VIRGINIA DIVISION OF GEOLOGY AND MINERAL RESOURCES

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GEOLOGY OF THE WAYNESBORO EAST AND WAYNESBORO WEST QUADRANGLES, VIRGINIA

THOMAS M GATHRIGHT II,
WILLIAM S. HENIKA, AND JOHN L. SULLIVAN III

PUBLICATION 3

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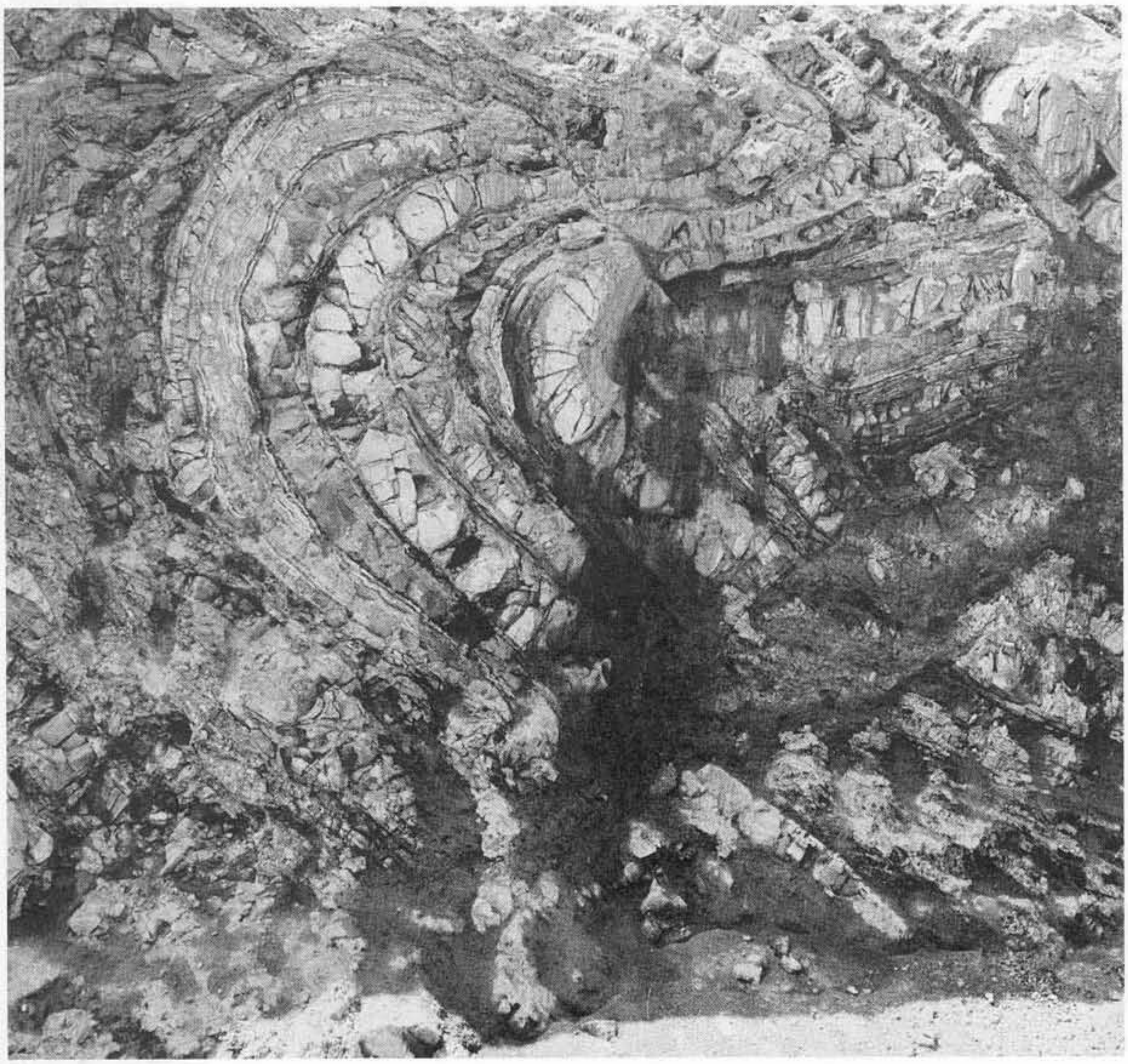

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES
James L. Calver, Commissioner of Mineral Resources and State Geologist

CHARLOTTESVILLE, VIRGINIA
1977

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GEOLOGY OF THE WAYNESBORO EAST AND WAYNESBORO WEST QUADRANGLES, VIRGINIA

By

Thomas M. Gathright II, William S. Henika, and John L. Sullivan III

ABSTRACT

The Waynesboro East and Waynesboro West quadrangles comprise an area of approximately 117 square miles (304 sq km) in portions of Albemarle, Augusta, and Nelson counties in north-central Virginia. Included in the quadrangles are portions of the Piedmont, Blue Ridge, and Valley and Ridge physiographic provinces and two major regional structures — the Blue Ridge anticlinorium and the Massanutten synclinorium.

The rocks of the Blue Ridge anticlorium are complexly folded and faulted and consist of five sequences, the oldest being the Precambrian gneisses that include the Lovingston and Pedlar formations. Unconformably overlying these rocks or in fault contact with them is a sequence of Precambrian(?) stratified rock units including the metamorphosed, fluvial, sedimentary, and basic volcanic strata of the Swift Run and Catoctin formations. These are overlain by a sequence of Cambrian clastic rocks that include the Weverton, Harpers, and Antietam formations. The Massanutten synclinorium within the study area is formed from the overlying Cambrian and Ordovician carbonate sequence that includes the Shady, Waynesboro, Elbrook, Conococheague, Chepultepec, Beekmantown, New Market, and Lincolnshire formations. These carbonate rocks are overlain by the Ordovician clastic sequence of the Martinsburg Formation. Many of these rock units are locally intruded by diabase dikes of Triassic age and are locally covered by alluvial Quaternary sediments.

The intensity of deformation increases from northwest to southeast with recumbent folds, thrust faults, and zones of cataclastic rocks present in the southeastern half of the area. All of the rocks are altered with the metamorphic rank being somewhat greater to the southeast.

Sources of agricultural limestone, limestone aggregate, and in limited quantities high-calcium limestone are present. Ceramic clay, crushed stone, sand and gravel, and iron and manganese have been produced in small quantities.

Fourteen environmental geologic units having similar geologic factors — bedrock, residuum, and soil properties — affecting land modification have been delineated. Each is briefly evaluated with respect to slope stability, erodibility, and response to excavation or other types of land modification. Rockfall, karst, cave areas, and flood-prone regions have been delineated.

INTRODUCTION

The Waynesboro East and Waynesboro West 7.5-minute quadrangles are located in Albemarle, Augusta, and Nelson counties in central Virginia, and include the City of Waynesboro (Figure 1). They encompass an area

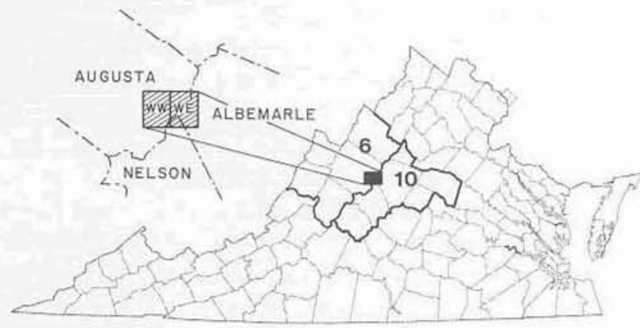


Figure 1. Index map showing location of the Waynesboro East (WE) and Waynesboro West (WW) quadrangles in Planning Districts 6 and 10, Virginia.

of approximately 117 square miles (304 sq km) and are bounded by 78°45′ and 79°00′ west longitudes and 38°00′ and 38°07′30″ north latitudes. The quadrangles are in the Piedmont, Blue Ridge, and Valley and Ridge physiographic provinces and can be divided into four distinctive topographic areas. (1) The uplands of the Piedmont province are characterized by a subdued, rolling topography that forms a plain broken by scattered foothills such as Round Top (Plate 1). Major streams that drain the area have broad valleys with local bluffs and incised banks. Segments of Lickinghole Creek that drain the Jarman Gap area of the Blue Ridge, Stony Run that drains the Greenwood Hollow area, and Stockton, Yellow Mountain, Dollins, and Stockton Mill creeks are all tributaries to Mechums River. Williams and Andersons creeks are tributaries to the North Fork of Rockfish River. (2) Arcuate to linear mountain ridges with steep, V-shaped valleys characterize the topography within the Blue Ridge province. Major mountain ridges include Bear Den, Bucks Elbow, Calf, Elk, Ramsey, Scott, and Turk mountains, Miller Knob, and Sawmill and Stony ridges. Their maximum relief is nearly 2,400 feet (732 m) above the Piedmont province to the east and over 1,800 feet (549 m) above the Valley and Ridge province to the west. (3) A very gently sloping to nearly flat lowland is present along the eastern edge of the Valley and Ridge province. It includes large alluvial fans east of South River at the foot of Sawmill Ridge, Ramsey Mountain, and Mikes Knob northeast of Waynesboro (Plate 1), and broad alluvial plains along South River and Back Creek southwest of Waynesboro (Plate 2). (4) Low, elongate ridges and hills such as Kiser Hill are flanked by broad valleys such as that of Porterfield Run. This fourth topographic area lies north and west of South River (Plate 2), and is entirely within the Valley and Ridge province. Elevations range from less than 640 feet (195 m) along Stockton Creek at the east edge and an unnamed creek at the south edge of the Waynesboro East quadrangle to 2,974 feet (906 m) on top of Calf Mountain (Plate 1).

The City of Waynesboro is served by both the Chesapeake and Ohio and the Norfolk and Western railroads. East-west highway access to the quadrangles is provided by Interstate Highway 64 and U. S. Highway 250. Blue Ridge Parkway and Skyline Drive provides access to excellent recreational areas in the northeastward-trending Blue Ridge, and U. S. Highway 340 traverses the eastern portion of the Valley and Ridge province. Several state highways and roads give access to additional areas.

Previously published geologic maps that cover parts of the area are regional studies (Butts, 1933, 1940-41; Bloomer and Werner, 1955; Nelson, 1962; Virginia Division of Mineral Resources, 1963). Several specialized reports that cover some aspects of the geology include publications on the mineral resources (Stose and others, 1919; Knechtel, 1943; Edmundson, 1945), regional stratigraphy (Schwab, 1970, 1971), and geomorphology (Hack, 1965).

