode fauna the Ridgeley-Needmore contact is unconformable (Rader, 1962). The lower contact is placed at the base of the first greenish-gray shale overlying the Ridgeley Sandstone. The upper contact with the Marcellus is gradational and is placed at the base of the first black shale. The Needmore is a greenish-gray, silty shale (R-6152) and siltstone. The thickness is estimated to be 100 feet (30 m) in the western belts. Dennison (personal communication) reports a thickness of 530 feet (162 m) in the Seven Fountains area. North of Seven Fountains the Needmore probably does not exceed 450 feet (137 m). Fossils are common to abundant and include brachiopods, ostracodes, and bryozoans.

TIOGA BENTONITE

For mapping purposes the lower Tioga is mapped with the Needmore Formation; the upper Tioga is mapped with the Marcellus Shale. The distribution is the same as the Needmore (Plates 1, 2) and the most complete section is south of Seven Fountains (location given under Needmore Formation). Lithologically, the Tioga is composed of alternating gray silty shales and siltstones and brown, biotite-bearing calcareous tuffs (R-6147, R-6149, R-6150). The volcanic beds are interbedded with typical lithologies of the upper Needmore and the lower Marcellus. John M. Dennison (personal communication) reports a thickness of 110 feet (34 m) near Seven Fountains. The unit appears to be about 80 to 100 feet (24-30 m) thick in the Massanutten synclinorium. West of Little North Mountain the Tioga is absent due to faulting.

MARCELLUS SHALE

The Marcellus Shale occurs northwest of Little North Mountain in the extreme northwest corner of Plate 2. Outcrops are sparse in the area. In Fort Valley a thin belt of black shale outlines the main valley. Outcrops are not common and the best section is exposed south of Seven Fountains (see discussion of Needmore Formation for location). A partial section occurs along State Road 678, 500 feet (152 m) west of BM 810 (Figure 17). The lower contact is discussed with the Needmore. West

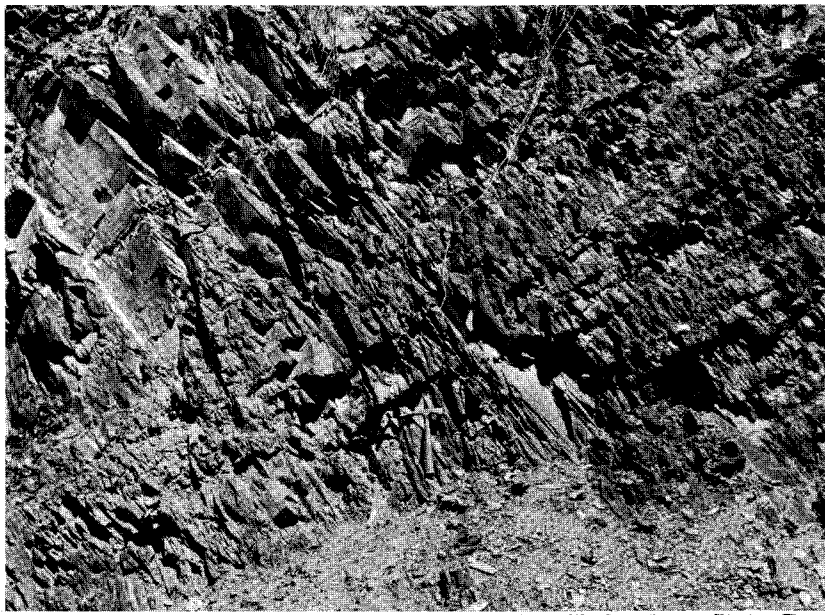

Figure 17. Black fissile shale of the Marcellus Shale along State Road 678, 500 feet (152 m) west of BM 810 (Plate 1).

Figure 18. Limestone concretion of Tully age in the black Marcellus Shale on State Road 758, 1.2 miles (1.9 km) south of Seven Fountains (Rileyville 7.5-minute quadrangle).

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Figure 18. Limestone concretion of Tully age in the black Marcellus Shale on State Road 758, 1.2 miles (1.9 km) south of Seven Fountains (Rileyville 7.5-minute quadrangle).

of Little North Mountain the Marcellus is the youngest formation present. In Fort Valley the upper contact is placed at the top of the youngest black shale overlain by greenish-gray siltstone of the Mahantango. The Marcellus is composed of dark-gray to black, fissile shale. Pyrite is disseminated throughout the formation. Limestone concretions are present near the middle of the Marcellus at Seven Fountains (Figure 18). Dennison (personal communication) believes that these concretions represent the Purcell Limestone of West Virginia. The thickness is estimated to be between 350 and 400 feet (107-122 m).

MAHANTANGO FORMATION

The Mahantango Formation occurs in the central portion of Fort Valley (Plates 1, 2). Good exposures occur in the bluffs along Passage Creek and State Road 678 (Plates 1, 2). Additional good exposures are found along State Roads 774 and 771 (Plate 2). The lower contact is described with the Marcellus. The upper portion of the Mahantango is not present in the area.

Silty shale, siltstone, and very fine grained sandstone are present in the formation. The siltstone (R-6155) is gray, rusty brown weathering, locally calcareous, and fossiliferous. The fossils occur in distinct layers with barren zones between fossil layers. Interbedded with siltstones are greenish-gray, siliceous shales. Scattered throughout the formation and marking small-scale structures are greenish-gray, very fine grained sandstones.

The thickness is estimated to be 900 feet (274 m). Fossils include bryozoans, several species of brachiopods, and an ostracode, probably *Hollinella* cf. *H. sella*. The youngest portion of the Mahantango is probably equivalent to the Chaneysville of Pennsylvania (John Dennison, personal communication).

QUATERNARY SYSTEM

Surficial deposits in this area can be grouped into three broad types: (1) alluvium, which includes flood-plain deposits, terrace deposits, and alluvial fans; (2) talus deposits; and (3) sedentary soil. Each type of alluvial and talus deposit was mapped and the discussion is based on field data. Type three is described in the section on Environmental Geology.

TALUS DEPOSITS

Associated with steep slopes and cliffs underlain by the Massanutten, Tuscarora, Rose Hill, and Keefer formations, loose, angular blocks have accumulated (Figure 19). These

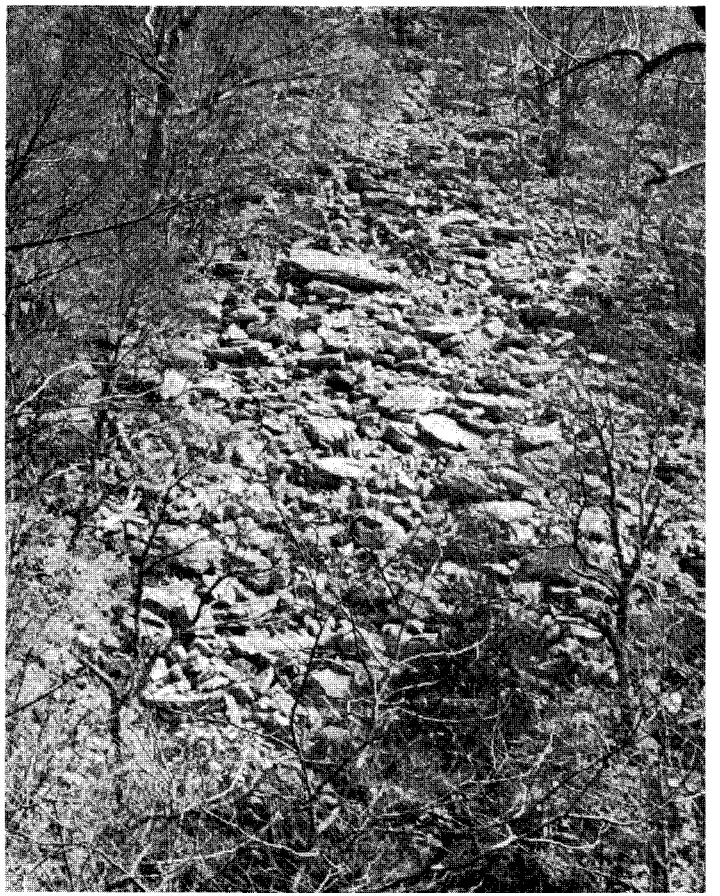

Figure 19. Talus deposit along the west slope of Massanutten Mountain west of Buzzard Rock (Plate 1).

accumulations are composed of angular cobbles and boulders (64-256+ mm) of white quartz sandstone, quartz sandstone, quartzite, and quartz-pebble conglomerate. The interstices are open and the percolation rate is extremely high. Vegetation is sparse to nonexistent on most of the deposits. Only where the deposits are thin and have large openings between blocks has

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vegetation been successfully established. The thickness of talus deposits are highly variable, ranging from 3 to 20 feet (1-6 m).

TERRACE DEPOSITS

Associated with the Shenandoah River and Passage Creek are elevated, flat areas composed of fluvial deposits of sand, silt, clay, and roundstones. These deposits are above the reach of modern floods and many cover ridgetops. Roundstones are defined in this report to be the subrounded to rounded framework fragments of a terrace deposit. Locally a low-level terrace sloping gently toward and adjoining the modern flood plain may be recognized. Frequently the upslope edge of the low-level terrace merges with the downslope edge of the higher level deposit. In the mapped area the higher level deposits correspond roughly to the middle-level terraces near Front Royal.

Roundstones 1 to 6 inches (2 to 15 cm) in longest dimension are abundant in artificial cuts. These framework fragments are composed of quartz sandstone, quartzite, and quartz-pebble conglomerate. The matrix material is fine-grained quartz sand, silt, and minor clay. Roundstones are concentrated in the surface layer due to the removal of the finer matrix. Below the surface layer roundstones appear to be randomly distributed. Along Passage Creek the average size of the roundstones is larger and boulder-size material is common to abundant locally. The thickness of the terrace deposits ranges from 0 to approximately 25 feet (8 m).

ALLUVIUM

Alluvium is defined for purposes of this report to include unconsolidated deposits of water-transported products of rock weathering. These weathering products may range from clay to boulder size.

Flood-plain deposits: Overbank deposits occur along the North and South forks of the Shenandoah River and all the major tributaries. A broad flood plain is developed all along the North Fork on the inside of the meanders and along the straight portions of the meanders. Older flood-plain and channel deposits along the North Fork are preserved in the three cutoff meanders northwest of Three Top Mountain (Plates 1, 2) and old channel and flood-plain deposits are preserved northwest of Waterlick (Plate 1). Along the South Fork in the southeast corner of

Plate 1 flood-plain deposits are developed along both sides of the river. Along Cedar Creek and in its cutoff meander, flood-plain development is extensive. Significant flood-plain development has occured along Passage Creek and its tributaries (Plates 1, 2), and along Toms Brook and South Fork (Plate 2).

The deposits along both forks of the Shenandoah River and Cedar Creek are composed of fine-grained, dark-brown quartz sand and silty clay. Pebble-size fragments of quartzite and sandstone are scattered throughout the deposits and may be concentrated in a thin layer near the bottom of the deposit. Channel deposits of abundant cobble size (64-256 mm) material in a sand and clay matrix are preserved in the cutoff meanders and in the area northwest of Waterlick.

Along Passage Creek and its tributaries the deposits contain a higher percentage of pebble- and cobble-size material. Boulder-size material is common in channel deposits. The bulk of the finer-grained fraction of the flood-plain deposits is a brown, fine- to medium-grained quartz sand and silt with very minor clay.

Flood-plain deposits along Toms Brook and South Fork have developed over carbonate rocks. The deposits are composed of reddish-brown, sandy clay with small angular fragments of chert concentrated near the base.

Flood-plain deposits are thicker along the Shenandoah River and near the mouth of Passage Creek, ranging from 15 to 25 feet (5-8 m) thick. Along Cedar Creek the thickness ranges from 10 to 15 feet (3-5 m). Deposits in the carbonate area (Toms Brook and South Fork) range from 3 to 10 feet (1-3 m) thick.

Alluvial fan deposits: Alluvial fan deposits occur in the typical fan-shaped development or as small-scale coalescing fans (Plate 1, 2). Along the upper slopes of Fort and Little Fort valleys (Plates 1, 2), the east slope of Massanutten Mountain (Plate 1), the west slope of Three Top Mountain (Plates 1, 2), and northwest slope of Little North Mountain extensive coalescing alluvial fans are developed. Fan deposits are composed of angular to subrounded pebbles, cobbles, and boulders (4-256+ mm) of white quartz sandstone, quartz-pebble conglomerate, and quartzite with minor amounts of red, brown, and gray sandstone. The interstices are filled with fine- to medium-grained quartz sand. The upper 1.5 to 2.0 feet (0.5-0.6 m)

is a black organic-rich zone. The filled interstices was the main characteristic used to distinguish alluvial-fan deposits from talus deposits. Percolation rates are moderate to high in fan deposits. Permanent streams rarely flow on fans but are restricted to the edges. The slopes of accumulation range from less than 3 percent to about 15 percent. The thickness of the fan deposits ranges from 10 to 30 feet (3-9 m).

PERIDOTITE DIKE

Mica peridotite occurs 2.8 miles S. 11° E. of the junction of State Highway 55 and State Road 678 at Waterlick. Weathered exposures of the dike were found in several caved prospect pits and sample R-6137 was collected from the easternmost pit. A sample of the dike material from the westernmost pit and two thin sections were obtained from Roy A. Bailey of the U. S. Geological Survey. Two highly weathered samples (R-6184, R-6185) were obtained from pits dug to a depth of 3 feet (1 m) in the central portion of the dike. Four traverses were made across the area with a total field portable proton magnetometer (GeoMetrics model G-806) having a sensitivity of 1 gamma. Ten soil samples along two traverses were collected.

From thin-section analyses Young and Bailey (1955) report the following mineral assemblage: chlorite, 43 percent; phlogopite, 31 percent; hydrobiotite(?) pseudomorphs after olivine and pyroxene, 13 percent; secondary pyrite, 5 percent; perovskite partly altered to leucoxene, 4 percent; apatite, 2 percent; dolomite, 1 percent; and ilmenite, magnetite, and epidote, 1 percent. X-ray analyses of the samples by the Division provided the following results: (1) R-6137 (easternmost sample)—ankerite, chlorite, quartz, pyrite, and serpentine(?); (2) R-6184 (central sample)—clays, magnetite, garnet (andradite) and rutile; and (3) westernmost sample—chlorite, phlogopite, talc, calcite, ankerite, and serpentine(?).

The igneous body was originally a mica peridotite that has been chloritized. The shape of the body is elliptical, roughly 600 feet (182 m) along the northeast axis and 150 feet (46 m) along the northwest axis. Magnetitic traverses (Figure 20) show a magnetic zone within the body about 6 feet (2 m) thick that has a dip 65 degrees southeast and a strike N. 20° E. One traverse (not shown in Figure 20) was made along the strike of the body to determine the length. Based on this traverse

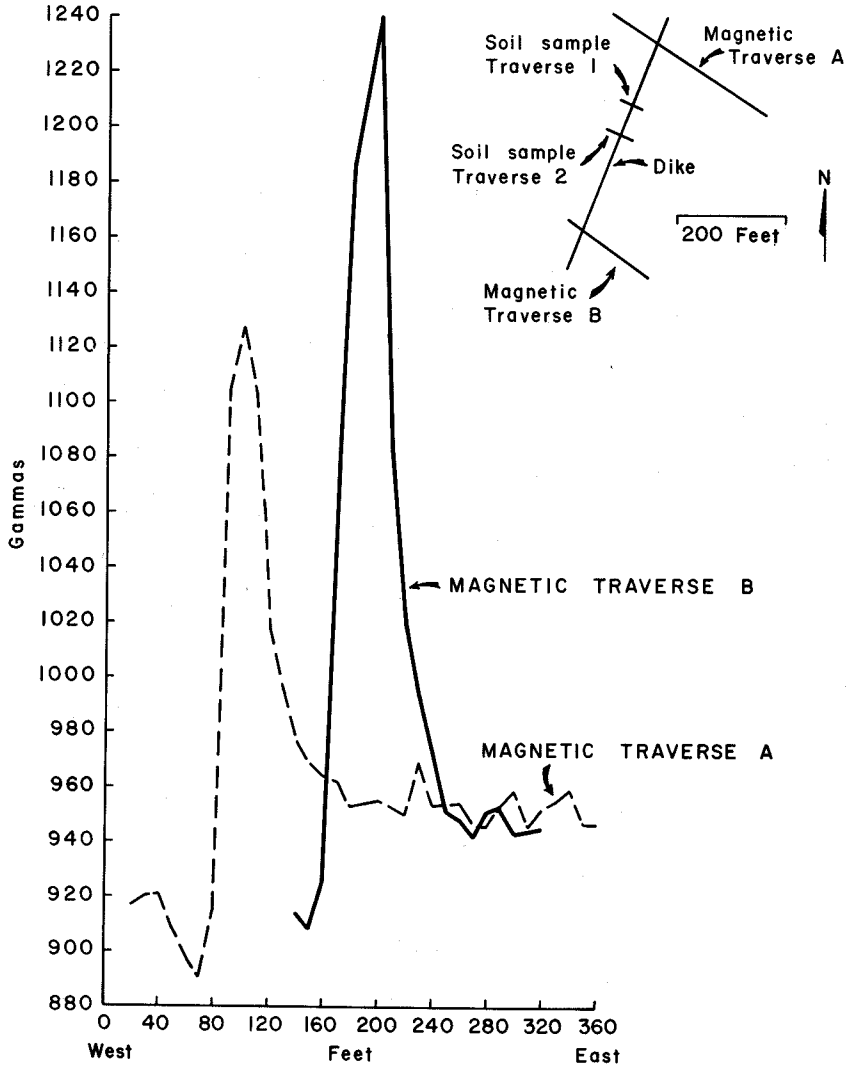


Figure 20. Magnetic profiles across mica peridotite dike 0.35 mile (0.56 km) northeast of the junction of State Roads 626 and 617 and about 500 feet (152 m) north of State Road 626 (Plate 1).

a length of about 500 feet (152 m) was established. Traverses across the prospect pits gave only background magnetic values.

Soil samples were collected with a post-hole-digger at a depth of 2.5 to 3.0 feet (0.8-0.9 m). Analyses for zinc, lead, copper, chromium, nuckel, calicium, and magnesium were run by atomic absorption. The results are presented in graphic form in Figure 21.

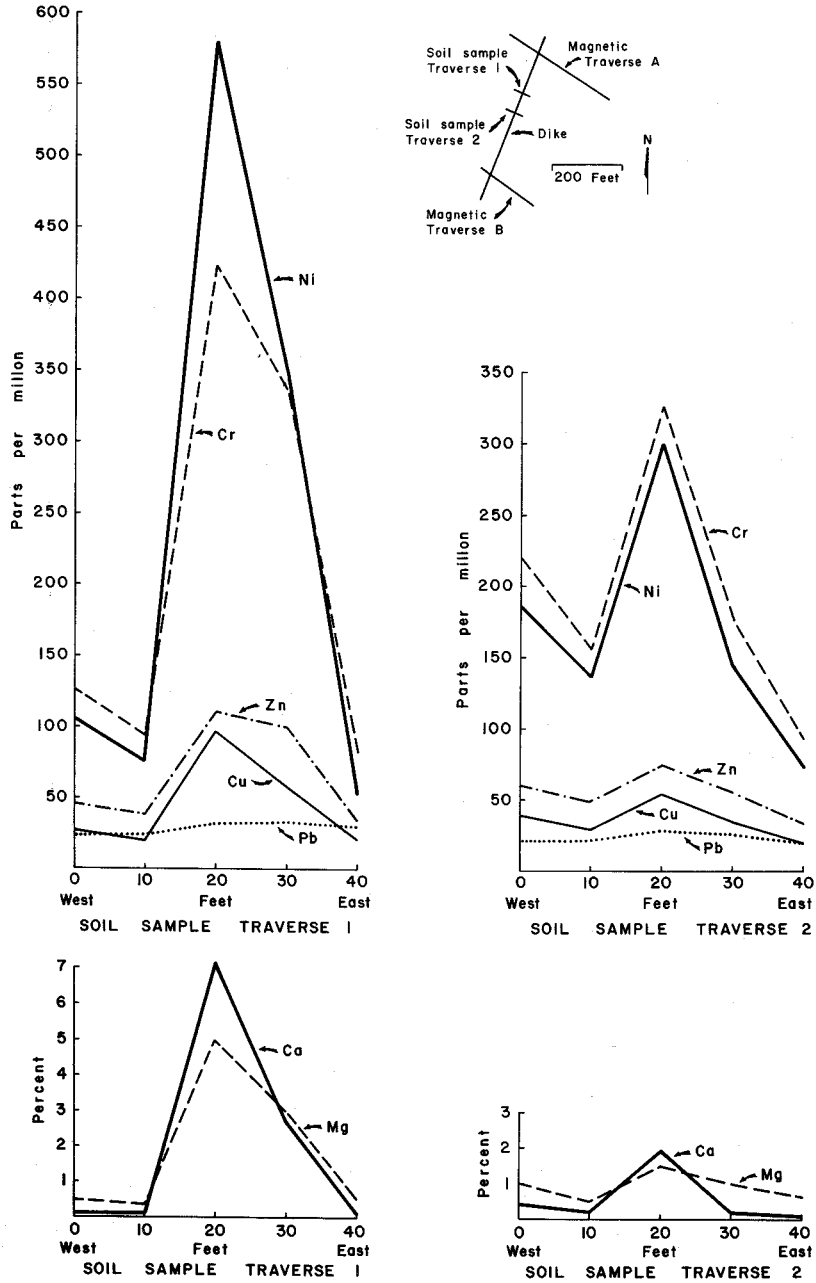


Figure 21. Analyses of soil samples from two traverses across mica peridotite dike 0.35 mile (0.56 km) northeast of the junction of State Roads 626 and 617 and about 500 feet (152 m) north of State Road 622.