The writers wish to acknowledge the work of Paul G. Nystrom, Jr., who prepared the geologic map of the Waynesboro West quadrangle during 1973 and 1974. The information concerning environmental geology in the text and the geologic factors affecting land modification shown on Plates 1 and 2 were compiled from field data and basic information supplied by Nystrom and from supplemental geologic data collected by the writers. The Waynesboro East quadrangle was mapped by the writers in 1975. Richard H. DeKay, who supervised the project, visited Nystrom and the writers in the field and offered important suggestions and criticisms of the work and manuscript. The writers also wish to acknowledge the work of Donald H. Fulkerson, who conducted field investigations during 1969 and 1970; Roy Murphy, District Geologist, Virginia Department of Highways and Transportation, who provided valuable core samples and engineering data; J. B. Carter, U. S. Soil Conservation Service, who furnished valuable soils data for portions of western Albemarle County; Roger Rinner, Assistant Materials Engineer, Virginia Department of Highways and Transportation, who provided bore-hole data and copies of soils investigations for sections of the U. S. Interstate Highway 64 right-of-way; M. J. Bartholomew for many discussions on stratigraphy and structure of the Blue Ridge; and Wallace Sullivan, geology student at James Madison College, who provided magnetic profiles for one of the windows in the Rockfish Valley fault and disbase dike swarms.

Numbers preceded by "R" in parentheses (R-6572) correspond to sample localities; those preceded by "F" (F-934) 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

All major bedrock units (Table 1) have been folded and steeply tilted, producing elongate, northeastward- to southwestward-trending outcrop belts. Bedrock consists of five gross lithologic sequences that represent stages in the development and sedimentation of the Appalachian basin. The oldest Precambrian rock (Lovingston and Pedlar formations), consisting of gneiss, forms the floor upon which the younger, stratified sequences were deposited. The upper Precambrian(?) stratified sequence is composed of metamorphosed clastic and volcanic rocks of the Catoctin and Swift Run formations that were deposited unconformably on the eroded surface of the Precambrian gneisses and is conformably overlain by metamorphosed sandstone of the Lower Cambrian clastic sequence. The rocks of these two sequences form the ridges that define the Blue Ridge physiographic province. Rocks of the Lower Cambrian clastic sequence comprise the Weverton, Harpers, and Antietam formations. The limestones and dolomites of the Cambrian and Ordovician carbonate sequence are characteristically cyclic, shallow-marine sediments — the Waynesboro, Elbrook, Conococheague, Chepultepec, Beekmantown, New Market, and Lincolnshire formations — that are transitional upward to the dark, deep-water slates of the basal part of the Martinsburg Formation. The upper Ordovician clastic sequence includes a basal black-slate unit and the overlying slate-argillite-limestone and sandstone-slate units of the Martinsburg Formation.

PRECAMBRIAN ROCKS

Gneissic bedrock occurs in a large overthrust sheet that has overridden the Blue Ridge along the Rockfish Valley fault at the southeastern foot of the Blue Ridge (Plate 1). Precambrian granite gneiss and granodiorite gneiss northwest of the Rockfish Valley fault is overlain unconformably by stratified metasedimentary and metavolcanic rocks of the Swift Run Formation. Precambrian gneiss in the thrust sheet includes the Lovingston gneiss that has been transformed into a cataclastic gneiss along the western edge of the sheet.

Table 1. — Geologic formations in the Waynesboro East and Waynesboro West quadrangles.

Age	Name	Character	Thickness in feet (meters)
Quaternary	Alluvium	Clayey sand and silt overlying gray silty clay and gravel; large cobbles present (lowland deposits).	0-15 (0-5)
		Cobbles, boulders, other gravel, and angular blocks in a sand matrix (upland deposits).	0-15 (0-5)
	Talus deposits	Cobbles, boulders, and angular blocks in a sand matrix.	0-25 (0-8)
	Terrace and alluvial-fan deposits (southeast of Blue Ridge)	Gravel and sand with a red clay matrix; coarse material consists of cobbles and boulders of metabasalt and granodiorite gneiss.	0-30 (0-9)
	Terrace and alluvial-fan deposits (northwest of Blue Ridge)	Gravel and sand derived from quartzite and sandstone.	0-75+ (0-23+)
Triassic	Diabase dikes	Dark greenish gray to black diabase; predominantly composed of labradorite and augite.	
Ordovician	Martinsburg Formation	*Unit "s":* thick-bedded, brown-weathering, bluish-gray, medium-grained, metamorphosed lithic sandstone alternating with thin-bedded, dark-gray to black calcareous slate. *Unit "a":* very thin to medium-bedded, dark-gray to black calcareous slate alternating with tan-weathering argillite and argillaceous limestone. *Unit "c":* black graptolitic slate; very rarely argillite lamelli.	*Unit "s":* lower 100-300 (30-91) *Unit "a":* 1,500-2,000 (457-610) *Unit "c":* 100-300 (30-91)
	Lincolnshire Formation	Dark-gray, medium-grained, medium- to thick-bedded limestone with abundant black nodular chert and thin, irregular pink or brown partings. Gray, to dark-gray, abundantly fossiliferous, coarsely crystalline bioclastic limestone is present locally.	0-140 (0-43)
	New Market Limestone	Dove-gray, massive micritic limestone.	0-60 (0-18)
	Beekmantown Formation	Interbedded dove-gray micritic limestone and thick-bedded, fine- to medium-grained, light-gray dolomite (upper part). Massive beds of light- and dark-gray dolomite with interbedded chert (middle part). Interbedded dark-gray, laminated limestone and gray, medium- to coarse-grained, thick-bedded dolomite (lower part). Dark-gray dolomitic marble common at basal contact.	3,000+ (914+)
	Chepultepec Formation	Dark-gray to bluish-black, fine-grained, thick-bedded limestone with a few thin interbeds of orangish-yellow weathering, gray dolomite. Black chert nodules are common. Siliceous laminae are abundant in the lower part. Fossils are locally abundant.	300-400 (91-122)

Age	Name	Character	Thickness in feet (meters)
Cambrian	Conococheague Formation	Dark-gray, fine-grained algal limestone alternating with ribbon-banded limestone, thinly laminated limestone, and light-brown weathering, laminated to thick-bedded dolomite. Light-tan to brown, medium- to coarse-grained quartz sandstone occurs as thin beds in the lower part and thicker, more persistent beds in the middle part. Algal structures are common, but other fossils are rare.	1,600 (488)
	Elbrook Formation	*Upper member:* characteristically orangish-yellow weathering, fine- to medium-grained, gray to dark-gray crystalline dolomite interbedded with some thin, dark-gray algal limestone, phyllitic and slaty beds, and a minor amount of clastic rocks. *Lower member:* laminated to thin-bedded, pale-green phyllite and slaty dolomite; interbeds of laminated, fine-grained, buff to light gray weathering, light- to dark-gray dolomite. Laminated red phyllite occurs locally about 100 feet (30 m) above basal contact.	2,800-3,000 (853-914)
	Waynesboro Formation	Gray, brown, green, and red argillite and phyllite with interbeds of laminated to thin-bedded, light- to dark-gray dolomite and limestone, and gray, fine-grained, thin- to thick-bedded sandstone.	
	Shady Formation	In subsurface only; rock characteristics not determined.	
	Antietam Formation	Thin-bedded, tan to white, metamorphosed feldspathic sandstone interlayered with green and pink, laminated phyllite and argillite (upper part). Massive, fine-grained, white- to light-gray, *Skolithos*-bearing, vitreous quartzite (lower part).	
	Harpers Formation	Green to bluish-gray, quartz-chlorite-sericite phyllite with thin to massive interbeds of grayish-green to bluish-gray metamorphosed sandstone; light-tan, prominent quartzite and ferruginous, metamorphosed sandstone.	1,500-2,700 (457-823)
	Weverton Formation	Light-brown weathering, green quartzose phyllite; coarse-grained, reddish-purple, metamorphosed ferruginous sandstone and light-gray pebble quartzite; laminated green or dark purplish gray phyllite locally at base.	350-400 (107-122)
Precambrian(?)	Catoctin Formation	Fine-grained, dark greenish-gray chlorite-epidote-albite schist and actinolite-epidote-chlorite-albite schist; massive schistose metabasalt and amygdaloidal metabasalt; fine-grained, light greenish gray epidosite; coarse-grained, massive epidote-quartz breccia; greenish-gray metatuff; mottled greenish-purple phyllitic metatuff; and medium- to coarse-grained, light-green, metamorphosed lithic sandstone.	1,500-3,000 (457-914)
	Swift Run Formation	Medium- to coarse-grained, tan-weathering, light- to greenish-gray quartz-sericite schist and quartz-sericite-chlorite schist; some schistose, metamorphosed lithic sandstone.	80-200 (24-61)

Age	Name	Character	Thickness in feet (meters)
Precambrian	Pedlar Formation	Dark bluish- to greenish-gray, coarse-grained, massive to sheared granodiorite gneiss; light-gray, greenish-gray, or pink, very coarse grained, porphyritic, massive to sheared granite gneiss.	
	Lovingston Formation	Dark-gray to black and white, medium- to coarse-grained, massive to foliated granitic gneiss and weakly foliated mylonitic, augen-bearing biotite gneiss.	
	Cataclastic rocks	Dark- to light-gray, medium- to coarse-grained protomylonite, mylonite, phyllonite, blastomylonite, and mylonite gneiss altered in Paleozoic time from the Lovingston Formation and to a lesser extent from the Pedlar Formation.	

Lovingston Formation

The Lovingston Formation consists of dark-gray to black and white, medium- to coarse-grained, massive to foliated granitic gneiss and weakly foliated mylonitic, augen-bearing biotite gneiss. The formation has been described in the Greenfield 7.5-minute quadrangle, just south of the Waynesboro East quadrangle, by Bartholomew (personal communication, 1976) who recognized the granitic gneiss and biotite gneiss as two separately mappable units. The granitic gneiss is present only in the extreme southeastern corner of the Waynesboro East quadrangle where it is covered by thick residual soils (Plate 1).

Isolated masses of Lovingston mylonitic biotite gneiss crop out as massive ledges along the stream 1.2 miles (1.9 km) south of the intersection of State Roads 691 and 692. The rock is dark gray to black and white, coarse-grained, weakly foliated, and generally homogeneous. The weak gneissic foliation is defined by discontinuous light- and dark-colored segregations that consist of stretched feldspar augen surrounded by nonaligned masses of black biotite, and pod-like masses of coarse-grained blue quartz. The foliation generally has a low dip, and is offset and contorted by one or more sets of spaced-cleavage planes along which there has been some mica development. Joints are generally widely spaced and steeply inclined.

The mineral composition of the mylonitic biotite gneiss ranges from that of a quartz-monzonite to a granite (Figure 2). Augen generally consist of large (1-5 mm) xenoblastic microcline or polycrystalline aggregates of microperthite with numerous inclusions of quartz and plagioclase, and are commonly granulated about their margins. Most of the biotite that occurs in nonaligned masses surrounding augen or which is strung out along the gneissic foliation consists of ragged laths (0.5 to 2.0 mm) that have a brown pleochroism (R-6522).