STRUCTURE

Structures in the Strasburg and Toms Brook quadrangles include the Massanutten synclinorium and the Little North Mountain structural front. The present structural configuration of the rocks is related to forces that produced a westward tectonic transport. Folds are asymmetric with the west limbs of the anticlines and east limbs of the synclines steep to overturned. One major northeastward-trending reverse fault disrupts the normal stratigraphic sequence. A transverse fault trending northwesterly is mapped on Massanutten Mountain. Two well-developed generations of southeastward-dipping cleavage pervade the less competent rock units.

The area can be divided into four broad lithotectonic units, three of which (Massanutten mountain range, Martinsburg Formation belt, and carbonate lowland) are in the Massanutten synclinorium.

MASSANUTTEN MOUNTAIN RANGE

The Massanutten mountain range lithotectonic unit includes topographic areas 4, 5, and 6 (Figure 2). Except for the thin carbonates of the Wills Creek, Keyser, and Helderberg the formations are composed of clastic rocks. The lithologies present are quartzite, sandstone, conglomerate, shale, siltstone, mudstone, and volcanic tuff. This lithologic unit has been folded into a synclinorium composed of three major synclines and two major anticlines (Plate 1, cross section A-A′). Many minor folds are also present in all formations. On Bear Wallow Trail and along the south side of the hollow north of that trail small folds with a wave length of 50 to 100 feet (15-30 m) are exposed in the Massanutten Sandstone. The major anticline is a relatively symmetrical fold with a near vertical axial surface. Axial surfaces of the minor folds are inclined to the southeast but progressively bend until they have a dip to the northwest. Little Crease Mountain, near the southwest corner of Plate 1, is an anticlinal mountain. The northwest flank has a gentle dip to the northwest; however, the southeast is marked by several minor folds similar to those described along Bear Wallow Trail. The only exposure of these folds is in Veach Gap, 1,500 feet (457 m) south of the south boundary of Plate 1 (Figure 22).

Green Mountain on the west side of Fort Valley is an anticlinal mountain with no evidence of minor folding of the type seen in the anticlines to the east.

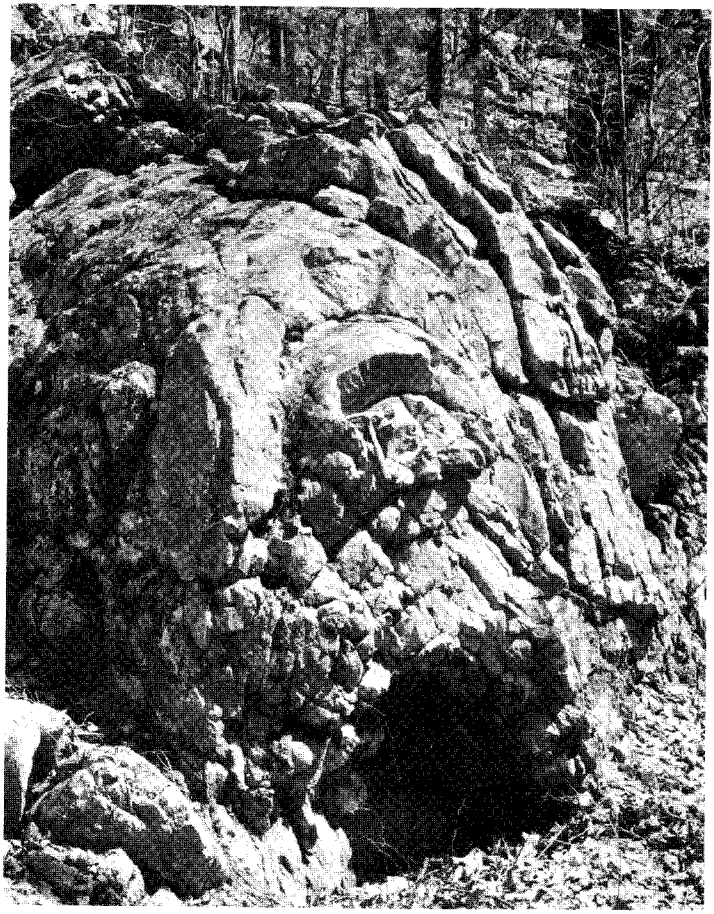
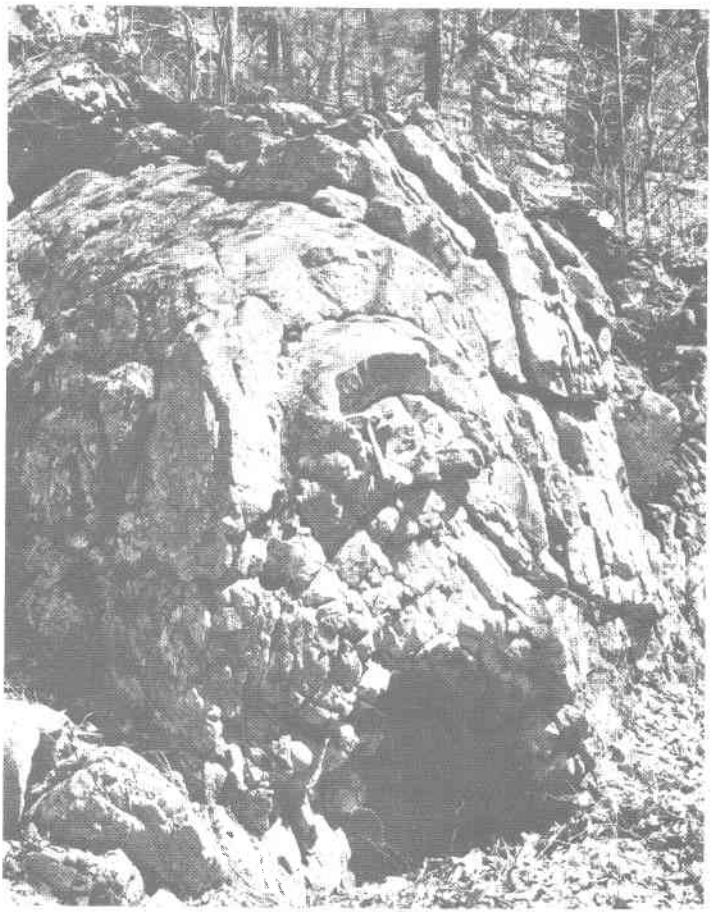


Figure 22. Small fold in the Massanutten Sandstone in Veach Gap (Bentonville 7.5-minute quadrangle).

A northwestward-trending, near vertical, pivotal fault with apparent right-lateral movement extends through Shawl Gap on the east, across Fort Valley, and to the east of Meneka Peak. Evidence for this fault includes the offset of formation contacts and fold axes, and brecciation in the Massanutten Sandstone at Shawl Gap. Along State Road 678 about 300 feet (91 m) west of Blue Hole several northwestward-trending vertical faults with minor displacement are well exposed. The major joint pattern is about N. 48° W. Two generations of cleavage with essentially parallel strikes and steep, nearly parallel southeasterly dips are present in the less competent units.



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MARTINSBURG FORMATION BELT

The second lithotectonic unit is composed of one formation estimated to be 3,200 feet (975 m) thick and includes topographic area 3 (Figure 2). Several lithofacies are present in the formation including black argillaceous limestone, black calcareous shale, metabentonite, lithic sandstone, silty shale, and siltstone. The latter three lithologies comprise the bulk of the formation. Small-scale, nearly isoclinal folds with southeastward-dipping axial surfaces are numerous (Figure 23). The best areas to see

Figure 23. Small fold in the Martinsburg Formation along State Road 758, 0.5 mile (0.8 km) southeast of Burnshire Bridge (Plate 2).

this folding are along the south side of Rittenour Ridge and along State Road 600 north of Rittenour Ridge (Plate 2), and along State Roads 615, 618, and 626 northwest of the Warren County Airport and along State Road 626 north of Lake John (Plate 1). Small displacement faults that range from nearly vertical to nearly horizontal are present in most large exposures.

Two generations of spaced cleavage are present in the Martinsburg lithotectonic unit. The earliest cleavage appears to be parallel to the axial surfaces of the small-scale isoclinal folds.

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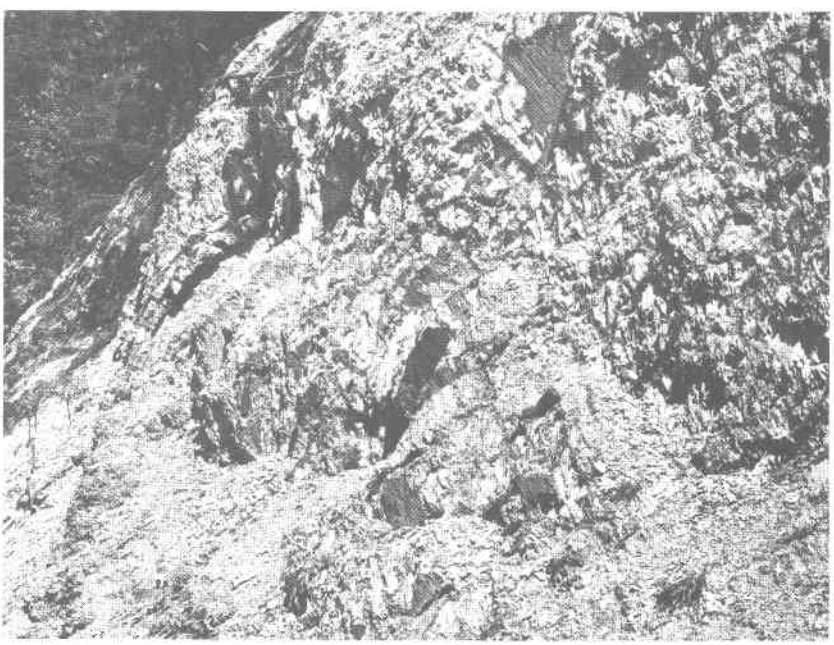

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This cleavage cuts the shale, siltstone, and sandstone. A second generation of spaced cleavage nearly parallel in strike to the first but with slightly divergent dips is exposed in a few outcrops. The second cleavage may be axial-plane cleavage and related to a sequence of broad, open folds that would explain the outcrop width observed on Plates 1 and 2. The presence of these folds has not been proved but their existence is consistent with the observed cleavage data.

CARBONATE LOWLAND

The area between about U. S. Highway 11 and the North Mountain fault is underlain by limestone and dolomite with only minor shale and sandstone (topographic area 2, Figure 2). Two minor faults and the northeast termination of the Edinburg fault occur in this area. In the adjoining Woodstock and Edinburg quadrangles the dominant apparent movement on the Edinburg fault was left lateral. South of Saumsville where the fault terminates, the apparent movement was dominated by the vertical component of motion. About 1.0 mile (1.6 km) east of Saumsville a small fault with a northwesterly dip marks the Stonehenge-Conococheague contact. Displacement along this fault does not appear to be great. West of State Road 623 and parallel to the North Mountain fault the Elbrook is thrust over the west limb of a syncline of Conococheague. Minor folds are common in the carbonate rocks. The largest, a syncline, extends from Pughs Run northeasterly to Harrisville. Incompetent beds in the Conococheague show very small flow folds with an amplitude of 1 to 2 inches (2.5-5.0 cm). These flow folds are cut by southeastward-dipping spaced cleavage.

Carbonate rocks also occur in the southeast corner of Plate 1. The rocks are overturned probably by forces related to the Front Royal fault that is exposed just east of the mapped area. Two generations of steep, southeastward-dipping cleavage similar to that described in the Front Royal area (Rader and Biggs, 1975) are present.

LITTLE NORTH MOUNTAIN

This lithotectonic unit is bounded by the North Mountain fault on the southeast and includes the entire northwest corner of Plate 2 and topographic area 1 (Figure 2). The structure is basically the overturned west limb of an anticline which has

been overridden by the North Mountain sheet (Plate 2, cross section B-B′). The North Mountain fault has a low dip to the southeast. Lower and Middle Ordovician carbonate rocks are exposed in slices along the fault. These slices probably were plucked from the underlying sheet.

Along the northwest side of Little North Mountain, Needmore and Marcellus are in fault contact. The fault is exposed along State Road 600 on the Woodstock quadrangle (Young and Rader, 1974) where the stratigraphic throw has increased and the Silurian Bloomsburg Formation is in contact with the Needmore. Where the fault is exposed it has a dip of about 80 degrees to the southeast and appears to be a normal fault with the younger Needmore overlying the older Bloomsburg. However, K. F. Bick and W. J. Perry, Jr. (personal communication) indicate that an interpretation of the fault as a folded originally northwestward-dipping thrust is more compatible with the mapped formational pattern. The present writers accept this interpretation over that proposed by Young and Rader (1974, p. 43).

ECONOMIC GEOLOGY

Limestone, dolomite, sandstone, and shale are available raw materials in the Strasburg and Toms Brook quadrangles. Carbonates are being and have been quarried to produce crushed and broken stone for road aggregate, concrete, and lime. Clays and shales of the area are suitable for common brick and lightweight aggregate. In the past iron and manganese were produced.

INDUSTRIAL LIMESTONE AND DOLOMITE

Certain uses of limestone and dolomite are dependent upon their chemical composition, whereas other uses are determined by their physical characteristics. Carbonate materials are present in the Strasburg and Toms Brook quadrangles that have the chemical requirements for some of the standardized uses for limestone and dolomite by various consuming industries. These requirements are listed in Table 2.

Carbonate rocks of potential industrial use are roughtly subdivided into *high-calcium limestone,* which contains more than 95 percent calcium carbonate; *high-magnesium dolomite,* which contains more than 40 percent magnesium carbonate and gen-

Table 2.—Chemical requirements for uses of limestone and dolomite (from O'Neill, B. J., 1964, Table 2).

Uses	Chemical requirements
Lime (calcium)	$CaCO_3$ content not less than 97%, preferably 98% or more.
Steel flux (open hearth)	$CaCO_3$ content should exceed 98%, but some limestone as low as 97% is sometimes accepted.
General chemical use	$CaCO_3$ content should exceed 98%, but limestone as low as 97% is sometimes used.
Glass (calcium)	$CaCO_3$ content should exceed 98% and Fe_2O_3 not more than 0.05%.
Paint and filler	$CaCO_3$ content should exceed 96%; $MgCO_3$ not more than 1%. Other maxima: Fe_2O_3, 0.25%; SiO_2, 2.0%; and SO_3, 0.1%.
Glass (magnesium)	$CaCO_3$-$MgCO_3$ content should exceed 98% and Fe_2O_3 not more than 0.05%.
Refractories	$MgCO_3$ not less than 37.5%. SiO_2, Fe_2O_3, and Al_2O_3 not to exceed 1% each.
Portland cement	$MgCO_3$ not more than 6.3%. Minimum $CaCO_3$ content varies from plant to plant depending on availability of other raw materials.
Lime (magnesium)	$MgCO_3$ content should be between the limits of 21 and 31.5%.
Steel flux (blast furnace)	$MgCO_3$ less than 8% to less than 31%. SiO_2 less than 5%, Al_2O_3 less than 2%. Phosphorous content should not exceed 0.01%.
Agricultural limestone	Minimum of 85% $CaCO_3$.
Agricultural dolomite	$CaCO_3$-$MgCO_3$ content should total at least 85%.

erally less than 4 percent noncarbonates; and *impure limestone,* a broad term used to describe rocks which are commonly low in magnesium carbonate or contain more than 5 percent noncarbonates. The noncarbonate constituents, chiefly silica, alumina, and iron oxides, are an important consideration in some industrial processes. Chemical analyses of samples from the Strasburg-Toms Brook area are shown in Table 3.

Table 3.—Chemical composition of carbonate rocks from selected localities in the Strasburg and Toms Brook quadrangles.

Location	Formation	Sampled Thickness Feet	(m)	$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	K_2O	Total
Along State Road 638 between Strasburg and Strasburg Junction[1]	Edinburg	250	(76)	92.41	0.59	6.03	1.21	0.58	—	100.82
	Edinburg	250	(76)	83.49	1.48	10.05	0.97	3.13	—	99.12
Northeastern end of Chemstone Corporation quarry at Strasburg Junction (Plate 2, abandoned quarry number 9)[1]	Lincolnshire	50	(15)	96.97	1.21	0.92	0.08	0.56	—	99.74
Chemstone Corporation quarry, 0.5 mile (0.8 km) southwest of Strasburg Junction (Plate 2, abandoned quarry number 10)[1]	New Market	64	(20)	98.45	0.91	0.18	0.08	0.40	—	100.02
About 800 feet (244 m) west of U. S. Highway 11 and 1.25 miles (2.01 km) southwest of Tumbling Run[1]	New Market	60	(18)	98.35	0.73	0.24	0.04	0.34	—	99.70
About 300 feet (91 m) east of U. S. Highway 11 and 1.0 mile (1.6 km) northeast of Toms Brook[1]	Edinburg	100	(30)	90.29	3.37	6.19	0.55	1.03	—	101.43
	Lincolnshire	100	(30)	95.28	1.65	3.77	0.26	0.43	—	101.39
	New Market	80	(24)	96.94	1.33	0.34	0.08	0.84	—	99.53
Quarry along Pughs Run, 0.25 mile (0.40 km) east of U. S. Highway 11 (Plate 2, abandoned quarry number 18)[1]	New Market	32	(10)	98.26	1.59	0.79	0.24	0.09	—	100.97

Table 3.—Continued

Location	Formation	Sampled Thickness Feet	(m)	$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	K_2O	Total
About 600 feet (183 m) southwest of The Central Chemical Company plant and 2 miles (3 km) northeast of Strasburg (adjoining Middletown quadrangle)[1]	Upper Rockdale Run	100	(30)	54.79	41.55	3.43	0.46	0.64	—	100.87
		100	(30)	53.99	38.20	4.12	0.43	0.52	—	97.26
		100	(30)	56.40	36.46	5.91	0.55	1.07	—	100.39
200 feet (61 m) east-southeast of junction of State Roads 653 and 655; begin at north end of bridge over Toms Brook (R-6597)[2]	Middle Rockdale Run	25.0	(7.6)	53.86	35.02	5.95	0.45	0.73	0.53	99.90
400 feet (122 m) east-southeast of junction of State Roads 653 and 655 (R-6598)[3]	Middle Rockdale Run	75.0	(22.8)	49.53	35.72	9.10	0.66	1.10	0.79	99.76
East side of valley, 0.15 mile (0.24 km) northeast of junction of State Roads 642 and 662 (R-6599)[4]	Stonehenge	125.0	(38.1)	92.00	3.91	2.70	0.13	0.26	0.15	100.26

[1]Modified after Edmundson, 1945, p. 46-49.
[2]Volatiles lost, 3.36 percent.
[3]Volatiles lost, 2.86 percent.
[4]Volatiles lost, 1.11 percent.

HIGH-CALCIUM LIMESTONE

Formations in the mapped area which generally can be classified as high-calcium limestone include the upper New Market Limestone, the overlying Lincolnshire Formation where free of chert, and locally the upper member of the Stonehenge Formation where free of dolomite. Table 3 includes chemical analyses of several potential high-calcium limestone areas.

The New Market Limestone outcrop belt extends from the western edge of the town of Strasburg to the southwestern corner of the mapped area at the town limits of Woodstock (Plates 1, 2). The thickness of the formation is highly variable due to its deposition upon the irregular paleoerosional surface of the underlying Rockdale Run. Generally the New Market ranges between 40 to 100 feet (12-30 m) thick, though 162 feet (49 m) was measured near the Powhatan Lime Company (abandoned quarry number 1) 0.5 mile (0.8 km) northeast of Strasburg Junction.

The Lincolnshire Formation overlies the New Market Limestone and is also thin. The amount of black chert, which reduces the unit's value as a high-calcium source, varies within the formation. The unit is very cherty at the Tumbling Run exposure, but 1.3 miles (2.1 km) to the northeast in the Chemstone Corporation quarry (Plate 2, abandoned quarry number 9) Lincolnshire limestone is of high-calcium grade (Table 3).

The upper part of the Stonehenge Formation contains units of dark-gray limestone which could prove to be of high-calcium quality (R-6599). Occasional interbeds of dolomite or scattered chert nodules, however, may make the Stonehenge limestone unusable for high-calcium purposes.

IMPURE LIMESTONE

Formations which contain quantities of impure limestone include the New Market, Lincolnshire, and Stonehenge formations (where not of high-calcium grade), and Edinburg Formation. Other relatively impure limestones interbedded with dolomites are referred to under "Crushed and Broken Stone."