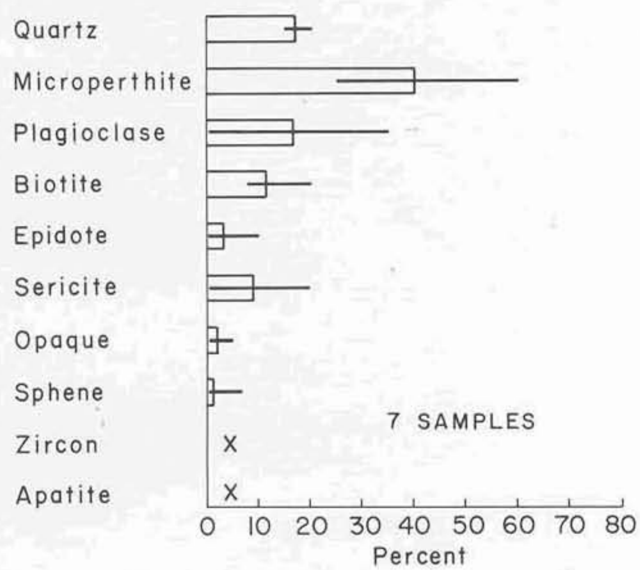


Figure 2. Mineral composition ranges (lines) and averaged estimated composition (bars) of mylonitic biotite gneiss from the Lovingston Formation. Minerals in amounts less than 5 percent indicated by x.

A second biotite consisting of red pleochroic laths (0.3 mm) arranged in radial aggregates seems to have formed after the Paleozoic deformation that produced the schistosity (R-6524). This red biotite may be the result of a later Paleozoic metamorphic event.

Pedlar Formation

The Pedlar Formation consists mostly of massive to slightly foliated to sheared, medium- to coarse-grained, dark bluish to greenish gray metamorphosed granodiorite. Locally, a granite gneiss unit is present. The granodiorite gneiss forms thick resistant ledges and large, rounded boulders that have a characteristically rough, warty surface texture and an ocherous yellow to light gray weathering rind. The rock is relatively resistant to weathering and forms rounded hills in the Piedmont and steep slopes along the southeastern foot of the Blue Ridge.

Easily accessible outcrops include those on the north side of the railroad-access road south of the Interstate Highway 64 overpass on the Chesapeake and Ohio Railway 0.7 mile (1.1 km) southwest of Newtown, and along State Road 637 in the gap between Turks Mountain and Round Top 0.5 mile (0.8 km) south of Critzers Shop. Contacts are generally sheared and may appear gradational where massive protomylonitic rocks are adjacent to the granodiorite gneiss, but they may also be quite sharp against phyllonite such as along the western slope of Turks Mountain. Similarly, the contact between granodiorite gneiss and sheared Swift Run phyllite can be located within a few feet.

The mineral composition of the granodiorite gneiss (Figure 3) shows little variation in samples from place to place. In the interior of large bodies such as Turks

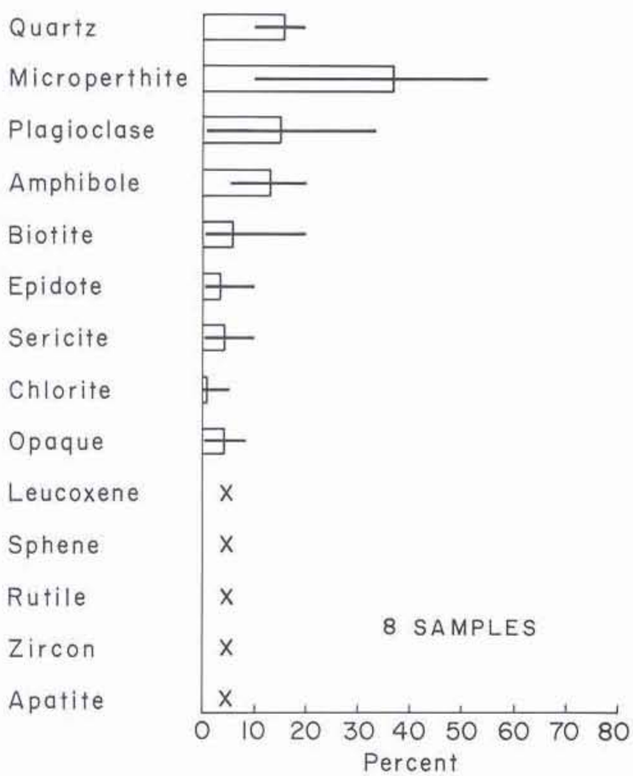


Figure 3. Mineral composition ranges (lines) and averaged estimated composition (bars) of granodiorite gneiss from the Pedlar Formation. Minerals in amounts less than 5 percent indicated by x.

Mountain, it has a relict igneous texture (R-6536, R-4407) and is more massive in outcrop than the augenous, cataclasized granodiorite gneiss near the Rockfish Valley fault (R-6537, R-6538, R-6539). This augenous granodiorite gneiss has a greenish-gray color and a dull waxy luster, due to amphibole minerals, which distinguish it from cataclastic gneiss with a similar foliated appearance. Thus, the major variation between samples of granodiorite gneiss seems to be a function of both the intensity of cataclasis and retrograde metamorphism rather than primary differences in igneous mineralogy.

Texture and relict mineralogy may show that the granodiorite gneiss was derived from massive charnokitic intrusions similar to those associated with the Roseland anorthosite, which intrudes the Lovingston Formation near its type locality in Nelson County (Herz, 1969, p. 361). Both Herz (1969) and Hillhouse (1960) studied the Roseland area in detail and cite positive evidence that the massive charnokites are younger than the Lovingston Formation. Although the delicate contact relationships described by Hillhouse (1960) did not survive cataclasis in the Waynesboro East quadrangle, xenoliths of biotite gneiss (Lovingston?) occur in massive granodiorite gneiss at two localities in this study area. One is in a large boulder at the head of a hollow just south of the Chesapeake and Ohio Railway about 0.4 mile (0.6 km) northeast of Greenwood and the other is in an outcrop in mountain pastureland on the north side of Interstate Highway 64 approximately 0.75 mile (1.21 km) east of Newtown.

Granite gneiss: Very coarse-grained, porphyritic, light-gray, greenish-gray, or pink granite gneiss, assigned to the Pedlar Formation, occurs in a small area on the southeastern slope of the Blue Ridge northeast of Greenwood (Plate 1). Its presence in the cores of small isoclinal folds results in local occurrences of the Swift Run Formation structurally above and below the granite. Phyllitic rocks separate the granite gneiss from the main mass of the Pedlar Formation to the southeast. The contact between the Swift Run Formation and the granite gneiss is interpreted to be nonconformable because of the relict igneous textures preserved in the granite gneiss and the sedimentary structures preserved in the Swift Run metasediments.

Boulders and scattered outcrops of the granite gneiss occur in orchard land along the northeast side of State Road 611 (Plate 1). However, the best exposures are along the Chesapeake and Ohio Railway approximately 0.3 mile (0.5 km) southwest of the quadrangle boundary where the gneiss (R-6540) has very large, white to pinkish masses of potassic feldspar (40 mm in diameter) and contorted, discontinuous, elongate masses of bluish-gray quartz that stand out in relief above a fine, greenish-gray matrix.

The greenish-gray matrix has a strong sericite-chlorite foliation that developed by partial replacement of plagioclase and original mica. Tiny grains of reddish-brown biotite occur in fractures that cut across the chlorite foliation.

PRECAMBRIAN(?) ROCKS

Swift Run Formation

The Swift Run Formation consists of medium- to coarse-grained, light- to greenish-gray, tan-weathering, quartz-sericite schist and quartz-sericite-chlorite schist with lesser amounts of schistose, metamorphosed lithic sandstone. The base of the formation has a nonconformable contact with the Pedlar Formation and has fault contacts with other rock types along the southeastern slopes of the Blue Ridge. Its upper contact is conformable, but has an intertonguing relationship with metamorphosed lava flows of the Catoctin Formation. Thicknesses computed from the width of the outcrop belt at several locations in the Waynesboro East quadrangle range from approximately 80 to 200 feet (24 to 61 m).

A fault contact between deeply weathered Swift Run quartz-sericite schist and laminated, light-tan, weathered protomylonite can be determined within an interval of 10 feet (3 m) along the northwest side of State Road 631, approximately 0.45 mile (0.72 km) northwest of the intersection of State Roads 631 and 840 (Plate 1). A nonconformable contact between schistose units of the Swift Run Formation and greenish-gray, massive granodiorite gneiss can be observed along State Road 690 approximately 150 feet (46 m) southeast of the Chesapeake and Ohio Railway, about 0.25 mile (0.40 km) southeast of Greenwood. A "knife-edge" contact between dark, greenish-gray, metamorphosed basalt of the Catoctin Formation and light-gray, quartz-sericite schist is exposed along the Chespeake and Ohio Railway immediately north of the Interstate Highway 64 bridge 0.7 mile (1.1 km) west of Newtown. Thin Catoctin metamorphosed basalt flows, generally between 1.0 and 2.0 feet (0.3 and 0.6 m) thick are interlayered with quartz-sericite schist in the upper part of the Swift Run Formation about 200 feet (61 m) south of the Chesapeake and Ohio Railway approximately 0.7 mile (1.1 km) northeast of Greenwood.

Although highly metamorphosed, bedding can be recognized in some exposures of the Swift Run Formation, and individual blue quartz granules are generally strung out along cleavage. Two intersecting cleavages are common. A sample of coarse-grained quartz-sericite schist from outcrops approximately 500 feet (152 m) west of the intersection of State Road 631 and State Highway 151 southeast of Afton (R-6541) contains large, rounded to irregularly shaped quartz granules 1 to 5 mm in diameter. The sedimentary fabric preserved in schist from the Swift Run Formation (R-4417) shows it was a sandy mudstone derived from the Precambrian gneisses. The presence of intersecting cleavage and schistosity are indicative of two periods of deformation.

Catoctin Formation

The eastern ridges of the Blue Ridge are underlain by metavolcanic and metasedimentary rocks of the Catoctin Formation (Table 1). The metamorphosed basalt flows have a characteristic step-like topographic expression on Bucks Elbow, Calf, and Bear Den mountains in the northeastern part of the Waynesboro East quadrangle where flow boundaries are gently inclined. The predominant rock types within the flows are homogeneous, dark greenish gray chlorite-epidote-albite schist and actinolite-epidote-chlorite-albite schist (Figure 4). Highly amygdaloidal schists are common, and portions of the

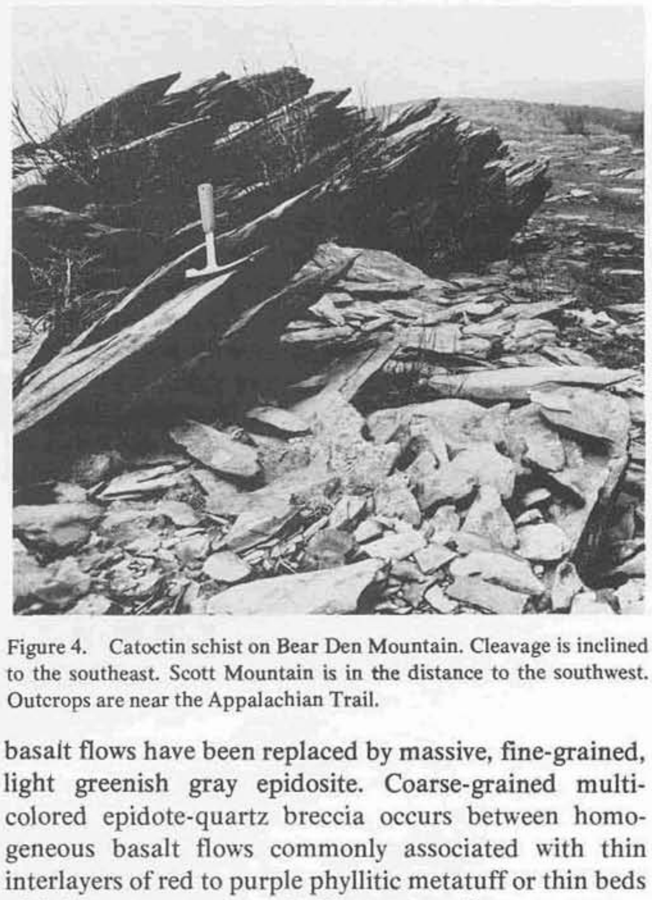


Figure 4. Catoctin schist on Bear Den Mountain. Cleavage is inclined to the southeast. Scott Mountain is in the distance to the southwest. Outcrops are near the Appalachian Trail.

basalt flows have been replaced by massive, fine-grained, light greenish gray epidosite. Coarse-grained multicolored epidote-quartz breccia occurs between homogeneous basalt flows commonly associated with thin interlayers of red to purple phyllitic metatuff or thin beds of light-gray quartzose phyllite and medium- to coarse-grained, light-green metamorphosed sandstone. The Catoctin is approximately 1,500 to 3,000 feet (457 to 914 m) thick.

Light-gray quartzose phyllite; medium- to coarse-grained, light pinkish tan metamorphosed feldspathic sandstone; coarse-grained metamorphosed lithic conglomerate; and purple phyllitic metatuff are present in the uppermost part of the Catoctin Formation. The contact of the Catoctin Formation with the overlying Weverton Formation has been consistently placed at the top of the volcanic section, generally between phyllitic or schistose rocks that have recognizable volcanic textures and either metamorphosed, conglomeratic metasandstones or laminated to thinly layered, purplish-gray phyllite of sedimentary origin. This is considered to be a conformable contact.

Probably the best exposed section of the Catoctin Formation in the Blue Ridge in Virginia occurs along Interstate Highway 64 between the bridge over the Chesapeake and Ohio Railway at the southeastern foot of the Blue Ridge and the sewage disposal pond 0.5 mile (0.8 km) west of Rockfish Gap. No other single section gives a better impression of the intensity and character of metamorphism or of the diversity of lithologic types within the formation. The dominant structure exposed in this section is cleavage and the predominant rock type is schist. The least-metamorphosed basalt sampled in this area (R-6542) is a lustrous, greenish-grayish schist with characteristically gray to light yellowish green quartz-epidote amygdules that stand out in relief on the cleavage as lumps or crater-like depressions 2 to 6 mm in maximum diameter. The rock contains few, if any, originally igneous minerals although the igneous (subophitic) texture is well preserved by lath-like, twinned-albite pseudomorphs (0.03 to 0.35 mm) after more calcic plagioclase and fine, granular masses of chlorite, magnetite-ilmenite, and leucoxene that have replaced the original mafic minerals. A weak schistose structure can be recognized in thin sections by the subparallel arrangement of scattered thin, wispy plates of green chlorite and dark bands of opaque minerals distributed in streamline fashion around larger albite grains and amygdules. The mineral composition is typical of the chlorite-epidote-albite schist (R-6543, R-6546), which is one of two predominant metabasalt lithologies (Figure 5). The other predominant metabasalt lithology (actinolite-chlorite-epidote-albite schist) contains minute needles of actinolite (0.1 mm long) along the schistosity and as radiating fibrous growths around the margins of some amygdules (R-4414, R-6807).

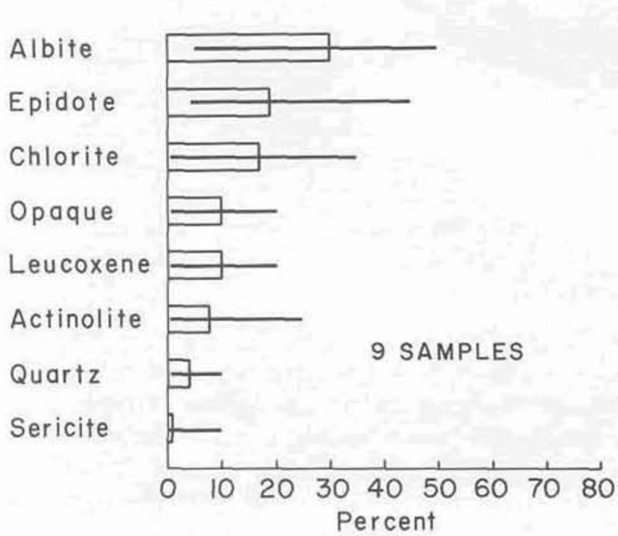


Figure 5. Mineral composition ranges (lines) and averaged estimated composition (bars) of metabasalt from the Catoctin Formation.

Amphibole-bearing schist (R-4414, R-6807) is commonly distinguishable from the chlorite-epidote-albite schist in the field by a harsh or hackly surface that can be felt when the hand is drawn across cleavage of rock that contains needles of amphibole. It is colorless to green in thin sections and generally occurs in minute, needle-shaped grains (0.1 mm long) along the schistosity and as radiating fibrous growths around the margins of some amygdules.

In the exposures along Interstate Highway 64 two varieties of metatuff can be recognized (Figure 6): varved to laminated, gray to purple chlorite-ilmenite-sericite phyllite interlayered with metasedimentary rocks that seem to be water-lain deposits, and mottled, purple and green ilmenite-chlorite phyllite (chlorite-ilmenite phyllite) that contains structures characteristic of welding or deposition by hot ash flows (ignimbrites; Gathright, 1976, p. 24). A spectacular exposure of the purple laminated variety is located on the north side of Interstate Highway 64 approximately 0.4 mile (0.6 km) west of the Chesapeake and Ohio Railway (R-6547) where the metatuff unit forms the face of the cut inclined steeply toward the roadway. The laminae in the purple phyllite consist of light-gray, sericitic beds 1 to 2 mm thick; light greenish gray, detrital epidote-quartz beds 1 to 5 mm thick; and dark-gray, ilmenite-rich lamelli 0.5 to 1 mm thick.

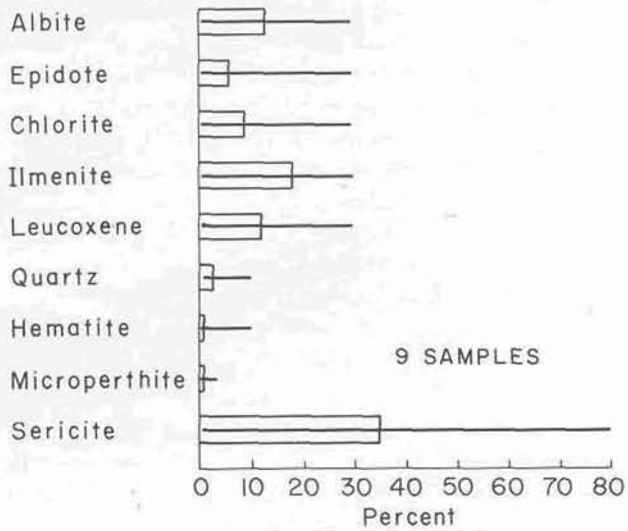


Figure 6. Mineral composition ranges (lines) and averaged estimated composition (bars) of metatuff from the Catoctin Formation.

The purplish, mottled metatuff is interlayered with metabasalt along the northwest side of Interstate Highway 64, approximately 700 feet (213 m) east of its intersection with Skyline Drive. Similar rocks are exposed in the top of the Catoctin Formation along the northeast side of the Chesapeake and Ohio Railway near the northwest portal of the Blue Ridge railroad tunnel. These were previously correlated with parts of the Unicoi Formation (Bloomer and Werner, 1955). Thin sections of this rock type (R-6548 through R-6551) show a well-preserved vitroclastic texture characterized by curving, cuspate, and cresent-shaped masses of opaque minerals recrystallized in the walls of plastically deformed, devitrified glass shards around contorted pumice lapilli and phenocrysts. The resultant structure describes a curlicue pattern and produces some of the mottling visible in hand specimens.

An excellent exposure of a typical metasedimentary unit interlayered in coarse-grained, amygdaloidal metabasalt occurs on the north side of Interstate Highway 64 approximately 0.3 mile (0.5 km) west of the bridge over the Chesapeake and Ohio Railway. The interlayer ranges from approximately 1.0 to 3.0 feet (0.3 to 0.9 m) in thickness and contains three lithologic types: medium- to coarse-grained, light-green metamorphosed sandstone (R-6552); medium-grained, light maroon gray, impure, matrix-rich metamorphosed sandstone (R-6553); and light-gray, quartz-sericite schist with medium- to coarse-grained, rounded quartz clasts (R-6554). Primary sedimentary structures, including cross bedding, bedding lamination, and detrital grains are preserved in this exposure. Some variations include a metabasalt cobble-conglomerate exposed on Turk Branch Trail (R-4405) about 0.5 mile (0.8 km) northeast of Sawmill Ridge Overlook and a feldspathic metasandstone that occurs along Skyline Drive northeast of Calf Mountain Overlook (R-6555, R-6556).

The mineral composition of Catoctin metasedimentary rocks is summarized in Figure 7. Quartz is the predominant clastic framework mineral with equal or lesser amounts of microcline or perthite and minor amounts of detrital plagioclase. The sedimentary beds contain many large angular to rounded clasts of Precambrian granite and granodiorite, metabasalt, metatuff, and quartz and much sand-sized magnetite, ilmenite, and some garnet (R-6557) showing multiple source areas for the deposits. Pale-green epidote cement is present in the upper portion of the beds where they are overlain directly by metabasalt. Epidosite occurs as lenses and beds, and as cement, in breccia masses within the metabasalt sequence and locally as replacement masses of the metabasalt, metatuff, and sedimentary beds (R-6558, R-6559).

Epidote-Amphibolite Dikes and Sills

Green to greenish-gray, massive to foliated metadiabase dikes and sills similar in composition to Catoctin metabasalt intrude the cataclastic gneiss southeast of the Catoctin outcrop belt. None of these dikes and sills are shown separately on the geologic maps (Plates 1, 2) from the formations that they intrude because of limited exposure. One outcrop occurs in the bottom of Stockton Creek, just upstream from a private lane about 0.4 mile (0.6 km) southeast of Lebanon Church on U. S. Highway 250 (R-6564). The dike, which forms a narrow ledge

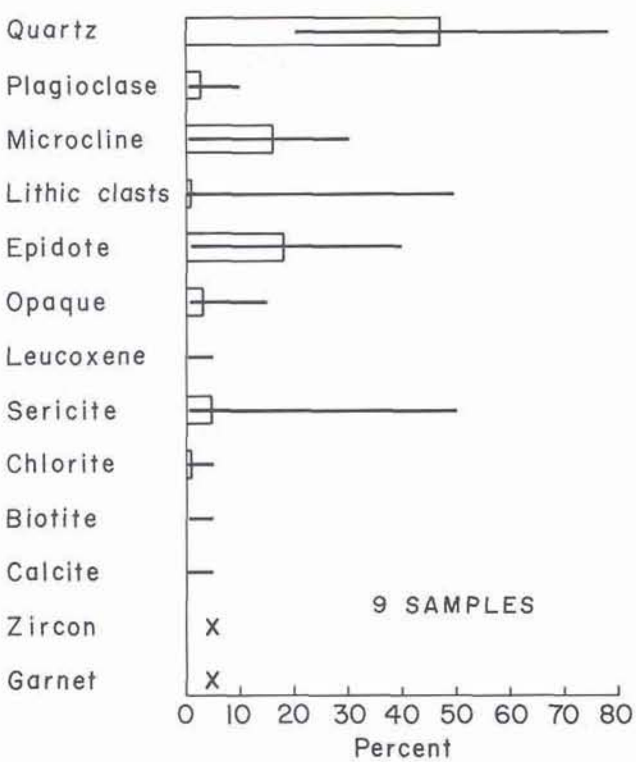


Figure 7. Mineral composition ranges (lines) and averaged estimated composition (bars) of metasedimentary rocks from the Catoctin Formation. Minerals in amounts less than 5 percent indicated by x.