The Stonehenge crops out in a northeastward-trending belt on the Toms Brook quadrangle (Plate 2). The main belt parallels and is generally covered by the Interstate Highway 81 right-of-way, but this belt is repeated by folding between Harrisville and the southwestern edge of the mapped area.

Table 4.—Physical test data of coarse aggregate from potential sources.

Formation (Lithology)	Location Latitude	Location Longitude	Specific Gravity	Absorption	Los Angeles Loss Abrasion	Grading	Soundness	Bituminous Adhesion Weight	Bituminous Adhesion Estimated
Martinsburg (shale)[1]	38° 52′ 36″	78° 29′ 54″	2.72	0.79	47.0	A	—	10	96
New Market (limestone)[1]	38° 54′ 54″	78° 27′ 54″	2.70	0.61	26.2	A	OK	62	97
Edinburg (limestone)[1]	30° 59′ 06″	78° 23′ 06″	2.72	0.33	36.6	A	OK	99	99
Rockdale Run (limestone)[1]	38° 54′ 12″	78° 29′ 06″	2.78	0.85	21.9	A	OK	—	—
Martinsburg (shale)[1]	38° 54′ 06″	78° 27′ 48″	2.72	0.78	25.2	A	OK	—	—
New Market (limestone)[1]	38° 54′ 06″	78° 29′ 00″	2.66	0.52	23.8	A	OK	67	85
Conococheague (limestone)[1]	38° 54′ 48″	78° 29′ 42″	2.68	0.70	22.8	A	—	97	99
Rockdale Run (limestone)[1]	38° 56′ 54″	78° 26′ 54″	2.76	0.59	28.6	A	OK	27	50
Rockdale Run, New Market, Lincolnshire, and Edinburg[2]	Riverton Corporation quarry, 0.25 mile (0.40 km) east of Toms Brook on State Road 653 (active quarry number 16)		2.72	0.20	18.9	—	—	—	—

[1]Modified from Parrott, 1954, p. 47-49. [2]Modified from Gooch, Wood, and Parrott, 1960, p. 24-25.

The St. Luke Member of the Edinburg Formation is predominantly impure limestone, but the member is rather thin. The lower portion of the Edinburg has been quarried in several areas with the New Market and Lincolnshire (Table 4).

CRUSHED AND BROKEN STONE

When rock is to be used for dimension stone, riprap, or construction purposes, the physical properties are the most important aspect. The most important use of crushed stone today is highway construction. In order for a material to be utilized for various highway aggregate purposes it must meet certain specifications such as resistance to abrasion, absorption, specific gravity, resistance to freeze-thaw breakdown (soundness), and affinity for bituminous material (Gooch, Wood, and Parrott, 1960).

Samples from the Ordovician carbonates as well as the Cambrian Conococheague Formation were tested (Parrott, 1954) and found to have grade A classification (Table 4). The numerous active and abandoned quarries within the mapped area show that large amounts of crushed stone are and have been produced. Presently, the Riverton Corporation is operating a limestone quarry (formally the Toms Brook Lime and Stone Company quarry) just east of the town of Toms Brook on an intermittent basis (Plate 2, active quarry number 16). The corporation operates a portable crusher at the site about three months per year to maintain adequate stockpiles for sales. Chemstone Corporation, the Powhatan Lime Company, the Shenandoah Lime Company, and the Strasburg Lime Company have all operated limestone quarries in the Strasburg area in the recent past though no operations are presently active (abandoned quarry numbers 1, 9, 10, 11, 12, 13). The Salem Stone Corporation operated a small portable limestone crusher 2 miles north of Woodstock along Pughs Run (abandoned quarry number 17) that utilized the Stonehenge Formation in the construction of Interstate Highway 81. Other abandoned quarries are scattered in the area; these were small operations usually opened for a specific project and worked with a portable crusher.

HIGH-SILICA SAND

The Massanutten Sandstone is locally pure and may be a potential source of high-silica sand. The sand grains are ce-

mented with silica and are commonly pressure welded which makes the rock expensive to crush. Red and gray discoloration in the rock, caused by iron, and the presence of thin shale interbeds in some portions of the unit further decrease the formation's suitability for high-silica purposes.

The Tuscarora Sandstone, though commonly pressure welded and very hard, is generally more pure than the Massanutten Sandstone. The unit is generally inaccessible in the study area, however, and was not tested for high-silica value.

SAND AND GRAVEL

There are at present no known active sand and gravel operations in the mapped area. Some areas of alluvial and terrace fill may prove to be of sufficient thickness for economic purposes. The talus deposits and fans on the slopes of the Massanutten mountain range and Little North Mountain could also prove of value on a limited scale for gravel or building stone.

CLAY, SHALE, AND RELATED MATERIALS

Tests and determinations of properties required to evaluate the potential ceramic and nonceramic uses of raw materials in the project area have been published by Ries and Somers (1920) and Calver, Hamlin, and Wood (1961). Tests were conducted on several samples from the Martinsburg Formation and one sample each from the residual clay formed on the Middle Ordovician limestones and the shales of the Devonian Mahantango Formation. The tests are summarized in Table 5. Detailed exploration, sampling, and testing should be carried out to prove any particular locality for commercial development.

IRON AND MANGANESE

Mines and prospects of iron and manganese oxides have been described from several localities in the Massanutten mountain range and the Shenandoah Valley (Watson, 1907; Harder, 1910; Stose and Miser, 1922). In the late nineteenth and early twentieth centuries much active mining and production took place in Little Fort Valley and, to a lesser degree, in Fort Valley. The ruins of two iron-smelting furnaces, Elizabeth Furnace on the banks of Passage Creek (Plate 1) and Boyer (or Mine Run) Furnace in Mine Gap (Plate 2), remain in the area.

Table 5.—Potential uses of clay and shale materials from the Strasburg and Toms Brook quadrangles.

Location	Formation	Sampled Interval	Potential Use
Outcrop on the south side of State Highway 55 approximately 2.25 miles (3.62 km) northwest of Waterlick (R-648)[1]	Martinsburg	Composite across 105 feet (32 m) of dark-gray and olive-gray shale and fine-grained sandstone	Common brick and lightweight aggregate
Roadcut of the Southern Railway, 2.25 miles (3.62 km) southeast of Strasburg[2]	Martinsburg	Fresh and weathered shale	Dry press or plastic brick, fireproofing
Outcrop on north side of State Highway 55 about 1.0 mile (1.6 km) southeast of Strasburg (R-657)[1]	Martinsburg	Composite across 35 feet (11 m) of light olive gray shale and brown sandstone	Low-grade brick
Exposures along road 1.5 miles (2.4 km) east of Strasburg[2]	Martinsburg	Weathered shale	Common brick
Outcrop along State Road 758 approximately 2.5 miles (4.0 km) east of Woodstock (R-674)[1]	Martinsburg	Composite across 130 feet (40 m) of light olive gray shale and olive-green and yellowish-orange sandstone	Common brick, tile, and lightweight aggregate
Roadcuts on State Road 758, 1.5 miles (2.4 km) east of Woodstock[2]	Martinsburg	Weathered shale	Common brick and fireproofing
Outcrop on northeast side of State Road 600 about 1.5 miles (2.4 km) southeast of Maurertown (R-658)[1]	Martinsburg	Composite across 300 feet (91 m) of grayish-olive and dusty-yellow shale and fine-grained, brown sandstone	Lightweight aggregate
Just northeast of Strasburg at site of old brickyard[2]	Edinburg (?)	Residual material developed on the limestone	Common brick
Outcrop on west side of State Road 678 about 1.5 miles (2.4 km) northeast of Seven Fountains P. O. (R-665)[1]	Mahantango	Composite across 60 feet (18 m) of olive-gray shale	Common brick and lightweight aggregate

[1]Modified after Calver, Hamlin, and Wood (1961); sample on file in the Virginia Division of Mineral Resources repository where it is available for examination. [2]Modified after Ries and Somers (1920).

The primary iron-bearing zones in the Massanutten mountain range are in or just below the Ridgeley Sandstone. Commonly the iron-bearing beds classified as Oriskany limonite by Holden (1907) are locally high in manganese and in some places iron is in small quantities or entirely absent. The minerals were probably leached from the overlying black Devonian shales and deposited along bedding planes and fractures formed by solution-caused collapse breccias in the Ridgeley Sandstone and underlying limestone (R-6163).

There are numerous prospect pits and small surface mines scattered along the Ridgeley outcrop belts (and occasionally in the Silurian Bloomsburg Formation and Massanutten Sandstone) in both Fort Valley and Little Fort Valley. Most of these workings recovered iron ore which was taken by wagon to the nearest furnace. The rock was melted and fluxed to separate the ore from the silica and other impurities, and the iron was shipped by wagon to the nearest railroad. No production figures are available and it appears that the Massanutten mountain range area produced only a minor amount of Virginia's iron ore.

There was one iron ore prospect reported in the main Shenandoah Valley portion of the project. The Scott prospect (abandoned prospect number 15), located on the northwest side of Round Hill, was worked briefly in 1915. No production figures are available, but the ore was described as iron oxide with a pyrite core occuring as porous masses in the chert and clay from the weathered Rockdale Run dolomite (Stose and Miser, 1922, p. 93).

Little Fort Valley has produced commercial amounts of manganese ore. There were three major mines in the valley, but numerous prospect pits indicate extensive exploration and minor ore strikes. The mines were operated intermittently from 1880 until 1919; most of the production records are incomplete.

The most important of these manganese mines was the Powells Fort or Baltimore mine, which was located just south of Mine Gap (abandoned mine numbers 23 and 24). Geologically, the mine is located at the base of the Ridgeley Formation on the southeast flank of the syncline which forms Little Fort Valley. The ore, which was described as a good grade of soft crystallized pyrolusite (Watson, 1907, p. 253), was recovered by both surface and underground mining techniques. Watson (1907) reported two sample analyses which showed 59.3 and 48.59 percent manganese oxide present; Harder (1910), p. 67)

noted a sample which showed 94.3 percent manganese. Using X-ray diffraction tests, the present authors found that traces of nickel, cobalt, zinc, and copper were also present. A relatively complete description of the mine, including diagrams, was presented by Stose and Miser (1922, p. 93-99).

The Philadelphia mine (abandoned mine number 20) was located approximately one-half mile west of Mudhole Gap on the northeast limb of the Little Fort Valley syncline. The mine appears to have been worked on the surface with little tunneling; several hundred tons of ore were reported shipped (Harder, 1910, p. 68). The Oregon mine was some 4 miles (6 km) northeast of the Powells Fort mine in the same strike belt of the Ridgeley (Stose and Miser, 1922, p. 100). This mine consisted of a number of shallow surface cuts but apparently little actual mining was done and the abandoned mine could not be located during the present study. Samples R-6155 and R-6156 (botryoidal manganese minerals) were collected in a wildlife clearing near where the Oregon mine may have been.

HYDROGEOLOGY

by Richard H. DeKay

Any assessment of the hydrogeology of an area is partially predicated on well data that are necessary to verify the permeability evaluations of the several types of bedrock. In this regard the writer obtained information from Virginia Geological Survey Bulletin 45 (Cady, 1936) and from well records submitted to the Division of Mineral Resources by drilling contractors since 1948. Among the local well drillers who for many years have generously shared their time and experiences are D. T. Russell of Winchester, Virginia, C. E. Shirley of Stephenson, Virginia, and particularly Larry LeHew of Front Royal, Virginia whose extensive knowledge and records of water wells in the immediate area has been a major contribution to this report. It should be noted, however, that most of these data are for relatively shallow farm and domestic wells drilled for only small water supplies, the yields are estimates, and the well sites were selected mainly for convenience rather than for hydrogeologic favorability. The resultant evaluations therefore reflect only area conditions relevant to those in another area (Cederstrom, 1972) and not the optimum permeability characteristics of the various rock types considered.

Unlike unconsolidated sediments such as gravel and sand that occur at the foothills of some mountains and along many rivers and seacoasts, most consolidated sediments (bedrock) have a very low primary permeability. Whereas the sand and gravel deposits are true aquifers in the sense that they are comprised of permeable material that will yield gravity ground water in appreciable quantities (Wisler and Brater, 1963), most undeformed bedrock transmits water in such small amounts as to be impermeable for all practical purposes. Such is the case for bedrock in the Strasburg and Toms Brook quadrangles, where the water-bearing potential of the bedrock is largely a matter of secondary permeability (physical and chemical openings developed after the rock was formed). Since the mode of occurrence of ground water in the rocks of an area is therefore largely determined by the geology of that area (Wisler and Brater, 1963), the permeability characteristics of most rocks are dependent upon their structure and lithology. As all 24 geologic formations in the Strasburg and Toms Brook quadrangles are sedimentary rocks that have been slightly metamorphosed during folding and faulting subsequent to their deposition, their hydrogeologic properties are evaluated in this report according to the clastic, clastic-carbonate or carbonate lithologic category in which they occur.

CLASTIC ROCKS

Sandstone, shale, and siltstone comprise most of the clastic rocks; some quartzite, claystone, "slate," and a few conglomeratic rocks are also present. However, 11 of the 12 formations in this category are located in the central (Massanutten mountain range) and northwestern (Little North Mountain) portions of the two quadrangles. As there is no habitation in the latter no water-well data are available; a small population is present in the Fort Valley part of the Massanutten range where it is reported (personal communication, Larry LeHew, 1976) that more than adequate domestic supplies of ground water are available from wells less than 150 feet (46 m) deep in the Devonian sandstone, siltstone, and shale. As a result of this situation the only clastic rock unit that can be evaluated for its permeability characteristics is the Martinsburg Formation that underlies approximately half the two quadrangles and for which considerable well data is available.

The Martinsburg consists predominantly of sandstone, siltstone, and "shale" in the upper and middle portions, and of limestone and "slate" in the lower portion. Nearly all of the wells for which records are available penetrate the upper and middle portions in which the very fine to medium-grained rocks are cemented mostly in a siliceous or argillaceous matrix that so clogs the interconnected pore spaces as to negate most of the primary permeability in undeformed rocks of this type. These rocks have been deformed, however, being folded locally and downwarped regionally into a broad syncline with the west and east limbs exposed on opposite sides of the Massanutten mountain range (cross sections, Plates 1 and 2). As result of this deformation cleavage planes were developed that, together with bedding planes, have parted in places creating voids of varying extent. Most of these openings are of relatively shallow inclination and are transected by more steeply dipping fractures developed as tension cracks and minor faults during folding. With the steeply inclined fractures to intercept surface-water runoff at the base of the weathered rock zone and transmit it to the nearly horizontal openings, an exploitable secondary permeability has been developed. Since these friable, thin-bedded rocks are susceptible to the pressures of crustal loading, however, this hydrogeologic condition is usually terminated at more shallow depths than in massive, resistant rocks. As data are available for only two wells deeper than 400 feet (122 m) it has not been possible to assess these secondary permeability characteristics at greater depths, but that they are present at shallow and moderate depths has been amply demonstrated by the consistent production of small to moderate yields from water wells less than 250 feet (76 m) deep (Table 6). This is mainly due to the relatively large number of nearly horizontal openings, several of which may be penetrated by each well and more than one of which are generally water-bearing. The few wells that produce less than 5 gallons (19 liters) per minute are located where the fractures and partings are steeply dipping, reducing the probability of interception by a well, or where the rocks are less deformed in areas of siltstone and shale that have virtually no primary permeability (Lynch, 1962).

Other factors that contribute to the favorable hydrogeologic properties of the Martinsburg Formation are a low relief, an ample number of influent streams, and the moderate thickness of the soil cover. In both the eastern and western belts the

Table 6.—Composite record of reported-depth and estimated-yield data for 102 water wells in clastic rocks in the Strasburg and Toms Brook quadrangles, Virginia.[1]

Geologic formation	Depth in feet (m)			Yield in gpm (l/m)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Martinsburg east	27(8)	400(122)	160(49)	0(0)	50(189)	14(53)
Martinsburg west	45(14)	700(213)	214(65)	1(4)	50(189)	14(53)
All Martinsburg	27(8)	700(213)	181(55)	0(0)	50(189)	14(53)

[1]Of the 12 clastic formations that occur in these quadrangles, records are available only for wells drilled in the Martinsburg Formation.

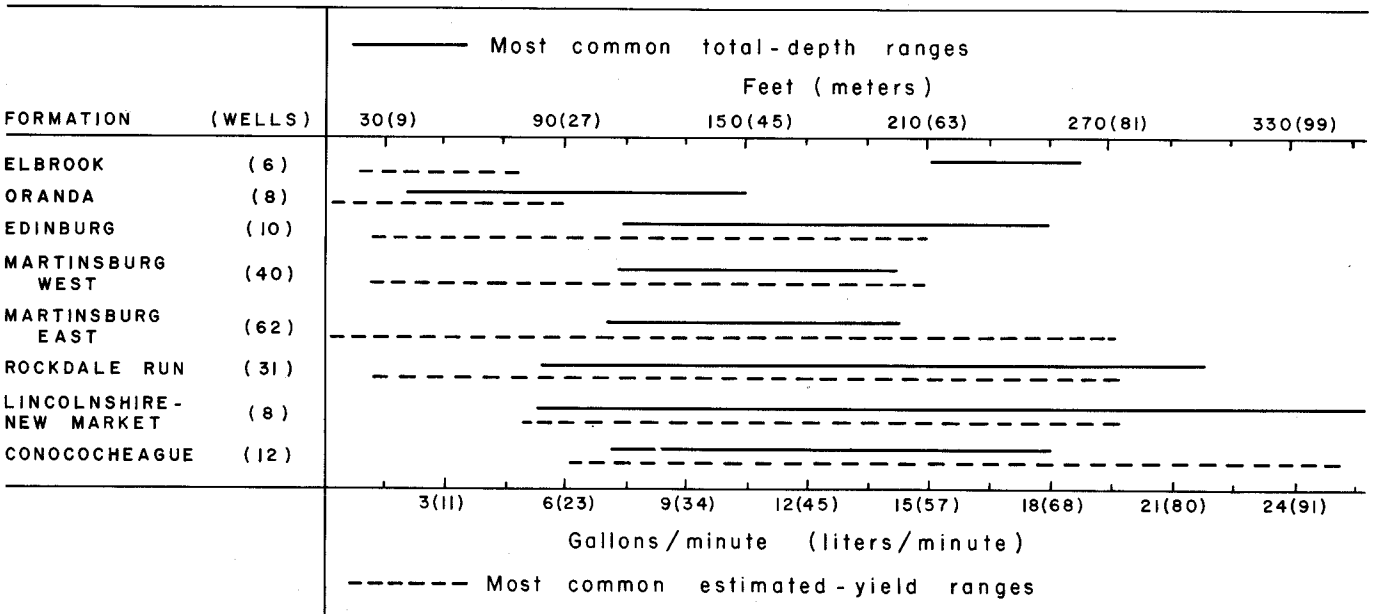
relief is only 200 feet (61 m) on a gently sloping surface, which reduces the rate of runoff waters. Each of these belts is traversed in its long (northeast) dimension by a major stream (the North and South forks of the Shenandoah River) and crossed by numerous southeastward-flowing tributaries. The amount of soil and weathered rock that overlies bedrock in most places is of equal importance to its overall permeability (Trainer, 1975). Although clastic terrane is often thinly mantled, more than 20 feet (6 m) of weathered material covers the Martinsburg strata in most places; on some low hills residual soil plus remnants of alluvial and terrace deposits exceed 100 feet in thickness. This unconsolidated material absorbs runoff from the influent streams and diverts it to the interconnected bedrock openings.

The distinguishing characteristic of the Martinsburg hydrogeologic properties is the dependable production of water from shallow depths compared to the erratic yields and depths of wells in other rock units in these quadrangles (Table 7). Few attempts have been made to obtain large water supplies from individual wells or to develop deep water-bearing zones, but it is likely that moderate yields can be obtained from wells 300 to 500 feet (91 to 152 m) deep in most areas underlain by this clastic rock unit. Treatment of the water from these rocks may be necessary for specific purposes as, in general, it is highly mineralized, hard, and may be high in sulfate and iron (Cady, 1936).

CLASTIC-CARBONATE ROCKS

Although the geologic formations that occur in the Strasburg and Toms Brook quadrangles are generally categorized as being either clastic or carbonate, from the viewpoint of permeability a third category is necessary to isolate those rock units that contain appreciable amounts of each lithology. Six of the formations mapped (Plate 2) are so constituted and have permeability characteristics distinguishable from those of clastic or carbonate rocks. As no data are available for wells in the Helderberg, Keyser and Wills Creek, however, the hydrogeologic properties of only the Elbrook, Edinburg, and Oranda formations are here evaluated. It should also be noted that with the exception of one well in the Edinburg Formation all the data are for wells located in the Toms Brook quadrangle. The Oranda and Edinburg formations are composed of nearly equal amounts of soluble (carbonate) and insoluble (clastic) material, but the

Table 7.—Composite of the most commonly reported total-depth and estimated-yield ranges for 177 water wells in eight geologic formations in the Strasburg and Toms Brook quadrangles (arranged in order of increasing average yields).



Elbrook Formation is mostly a carbonate rock unit. As the few wells drilled into this formation penetrate the interbedded silty and shaly portion, however, the permeability characteristics are not conformable with those for carbonate rocks.