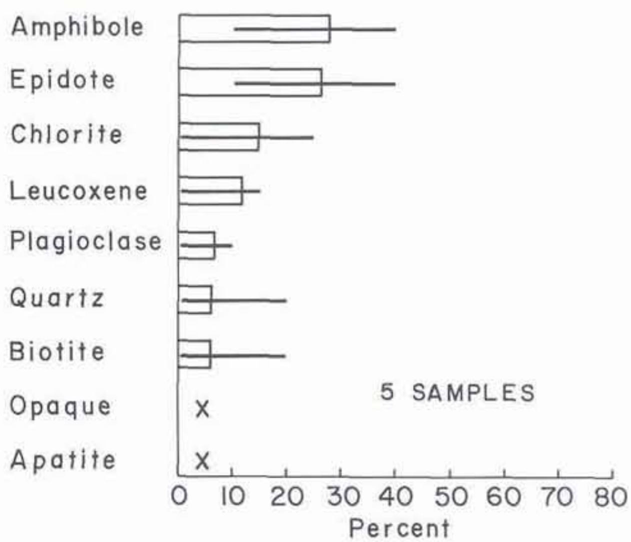


Figure 8. Mineral composition ranges (lines) and averaged estimated composition (bars) of epidote-amphibolite (metadiabase) dikes and sills. Minerals in amounts less than 5 percent indicated by x.

across the creek, has a more northerly trend than foliation measured in the surrounding cataclastic rocks. At other localities to the southeast (R-6566, R-6569) similar rocks that may be sills are present in float along a narrow zone that seems parallel to the strike of schistosity in the cataclastic rocks.

The rocks of the sills and dikes are generally medium grained, range in texture and composition from granoblastic amphibolite to chlorite-epidote-amphibole schist (Figure 8), and have a metamorphic fabric similar to that of the enclosing cataclastic rocks, including two intersecting schistosities and radial aggregates of a late-formed, red biotite.

Several samples (R-6564, R-6563, R-6566) contain relict textures and structures that are similar to those in the metamorphosed basalts of the Catoctin Formation, suggesting that these dikes or sills may have fed basaltic magma to the surface during Catoctin time.

CAMBRIAN SYSTEM

Weverton Formation

The Weverton Formation consists of light brown weathering, coarse-grained, sandy and pebbly metamorphosed sandstone interbedded with silvery-green, quartzose phyllite and thick-bedded, coarse-grained, reddish-purple, metamorphosed ferruginous sandstone. Laminated to thinly layered, dark purplish gray phyllite occurs locally near the base. Because of intense folding the true thickness of the formation cannot be determined, but estimates based on the width of its narrow, northeastward-trending outcrop belt range from 350 to 400 feet (107 to 122 m). The light-tan to brown, pebbly metasandstone is a lithotype unique to the formation. In the Waynesboro East quadrangle the uppermost of these resistant beds is the marker bed that separates the Weverton from the predominantly phyllitic rocks of the overlying Harpers Formation. In the Waynesboro West quadrangle the uppermost resistant ledge of reddish-purple, metamorphosed ferruginous sandstone is the top of the formation.

The formation is exposed along the northwestern slopes of the Blue Ridge from Elk Mountain to the Jarman Gap area. North of Jarman Gap the formation has been traced across the crest of the Blue Ridge near Skyline Drive, and crops out on the southeast slopes along Turk Branch Trail. The lower contact of the unit is exposed along Skyline Drive approximately 500 feet feet (152 m) north of Jarman Gap where fine-grained metamorphosed sandstone overlies metamorphosed basalt and epidote-rich metamorphosed sandstone of the Catoctin Formation. Phyllite also occurs along this contact between Jarman Gap and Sawmill Ridge Overlook. The characteristically light-tan sericite-quartz phyllite and coarse-grained metamorphosed sandstone are very well exposed along Skyline Drive at Sawmill Ridge Overlook.

The coarse-grained metamorphosed sandstone consists of a framework of rounded, coarse quartz sand grains, weathered feldspar grains, and opaque minerals in a light, silvery-gray sericite matrix. The framework minerals constitute about 60 percent of the rock (Figure 9) and range from 1 to 9 mm in maximum diameter.

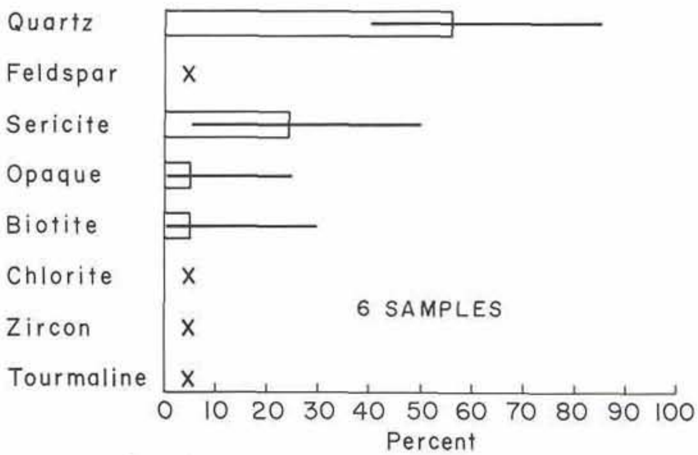


Figure 9. Mineral composition ranges (lines) and averaged estimated composition (bars) of metasedimentary rocks from the Weverton Formation. Minerals in amounts less than 5 percent indicated by x.

Metamorphic biotite is a common accessory mineral, especially within the recrystallized matrices of the more impure metamorphosed sandstones (R-4416, R-4413, R-6560).

Sericite-quartz and chlorite-sericite-quartz phyllites are the most abundant lithotypes in the formation, and are composed of the same minerals and have a schistose fabric very similar to the coarse-grained metamorphosed sandstone. The major lithologic differences within the formation are mostly the result of changes in grain size and variations in coloration because of relatively minor amounts of secondary iron-oxide in the rock matrix. Comparison of Figures 7 and 9 indicates that the major mineralogic differences between metasedimentary units in the Catoctin and Weverton formations are a greater abundance of unstable grains (feldspar and rock fragments) and the presence of significant amounts of epidote in the Catoctin, and a greater abundance of recrystallized matrix minerals (largely derived from clay) in the Weverton.

Harpers Formation

The Harpers Formation consists of greenish- to bluish-gray, quartz-chlorite-sericite phyllite with thin to massive interlayers of grayish-green to bluish-gray metamorphosed sandstone (Figure 10). It occurs in a continuous outcrop belt that ranges from approximately 0.4 to 1.9

Figure 10. Harpers phyllite with metamorphosed sandstone interbeds along the Chesapeake and Ohio Railway approximately 0.25 mile (0.40 km) east of abandoned Chesapeake and Ohio Railway quarry in Waynesboro.

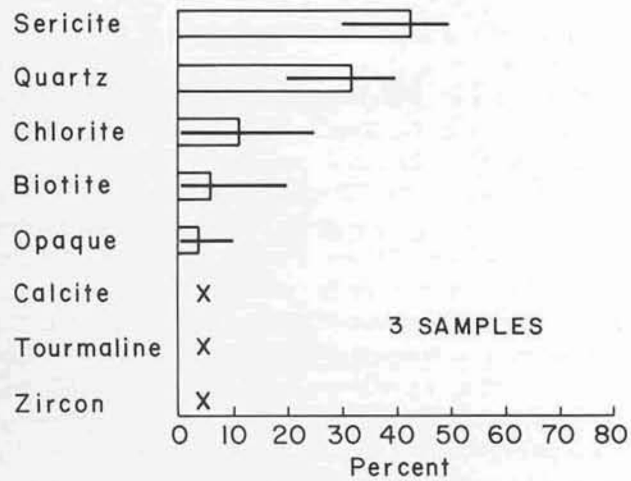


Figure 11. Mineral composition ranges (lines) and averaged estimated composition (bars) of phyllite from the Harpers Formation. Minerals in amounts less than 5 percent indicated by x.

miles (0.6 to 3.1 km) in width along the northwestern flank of the Blue Ridge from the headwaters of Sawmill Run (Plate 1) to Robinson Hollow (Plate 2). The phyllite that comprises the bulk of the formation is generally deeply weathered and forms valleys, whereas the more resistant metamorphosed sandstone forms discontinuous, elongate ridges, such as Stony Ridge west of the Swannanoah Golf and Country Club (Plate 2). The formation has been intensely folded, precluding accurate measurement of total thickness, but estimates across sections devoid of obvious repetitions range from 1,500 to 2,700 feet (457 to 823 m).

Excellent examples of weathered rocks are exposed in an overturned section along the Chesapeake and Ohio Railway southeast of Waynesboro; fresh rock is exposed in the deep excavations for Interstate Highway 64 northwest of Rockfish Gap. Although bedding is subtly preserved in these exposures, the most prominent structure observed is schistosity. Fossil worm tubes *(Skolithos?)* have also been found in metamorphosed sandstone beds from this locality. Samples of the phyllite (R-4409, R-6561, Figure 11) contain fine (.04 to 0.1 mm), angular, recrystallized, detrital quartz grains and some larger, rounded to angular feldspar clasts (0.5 mm in maximum diameter) in a foliated, chlorite-sericite or biotite matrix. The metamorphosed sandstone beds in the Interstate Highway 64 excavations are very dark and bluish gray, but there is much lateral variation in coloration along strike, ranging from very light gray to black. The top of the formation is mapped at the base of the first massive, ledge-forming, white quartzite of the overlying Antietam Formation.

Thin sections of metamorphosed sandstone (R-4418, R-4406, Figure 12) have a strong metamorphic fabric (granoblastic elongate) similar to those described in

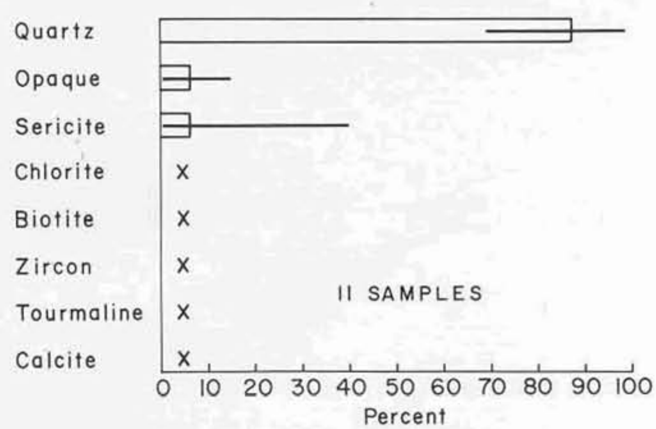


Figure 12. Mineral composition ranges (lines) and averaged estimated composition (bars) of metamorphosed sandstone from the Harpers Formation. Minerals in amounts less than 5 percent indicated by x.

Weverton metamorphosed sandstone, but are generally richer in quartz. Magnetite-ilmenite and hematite are responsible for the dark coloration in these sandstone beds and a late-formed, red biotite similar to biotite noted in Precambrian rock units was identified in two samples.

Antietam Formation

The Antietam Formation consists of predominantly thin-bedded, tan to white, metamorphosed feldspathic sandstone interlayered with green and pink laminated phyllite and argillite. Several massive, fine-grained, white to light-gray, vitreous quartzite ledges in the lower part of the unit form its characteristic ridge-forming topographic expression. The formation is poorly exposed except for the prominent ledges on Turk Mountain, Sawmill Ridge, and Ramsey Mountain northeast of Waynesboro (Plate 1) and the chain of unnamed ridges that flank Miller Knob south of the city (Plate 2). Angular blocks eroded from the massive ledges form broad talus deposits that obscure most of the formation and its lower contact with the Harpers Formation.

The massive quartzite ledges on the crest of Turk Mountain contain abundant, poorly to well-preserved fossil worm burrows (*Skolithos*) that appear as round to elliptical depressions on bedding surfaces and resemble striations on surfaces broken across the bedding (Figure 13). At least five quartzite ledges, each 10 to 15 feet (3 to 5 m) thick, are exposed on the northeastern end of Ramsey Mountain, and a thin section from one (R-4419) at the gap on the southwestern end contains approximately 92 percent quartz and 8 percent feldspar.

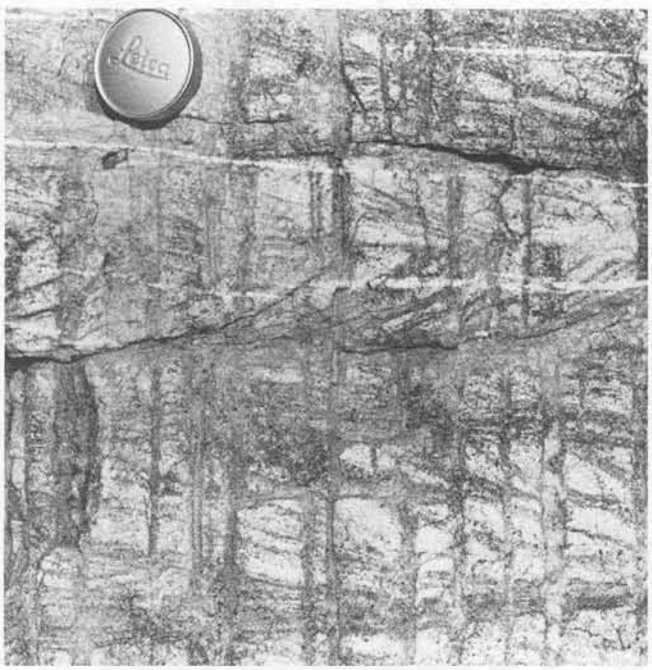


Figure 13. *Skolithos* tubes in cross-bedded Antietam quartzite in talus blocks along Sawmill Ridge fire trail approximately a mile southwest of Turk Mountain. Vertical striations are tubes; dark, horizontal, and gently inclined, concave-upward lines are bedding and cross-bedding respectively.

The thinly bedded metamorphosed sandstone and phyllite have generally been deeply weathered to sandy and clayey saprolite, such as that exposed in a borrow pit approximately 0.4 mile (0.6 km) southeast of the intersection of U. S. Highway 250 (Main Street) and State Road 624 (Delphine Avenue) in Waynesboro. The relatively large amount of clay in the weathered matrix of the sandstone is an implication that it was much less pure than the massively bedded quartzite. The phyllite is weathered to green and pink laminated clays, and the sericitic matrix retained in some stream-bed exposures shows a general similarity in metamorphic grade to phyllite in the underlying Harpers Formation.

The upper part of the Antietam Formation is poorly exposed but limited exposures in stream bottoms southeast of Miller Knob (Plate 2) are predominantly phyllitic. No data are available for the upper contact or thickness of the Antietam as its uppermost beds and adjacent (west) strata of the overlying formation (Shady?) are covered by rock debris and alluvium or have been removed by faulting.

Shady Formation

The Shady Formation is not exposed, but is inferred to be present in the subsurface. This interpretation is based on the presence of sinkholes in Quaternary alluvial sediments at the western foot of the Blue Ridge and on reports by Stose and others (1919) and Knechtel (1943) that Shady dolomite was encountered in mines and exploratory holes in the Sherando 7.5-minute quadrangle to the southwest and the Crimora 7.5-minute quadrangle to the northeast.

To demonstrate the subsurface occurrence of the formation and the thickness of unconsolidated sediments covering it, three exploratory holes were drilled. Two were along the State Road 619 right-of-way northwest of Sawmill Run Ranger Station: one 110 feet (34 m) deep and the other 165 feet (50 m) deep. Each penetrated only unconsolidated material. The third was along the State Road 621 right-of-way northwest of Mikes Knob; after penetrating 365 feet (111 m) of unconsolidated sediments, drilling had to be terminated because of sloughing of the sidewalls and resultant closure of the hole. No total thickness estimates are available for the Shady Formation.

Waynesboro Formation

The Waynesboro Formation consists of interlayered gray, brown, green, and red argillite and phyllite with interbeds of laminated to thin-bedded, light- to dark-gray dolomite and limestone, and minor amounts of tan, fine-grained, thin- to thick-bedded sandstone. It is partially exposed within the meander belt of South River from its confluence with Back Creek northward for a distance of approximately 4.5 miles (7.2 km) to the northeast side of Waynesboro (Plate 2). Much of the formation is covered by Quarternary sediments. As its lower contact is completely covered, no thickness estimates have been made.

Maroon phyllite and argillite beds are exposed along State Road 624 approximately 0.2 mile (0.3 km) southwest of its intersection with State Road 650 and are the oldest exposed Waynesboro rocks. Medium- to thick-bedded, irregularly dolomitized limestone and maroon phyllite form ledges in low bluffs along Back Creek and South River northeast of Lyndhurst and are the most accessible exposures of the predominantly carbonate section of the formation. Similar lithologies have been observed in drill cuttings from water wells at the DuPont plant on Delphine Avenue in southeastern Waynesboro. The rocks penetrated by these wells consist predominantly of dark-gray, fine- to medium-grained crystalline dolomite with lesser amounts of light-gray, crystalline limestone; intervals of yellowish-brown, weathered phyllite; minor amounts of pale-green, light-gray or mottled red and green phyllite or argillite; and white to buff metamorphosed sandstone.

Metamorphosed clastic rocks typical of the upper part of the Waynesboro Formation are exposed along the Chesapeake and Ohio Railway at the Florence Avenue bridge in Waynesboro (Figure 14). The upper 200 to 300 feet (61 to 91 m) consists predominantly of silty, maroon argillite, phyllite, and a few thin-bedded, fine-grained sandstone beds with cross-bedding, graded layers, and ripple marks. Siltstone ledges about 100 feet (30 m) east of the bridge contain brachiopods oriented with their convex side downward on the bedding surfaces. This is in agreement with the overturned position of the beds determined from cross-bedding and the nearly horizontal cleavage in the silty argillite. A sample of the maroon argillite from this locality (R-6572) has weak schistosity and a phyllitic sheen caused by minute flakes of sericite and microcline that are visible on freshly broken surfaces. X-ray analyses show the argillite contains crystalline quartz, muscovite, hematite, and microcline.

Figure 14. Metamorphosed clastic beds in the Waynesboro Formation along the Chesapeake and Ohio Railway at the Florence Avenue bridge in Waynesboro. Beds are inverted and have a southeasterly dip. Quarry in the Blue Ridge to the southeast was operated by the Chesapeake and Ohio Railway for ballast stone, which was brecciated Antietam quartzite.

The contact between the Waynesboro and the overlying Elbrook Formation is exposed along the railway tracks west of the Florence Avenue bridge, and is placed at the top of the uppermost clastic sequence containing massive, maroon argillite and phyllite. Immediately above these clastic rocks there is a dominantly dolomite interval approximately 100 feet (30 m) thick that represents the basal Elbrook Formation.

Two genera of small brachiopods were found in the clastic rocks of the uppermost Waynesboro Formation. *Acrotreta buttsi* was found in the Chesapeake and Ohio Railway cut just east of the Florence Avenue bridge in Waynesboro (F-934) and also at the southwest corner of the Hemlock Street-Highland Street intersection in Waynesboro. *Kutorgina* was identified in partially weathered exposures (F-935) near the southeastern corner of the Waynesboro West quadrangle. Also, stromatolitic algal features occur in the carbonate rocks.

Elbrook Formation

Lower member: The lower member of the Elbrook Formation is composed of laminated to thin-bedded, pale-green phyllite; laminated argillite; slaty dolomite; and interbedded laminated, fine-grained, buff to light-gray weathering, light- to dark-gray crystalline dolomite. Laminated, red, crenulated phyllite occurs locally about 20 feet (6 m) above the base. Stromatolitic algal-mat structures and well-defined cryptozoon, "cabbage-head" shaped algal masses are present.

The basal 100 feet (30 m) is well exposed in ledges along South River just downstream (east) from an old power dam, approximately 1,000 feet (305 m) west of Wayne Avenue in Waynesboro. Dolomite ledges in the riverbed are generally laminated to thin-bedded and contain thin, intraformational conglomerate beds near the base. A highly crenulated, laminated, red phyllite occurs in saprolite along the access road approximately 200 feet (61 m) north of the dam. Massive, finely laminated, dark-gray, crystalline dolomite beds in the upper part of the lower member are exposed along the city sewer line on the west bank of South River, between Lovers Lane and Meadowbrook Lane north of the Waynesboro Country Club. This member is estimated to be from 1,000 to 1,200 feet (305 to 366 m) thick.

Upper member: The upper member consists of fine- to medium-grained, characteristically orangish-yellow weathering, gray to dark-gray crystalline dolomite with phyllitic and slaty interbeds; some thin interbeds of dark-gray algal limestone; and a minor amount of clastic rocks. Stromatolitic algal-mat structures and cryptozoon, "cabbage-head" shaped algal masses are present.

Rock in the upper member is exposed approximately 330 feet (101 m) northeast of the intersection of State Highway 254 and State Road 799 (Plate 2). It consists of thin- to medium-bedded dolomite that ranges from approximately 6 to 36 inches (15 to 91 cm) in thickness. The fine-grained rock weathers yellowish brown and gray and is dark gray on freshly broken surfaces.