Most dense crystalline carbonates have a low primary permeability (Davis and DeWiest, 1966) and fine-grained clastic rocks with an insoluble matrix are impermeable for all practical purposes. Unless these rocks are deformed by fracturing or solution their exploitable ground-water potential is extremely limited. In the Toms Brook quadrangle the Elbrook, Edinburg, and Oranda formations have been slightly inclined by folding that has locally developed small fracture openings; the clastic rocks are insoluble for the most part, and there is little evidence that much solution activity has occurred to enlarge any fracture openings in the carbonate rocks. The openings that do occur are apparently small, few, and steeply inclined as one-third of the wells for which data are available are deeper than 400 feet (122 m) and yield only one-half as much water as shallower wells in the clastic (Martinsburg) rocks (Tables 6 and 8).

The combination of several negative hydrogeologic factors is the reason for the relatively poor permeability characteristics of the clastic-carbonate rocks. In addition to the aforementioned slight deformation and solution activity, the surface-drainage network is only fair at best, and the soil cover is thin in most places. The Edinburg and Oranda formations underlie local high areas or the flanks thereof on which the few influent streams have a much faster runoff rate; the Elbrook Formation underlies a varied topography of low relief, but very few perennial streams cross the formation. The soil cover, which is usually thicker on carbonate than on clastic rocks is here poorly developed and bedrock is commonly seen exposed at the land surface. Few bedrock openings, rapid or inadequate drainage, and a thin soil cover has resulted in moderately deep wells in the search for ground-water supplies that have the smallest range and average yield of the three lithologic categories (Table 7). Because most fracture and solution permeability is steeply inclined and the wells are located at sites of convenience, it is probable that larger yields can be obtained from wells drilled at sites selected on the basis of rock deformation in low, well-drained areas. In addition to low quantities of water, the quality is not usable for some purposes without treatment; most of the water is hard, with relatively high concentrations of iron and nitrate locally (Cady,

Table 8.—Composite record of reported-depth and estimated-yield data for 24 water wells in clastic-carbonate rocks in the Toms Brook quadrangle, Virginia.[1]

Geologic formation	Depth in feet (m)			Yield in gpm (l/m)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Elbrook	115(35)	460(140)	278(85)	1(4)	16(61)	7(25)
Edinburg	109(33)	494(151)	273(83)	0(0)	25(95)	9(34)
Oranda	45(14)	400(122)	186(57)	0(0)	16(61)	7(25)
All formations	45(14)	494(151)	245(75)	0(0)	25(95)	8(30)

[1]Data is available for only 1 well in the Edinburg Formation in the Strasburg quadrangle; the Elbrook and Oranda formations do not occur in the Strasburg quadrangle.

1936). Also, steeply inclined fracture and solution openings are commonly filled with sediment to some degree, causing the water to periodically be discolored as the fine-grained material is dislodged and washed toward the uncased well bore.

CARBONATE ROCKS

Although all carbonate rocks are impure to some degree (Edmundson, 1945), six of the formations mapped in the Strasburg and Toms Brook quadrangles (Plates 1, 2) are dominantly of a carbonate lithology. Data are available for wells in only four of these rock units in the Toms Brook quadrangle, and the Lincolnshire and New Market formations are considered as a single unit (Tables 7, 9) because of their lithologic similarity, thinness, and scarcity of well data. The Rockdale Run, Lincolnshire, New Market, and most of the Conococheague formations are composed of dense, massive limestone and dolomite that generally have a very low primary porosity and permeability. Their water-bearing potential is therefore of a secondary-permeability nature, of which solution openings are the most important (Todd, 1963).

In general the fractures and solution openings are widely spaced and steeply inclined, which results in more than occasional low yields and dry holes and in relatively few shallow water-bearing zones.

The Lincolnshire and New Market formations have the purest calcium carbonate content of these rock units and should therefore be most susceptible to the solution activity of circulating ground waters. However, fractures are necessary for such subsurface circulation in relatively impermeable rocks, and in this area the amount of deformation has been minimal as the fractures are apparently few and small. Insufficient recharge in many areas is equally important, as the moderate zone of soil cover and low relief to reduce runoff would be adequate for recharge to bedrock openings under better drainage conditions. Because of the many deep wells drilled for municipal water supplies near Toms Brook and Maurertown, the depth and yield averages for wells in these formations are greater than expected for farm and domestic wells.

Wells in the Rockdale Run Formation have the typical erratic permeability of most carbonate rocks, with an extreme range in both depth and yield (Tables 7, 9). The middle portion

Table 9.—Composite record of reported-depth and estimated-yield data for 51 water wells in carbonate rocks in the Toms Brook quadrangle, Virginia.[1]

Geologic formation	Depth in feet (m)			Yield in gpm (l/m)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Conococheague	25(8)	398(121)	169(52)	1(4)	70(265)	23(87)
Rockdale Run	35(11)	1,000(305)	254(77)	1(4)	60(227)	17(64)
Lincolnshire-New Market	79(24)	688(210)	356(109)	5(19)	47(178)	21(79)
All formations	25(8)	1,000(305)	250(76)	1(4)	70(265)	19(72)

[1]The Conococheague Formation occurs only in the Toms Brook quadrangle; no data are available for wells in the Lincolnshire, New Market, and Rockdale Run formations in the Strasburg quadrangle.

of this rock unit is one of relatively high relief as a result of differental erosion on carbonates with large concentrations of chert. Drainage on the resistant low ridges and conical hills is extremely poor, the soil cover thin, and the fracture and solution openings few. Wells on such ridges and hills must be of greater depth to reach the water table, above which fracture and solution openings are dry. The deepest reported well in either quadrangle is located atop such a ridge, and although it is 1,000 feet (305 m) deep only 2 gallons (8 liters) per minute was obtained. Several other wells are located in low areas crossed by perennial streams whose course may have been determined by cross faults. One well in such a location is only 120 feet (37 m) deep and produces 20 gallons (76 liters) per minute. Broken rocks under a moderate soil cover traversed by influent streams are favorable hydrogeologic well sites and may be the reason for the moderate depth and yield averages of farm and domestic wells in this rock unit.

Although data are available for only 12 wells in the Conococheague Formation, the shallow average depth and relatively high average yield (Table 9) is consistent with averages for wells in this rock unit in most places in the Shenandoah Valley. Composed of soluble rocks that include permeable calcareous sandstone and siltstone strata, the Conococheague is perhaps the most favorable hydrogeologic unit in the Shenandoah Valley wherever deformed and associated with adequate drainage and soil cover. In the Toms Brook quadrangle the deformation has been slight and the drainage and soil cover only fair to good, but the interbedded sandstone and siltstone strata add a dimension to the permeability of the Conocoheague not present in the other carbonates. This is due to both their structure and lithology; the beds are only gently inclined as opposed to the usual steeply dipping fractures and solution openings, and they generally transmit water due to the desolution of the calcareous cement. Such hydrogeologic conditions are condusive to relatively shallow wells of moderate yield as is the case in this area (Tables 7, 9).

From the viewpoint of reported drilling results for farm and domestic wells in the Toms Brook and Strasburg quadrangles, it has been demonstrated that the average yield of wells in the carbonate rocks are nearly three times that of wells in the clastic-carbonate category, and half again as great as the average yield for wells in the clastic rocks (Tables 6, 8, 9). The

quality of water from the carbonate rocks is moderately hard to hard, and may contain iron or nitrite in some localities (Cady, 1936).

FORMATION PROCTECTION

Given the stability of natural conditions, man's activities pose the greatest threat to the degradation of ground-water supplies. In an area that receives approximately 40 inches (102 cm) of annual precipitation and has a better than average network of surface drainage, the quantity of available ground water does not appear endangered in the forseeable future. However, if the same area is underlain at shallow to moderate depths by bedrock with a secondary permeability, protection against contamination from unsanitary surface installations should be considered.

It has been previously stated in this report that the clastic rocks in the Strasburg and Toms Brook quadrangles lack primary permeability, but a well-developed secondary permeability occurs at relatively shallow depths. In such an area where a near-surface water table is present in rocks and soil that contain sulfide-bearing minerals, the unconfined water on top of bedrock is often mildly acidic. Metallic or concrete septic tanks in areas of thin soil cover and a shallow water table are particularly subject to corrosion and to eventual rupture. Leakage of effluent from the tanks or a drainfield will permeate the shallow fracture and cleavage openings, polluting ground-water supplies in nearby shallow wells (Ecolsciences, 1974). Untreated industrial wastes, landfills, and sludge disposal by land-spreading are other potential means by which shallow ground-water supplies in clastic rocks may be polluted.

In carbonate rocks the secondary permeability usually consists of more widely spaced and steeply inclined fracture and solution openings that generally results in wells of greater depth. Whereas the shallow ground-water supplies are therefore not as widespread or well-developed as those in the clastic rocks, the size of the openings may be larger and transmit pollutants without the benefit of any natural filtration. In addition, in some areas of advanced solution activity a karst region may be developed, and the resultant sinkholes are connected to solution openings capable of transmitting pollutants much greater distances than in unconsolidated or permeable rocks (Todd, 1959). The location of surface facilities that may discharge unsanitary

materials onto or into the ground should therefore be sited after a careful study of the local geology.

Hydrogeologic conditions in the clastic-carbonate terrane combine the permeability characteristics of both the clastic and carbonate rocks—the shallow ground-water supplies may be susceptible to pollution in some areas, and the deeper supplies in others. Because of this it may be necessary to give the local structure and lithology of these rocks the closest scrutiny of all before selecting water-well or waste-disposal sites.

ENVIRONMENTAL GEOLOGY

The geology of a region involves studies of the physical, mineralogical, and chemical characteristics of the rocks and their stratigraphic relationships, structural attitude, and economic potential. Environmental geology may be defined as the application of geologic factors and principles to the problems created by human occupancy and use of the physical environment. To produce an overall long-range plan for the most efficient and beneficial use of the land, all factors of environmental science must be considered.[1]

The basic human requirements for food and shelter must be available from the physical environment. Areas where food can be found or produced depend on a variety of factors such as kind of soil as influenced by physical and chemical properties of the bedrock; presence, quality, and quantity of water; climate; and the topography of the land's surface. Living in a modern civilization requires mineral resources, stable building sites, and waste disposal capability. To the older necessities, modern man has added the desire for recreational facilities with their special environmental problems.

Environmental geology maps (Plates 3, 4) that delineate units with similar properties of the residuum and bedrock in the Strasburg and Toms Brook quadrangles were prepared by grouping together lithologic units which could have similar

[1]Additional data on soils, water, regional planning, and forestry may be obtained from the following agencies; (1) Soil Conservation Service, U. S. Department of Agriculture, P. O. Box 10026, Richmond, VA 23240; (2) State Water Control Board, P. O. Box 11143, Richmond, VA 23230; (3) Lord Fairfax Planning District Commission, 103 East Sixth Street, Front Royal, VA 22630; (4) Virginia Division of Forestry, P. O. Box 3758 Charlottesville, VA 22903.

responses to human occupation. Observed lithology, slope stability, joints, and geologic erodibility, were considered when compiling the maps. Geologic data was obtained during field work for the preparation of the geologic maps (Plates 1, 2). The environmental geology maps (Plates 3, 4), prepared from the geologic maps and from environmental data observed in the field, should be used only as a guide to the distribution of the broad units with similar physical properties. *(A detailed evaluation of an individual site for a particular use should be conducted by professional personnel such as geologists, engineers, soil scientists, or agronomists.)* Major drainage basins are outlined on the maps (Plates 3, 4). Locations of large sinkholes are plotted and potential or actual rockfall and landslide areas are delineated.

The soils information was obtained from the U. S. Soil Conservation Service. Detailed information concerning the soils and specific interpretations for specific uses can be obtained from the local Soil Conservation Service office. The names of the soils used in the descriptions are tentative and subject to change pending a final correlation of the soils of Warren and Shenandoah counties. Soil in this report is defined as the material from the surface to the lower limit of biological activity (i. e., root penetration) or to rock if it occurs within a depth of 60 inches (152 cm) and residuum is considered to be the weathered material between the soil and bedrock. Thicknesses of soil and residuum are based on observations from natural and artificial cuts and on data supplied by the Soil Conservation Service. Slopes are defined as follows: nearly level, less than 3 percent; gently sloping, 3 to 8 percent; sloping, 8 to 15 percent; and steep, more than 15 percent. Thickness of soil is defined as follows: deep, greater than 40 inches (102 cm); moderately deep, 20 to 40 inches (51-102 cm); and shallow, less than 20 inches (51 cm). Limitation on liquid waste disposal facilities are subject to change with an increase in the number of drain fields per unit area. For example 1 drain field per 5 acres may be subject to slight or moderate limitations; however, if the number is increased to 5 or 10 per 5 acres limitations may be severe.

UNIT 1

A small area 1.5 miles (2.4 km) north-northeast of Mt. Olive (Plate 4) is underlain by maroon and yellow shale and siltstone,

sandstone, and minor gray dolomite. Steep southeastward-dipping cleavage is well developed and the frequency of jointing is locally high. Outcrops are rare. Slopes are gently sloping to sloping. Erosion is severe if the vegetative cover is removed. Major soils in this unit are in the Monongahela, Edom, and Dandridge series. Monongahela soils that have formed in old loamy sediments have a dense "pan-like" layer at a depth of 18 to 30 inches (46-76 cm) that restricts root development and water movement. Seasonally, the Monongahela soils have a "perched" water table. Edom and Dandridge soils have formed in residuum weathered mostly from shale with some interbedded sandstone and dolomite. Both soils have a clayey subsoil, but they are well drained. Dandridge soils have a high content of shale fragments throughout and are shallow. Edom soils are only moderately deep to bedrock, and have moderately slow to moderate permeability. The "pan" layer in the Monongahela soils causes them to be wet in winter and spring. The restricted root zone is droughty in summer unless rains are timely. Shallowness to rock is a severe limitation for many uses of the Dandridge soils. The depth to bedrock and permeability limit many uses of the Edom soils except for farming. They have a good potential for crops, pasture, or woodland.

UNIT 2

Fort Valley and the area northwest of Little North Mountain are underlain by shale, siltstone, and fine-grained sandstone. Little Fort Valley is underlain by shale and siltstone. The sandstones in Fort Valley form narrow linear ridges with low to moderate slopes on the crest and moderate to steep slopes on the flanks. Artificial cuts parallel to bedding and cleavage tend to sluff and slide. Cuts perpendicular to bedding and cleavage are more stable, but where significant amounts of shale are interbedded with the sandstone, sluffing may present problems. The major soils in this unit are in the Weikert, Dekalb, and Lehew series. The Weikert soils are shallow to interbedded shale. The Dekalb and Lehew soils are moderately deep to sandstone bedrock. All of these soils are well drained, and they are droughty. They have moderate limitations for farming and moderate to severe limitations for most other uses, but they do have a good potential for woodland, wildlife habitat, and recreational uses.

UNIT 3

Along the North Mountain fault northwest of State Road 623 fault-bounded slivers of carbonate rocks occur. Limestone is the dominant lithology with dolomite and black calcareous shale being minor components. The rocks are intensely sheared. The dominant soils of Unit 3 are Frederick, Hagerstown, and Greendale soils. Frederick and Hagerstown soils are on the uplands; the Greendale soils occur in swales and low areas along drainageways. Frederick and Hagerstown soils are deep and well drained. Areas of Greendale soils are subject to periodic overflow due to rapid runoff from surrounding areas. Slopes are sloping to steep. Small sinkholes and the sheared nature of the rock pose a potentially dangerous ground-water pollution hazard. Because of the pollution hazard, waste disposal facilities are subject to severe limitations. Unit 3 is good for farming except where limited by slope, rock outcrops, or sinkholes. Areas of Greendale soils are best suited to pasture.

UNIT 4

Three Top, Green, Little Crease, Massanutten and Little North Mountain are underlain by sandstone, quartzite, and conglomerate and red mudstone, shale, and sandstone. Depth to bedrock is shallow in areas underlain by sandstone, quartzite, and conglomerate and rock outcrops are abundant. Locally joints are closely spaced. The crest and upper slopes are composed of massive quartz rocks which produce abundant rubble. Intermediate mountain slopes are underlain by interbedded mudstones, shales, and sandstones. Slopes are steep except on the crest of ridges and knobs where the slopes are moderate to steep.

The dominant soils in this unit are in the Dekalb, Lehew, Hazelton, and Jefferson series. These soils are dominantly steep, moderately deep to mudstone and shale bedrock and well drained to excessively drained resulting in high runoff. Jefferson soils are formed in colluvial material derived from the other soils listed above. Jefferson soils are deep, generally steep, and well drained. Many areas of all of these soils are stony or very stony. All of the soils have a high content of stone or shale fragments throughout. Slope, stoniness, and limited depth to bedrock are limitations to most uses of these soils. The soils are well suited

to trees and much of the unit is wooded. Unit 4 has good potential for wildlife and recreational uses.

UNIT 5

Unit 5 is a narrow belt of limestone, shale, and sandstone in Fort and Little Fort valleys and on the northwest flank of Little North Mountain. Outcrops of the shale and limestone are rare except in streams or in artificial cuts. The sandstone is calcareous and thin. It forms a low ridge along the west side of Fort Valley and along the east side of Little Fort Valley as far north as Powell's Fort Camp (Plate 4). Soils in the Berks, Gilpin, Jefferson, and Buchanan series are dominant in this unit. Berks and Gilpin soils are moderately deep to bedrock of shale and interbedded limestone and sandstone. These soils are shaly and well drained. Jefferson and Buchanan soils occupy the foot of colluvial and fan positions. They are deep and are well drained and moderately well drained respectively. Buchanan soils have a dense subsoil layer that inhibits root development and air and water movement. Slope, stoniness, and droughtiness are major limitations to many uses of the soils in this unit. Interstream divides are gently sloping to sloping and are commonly covered with a thin layer of resistant sandstone blocks derived from the Massanutten Sandstone. Valley walls tend to be steep with a very narrow boulder-choked valley floor. Waste disposal facilities, building sites, and farming are subject to severe limitation in this unit. Woodland and recreational activities have a good potential in this area.

UNIT 6

Carbonate rocks underlay a broad belt averaging 2.6 miles (4.2 km) wide extending from the north edge of the Toms Brook quadrangle southwestward to the west edge (Plate 4). Also, small areas of similar carbonate rocks are found in the northwest and southeast corners of Plate 3. Limestone and dolomite are the dominant rock types; however thin sandstone beds in the Conococheague Formation are shown on Plate 4. Chert is locally abundant in the Rockdale Run Formation and forms conical-shaped hills such as Round Hill. In the Lincolnshire Formation the chert forms low, linear ridges. The occurrence of high-calcium limestone is shown on the maps (Plates 3, 4).

The dominant soils in Unit 6 are Frederick, Christian, Greendale, and Carbo. Frederick, Christian, and Carbo soils are on

the uplands; Greendale soils occur in swales and low areas along drainageways. Frederick and Christian soils are deep to rock whereas the Carbo soils are moderately deep. All of the soils are well drained. The Carbo soils have a sticky, plastic clay subsoil that has critical shrink-swell values and slow permeability. Locally the Frederick soils are cherty. The bedrock-soil-residuum interface is highly irregular—soil and residuum thickness determination for construction purposes must be closely spaced because the thickness may vary as much as 40 feet (12 m) over a short horizontal distance due to pinnacle weathering. Slopes range from gently sloping to sloping on the ridges; along valley walls the slope is moderate to steep. Slope stability depends on the presence or absence of subsurface solution cavities; the spacing and dip of joints, surface and bedrock slope; and their relative directions. Where openings are closely spaced and have dips in the same direction as the surface slope the potential hazard from mass movement is increased. Rockfalls are common along the Norfolk and Western Railway where it paralles the South Fork of the Shenandoah River. In this area weathering has loosened joint blocks. The presence of sinkholes poses a high potential ground-water pollution hazard. Because of this pollution potential, location of solid and liquid waste disposal facilities on unit 6 is subject to severe limitations. Frederick and Christian soils have good potentials for farming except where limited by sinkholes, steep slope, or rock outcrops. Christian soils are especially well suited to orchards. Carbo soils are especially well suited to pasture or hay production. Greendale soils in the swales and low areas are better suited to pasture than most other uses because of periodic overflow due to rapid runoff from surrounding areas. Construction near sinkholes and excavation at the toe of steep slopes should be avoided because of problems with foundation stability and slides. In areas where chert is abundant the cost of excavating increases. Care should be used to exclude high shrink-swell soil from the immediate area of any type of construction (such as do not use high shrink-swell soil in fill). High-calcium limestone is a nonrenewable resource and careful planning must preceed any decision to preclude mining or quarrying operations. The construction of any facility which discharges liquid waste on the sandstone areas should be avoided because of ground-water pollution hazard.

UNIT 7

Black argillaceous limestone and shale underlie much of the town of Strasburg (Plate 3). Similar lithologies underlie a belt about 0.3 mile (.05 km) wide extending from Strasburg Junction southwestward to Woodstock (Plate 4). A small area near the southeast corner of Plate 3 is underlain by black limestone and shale interbedded with thin metabentonites. These layers weather to a waxy clay which is very slippery when wet.