In the upper 500 feet (152 m) the crystalline dolomite is commonly associated with dark-brown to black, laminated, slaty interbeds from less than 0.4 to 4 inches (1 to 10 cm) thick (Figure 15); silty, dark-brown weathering, argillaceous dolomite; and rarely, thin-bedded sandstone. Limestone beds are most abundant in the interval between 1,000 to 1,500 feet (305 to 457 m) below the top of the formation. They are thin-bedded, fine-grained, dark gray, medium to light bluish gray weathering and are similar to limestone of the younger Conococheague Formation.

Figure 15. Slaty dolomite of the upper member of the Elbrook Formation approximately 0.75 mile (1.21 km) east of Ladd. Beds are overturned and inclined toward the southeast.

Sedimentary structures in the upper member include mud cracks on bedding surfaces in the dark slaty interbeds, ripple marks, and cross-bedding in sandstone layers and thin, flat pebble conglomerate beds in the limestone, all of which are generally characteristic of very shallow-water deposition.

The upper member is estimated to be about 1,800 feet (549 m) thick. The boundary between the Elbrook and the overlying Conococheague Formation is placed at the top of the thick sequence of yellowish brown to buff-weathering dolomite interlayered with distinctive black slaty beds that are commonly less than a foot (0.3 m) thick.

Conococheague Formation

The Conococheague Formation consists of dark-gray, fine-grained algal limestone alternating with ribbon-banded, thinly laminated limestone, flat-pebble limestone conglomerate, and light-brown weathering, laminated to thick-bedded dolomite and interbedded persistent thin beds of light-tan to brown, medium- to coarse-grained quartz sandstone. These rocks are interfolded with the upper member of the Elbrook Formation, and together they form a broad outcrop belt that can be traced across the Waynesboro West quadrangle (Plate 2). Northwest of Waynesboro, the persistent sandstone interbeds form a series of low, northeastward-trending ridges including Hickory Hill and Kiser Hill.

The ribbon-banded limestone characteristic of the formation is well exposed along the southeastern side of Bookerdale Road (State Road 1022) about 0.9 mile (1.4 km) south of U. S. Highway 250, and in several outcrops along State Road 1006 near the Waynesboro airport (Figure 16). The limestone beds form massive ledges and weather light gray with buff to light-tan lamellae along the closely spaced bedding planes. At the Bookerdale Road locality a steeply inclined penetrative cleavage is prominently developed along which 1- to 2-centimeter thick light and dark bands of limestone have been trans-

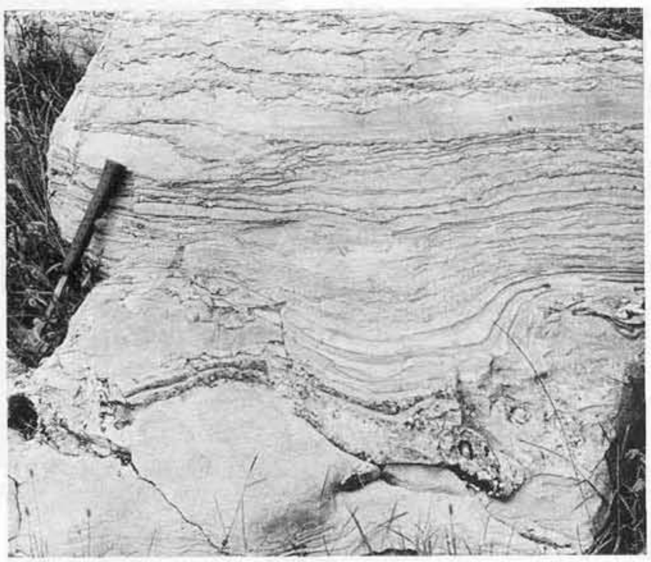


Figure 16. Ribbon-banded Conococheague limestone along the north side of U. S. Highway 340 about 2.6 miles (4.2 km) west of Ladd.

posed into small z-shaped folds. Where stretching was more intense, the smaller folds were further transposed to boudin structures along bedding planes. In contrast to these small tectonic features, accute, asymetric bedding folds in outcrops along the airport access road appear to be penecontemporaneous soft-sediment features. Both types of interformational folds are characteristic in the ribbon-banded limestone.

Thin sections and X-ray analyses of a ribbon-banded limestone sample (R-6576) show general recrystallization under conditions of low-grade regional metamorphism. The dark-gray limestone layers consist of calcite with trace amounts of microcline, quartz, dolomite, chlorite, and mica. The buff-weathering lamellae contain calcite, dolomite, quartz, microcline, and a trace of chlorite.

The sandstone interbeds are poorly exposed, and were mapped on the basis of scattered aligned outcrops such as those on the low ridge north of the Chesapeake and Ohio Railway, approximately 0.3 mile (0.5 km) northwest of the intersection of State Road 640 and 795. They are generally less than a foot thick, but float blocks that persist in the sandy, residual soils along ridgetops can usually be traced between outcrops. Some of the sandstone (R-6590) is recrystallized to a fine-grained quartzite.

Weathered sandstone beds are generally porous where carbonate cement has been dissolved (R-6573) and are stained tan or reddish orange by iron oxides. Where silica cement is present the beds are quartzite and argillaceous material has been recrystallized to white mica.

Stromatolitic-algal and algal-mat features that trapped silty and silicous sediment and persisted after recrystallization are common and prominent in Conococheague outcrops. Similarly, small burrow features are abundant. Spine-like fragments and part of the cephalon of a tricrepicephalous-type trilobite were recognized on a bedding surface.

The thickness of the Conococheague Formation is estimated to be about 1,600 feet (488 m). The contact with the overlying Chepultepec Formation is conformable and gradational over a stratigraphic interval of less than 100 feet (30 m), which is seldom well exposed. Below the contact unfossiliferous, ribbon-banded limestone beds typical of the Conococheague are abundant; similar limestone occurs only sparsely in the Chepultepec Formation.

ORDOVICIAN SYSTEM

Chepultepec Formation

The Chepultepec Formation consists of fine-grained, dark-gray to bluish-black, thick-bedded limestone that commonly contains nodular, black chert. Interbedded in the limestone are a few thin, laminated, orangish-yellow weathering, fine- to medium-grained, light- to dark-gray dolomite strata. Siliceous laminae are abundant in the lower part. The thickness of the formation is estimated to be less than 400 feet (122 m).

The Chepultepec Formation underlies a narrow, gently sloping valley between discontinuous, steep, dolomite-chert ridges of the overlying Beekmantown Formation and the low sandstone ridges of the underlying Conococheague Formation. The outcrop belt can be traced from just south of Cave Hill northeasterly to the west side of Kiser Hill (Plate 2).

Thick-bedded strata are common in the lower and middle parts of this unit, the more massive portions exposed in conspicuous, chalky, white outcrops. The most accessible outcrops are on the east side of State Road 635, about 1.2 miles (1.9 km) north of U. S. Highway 340. Here, the massive gray limestone is gently inclined and interlayered with thin, serrated laminae, some containing nodules of chert (Figure 17). Cleavage is inclined moderately to the southeast, and in some places the laminae have been displaced along cleavage planes. Coiled cephalopods (*Dakeoceras* sp. and *Levesoceras* sp.) are well preserved along bedding planes.

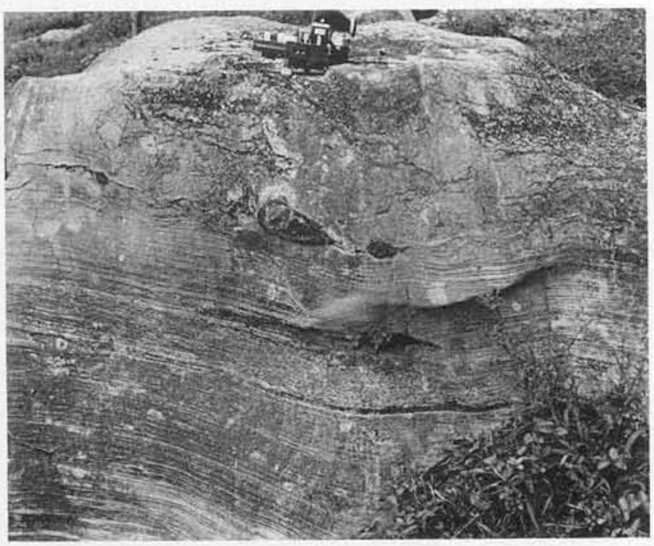


Figure 17. Chepultepec limestone in pasture approximately 0.8 mile (1.3 km) southwest of Cave Hill.

The upper part of the formation consists of thin-bedded silty limestone with a few thin dolomite layers. The limestone weathers medium to light gray and is characterized by coarse fossil fragments, flat pebble conglomerate, dessication cracks, and purple silty laminae; it contains the brachiopod *Finkelnburgia* sp.

The conformable contact with the overlying Beekmantown Formation is exposed in a field south of Cave Hill, and appears to be somewhat abrupt or to grade over a shorter stratigraphic interval than the transitional contacts between older carbonate units. This contact is mapped at the lithologic change from thin-bedded, fossiliferous limestone (Chepultepec) to thick-bedded dolomite and limestone (Beekmantown). A distinctive, coarsely crystalline, massive dolomite is commonly exposed at this boundary.

Additional fossils are the gastropods *Eccyliomphalus* sp., *Ophileta* sp., and *Helicotoma* sp. Stromatolitic algae and algal-mat features are common.

Beekmantown Formation

Dark-gray laminated limestone similar to underlying Chepultepec limestone is regularly interbedded with thick beds of gray, medium- to coarse-grained, thick-bedded dolomite in the lower part of the Beekmantown Formation. Massive beds of light- and dark-gray dolomite with interbedded chert comprise the middle part, which constitutes about two-thirds of the formation. Dove-gray, micritic limestone similar to the overlying New Market Limestone is interbedded with light-gray, fine- to medium-grained dolomite in the upper part of the formation. Dark-gray dolomitic marble is common at the basal contact.

The outcrop belt (Plate 1) ranges in width from 0.6 mile (1.0 km) at Cave Hill to 1.2 miles (1.9 km) at Fishersville where its surface exposure has been doubled by folding. The maximum stratigraphic thickness is estimated to be greater than 3,000 feet (914 m) from exposures across the northeast end of Cave Hill.

The interbedded limestone and dolomite in the lower part of the formation can be seen in a barnyard on the northeastern end of Cave Hill. Coarse, crystalline dolomite (dolomitic marble) comprises the basal bed south of Cave Hill (R-6589) and contains a mineral assemblage of dolomite, calcite, chlorite, and quartz which serves as an indicator of low-grade regional metamorphism.

In the massive middle part of the unit thin lenticular bodies of chert form elongate hills and discontinuous ridges from Cave Hill northeast to the Chesapeake and Ohio Railway. This is the characteristic topographic expression of the formation where steeply dipping fold limbs are present; a more undulating topography of lower relief occurs where the outcrop belt contains fold crests and troughs such as in the area around Kidville. The best exposure of this part of the formation is in the Interstate Highway 64 roadcut through Gibson Hill. Of the 800 feet (243 m) of measured outcrop on the north side of the Interstate, the easternmost 700 feet (213 m) is entirely dolomite and chert. The westernmost (stratigraphically younger) 100 feet (30 m) contains dolomite with interbedded limestone.