The dominant soils in this unit are in the Carbo, Chilhowie, and Edom series. The well-drained Carbo and Chilhowie soils have a very plastic, waxy, clay subsoil. Carbo soils are moderately deep to rock and the Chilhowie soils commonly have bedrock at a depth of 18 to 24 inches (46-61 cm). Edom soils are moderately deep to rock and well drained.

Ridge tops in this unit tend to be broad and gently sloping while the ridge sides are sloping to steep. Gently sloping surfaces are relatively stable, but runoff may be rapid if the shale-fragment content of the soil is high. Runoff is rapid and severe erosion can be expected on steep slopes. A combination of moderate to steep slopes, bedrock dipping parallel to the slope, and weathered metabentonite establish conditions for slides. If bedding and slope are steep in the same direction, slides are probable. Artificial cuts in this unit require moderate clean-up maintenance. The amount of maintenance may be less if the cuts are perpendicular to bedding strike. Sinkholes are locally common. Moderate depth to rock and moderately slow to slow permeability of the Edom soils are limitations to most nonfarm uses of these soils. Edom soils are well suited to farming except where limited by slope, rock outcrops, or sinkholes. Carbo soils have a fair potential for farming, but they have a good potential for grass and pasture crops. The Chilhowie soils commonly have rock outcrops and are poorly suited to farming. They do have good potential for pasture. The presence of shallow to moderately deep Carbo and Chilhowie soils which have critical shrink-swell values and the presence of small sinkholes make waste disposal facilities hazardous and increase construction costs for other uses.

UNIT 8

This is the most extensive unit and it is underlain by interbedded thin sandstones and shales. Depth to relatively hard bedrock ranges from moderately deep to shallow (less than 40 inches

or 102 cm). Unit 8 extends in a horseshoe-shaped area around the north end of the Massanutten mountain range (Plate 3) and in a northeastward-trending belt on the southeast slope of Little North Mountain (Plate 4). The scenic Seven Bends of the North Fork of the Shenandoah River are in this unit.

Berks, Weikert, and Blairton soils are dominant in Unit 8. Berks and Weikert soils are moderately deep and shallow, respectively to shale bedrock. They both contain a high percentage of shale fragments throughout and are well drained. Blairton soils are moderately deep to shale bedrock and are moderately well to somewhat poorly drained. Berks and Weikert soils tend to be droughty, and the Blairton soils are seasonally wet. Blairton soils commonly occupy swales and lower positions on the landscape than either Berks or Weikert soils. The shallow Weikert soils are dominant on the steeper slopes. All of these soils, because of limited depth to bedrock and/or restricted drainage, have limitations for many uses. They have good potential for pasture and small grain crops except where limited by slope or severe erosion. Depth to bedrock and/or restricted drainage is a severe limitation for use of these soils for septic system absorption fields. Interstream areas are broad with low to moderate slopes; valley walls have steep slopes. Slope stability depends on bedding and/or cleavage orientation as related to slope angle and direction. Where the dip of the bedding and/or cleavage nearly parallels the slope, slides and sluffing are common. Erosion is a serious hazard on any slopes greater than 8 percent. Artificial cuts exceeding 10 feet (3 m) deep tend to sluff. The shales and soil of unit 8 could serve as fill to replace high shrink-swell soils from other units.

UNIT 9

Terrace deposits related to former channels of the Shenandoah River are scattered along both forks. Terrace deposits are also present along Passage Creek. These deposits, above the reach of modern floods, consist of 0 to 25 feet (0-8 m) of old alluvial/colluvial material with the dominant soils having a clayey or loamy subsoil. The dominant soils in this unit are in the Unison, Braddock, and Monongahela series. Unison and Braddock soils are well drained and have a clayey subsoil. Pebbles and cobbles of sandstone and quartzite are common throughout these soils. Monongahela soils are moderately well drained,

and they have a dense, compact loamy layer in the subsoil. This layer inhibits downward movement of water and penetration of plant roots. Seasonal "perched" water is present on this layer. Braddock and Unison soils typically have steeper slopes than Monongahela soils.

On low to moderate slopes of the interstream divides the material is stable but along stream-valley walls the matrix is removed rapidly leaving a deposit of gravel. These gravels may move downslope rapidly if the toe of the slope is disturbed and/or rainfall is moderate. Sluffing and slides are common in artificial cuts. Braddock and Unison soils have good potential for building sites. The Monongahela soils have limitations for this use due to seasonal wetness. Waste disposal in deep layers of any of these soils may pose a hazard of ground-water pollution.

UNIT 10

Extensive coalescing alluvial-fan deposits occur around the Massanutten mountain range, northwest of Little North Mountain, in Fort and Little Fort valleys, and along Mill Run. The deposits are composed of angular to subrounded pebbles, cobbles, and boulders of sandstone, quartzite, and conglomerate in a sand matrix. The upper portion of the matrix contains a high percentage of organic material. The deposits are well drained with an underlying clay layer which inhibits downward movement of water and promotes lateral water movement. Numerous springs and seeps along the edges of the fans are evidence of the lateral water movement. Slopes range from gently sloping to steep.

Zoar, Guernsey, and Ernest soils are dominant in this unit. All of the soils have formed from colluvial materials on terrace and fan positions. Zoar and Guernsey soils have a clayey subsoil. Ernest soils have a fragipan or dense compact subsoil layer. All of the soils exhibit seepage during wet periods. These soils are suited to farming except where limited by stones and/or slopes. Guernsey and Zoar soils are especially subject to slippage. The permeability of the dominant soils is a severe limitation to many nonfarm uses. The soils have good potential for pasture, woodland, wildlife and recreational uses. Stoniness is a severe limitation to farm and nonfarm uses. If the toe of a moderate to steep slope is cut, earth movements may occur. Under normal rainfall conditions the material may slowly creep downslope.

However, during periods of high rainfall the matrix material may be lubricated to such an extent that landslides will occur. The cost of excavating, low permeability, and lack of compacting material severely limit the use of the area.

UNIT 11

Low-level flood-plain deposits are extensive along both forks of the Shenandoah River, Passage Creek, Cedar Creek, Little Passage Creek, and Mine Run. Flood-plain deposits are also mapped along many of the smaller streams and in three cutoff meanders of the North Fork and one cutoff meander of Cedar Creek. The major soils in this unit are the well-drained Genesee, Chagrin, and Chavies series. Included in unit 11 are areas of unnamed, clayey soils that are poorly drained. The thickness ranges from 3 to 25 feet (1-8 m). Only about 5 percent of the deposit is gravel except along Little Passage Creek, Mine Run, and some of the smaller streams. Natural slopes are very low to low and are stable. Deep artificial cuts and excavations are subject to slides and sluffing when wet. The Genesee and Chagrin soils are prime agricultural areas and a good potential source of topsoil. The included poorly drained soils are better suited to pasture crops or trees. Because of periodic flooding the area has severe limitations for building sites or for waste disposal.

UNIT 12

Along the slopes of Little North Mountain and the Massanutten mountain range talus deposits consisting of angular blocks of rock 3 inches to 20 feet (8 cm to 6 m) in longest dimensions accumulate at the base of cliffs and on the steep slopes downslope from sandstone outcrops. The lack of fine material filling the large voids results in an extremely high rate of water movement.

The soils in this unit are dominantly in the Laidig, Buchanan, and Ernest series. All of the soils have a fragipan or dense compact subsoil layer. Soil water tends to move vertically to the fragipan and then laterally parallel to the slope of the surface. Toe slope springs are common during wet periods. In the winter and early spring water may be heard flowing at the base and seen at the toe as large springs. Most of these springs are dry in the summer and fall. Blocks move downslope under the influence of gravity as a continuous process forming the frame-

work material for the alluvial fans (Unit 10) on the lower slopes. Any activity which would disturb the toe of a talus deposit could lead to large-scale rock slides. Especially hazardous conditions exist in narrow valleys with talus deposits on both valley walls. This unit has potential for woodland, wildlife, and recreational uses; however, most other uses are subject to severe limitations.

ROCKFALLS AND LANDSLIDES

Scattered areas of actual or potential rockfalls and landslides are located on both forks of the Shenandoah River, Passage Creek, and along the Massanutten mountain range and they are also associated with unit 12. Where the bedrock is sandstone or carbonate, rockfalls are the most common manifestation of mass movement of weathered debris. In the Seven Bends area along the west slope of Three Top Mountain the highly jointed, cleaved, and folded Martinsburg Formation has been undercut by the river and steep slopes are subject to landslides when rainfall is moderate to heavy. Construction in areas of known or potential rockfalls and landslides is especially hazardous.

FILL

The major hazards related to fill in the mapped area involves potential to impound runoff. Where State Highway 55 and the Southern Railway cross the North Fork of the Shenandoah River (Plate 3) there are large fill embankments which could act as temporary dams during times of high water. Fills with culverts present no danger along many roads in the area. However, during times of abnormal rainfall or normal rainfall in combination with a vegetative mat damming the culvert a real danger of high water exists. An example of danger from the abnormal rainfall condition occured July 26, 1973 in the area where Toms Brook flows under Interstate Highway 81. In this area the rainfall was such that the fill temporarily impounded water to the point that it flowed across the highway rather than under it. In addition to property damage there was a loss of life.

KARST AREAS

Sinkholes are common in units 3, 6, and 7. In general the larger sinkholes are more numerous in unit 7. Those sinkholes with a diameter exceeding 20 feet (6 m) are plotted on Plates

3 and 4; these are restricted to units 6 and 7. They were located in the field and from interpretation of aerial photographs. Sinkholes less than 20 feet (6 m) in diameter, common in units 3 and 6, are not plotted on Plates 3 and 4. A primary conduit for recharge of ground water in areas underlain by carbonate rocks is provided by sinkholes and any activity which interferes with this recharge could affect the water table. The potential pollution hazard in areas of karst topography is great due to the network of solution channels associated with the sinkholes. Areas of numerous sinkholes indicate subsurface solution activity and potential collapse of the surface. For this reason the use of the area for buildings requiring high load-bearing strength of bedrock is severely limited.

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APPENDIX I

STRATIGRAPHIC SECTION

Section 1

Along unnamed tributary of Passage Creek, northwest of State Road 678, approximately 0.4 mile (0.6 km) northeast of BM 810 (38° 55′ N., 78° 21′ E.). Section begins 300 feet (91 m) upstream from State Road 678.

	Thickness	
	Feet	*(Meters)*
Needmore Formation (not measured)		
Siltstone, dark olive green with scattered very fine sand grains, fossil fragments	5.0	(1.5)
Covered	5.9	(1.8)
Ridgeley Sandstone (24.4 ft. or 7.5 m)		
Limestone, light-medium gray, coarse-grained, scattered coarse, well-rounded sand grains and fragments of black chert, yellow-brown limonitic interstitial clay, brachiopod fossils	16.6	(5.1)
Covered, sandstone float, prospect pit	3.9	(1.2)
Sandstone, olive-brown, fine-grained, well-sorted and subrounded to rounded, coarse-grained, subangular, weathers dark brown and friable, yellow-brown limonitic interstial clay and minor manganese and hematite stain	3.9	(1.2)
New Scotland limestone (12.9 ft. or 3.9 m)		
Limestone, medium-gray, medium- to fine-grained, very sandy, some manganese stain, thin-bedded (less than 2 inches)	12.9	(3.9)
New Creek Limestone (25.5 ft. or 7.8 m)		
Limestone, light gray, very coarse-grained, with scattered rounded quartz sand grains and minor limonite and clay, calcite-replaced crinoid stems, pink and green tinted calcite crystals. Massive outcrop, bedding 1 inch to 1 foot. numerous solution features	22.0	(6.7)
Covered	3.5	(1.1)
Keyser Formation (45.1 feet or 13.3 m)		
Limestone, medium-dark gray, fine-grained, silty, laminated, with calcite fracture-fillings; base is sandstone, medium-gray, very fine grained, thin-bedded, and silty; forms rapids in stream	12.5	(3.7)

	Thickness Feet	(Meters)
Sandstone, olive-brown to medium-gray, very fine-grained, poorly sorted, subangular, thin-bedded, calcareous, friable; interbedded siltstone, olive-green, fissile with mudcracks. Most of unit covered	6.5	(2.0)
Covered	10.5	(3.2)
Limestone, medium-dark gray, medium-grained, silt partings and calcite fracture fillings, with well-rounded, fine sand grains	0.7	(0.2)
Upper part: limestone, medium-gray, medium-grained, very sandy; middle part: sandstone, medium-gray, medium-grained, subangular, calcareous matrix, weathers friable; lower part: siltstone, olive-brown, calcareous, very thin-bedded, with fossil fragments	9.0	(2.7)
Covered	5.9	(1.8)
Tonoloway Formation (8.8+ ft. or 2.7+ m)		
Limestone, olive-brown to medium-gray, very fine grained, very silty, weathers yellowish-brown, thin-bedded (less 1 inch) with silt partings. Mostly covered	8.8	(3.7)
Covered (Tonoloway-Wills Creek within interval)	119.7	(36.5)
Wills Creek Formation (63.5+ ft. or 19.3+ m)		
Siltstone, medium- to light-gray, thin-bedded, slightly calcareous, poorly exposed	5.0	(1.5)
Sandstone, dark-brown, medium-grained, subrounded; brachiopod fossils, friable, with shale partings. Basal 6 inches (15 cm) sandstone, medium buff-gray, very fine grained, very calcareous; thin bedded with silty partings	4.5	(1.4)
Covered	12.2	(3.7)
Limestone, medium- to dark-gray, very fine-grained; silty laminations, white-weathered coating. Prominent northwestward-dipping cleavage	9.2	(2.8)
Limestone, medium-gray, fine-grained, argillaceous, some beds of fossil hash, thin-bedded, northwestward-dipping cleavage very prominent. Basal 15 feet (5 m) is limestone, pink, fine-grained, with scattered subrounded sand grains, very prominent northwesterly cleavage	32.6	(9.9)
Bloomsburg Formation (Not measured)		
Sandstone, light- to medium-brown, fine-grained, subangular grains, friable, interbedded with siltstone, olive-brown, weathered yellow, fossil fragments. Red shale chips also present.		

APPENDIX II

ROAD LOG

The following road log is a guide to important geologic features that can be seen along or near highways in the Strasburg and Toms Brook 7.5-minute quadrangles. Distances between points of interest, as well as cumulative mileage, are shown and the stops are places where features such as formational contacts, structures, fossils, and interesting rock types or minerals may be observed. *Permission should always be obtained before entering private property, as failure to do so violates trespass laws and is punishable under law.*

Cumulative miles (km)	*Distance miles (km)*	*Explanation*
0.0	0.0	Road log begins at Buckton on State Highway 55 (Strasburg 7.5-minute quadrangle). Continue west on State Highway 55.
0.9 (1.4)	0.9 (1.4)	Note good exposures of Martinsburg shale and sandstone.
1.5 (2.4)	0.6 (1.0)	*STOP 1.* Park on right side of State Highway 55 before crossing Passage Creek. At the junction of State Highway 55 and State Road 614 are excellent exposures of Martinsburg shale and sandstone. Note close folding. Continue ahead (west) on State Highway 55.
2.8 (4.5)	1.3 (2.1)	Junction of State Sighway 55 and State Road 678 at Waterlick. Turn left (south) on State Road 678. Note Massanutten Mountain and Passage Creek gap ahead (to the south).
4.0 (6.4)	1.2 (1.9)	Junction of State Roads 619 and 678. Continue straight on State Road 678.
4.4 (7.1)	0.4 (2.0)	Shenandoah-Warren county boundary.
4.5 (7.2)	0.1 (0.2)	*STOP 2.* Park on right side of road. Along road to right (north) of cliff the upper marine sandy beds of the Martinsburg are exposed. Graptolites, bryozoans, brachiopods, pelecypods, gastropods, cephalopods, and trilobites are reported by Secrist and Evitt (1943, p. 367) along with a measured section (p. 362). The upper 50 to 60 feet (15-18 m) of the Martinsburg is barren of marine fossils. The overlying Massanutten is a gray to white quartz

Cumulative miles (km)	*Distance miles (km)*	*Explanation*
		sandstone and quartzite with conglomeratic lenses. Cross-bedding is prominent and plant fossils have been found in the thin, black shale laminae (John Dennison, personal communication). About 0.10 mile (0.16 km) south of the parking area a small fault is exposed. Continue straight on State Road 678.
4.7 (7.6)	0.2 (0.3)	Note large talus slope to right (west).
4.8 (7.7)	0.1 (0.2)	Note Buzzard Rock, a sharp crest ridge of Massanutten Sandstone, to the left (east).
5.4 (8.7)	0.6 (1.0)	*STOP 3.* Park on right side of road. Here the upper beds of the Massanutten Sandstone are exposed. Exposures consist of thin- to thick-bedded dirty sandstone and thin shale with plant fossils. These beds are probably equivalent to the Rose Hill Formation of Little North Mountain and belts to the west. Continue straight on State Road 678.
5.8 (9.3)	0.4 (0.6)	*STOP 4.* Park in abandoned road on left. Along path to Passage Creek red sandstone and mudrock of the Bloomsburg is exposed. Upstream from the last red exposure, across small hollow, the Wills Creek Formation is exposed. Retrace path to abandoned road and walk to end of road (north). On the slope beyond the end of the road the lower sandstone of the Bloomsburg forms a ledge below which black, carbonaceous shale containing plant fossils is exposed. Return to State Road 678 and walk north to small drainage ditch on left side of road. In the ditch yellow shale, probably the McKenzie Formation, is exposed. Continue straight (south) on State Road 678.
5.9 (9.5)	0.1 (0.2)	*STOP 5.* Upper Silurian and possibly Lower Devonian limestones are exposed along the road and creek. Large *Rafinesquina*-type brachiopods may be collected from the exposures along the creek. Continue straight on State Road 678.
6.8 (10.9)	0.9 (1.4)	Elizabeth Furnace Recreational Area. An interesting self-guided tour of the old iron furnace is available beyond parking area.
8.1 (13.1)	1.3 (2.1)	Note good exposures of Needmore Formation on right (west).
8.5 (13.7)	0.4 (0.6)	Note good exposures of Mahantango Formation on right (west).

Cumulative miles (km)	*Distance miles (km)*	*Explanation*
9.0 (14.5)	0.5 (0.8)	*STOP 6.* Park on right. Black Marcellus shale and Tioga bentonite is exposed on farm road to right. Continue straight on State Road 678.
11.5 (18.5)	2.5 (4.0)	*STOP 7.* Junction of State Roads 678 and 771. Turn right (west) and park. At junction fossiliferous beds of the Mahantango Formation are exposed. Continue straight (west) on State Road 771.
12.5 (20.1)	1.0 (1.6)	*STOP 8.* Junction of State Road 771 and Forest Service Road 273. Ridgeley Sandstone is exposed at intersection and low ridge to right (north) of road. East along State Road 771 the Needmore is exposed. Continue straight (west) on Forest Service Road 273.
13.2 (21.2)	0.7 (1.1)	Note abandoned Boyce (Mine Run) iron furnace on right.
13.5 (21.7)	0.3 (0.5)	Junction of Forest Service Road 273 and road to Powells Fort Camp. Bear left on Forest Service Road 273.
13.6 (21.9)	0.1 (0.2)	Note good exposure of Bloomsburg Formation to right (west).
14.1 (22.7)	0.5 (0.8)	Location of abandoned iron ore crusher.
15.9 (25.6)	1.8 (2.9)	Junction of Forest Service Road 273 and State Road 758. Turn right (west) on State Road 758.
16.5 (26.5)	0.6 (1.0)	*STOP 9.* Top of Three Top Mountain (Powell Mountain); on adjoining Rileyville 7.5-minute quadrangle. Take trail southwest along crest of mountain to Woodstock Lookout Tower. Excellent view of the Seven Bends of the Shenandoah and the Shenandoah Valley looking west. Continue ahead (west) on State Road 758.
18.9 (30.4)	2.4 (3.9)	Shenandoah River bridge. Note good Martinsburg exposures to the left (east).
19.6 (31.5)	0.7 (1.1)	Junction of State Roads 758 and 665. Turn right (west) on State Road 665.
20.8 (33.5)	1.2 (1.9)	*STOP 10.* To left (south) of the road the St. Luke member of the Edinburg Formation is exposed. Note small sinkholes characteristic of the St. Luke. Continue on State Road 665.
21.0 (33.8)	0.2 (0.3)	Junction of State Road 665 and U. S. Highway 11. Turn right (north) on U. S. Highway 11.

Cumulative miles (km)	*Distance miles (km)*	*Explanation*
22.2 (33.7)	1.2 (1.9)	Junction of U. S. Highway 11 and State Road 663. Turn right (east) on State Road 663.
22.5 (36.2)	0.3 (0.5)	*STOP 11.* Begin examination of section in curve across from house. Dolomite of the upper Rockdale Run Formation is well exposed. Micrites of the New Market are poorly exposed in outcrop west of bridge. East of the bridge Lincolnshire and Edinburg formations are well exposed. Turn around and return to U. S. Highway 11.
22.8 (36.7)	0.3 (0.5)	Junction of U. S. Highway 11 and State Road 662. Turn left (west) on State Road 662.
23.5 (37.8)	0.7 (1.1)	*STOP 12.* Park on right in curve at gate to pasture. Stonehenge Formation is well exposed along road and in field to right (north) of road. Continue straight on State Road 662.
23.6 (38.0)	0.1 (0.2)	Junction of State Roads 662 and 642. Turn right (north) on State Road 642.
24.9 (40.1)	1.3 (2.1)	Junction of State Roads 642 and 600. Continue straight on State Road 642.
26.0 (41.9)	1.1 (1.8)	Junction of State Roads 642 and 652. Turn left (west) on State Road 652. Note Conococheague limestone exposures in field to right (north) of road.
26.4 (42.5)	0.4 (0.6)	*STOP 13.* Sandstone and dolomite of the Big Spring Station Member of the Conococheague Formation is well exposed along road. Continue on State Road 652.
26.7 (43.0)	0.3 (0.5)	Junction of State Roads 652 and 658. Turn right (west) on State Road 658.
27.2 (43.8)	0.5 (0.8)	Junction of State Roads 658 and 623. Turn right on State Road 623.
27.3 (43.9)	0.1 (0.2)	Junction of State Roads 623 and 658. Turn left (west) on State Road 658.
27.4 (44.1)	0.1 (0.2)	*STOP 14.* Exposure of the red siltstone and yellow shale in the lower Elbrook Formation. Turn around and return to State Road 623.
27.5 (44.2)	0.1 (0.2)	Junction of State Roads 658 and 623. Turn left (north) on State Road 623.
28.4 (45.6)	0.9 (1.4)	Junction of State Roads 623 and 655. Turn right (east) on State Road 655. Note good exposure of shaly Elbrook dolomite.

Cumulative miles (km)	*Distance miles (km)*	*Explanation*
28.9 (46.5)	0.5 (0.8)	Note good exposure of sandstone of the Big Spring Station Member of Conococheague Formation.
30.7 (49.4)	1.8 (2.9)	Junction of State Roads 665 and 653. Turn right (south) on State Road 653.
31.1 (50.0)	0.4 (0.6)	Junction of State Road 653 and U. S. Highway 11. Turn left (north) on U. S. Highway 11.
31.4 (50.5)	0.3 (0.5)	Cross Toms Brook (stream) and turn right at first street (no number or name). Drive slowly. Note house foundation. The two-story house which stood at this location was moved downstream to the large tree on the left of the road by the flash flood of July 26, 1973.
31.5 (50.7)	0.1 (0.2)	Junction with State Road 653. Turn right (east) on State Road 653.
32.2 (51.8)	0.7 (1.1)	*STOP 15.* Along road for several hundred feet the typical flysch deposits of the Martinsburg Formation are well exposed.
32.5 (52.3)	0.3 (0.5)	Junction of State Roads 653 and 650. Turn left (north) onto State Road 650.
32.8 (52.8)	0.3 (0.5)	*STOP 16.* Park and walk to right (east) to ridge top, about 50 feet (15 m). Good view of an abandoned meander of the North Fork of the Shenandoah River. Continue on State Road 650.
33.0 (53.1)	0.2 (0.3)	Junction of State Roads 650 and 651. Turn left (west) on State Road 651.
33.9 (54.6)	0.9 (1.4)	Junction of State Road 651 and U. S. Highway 11. Turn right (north) on U. S. Highway 11.
34.4 (55.4)	0.5 (0.8)	Note Round Hill to left (west). This hill is underlain by chert of the Rockdale Run Formation.
37.1 (59.7)	2.7 (4.3)	*STOP 17.* Junction of U. S. Highway 11 and State Road 601. Turn left (west) on State Road 601 and park. Walk south on U. S. Highway 11 across bridge. Here the lower portion of the Martinsburg is exposed. The rocks are black, argillaceous limestone and black, calcareous shale. Continue ahead (west) on State Road 601.
37.4 (60.2)	0.3 (0.5)	*STOP 18.* Park on right side of road beyond (west of) bridge. The Rockdale Run Formation and lower New Market Limestone are exposed on the east side of the creek. Along the road the

Cumulative miles (km)	*Distance miles (km)*	*Explanation*
		upper New Market, Lincolnshire, and most of the Edinburg formations are exposed. Consult Cooper and Cooper (1946, p. 76, 87-88, 95-96) for a measured section and complete description.
37.8 (60.8)	0.4 (0.6)	*STOP 19.* Park at junction of State Roads 601 and 757. Walk back (east) on State Road 601. Interesting black, bedded chert and recrystalline dolomites are associated with the typical light-gray, fine-grained dolomites of the Rockdale Run Formation. Return to junction and walk along State Road 601 to bridge and proceed upstream along stream bank. About 300 feet (91 m) above the bridge a breccia, possibly a collapse type, is well exposed. Return to junction and proceed to U. S. Highway 11 via State Road 601.
38.5 (62.0)	0.7 (1.2)	Junction of State Road 601 and U. S. Highway 11. Turn left on U. S. Highway 11.
40.5 (65.2)	2.0 (3.2)	Junction of U. S. Highway 11 and State Highway 55. Turn left (north) on U. S. Highway 11.
40.7 (65.5)	0.2 (0.3)	Junction of U. S. Highway 11 and State Highway 55. Turn left (west) on State Highway 55.
41.1 (66.1)	0.4 (0.6)	*STOP 20.* Park on right side of road. Type locality of the Oranda Formation. The Martinsburg and Edinburg formations are also exposed along road. Consult Cooper and Cooper (1946, p. 87-88) for a measured section and complete description of the exposure.
		END OF LOG

APPENDIX III

SOILS

The following definition of soil, discussion of how soils are mapped, and description of the soil series was supplied by R. L. Googins, State Soil Scientist, U. S. Department of Agriculture, Soil Conservation Service, Richmond, Virginia.

Definition of soil: Soil is that part of the earth's crust whose upper limit is air or shallow water. At its margins, it grades to deep water or to barren areas of rock. Its lower limit characteristically is hard rock or earthy materials devoid of roots, organisms, or other evidences of biologic activity. For practical purposes in the soil survey, 2 meters is recognized as the lower limit of deep soils.

How Soils Are Mapped: Individual soils are recognized in the field by observation of their morphological characteristics such as depth, texture, consistence, slope, and color. Proper classification of each soil depends upon an accurate description of these and other features including laboratory data such as clay mineralogy and base saturation. In mapping soils, trained soil scientists traverse a soil survey area and examine the soil at various locations on the landscape. Using an aerial-photo base map, they delineate, or outline on the map, areas having recognizably different kinds of soils. Depending upon the uses to be made of the soil survey, different phases of an individual soil may be recognized and shown on the map. Such phases may include slope groups, stony phases, differences in surface texture, or other external or internal characteristics that tend to influence use or management. Upon completion of a designated soil survey area, usually a county, a report is written that describes all of the different kinds of soils that were observed and mapped. Included in the published soil survey are maps that show the location of each kind of soil mapped. Also included are various interpretations for a variety of possible uses of the soils. The interpretations are based on field observations of the soils during actual use and laboratory data.

Soil Series Descriptions

Berks series consists of moderately deep, well-drained soils formed in material weathered from shale, siltstone, and sandstone. Typically these soils have a dark-brown shaly loam surface layer 10 inches (25 cm) thick. The subsoil is friable and about 16 (41 cm) inches thick. In sequence from the top, the upper 7 inches (18 cm) is yellowish-brown shaly loam; the next 4 inches (10 cm) is yellowish-brown, very shaly silt loam and the lower 5 inches (13 cm) is strong-brown, very shaly loam. The friable substratum is yellowish-brown,very shaly loam overlying bedrock at a depth of 33 inches (84 cm), slopes 0 to 70 percent.

Blairton series consists of moderately deep, somewhat poorly and moderately well drained soils on upland flats and streamheads. They formed in material weathered from shale bedrock. Typically these soils have a

dark grayish brown silt loam surface layer 9 inches (23 cm) thick. The subsoil from 9 to 26 inches (23-66 cm) is mottled, yellowish-brown, shaly, silty clay loam and from 26 to 34 inches (66-87 cm) is a mottled, light brownish gray shaly silt loam. The substratum from 34 to 38 inches (87-97 cm) is olive-weathered shale. Bedrock is at 38 inches (97 cm). Slopes range from 0 to 15 percent.

Braddock series consists of deep, well-drained soils on foot slopes, fans, and terraces. They formed in colluvial material or old alluvium. Typically, these soils have a yellowish-brown loam surface layer 9 inches (23 cm) thick. The subsoil from 9 to 13 inches (23-33 cm) is yellowish-red clay, from 13 to 38 inches (33-97 cm) is red clay, and from 38 to 48 inches (97-126 cm) is red clay loam. The substratum from 48 to 85 inches (126-216 cm) is mottled saprolite that crushes to loam. Slopes range from 0 to 30 percent.

Buchanan series consists of deep, moderately well to somewhat poorly drained soils on uplands. They formed in colluvium derived from sandstone, siltstone, and shale. Typically these soils have a dark yellowish brown, gravelly, loam surface layer 6 inches (15 cm) thick. The subsoil from 6 to 27 inches (15-69 cm) is mainly yellowish-brown, gravelly loam. A firm and brittle fragipan from 27 to 47 inches (69-123 cm) is yellowish-brown, gravelly loam. The substratum from 47 to 60 inches (123-152 cm) is yellowish-brown, gravelly loam. Slopes range from 0 to 25 percent.

Carbo series consists of moderately deep, well-drained soils on uplands. They formed in material weathered from limestone with some shale. Typically these soils have a brown, silty clay loam surface layer 6 inches (15 cm) thick. The subsoil from 6 to 9 inches (15-23 cm) is strong brown, silty clay loam, from 9 to 21 inches (23-53 cm) is yellowish-brown clay, and from 21 to 26 inches (53-66 cm) is strong brown, silty clay. The substratum from 26 inches (66 cm) to bedrock at 36 inches (91 cm) is silty clay loam material and weathered rock. Slopes range from 2 to 30 percent.

Chagrin series consists of deep, well-drained soils on flood plains. They formed in recent alluvial material. Typically these soils have a dark grayish brown, silt loam surface layer 10 inches (25 cm) thick. The subsoil from 10 to 44 inches (25-112 cm) is yellowish-brown silt loam. From 44 to 60 inches (112-152 cm) the substratum is brown silt loam. Slopes range from 0 to 3 percent.

Chilhowie series consists of moderately deep, well-drained soils on uplands. They formed in material weathered from bedrock. Typically these soils have a dark-brown, silty clay loam surface layer 5 inches (13 cm) thick. The subsoil from 5 to 13 inches (13-33 cm) is strong brown clay. The substratum from 13 to 25 inches (33-65 cm) is strong-brown, very channery clay; calcareous interbedded shale and limestone is at a depth of 25 inches (65 cm). Slopes range from 0 to 45 percent.

Christian series consists of deep, well-drained soils on uplands. They formed in material weathered from bedrock. Typically these soils have a yellowish-brown, silt loam surface layer 6 inches (11 cm) thick. The

subsoil from 6 to 15 inches (15-38 cm) is brown silt loam. From 15 to 38 inches (38-97 cm) is yellowish-red clay, and from 38 to 54 inches (97-137 cm) is red clay with common mottles. The substratum from 54 to 65 inches (137-165 cm) is mottled red, yellowish-brown, and light brownish gray clay loam. Slopes range from 2 to 30 percent.

Dandridge series consists of excessively drained soils on uplands underlain by calcareous shale. In a typical profile the surface layer is dark grayish brown, shaly, silty clay loam 6 inches (15 cm) thick. The subsoil is yellowish-brown, shaly silty clay to the contact with shale bedrock at a depth of 16 inches (41 cm). Slopes range from 10 to 50 percent.

Dekalb series consists of moderately deep, well-drained soils on uplands. They formed in material weathered mainly from sandstone. Typically these soils in a wooded area have a very dark gray, channery, sandy loam surface layer 2 inches (5 cm) thick over 6 inches (15 cm) of light yellowish brown, channery sandy loam. The subsoil from 8 to 29 inches (20-74 cm) is yellowish-brown, channery sandy loam. The substratum from 29 to 34 inches (74-87 cm) is strong-brown, very flaggy loam. Sandstone is at a depth of 34 inches (87 cm). Slopes range from 0 to 80 percent.

Edom series consists of deep, well-drained soils on uplands. They formed in material weathered from limestone and shale. Typically these soils have a dark-brown, silty, clay loam surface layer 8 inches (20 cm) thick. The subsoil from 8 to 36 inches (20-91 cm) is reddish-brown and yellowish-brown, silty clay and clay. The substratum from 36 to 46 inches (91-121 cm) is reddish-brown, very shaly silty clay. Bedrock is at 46 inches (121 cm). Slopes range from 2 to 45 percent.

Ernest series consists of deep, moderately well drained soils on uplands. They formed in colluvial material. Typically these soils have a dark grayish brown, silt loam surface layer 8 inches (20 cm) thick. The subsoil from 8 to 28 inches (20-71 cm) is yellowish-brown, silty clay loam mottled at 18 to 28 inches (46-71 cm). From 28 to 40 inches (71-102 cm) the subsoil is a firm and brittle fragipan that is mottled, yellowish-brown, silty clay loam. The substratum from 40 to 60 inches (102-152 cm) is brown, silty clay loam. Slopes range from 0 to 35 percent.

Frederick series consists of deep, well-drained soils on uplands. They formed in residuum derived mainly from dolomitic limestone. Typically these soils have a brown, silt loam surface layer 7 inches (18 cm) thick. The subsoil from 7 to 14 inches (18-36 cm) is strong-brown, silty clay loam and from 14 to 70 inches (36-178 cm) is mottled, yellowish-red clay. The substratum from 70 to 95 inches (178-241 cm) is mottled, yellowish-red silty clay. Slopes range from 2 to 60 percent.

Genesee series consists of deep, well-drained soils on flood plains. They formed in alluvium. Typically these soils have a brown, silt loam surface layer 8 inches (20 cm) thick. The subsoil from 8 to 24 inches (20-61 cm) is dark yellowish brown loam and silt loam and from 24 to 32 inches (61-81 cm) is yellowish-brown loam. The substratum from 32 to 60 inches (81-152 cm) is stratified loam, sandy loam, and silt loam. Slopes range from 0 to 2 percent.

Gilpin series consists of moderately deep, well-drained soils on uplands. They formed in material weathered from siltstone, shale, and sandstone. Typically these soils have a dark grayish brown, shaly, silt loam surface layer 8 inches (20 cm) thick. The subsoil from 8 to 24 inches (20-61 cm) is yellowish-brown, shaly silt loam. The substratum from 24 to 30 inches (61-76 cm) is brown, very shaly loam. Bedrock is at a depth of 30 inches (76 cm). Slopes range from 0 to 70 percent.

Greendale series consists of deep, well-drained soils. These soils formed in alluvium on bottom lands, in depressions, and along narrow drainways. In a representative profile, the soil is silt loam to a depth of 56 inches (142 cm). The upper part is brown, the middle part is dark yellowish brown and dark brown, and the lower part is yellowish brown with mottles. Slopes range from 0 to 6 percent.

Guernsey series consists of deep, moderately well and well-drained soils on uplands. They formed in material weathered from siltstone or shale bedrock. Typically these soils have a brown, silt loam surface layer 8 inches (20 cm) thick. The subsoil from 8 to 22 inches (20-56 cm) is yellowish-brown or brown silt loam and from 22 to 54 inches (56-137 cm) is mottled dark yellowish brown and grayish-brown silty clay. The substratum from 54 to 60 inches (137-152 cm) is mottled gray clay.

Hagerstown series consists of deep, well-drained, reddish soils on uplands. They formed in materials weathered from hard, fairly pure limestone. Typically these soils have an 8 inch (20 cm) plow layer of brown or dark-brown silt loam. The material below this depth and extending rather uniformly to bedrock is generally yellowish-red clay or silty clay, with limestone fragments common in the lower subsoil and in the substratum. Sinkholes occur in some places and limestone rock outcrops are common. Slopes range from 0 to 45 percent, but most are less than 15 percent.

Hazleton series consists of deep, well-drained soils on uplands. They formed in material weathered from sandstone. Typically these soils have a dark-brown, sandy, loam surface layer 6 inches (15 cm) thick. The subsoil between 6 and 32 inches (15-81 cm) is reddish-yellow to strong-brown, channery and very channery sandy loam. The substratum from 32 to 56 inches (81-142 cm) is reddish yellow very channery sandy loam. Sandstone bedrock is at a depth of 56 inches (142 cm). Slopes range from 0 to 80 percent.

Jefferson series consists of deep, well-drained soils on uplands. They formed in colluvial material. Typically these soils in a wooded area have a dark grayish brown gravelly loam surface layer 3 inches (8 cm) thick over 5 inches (13 cm) of dark yellowish brown, gravelly loam. The yellowish-brown subsoil from 8 to 15 inches (20-38 cm) is gravelly loam, from 15 to 38 inches (38-97 cm) is gravelly clay loam, and from 38 to 52 inches (97-132 cm) is gravelly loam. The substratum from 52 to 62 inches (132-157 cm) is mottled yellowish brown gravelly loam. Slopes range from 2 to 65 percent.

Laidig series consists of deep, well-drained soils on uplands. They formed in colluvium derived mainly from sandstone and shale. Typically these

soils in a wooded area have a very dark grayish brown, channery, loam surface layer 2 inches (5 cm) thick over a yellowish-brown, channery, loam subsurface layer 6 inches (15 cm) thick. The subsoil from 8 to 14 inches (20-36 cm) is yellowish-brown, channery loam and from 14 to 37 inches (36-94 cm) is strong-brown, channery, sandy clay loam. From 37 to 80 inches (94-203 cm) is a strong-brown, channery, sandy clay loam fragipan that is very firm and brittle. Slopes range from 0 to 45 percent.

Lehew series consists of moderately deep, well-drained to excessively drained soils on uplands. They formed in material weathered from sandstone, siltstone, and shale. Typically these soils have a reddish-brown, channery, fine, sandy, loam surface layer 6 inches (15 cm) thick. The subsoil from 6 to 20 inches (15-51 cm) is reddish-brown, channery, fine, sandy loam. From 20 to 22 inches (51-56 cm) the substratum is reddish-brown, very channery, fine, sandy loam. Bedrock is at 22 inches (56 cm). Slopes range from 0 to 70 percent.

Monongahela series consists of deep, moderately well drained soils on terraces. They formed in old alluvial material. Typically these soils have a dark grayish brown, silt loam surface layer 7 inches (18 cm) thick over 5 inches (13 cm) of yellowish-brown silt loam. The subsoil from 12 to 22 inches (30-56 cm) is yellowish-brown silt loam. From 22 to 52 inches (56-132 cm) is a firm to very firm fragipan that is yellowish-brown loam. The substratum from 52 to 60 inches (132-152 cm) is strong-brown and light-gray clay loam.

Unison series consists of deep, well-drained soils on foot slopes, colluvial forms, benches and terraces. They formed in colluvial and alluvial material. Typically these soils have a brown, loam surface layer 9 inches (23 cm) thick. The subsoil from 9 to 12 inches (23-30 cm) is reddish-brown clay loam. From 12 to 33 inches (30-84 cm) is yellowish-red clay, and from 33 to 50 inches (84-127 cm) is strong-brown clay. The substratum from 50 to 72 inches (127-183 cm) is strong-brown, cobbly clay loam.

Weikert series consists of shallow, well-drained soils on uplands. They formed in material weathered from shale, siltstone, and sandstone. Typically, these soils have a dark-brown, shaly, silt loam surface layer 7 inches (18 cm) thick. The subsoil from 7 to 14 inches (18-36 cm) is yellowish-brown, very shaly silt loam. The substratum from 14 to 18 inches (36-46 cm) is yellowish-brown, very shaly silt loam. Bedrock is at 18 inches (46 cm). Slopes range from 0 to 80 percent.

Zoar series consists of deep, moderately well drained soils on terraces. They formed in slack-water alluvial deposits. Typically these soils have a dark-brown, silt loam surface layer 8 inches (20 cm) thick. The subsoil from 8 to 11 inches (20-28 cm) is yellowish-brown silt loam, from 11 to 19 inches (28-48 cm) is yellowish-brown, silty clay loam, and from 19 to 38 inches (48-97 cm) is yellowish-brown and strong-brown silty clay. Mottles are below 19 inches (48 cm). The substratum from 38 to 60 inches (97-152 cm) is gray clay loam. Slopes range from 0 to 15 percent.

GENERAL INDEX

PAGE

Algae 9, 18, 21
Alluvial-fan deposits 38, 41-42, 79, 81
Alluvium 4, 38, 40, 63
Baltimore mine 58
Bear Wallow 25
Berks series 75, 78
Big Spring Station Member 7, 10
Biosparite 32
Blairton series 78
Bloomsburg Formation 5, 25, 29, 30, 31, 58
Blue Hole 24, 25, 26, 27, 28, 30, 31, 32, 33
Boyer Furnace 56
Brachiopod 12, 16, 18, 21, 24, 32, 33, 34, 35, 36, 38
Braddock series 78
Breccia, collapse 14
Bryozoan 16, 18, 21, 24, 32, 36, 38
Buchanan series 75, 80
Buzzard Rock 39
Carbonate lowland 45, 48
Carbo series 75, 76, 77
Cedar Creek 41, 80
Cephalopod 12, 24
Chagrin series 80
Chaneysville Siltstone Member 38
Chavies series 80
Chilhowie series 77
Christian series 75, 76
Cobalt 59
Collapse breccia 14
Conococheague Formation 7, 9-11, 12, 54, 55, 67, 68, 69, 75
Copper 43, 59
Coral 17
Cystoid 21
Dandridge series 73
Dekalb series 73, 74
Dike, peridotite 5, 42-44
Dolomite, high-magnesium 49
recrystalline 12, 13
Duncan Gap 25

PAGE

Edinburg fault 48
Edinburg Formation 6, 15, 19-21, 51, 53, 54, 55, 57, 63, 65
Edom series 73, 77
Elbrook Formation 7, 8-9, 22, 63
Elizabeth Furnace 56
Elizabeth Furnace Recreation Area 30
Ernest series 79, 80
Fetzer Gap 29
Fishers Hill 12, 14, 15, 19
Flood-plain deposits 40-41, 80
Flute casts 23
Flysch 22, 23
Fort Valley 3, 33, 34, 35, 36, 38, 41, 45, 56, 73, 75, 79
Fracture cleavage 8
Frederick series 74, 75, 76
Front Royal 40
Gastropod 12, 16, 18, 24
Genesee series 80
Gilpin series 75
Graded bedding 23
Graptolite 24
Greendale series 74, 75, 76
Green Mountain 25, 31, 45, 74
Guernsey series 79
Hagerstown series 74
Harrisville 11
Hazelton series 74
Helderberg limestones 30, 33-34, 45, 63
Intrasparite 32
Iron 49, 56, 58, 63, 65
Jefferson series 74, 75
Jordon Run 9
Juniata Formation 6, 24, 25
Karst 70, 81, 82
Keefer Formation 6, 29, 30, 63
Keyser Formation 5, 30, 33, 34, 45
Laidig series 80
Lake John 47
Lantz Mills 6, 20, 21
Lead 43

PAGE

Lehew series 73, 74
Liberty Hall 6, 20, 21
Limestone, high-calcium 49, 53, 76
Lincolnshire Formation 6, 15, 16, 17-19, 51, 54, 55, 67, 68, 75
Little Crease Mountain 25, 31, 45, 74
Little Fort Valley 3, 34, 35, 41, 56, 58, 73, 75, 79
Little Fort Valley syncline 59
Little North Mountain 8, 22, 24, 28, 29, 30, 48-49, 56, 60, 73, 74, 75, 78, 80
Little Passage Creek 80
Load casts 23
McKenzie Formation 5, 30, 31
Magnetic traverses 42
Mahatango Formation 5, 38, 56
Manganese 49, 56, 57-58
Marcellus Shale 5, 35, 36-37
Martinsburg Formation 6, 21-24, 25, 54, 56, 57, 60, 61, 62, 81
Martinsburg Formation belt 45, 47-48
Massanutten Mountain 15, 25, 31, 39, 41, 45, 74
Massanutten mountain range 2, 3, 8, 45, 56, 58, 60, 78, 79, 80, 81
Massanutten Sandstone 6, 22, 25-28, 30, 56, 58, 75
Massanutten synclinorium 15, 21, 22, 24, 25, 30, 34, 36, 45
Maysville age fauna 24
Meneka Peak 3, 46
Metabentonite 20, 21, 22, 77
Mine Run 35, 79, 80
Mine Run Gap 25
Monongahela series 73, 78
Mt. Jackson 12
Mt. Olive 8, 72
Mudhole Gap 25, 59
Neamatophyte 28
Needmore Formation 5, 35-36
New Creek Limestone 5, 30, 33, 34
New Market Limestone 7, 13, 15-17, 19, 51, 54, 55, 67, 68
New Scotland limestone 5, 30, 33, 34
Nickel 43, 59
Nitrate 65
North Mountain fault 12, 15, 48, 49, 74
Oranda 12

PAGE

Oranda Formation 6, 21, 22, 63, 65
Oregon mine 59
Ostracode 16, 17, 18, 24, 33, 36, 38
Oswego Formation 6, 22, 24-25, 29
Passage Creek 24, 27, 31, 33, 38, 40, 41, 56, 78, 80
Pelecypod 24
Pelsparite 16, 17
Peridotite dike 5
Philadelphia mine 59
Plant 28, 31
Powells Fort Camp 34, 35, 75
Powells Fort mine 58
Pughs Run 11, 12, 15, 17, 19, 55
Purcell Limestone 38
Pyrolusite 58
Ridgeley Sandstone 5, 30, 34-35, 58, 59
Rileyville 7.5 minute quadrangle 36
Rittenour Ridge 22, 47
Rockdale Run Formation 7, 11, 12-15, 16, 52, 53, 54, 58, 67, 68, 75
Rockfalls 76, 81
Rome Formation 7, 8
Rose Hill Formation 6, 28, 29, 30
Round Hill 14, 15, 58, 75
St. Luke Member 6, 19, 20, 21, 55
Sand, high-silica 55-56
Saumsville 8, 9
Scott prospect 58
Seven Bends 3, 78, 81
Seven Fountains 36, 38
Shawl Gap 46
Shenandoah County 2
Shenandoah River 3, 40, 41, 63
  North Fork 40, 63, 80, 81
  South Fork 12, 15, 19, 41, 63, 80, 81
Shenandoah Valley 15, 56
Signal Knob 22, 33
Sinkholes 70, 74, 76, 77, 81, 82
Snapps Run 9, 12
Stonehenge Formation 7, 9, 11-12, 13, 52, 53
Stoufferstown Member 7, 9, 11-12

PAGE

Strasburg 19, 21, 77
Strasburg Junction 12, 53, 77
Sulfate 63
Talus deposits 4, 38, 39, 42, 80, 81
Terrace deposits 4, 38, 40, 63, 78
Three Top Mountain 25, 26, 31, 41, 74, 81
Tibbet Knob 25
Tioga Bentonite 5, 36
Toms Brook 8, 9, 11, 12, 15, 17, 81
Tonoloway Formation 5, 30, 33
Trilobite 18, 21, 24
Tumbling Run 11, 12, 14, 15, 17, 19, 22, 53
Turbidite 23, 24
Tuscarora Formation 6, 24, 28-29, 56
Unison series 78
Valley and Ridge physiographic province 2
Veach Gap 45, 46
Warren County 2
Warren County Airport 47
Waterlick 41, 42
Waynesboro Formation 7, 8, 22
Weikert series 73, 78
Wills Creek Formation 5, 30, 31-32, 45, 63
Wolf Gap 7.5-minute quadrangle 29, 30
Woodstock 12, 17, 21, 55, 77
Woodstock 7.5-minute quadrangle 22, 24, 29, 30, 33, 34
Zinc 43, 59
Zircon 22
Zoar series 79

INDEX OF FOSSIL NAMES

PAGE

Arthrophycus alleghaniensis 28

Calliops sp. 18
Christiania sp. 21
Cryptolithus sp. 24

Dinorthis sp. 18

Eccyliomphalus sp. 12
Echinosphaerites aurantium 21

Finkelnburgia sp. 12

Girvanella sp. 18

Hollinella cf. *H. sella* 38
Homotelus sp. 18

Isotelus sp. 24

Leperditia fabulites 17
Leperditia sp. 33
Leptostrophia bipartita 33

Mastopora pyriformis 21
Multicostella sp. 18

Pseudorakverella altalirata 24

Resserella sp. 21

Sinuites sp. 24
Skolithos cf. *S. verticalis* 28, 29
Sowerbyella sp. 21
Sowerbyites sp. 18

Tetradium syringoporoides 17

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
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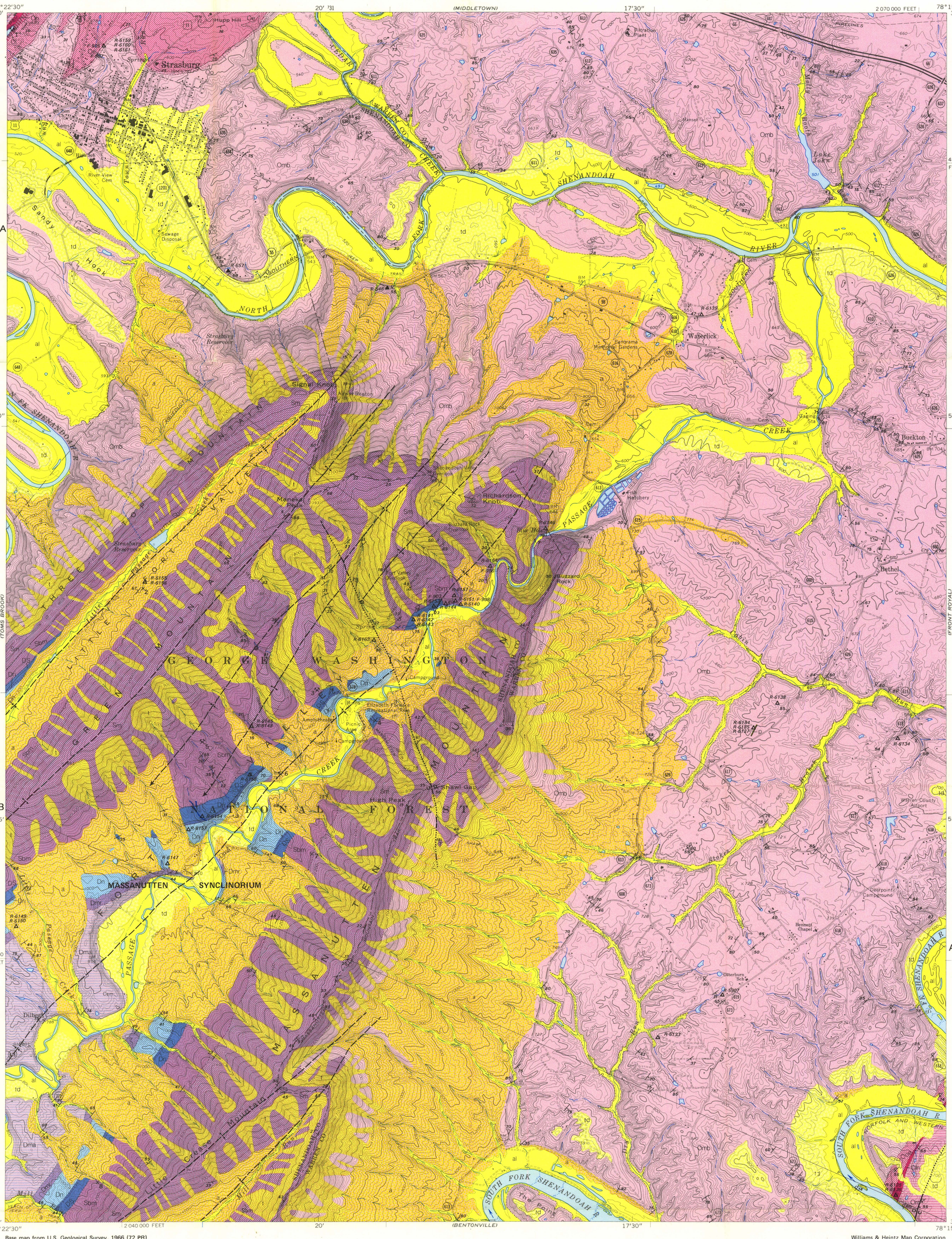

Base map from U.S. Geological Survey, 1966 (72 PR)
Strasburg Quadrangle, 7½ Minute Series

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GEOLOGIC MAP OF THE STRASBURG QUADRANGLE, VIRGINIA

Geology by Eugene K. Rader and Thomas H. Biggs

1976

MN GN 6½° 116 MILS 1°41′ 30 MILS
UTM GRID AND 1972 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000
1 ½ 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

VIRGINIA
QUADRANGLE LOCATION

EXPLANATION

CENOZOIC — QUATERNARY

al, a — Alluvium
al, flood-plain deposits of sand, silt, and clay with minor amount of rounded gravel; a, alluvial-fan deposits of pebbles, cobbles, and boulders in sand matrix.

td — Terrace deposits
Sand, silt, clay, and rounded pebbles and cobbles.

t — Talus deposits
Angular cobbles and boulders.

p — Peridotite dike
Chloritized mica peridotite.

PALEOZOIC

DEVONIAN

Dma — Mahantango Formation
Greenish-gray to gray silty shale, siltstone, and very fine-grained sandstone; fossiliferous.

Dmr — Marcellus Shale
Fissile, gray to black shale; limestone concretion layer near middle; brown calcareous tuff (Tioga) in lower portion.

Dn — Needmore Formation
Olive-green to greenish-gray shale and siltstone; sandy near base; fossiliferous; brown calcareous tuff (Tioga) in upper portion.

Dri — Ridgeley Sandstone
White to gray, coarse-grained, iron-stained calcareous sandstone and sandy limestone.

DS — Lower Devonian and Upper Silurian rocks
Helderberg limestones: gray, fine- to coarse-grained, silty, cherty limestone with thin crinoidal limestone beds. Keyser Formation: gray, fine- to medium-grained limestone with thin, very fine-grained calcareous sandstone and crinoidal limestone; fossiliferous. Tonoloway Limestone: thin-bedded, medium- to dark-gray limestone with shale partings. Wills Creek Formation: greenish-gray silty limestone and calcareous siltstone; thin, rusty-weathering sandstone and thin, maroon shale and siltstone; fossiliferous.

SILURIAN

Sbm — Bloomsburg Formation and McKenzie Formation
Bloomsburg: maroon- and green-mottled mudstone, maroon siltstone and sandstone, and gray sandstone near middle. McKenzie: yellowish-brown shale.

Sm — Massanutten Sandstone
Brownish-gray quartz sandstone with reddish-brown shale interbeds (upper part). White quartz sandstone and quartzite; locally conglomeratic (lower part).

ORDOVICIAN

Omb — Martinsburg Formation
Martinsburg: brown, medium- to coarse-grained sandstone (upper part); silty shale, dark-gray calcareous siltstone, and sandstone (middle part); black, calcareous shale and argillaceous limestone (lower part); fossiliferous.

Oo — Oranda Formation
Gray to brownish-gray calcareous siltstone, argillaceous limestone, and metabentonite; fossiliferous.

Ooe — Oranda Formation and Edinburg Formation
Oranda: gray to brownish-gray calcareous siltstone, argillaceous limestone, and metabentonite, fossiliferous. Edinburg: Dark-gray to black limestone; black, nodular-weathering limestone; and black shale; fossiliferous.

Oe — Edinburg Formation
Dark-gray to black limestone; black, nodular-weathering limestone; and black shale; fossiliferous.

Ol — Lincolnshire Formation
Dark gray, medium- to coarse-grained cherty limestone; fossiliferous.

Oln — Lincolnshire Formation and New Market Limestone
Lincolnshire: Dark-gray, medium- to coarse-grained, cherty limestone; fossiliferous. New Market: dove-gray micritic limestone, buff limestone, and conglomerate; fossiliferous.

On — New Market Limestone
Dove-gray micritic limestone, buff limestone, and conglomerate.

Orr — Rockdale Run Formation
Gray, fine-grained dolomite; minor bluish-gray limestone; and gnarly chert blocks; sparsely fossiliferous.

CONTACTS

Solid where exposed, dashed where approximate, dotted where covered or inferred

FOLDS

Anticline — trace of fold and direction of plunge

Syncline — trace of fold and direction of plunge

FAULTS

Solid where exposed, dashed where approximate, dotted where covered or inferred; tick mark indicates direction of dip

ATTITUDE OF ROCKS

20 — Strike and dip of beds
60 — Strike and dip of overturned beds
Strike of vertical beds
Horizontal beds

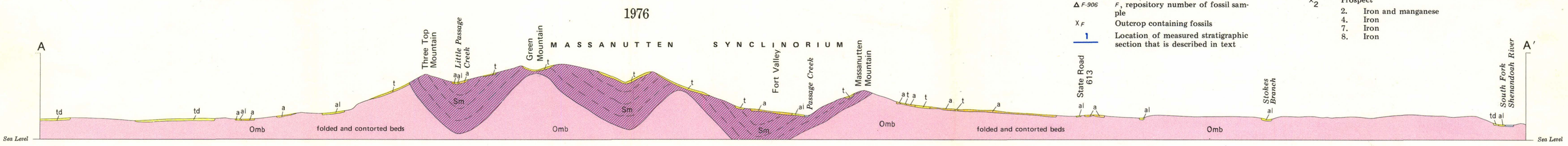
SAMPLE LOCATIONS

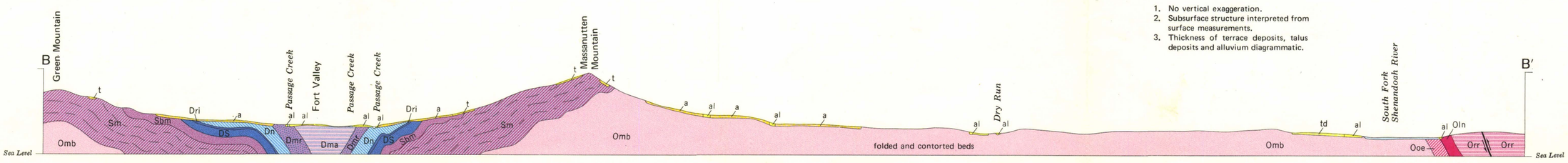
R-6149 — R, repository number of sample
R-657 — Sample of raw material having potential commercial use; R, repository number
X — Outcrop having distinctive lithology
F-906 — F, repository number of fossil sample
X F — Outcrop containing fossils
1 — Location of measured stratigraphic section that is described in text

MINES, QUARRIES, AND PROSPECTS

1 — Abandoned mine or quarry
1. Powhatan Lime Company quarry (limestone)
3. Iron mine
5. Iron mine
6. Shale quarry

2 — Prospect
2. Iron and manganese
4. Iron
7. Iron
8. Iron





CROSS SECTION DESIGN:

1. No vertical exaggeration.
2. Subsurface structure interpreted from surface measurements.
3. Thickness of terrace deposits, talus deposits and alluvium diagrammatic.

COMMONWEALTH OF VIRGINIA
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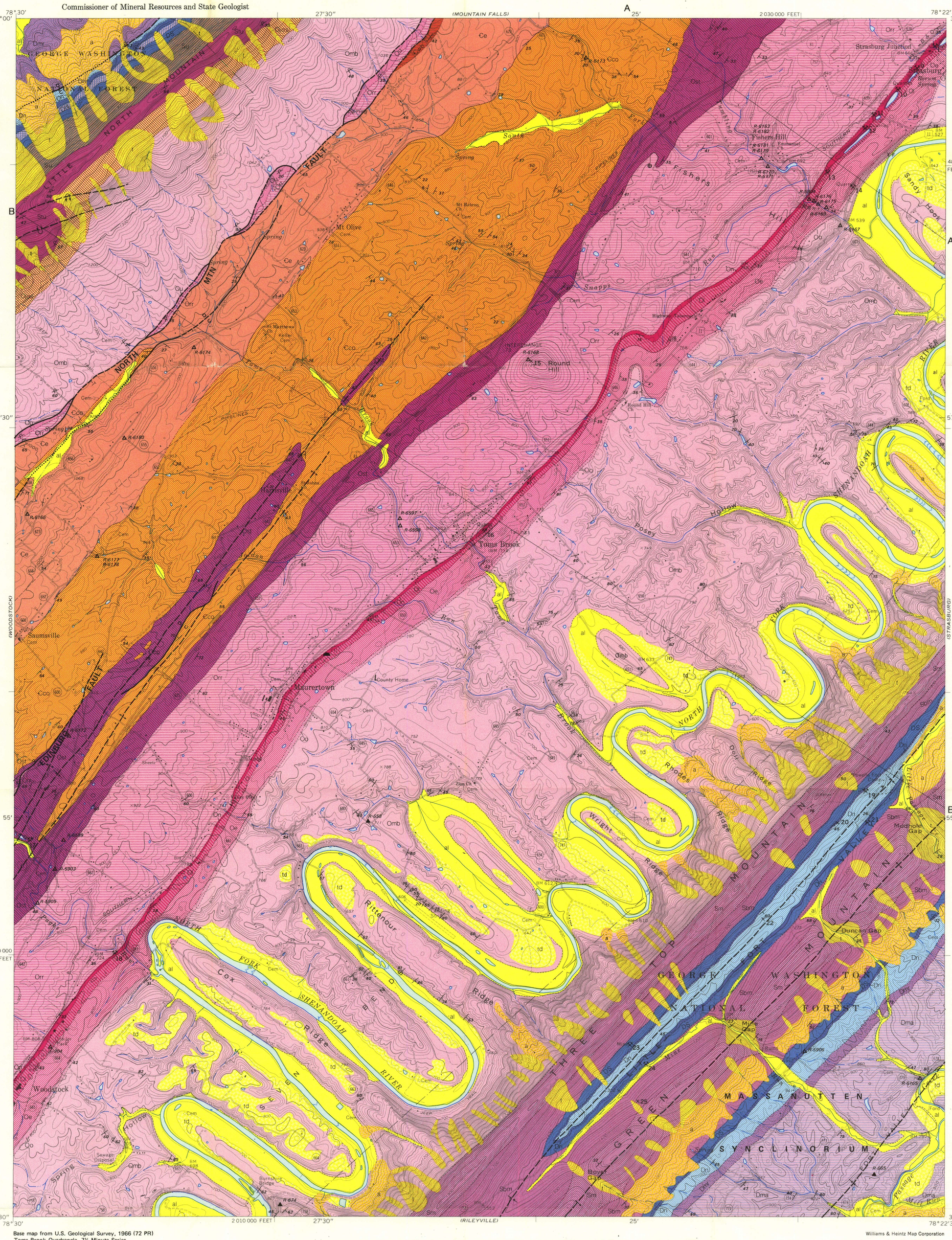

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Toms Brook Quadrangle, 7½ Minute Series

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GEOLOGIC MAP OF THE TOMS BROOK QUADRANGLE, VIRGINIA

Geology by Eugene K. Rader and Thomas H. Biggs

MN GN 6° 107 MILS 1°37' 29 MILS
UTM GRID AND 1966 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

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1976

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QUADRANGLE LOCATION

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t — Talus deposits
Angular cobbles and boulders.

DEVONIAN

Dma — Mahantango Formation
Greenish-gray silty shale, siltstone, and very fine-grained sandstone, fossiliferous.

Dmr — Marcellus Shale
Fissile, gray to black shale; limestone concretion layer near middle; brown calcareous tuff (Tioga) in lower portion.

Dn — Needmore Formation
Olive-green to greenish-gray shale and siltstone; sandy near base; fossiliferous; brown calcareous tuff (Tioga) in upper portion.

Dri — Ridgeley Sandstone
White to gray and brown calcareous sandstone; fossiliferous west of Little North Mountain.

Dhl — Helderberg limestones
New Scotland limestone: dark-gray, medium-grained, cherty limestone. New Creek Limestone: gray, coarse-grained crinoidal limestone.

DS — Lower Devonian and Upper Silurian rocks northwest of Little North Mountain
Keyser Formation: gray, fine- to medium-grained, partly cherty limestone; fossiliferous. Tonoloway Formation: finely laminated, gray and yellow argillaceous limestone; fossiliferous. Wills Creek Formation: yellow calcareous shale. Bloomsburg Formation: red sandstone and red- and green-mottled mudstone; gray sandstone near middle.

DS — Lower Devonian and Upper Silurian rocks southeast of Three Top Mountain
Helderberg limestones: gray, fine- to coarse-grained silty, cherty limestone with thin, crinoidal limestone beds. Keyser Formation: gray, fine- to medium-grained limestone with thin, brown to gray, very fine-grained calcareous sandstone and crinoidal limestone; fossiliferous. Tonoloway Limestone: thin-bedded, medium- to dark-gray limestone with shale partings. Wills Creek Formation: greenish-gray silty limestone and calcareous siltstone; thin rusty-weathering sandstone and thin maroon shale and siltstone; fossiliferous.

SILURIAN

Sd — Silurian rocks, undivided
McKenzie Formation: yellow calcareous shale. Keefer Formation: gray to white cross-bedded quartzite; Rose Hill Formation: yellowish-brown sandy shale and gray to brownish-gray, fine- to medium-grained sandstone.

Sbm — Bloomsburg Formation and McKenzie Formation
Bloomsburg: maroon- and green-mottled mudstone; maroon siltstone and sandstone; gray sandstone near middle. McKenzie: yellowish-brown shale.

Stu — Tuscarora Formation
White quartzite and quartz pebble conglomerate near base.

Sm — Massanutten Sandstone
Brownish-gray quartz sandstone with reddish-brown shale interbeds (upper part). White quartz sandstone and quartzite; locally conglomeratic (lower part).

PALEOZOIC — ORDOVICIAN

Ojos — Juniata Formation and Oswego Formation
Juniata: white, red, and chocolate, fine-grained sandstone with red clay galls. Oswego: fine-grained, greenish-gray sandstone and conglomerate.

Omb — Martinsburg Formation
Brown, medium- to coarse-grained sandstone (upper part); silty shale, dark-gray calcareous siltstone, and sandstone (middle part); black calcareous shale and argillaceous limestone; fossiliferous (lower part).

Oo — Oranda Formation
Gray to brownish-gray calcareous siltstone, argillaceous limestone, and metabentonite; fossiliferous.

Oe — Edinburg Formation
Medium- to dark-gray, medium- to coarse-grained and dove-gray, fine-grained limestone (St. Luke Member); dark-gray to black limestone; black nodular-weathering limestone; and black shale.

Ou — Ordovician rocks, undivided
Edinburg Formation: black, aphanic limestone. Lincolnshire Formation: dark-gray, cherty limestone. New Market Limestone: dove-gray, micritic limestone.

Ol — Lincolnshire Formation
Dark gray, medium- to coarse-grained, cherty limestone; fossiliferous.

On — New Market Limestone
Dove-gray micritic limestone, buff limestone, and conglomerate.

Orr — Rockdale Run Formation
Gray, fine-grained dolomite with white chert; bluish-gray limestone; bedded gray to black chert, and rusty gnarly chert; sparsely fossiliferous.

Ost — Stonehenge Formation
Thick-bedded, gray, fine- to medium-grained limestone; minor dark-gray to black chert. Dark-gray, fine- to medium-grained limestone with crinkly siliceous laminae; fossiliferous (Stoufferstown Member).

CAMBRIAN

Ꞓco — Conococheague Formation
Laminated, bluish-gray limestone; gray dolomite; gray sandstone. Rusty-weathering sandstone, bluish-gray limestone, light-gray dolomite, and intraformational conglomerate (Big Spring Station Member).

Ꞓe — Elbrook Formation
Yellow-weathering dolomite and bluish-gray, algal limestone (upper part). Bluish-gray limestone, greenish-gray, argillaceous dolomite, and light-gray dolomite (middle part). Light- to medium-gray dolomite with minor bluish- and greenish-gray dolomite; maroon and yellow shale (lower part).

Ꞓwb — Waynesboro (Rome) Formation
Maroon and yellow shale and siltstone with minor gray dolomite and sandstone.

CONTACTS

Solid where exposed, dashed where approximate, dotted where covered or inferred

FAULTS

Solid where exposed, dashed where approximate, dotted where covered or inferred; tick mark indicates direction of dip; U, upthrown side; D, downthrown side; T, upper sheet

FOLDS

- Anticline — trace of fold
- Syncline — trace of fold
- Overturned anticline — trace of fold
- Overturned syncline — trace of fold

ATTITUDE OF ROCKS

- 40 — Strike and dip of beds
- 70 — Strike and dip of overturned beds
- Strike of vertical beds
- Horizontal beds

MINES, QUARRIES, AND PROSPECTS

Active quarry
16. Riverton Corporation quarry (limestone)

Abandoned mine or quarry
1. Powhatan Lime Company quarry (limestone)
9. Chemstone Corporation quarry (limestone)
10. Chemstone Corporation quarry (limestone)
11. Limestone quarry
12. Limestone quarry
13. Limestone quarry
14. Limestone quarry
17. Salem Stone Corporation (limestone)
18. Limestone quarry
19. Iron and manganese mine
21. Philadelphia mine (manganese ore)
23. Powells Fort mine (manganese ore)
24. Powells Fort mine (manganese ore)

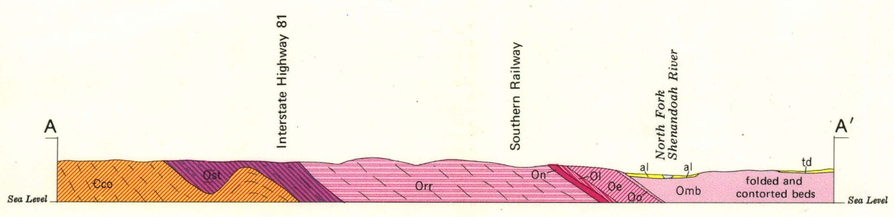
Prospect
15. Scott prospect (iron)
20. Iron and manganese
22. Iron and manganese
25. Iron and manganese

SAMPLE LOCATIONS

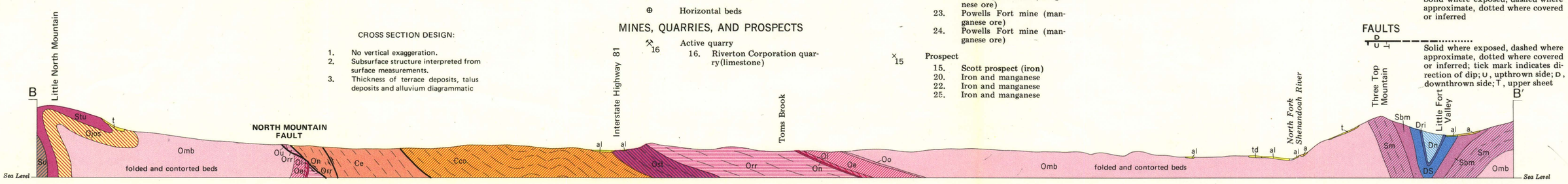
- R-5906 — R, repository number of sample
- R-674 — Sample of raw material having potential commercial use; R, repository number
- F-904 — F, repository number of fossil sample
- F — Outcrop containing fossils

MISCELLANEOUS SITES

Sanitary landfill



CROSS SECTION DESIGN:
1. No vertical exaggeration.
2. Subsurface structure interpreted from surface measurements.
3. Thickness of terrace deposits, talus deposits and alluvium diagrammatic



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

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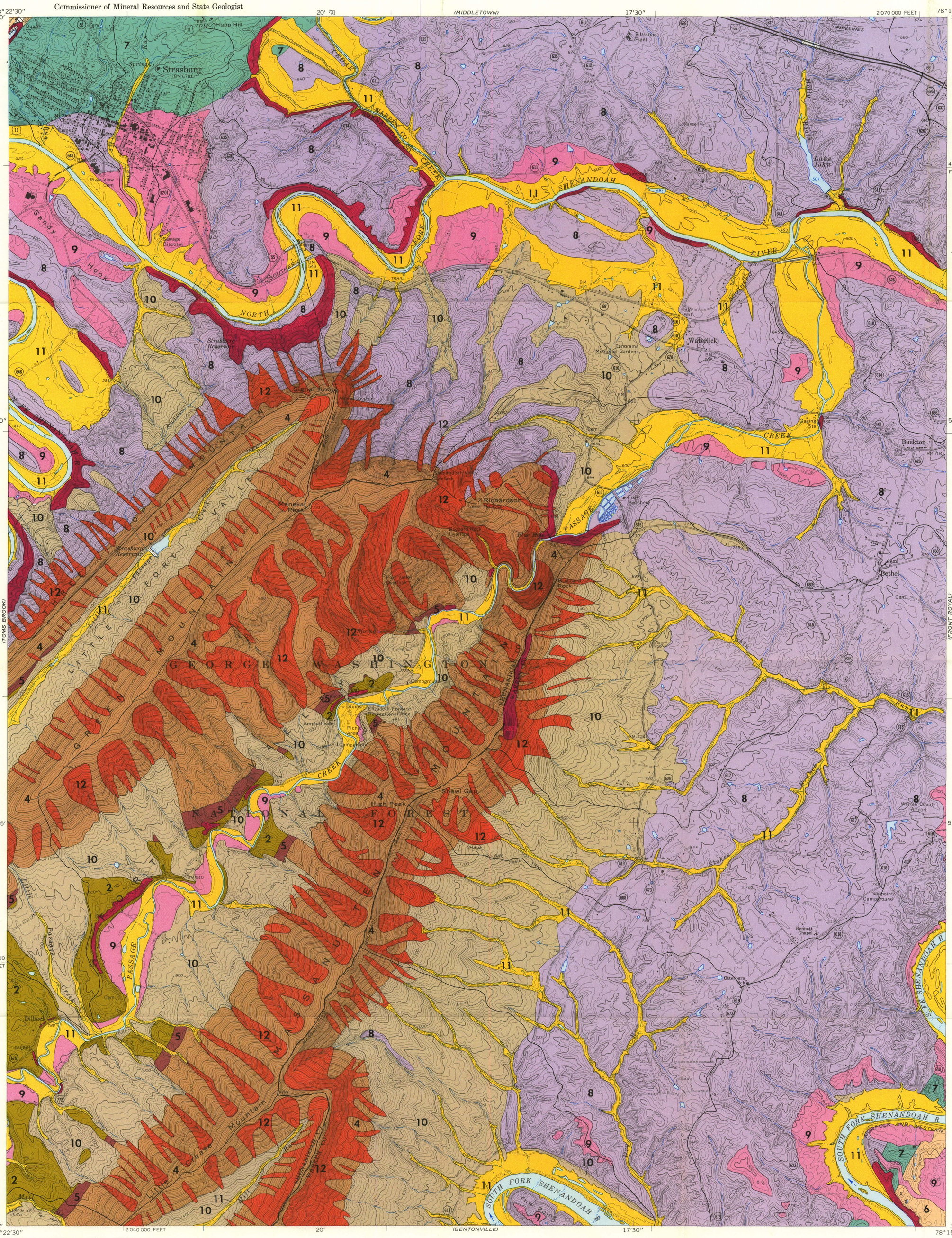

Base map from U.S. Geological Survey, 1966 (72 PR)
Strasburg Quadrangle, 7½ Minute Series

Williams & Heintz Map Corporation

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EXPLANATION

12
Unit 12
Unconsolidated talus deposits of angular rock blocks; subject to sliding.

11
Unit 11
Unconsolidated flood-plain deposits of sand, silt, and clay with a minor amount of gravel; cuts and excavations subject to sliding and sluffing.

10
Unit 10
Unconsolidated alluvial-fan deposits of pebbles, cobbles, and boulders in sand; subject to sliding.

9
Unit 9
Unconsolidated pebbles and cobbles in sandy and clayey soil; cuts and steep slopes subject to sliding and sluffing.

8
Unit 8
Shaly soil overlying interbedded shale and sandstone; cuts subject to sliding and sluffing; locally severe erosion.

7
Unit 7
Residual soil overlying shale and argillaceous limestone; subject to severe erosion; small sinkholes common; high shrink-swell clay.

ls 6
Unit 6
Variable soil thickness overlying limestone and dolomite; locally high shrink-swell clay; small sinkholes and solution channels common; ls, high-calcium limestone.

5
Unit 5
Residual soil overlying limestone, shale, and sandstone.

4
Unit 4
Thin residual soil overlying quartzite, sandstone, conglomerate, shale, and mudstone; steep slope and high runoff.

2
Unit 2
Thin residual soil overlying shale, siltstone, and sandstone; cuts subject to sliding and sluffing.

Rockfalls and Landslides
Area of actual or potential rockfalls or landslides.

Fill

X *Sinkhole; 20 feet (6 m) or more in diameter*

——— *Drainage divide*

GEOLOGIC FACTORS AFFECTING LAND MODIFICATION, STRASBURG QUADRANGLE, VIRGINIA

Geology by Eugene K. Rader and Thomas H. Biggs

MN GN
6½° 116 MILS
1°41' 30 MILS
UTM GRID AND 1972 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000
1 ½ 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

VIRGINIA
QUADRANGLE LOCATION

1976

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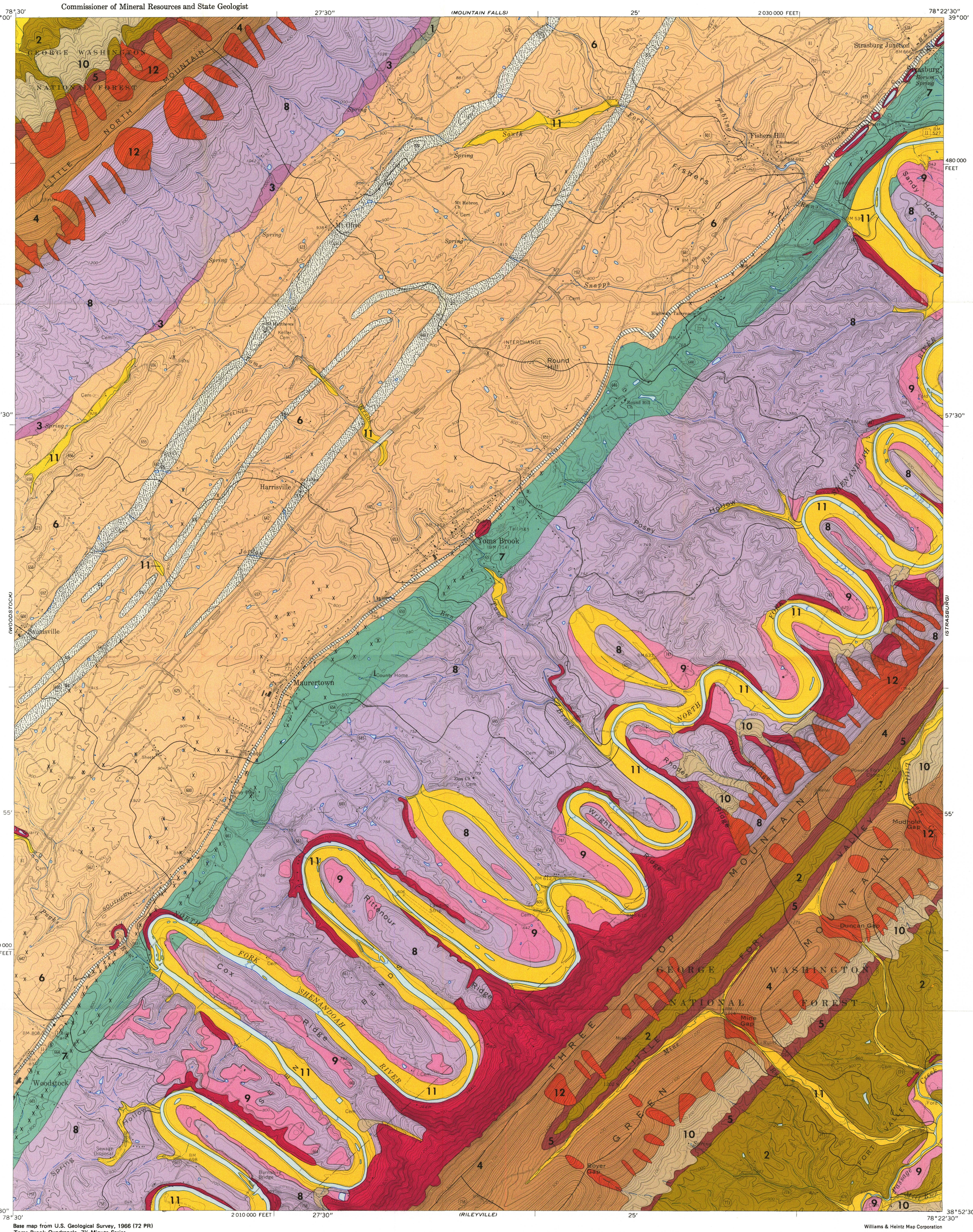

Base map from U.S. Geological Survey, 1966 (72 PR)
Toms Brook Quadrangle, 7½ Minute Series

Williams & Heintz Map Corporation

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EXPLANATION

Unit 12

Unconsolidated talus deposits of angular rock blocks; subject to sliding.

Unit 11

Unconsolidated flood-plain deposits of sand, silt, and clay with a minor amount of gravel; cuts and excavations subject to sliding and sluffing.

Unit 10

Unconsolidated alluvial-fan deposits of pebbles, cobbles, and boulders in sand; subject to sliding.

Unit 9

Unconsolidated pebbles and cobbles in sandy and clayey soil; cuts and steep slopes subject to sliding and sluffing.

Unit 8

Shaly soil overlying interbedded shale and sandstone; cuts subject to sliding and sluffing; locally severe erosion.

Unit 7

Residual soil overlying shale and argillaceous limestone; subject to severe erosion; small sinkholes common; high shrink-swell clay.

Unit 6

Variable soil thickness overlying limestone and dolomite; locally high shrink-swell clay; small sinkholes and solution channels common; ls, *high-calcium limestones;* ss, *interbedded sandstone and limestone.*

Unit 5

Residual soil overlying limestone, shale, and sandstone.

Unit 4

Thin residual soil overlying quartzite, sandstone, conglomerate, shale, and mudstone; steep slope and high runoff.

Unit 3

Residual soil overlying limestone, dolomite, and shale; small sinkholes common.

Unit 2

Thin residual soil overlying shale, siltstone, and sandstone; cuts subject to sliding and sluffing.

Unit 1

Residual soil overlying shale, siltstone, and sandstone; subject to severe erosion.

Rockfalls and Landslides

Area of actual or potential rockfalls or landslides.

Fill

X *Sinkhole; 20 feet (6 m) or more in diameter*

——— *Drainage divide*

GEOLOGIC FACTORS AFFECTING LAND MODIFICATION, TOMS BROOK QUADRANGLE, VIRGINIA

Geology by Eugene K. Rader and Thomas H. Biggs

MN GN
6° 107 MILS
1°37' 29 MILS
UTM GRID AND 1966 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000
1 ½ 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

VIRGINIA
QUADRANGLE LOCATION

1976