Interlayered limestone and dolomite that characterize the upper part of the Beekmantown Formation are exposed in the abandoned Vulcan Materials quarry on the northwest side of Cave Hill. Massive, compact, very fine-grained interbeds of limestone similar to New Market limestone are evident as much as 300 feet (91 m) below the top of the formation. A whole-rock X-ray analysis of the dominant dolomite lithology (R-6574) shows 70 percent dolomite and 30 percent calcite. The mineral dolomite in the sample has a 1:1 ratio for $CaCO_3$:$MgCO_3$.

The Beekmantown Formation is fossiliferous, particularly in the interbedded limestone and dolomite sections of its lower and the upper parts from which cephalopods (*Cambelloceras* sp., *Dakeoceras* sp., *Ceratopea* sp.), gastropods (*Lecanospira* sp., *Eccyliomphalus* sp., *Maclurites* sp., *Hormatoma* sp.), and brachiopods (*Finkelnburgia* sp.) were identified. Stromatolitic algal features and lamination resembling algal-mat features are common, as is the mottled dolomitic limestone that may be of algal origin (Swett and Smit, 1972). Intensely burrowed beds (Figure 18) of limestone with dolomite or dolomite with chert replacement of burrows also occur in the formation.

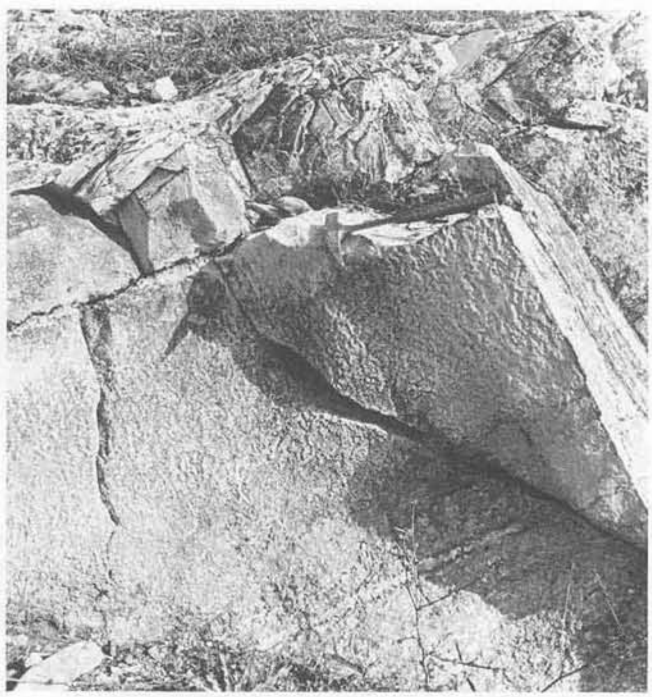


Figure 18. Beekmantown Formation with thick interbed of burrowed, dolomitic limestone.

The upper contact of the Beekmantown Formation is placed at the top of the uppermost thick dolomite bed that is overlain either by massive, fine-grained New Market Limestone or by coarse, angular limestone and dolomite cobble conglomerate deposited on the eroded surface of the unconformity between the Beekmantown and the New Market.

New Market Limestone

The New Market Limestone is composed of dove-gray, massive micritic limestone that is exposed discontinuously in a narrow, sinuous belt from just northwest of Cave Hill northeastward to the intersection of State Roads 608 and 796 (Plate 2). On the crest of a small anticline north of Tinkling Springs Church the New Market consists entirely of coarse, angular limestone and dolomite cobble conglomerate (Figure 19) less than 5 feet (2

Figure 19. Angular polymictic conglomerate of the New Market Limestone separates the Beekmantown and Martinsburg formations near the crest of an anticline. Dolomite clasts up to a foot in length and large gray limestone clasts in a fragmental limestone matrix in fields 600 feet (183 m) northwest of the intersection of State Roads 636 and 608 southwest of Fishersville.

m) thick, and is directly overlain by slates of the basal Martinsburg Formation. The maximum thickness of New Market Limestone is approximately 60 feet (18 m) on the southeastern limb of a syncline near Cave Hill. Because of the unit's very narrow, locally discontinuous outcrop pattern and because it has not been identified north of the intersection of State Roads 608 and 796, the New Market Limestone is shown on Plate 2 in combination with the overlying Lincolnshire Formation.

Typical New Market limestone is well exposed in a farmyard southeast of State Road 608 about 0.7 mile (1.1 km) south of Fishersville. The rock is very dense, high-calcium limestone that breaks with a conchoidal fracture, characteristically develops a conspicuous chalky, white film on weathered surfaces, and commonly contains zones and stringers of sparry calcite. A thin section from this locality (R-6580) shows that the parent lime mud has been totally recrystallized, producing a patchy microtexture and veins of sparry calcite that obliterate primary features in the rock.

The upper contact between the New Market Limestone and the overlying Lincolnshire Formation is placed at the bottom of either the oldest bed of typical dark-gray cherty Lincolnshire limestone or the oldest bed of gray bioclastic limestone.

Lincolnshire Formation

The Lincolnshire Formation consists of dark-gray, medium-grained, medium- to thick-bedded limestone with abundant black nodular chert and thin, irregular pink or brown partings. Gray to dark-gray, massive, coarsely crystalline, abundantly fossiliferous, bioclastic limestone is present locally. The thickness of the formation ranges from approximately 140 feet (43 m) along Goose Creek southeast of Tinkling Springs Church to nothing where it is locally absent such as on the crest of the anticline north of Tinkling Springs Church.

The cherty limestone is predominant on the southeastern limb of a small syncline where the formation has a positive topographic expression characterized by the low, elongate ridges just northwest of Cave Hill and Gibsons Hill. Typical outcrops of this lithology can be seen in a farmyard (Figure 20) on the east side of Goose Creek,

Figure 20. Lincolnshire limestone north of Interstate Highway 64, 0.2 mile (0.3 km) south of Tinkling Springs Church.

approximately 0.2 mile (0.3 km) south of Tinkling Springs Church where exposures have medium- to light-gray weathered surfaces on which black chert nodules stand out in relief. Stratification is commonly defined by irregular, pink or brown, silty laminae and by aligned chert nodules.

The bioclastic limestone is predominant as isolated masses at the crest of the small anticline north of Tinkling Springs Church and continuously northeasterly along the northwestern limb of the anticline to as far as the northern boundary of the Waynesboro West quadrangle. This lithology is well exposed on the northeast side of State Road 608, approximately 300 feet (91 m) northwest of its intersection with State Road 796. The rock (R-3164) contains abundant fossil fragments that have weathered out in relief, giving the massive, gray beds a rough, irregular surface. A polished section of another sample (R-6588) consists of more than two-thirds pink and gray, detrital calcite granules (2 to 4 mm) with grain-to-grain contact, and less than one-third sparry calcite cement.

Only a few fossil brachiopods and bryozoans were found in the cherty limestones, but fragments of fossil crinoids and bryozoans comprise a significant part of the bioclastic limestone. Dark-gray, rubbly-weathering, bioclastic limestone (R-6577) at the house just southwest of the Tinkling Springs Church contains abundant bryozoan debris, coiled cephalopods, and trilobite fragments.

The upper contact of the Lincolnshire Formation is placed at the base of the oldest, dark-gray to black graptolitic slate of the overlying Martinsburg Formation. The graptolitic slate that occurs at this stratigraphic horizon is clearly part of the overlying clastic sequence of the Martinsburg Formation (personal communication, E. K. Rader, 1976).

Martinsburg Formation

The Martinsburg Formation has been subdivided into three lithologic units: a basal black-slate unit ("c" on Plate 2), an overlying slate-argillite-limestone unit ("a" on Plate 2), and an upper sandstone-slate unit ("s" on Plate 2). The uppermost part of the formation is not present. The black, calcareous slate beds mapped as the Edinburg Formation in the adjacent (west) Stuarts Draft quadrangle (Rader, 1967) are included in the base of the Martinsburg Formation in this report. It is estimated that the Martinsburg is between 1,800 and 2,600 feet (549 and 792 m) in thickness in the mapped area, but the uppermost part is not present.

The basal black slate (unit "c") consists of dark-gray to black calcareous slate (Figure 21). It occurs in a sinuous outcrop belt from the headwaters of Goose Creek

Figure 21. Calcareous black slate (unit "c") of the Martinsburg Formation in a roadcut approximately 0.3 mile (0.5 km) west of the Interstate Highway 64-State Road 608 interchange.

northeastward through Fishersville and along Meadow Run (Plate 2). The black slate characteristically forms low, steep-sided ridges such as those northeast of Fishersville and southwest of Tinkling Springs Church. The slate is exposed on either side of State Road 608 just east of its intersection with State Road 635, 1.1 miles (1.7 km) southwest of Tinkling Springs Church. Bedding appears as a prominent lineation on slaty cleavage planes and freshly cleaved specimens have a well-developed sheen on the cleavage surface because of the parallel orientation of finely crystallized white mica and chlorite. A second lineation is delineated by crests and troughs of crenulations on the cleavage surfaces and appears to be unrelated to the bedding-cleavage intersection. At other localities bedding is delineated as a fine lamination. An X-ray analysis shows the black slate (R-6803) is composed of fine-grained calcite, quartz, mica, and chlorite. The dark coloration seems to be imparted by finely divided carbonaceous material. The thickness of the black slate unit ranges from approximately 100 to 300 feet (30 to 91 m). Graptolites (*Climacograptus* sp.) occur in exposures (R-6805) where cleavage has not transposed the bedding surfaces. The contact between the black slate unit ("c") and the overlying unit ("a") is placed at the gradational change from thin-bedded black slate to thin- to medium-bedded, fine-grained, dark-gray calcareous slate, thin argillite, and argillaceous limestone.

Unit "a" consists of very thin to medium-bedded, dark-gray to black calcareous slate alternating with tan-weathering argillite and dark-gray argillaceous limestone. Outcrops are present along Goose Creek and Meadow Run west of Fishersville and just east of the Woodrow Wilson Educational Center. The typical dark-gray calcareous slate and thin, tan-weathering argillite beds are exposed along State Road 636 about 0.6 mile (1.0 km) west of its intersection with State Road 608

Figure 22. Calcareous slate and thin argillite beds of unit "a" of the Martinsburg Formation along State Road 636 about 0.6 mile (1.0 km) west of State Road 608.

(Figure 22). A few beds of black limestone (R-6804), 6 inches (15 cm) thick, are present. Thin section and X-ray analyses of the slate (R-6548, R-6582) show approximately two-thirds of the rock is composed of calcite and quartz in a ratio of 2 to 1; about a third is chlorite and muscovite, with trace amounts of dolomite. The slate is generally lighter in color than that of the basal unit "c" and has a more highly developed, regular, planar schistosity and a fine sheen due to the metamorphic growth of parallel microscopic laths of mica and chlorite. Unit "a" is estimated to be 1,500 to 2,000 feet (457 to 610 m) thick and is in contact with the overlying unit "s" at the base of the thick-bedded lithic sandstone sequence that forms a prominent northeastward-trending ridge west of Fishersville.

The base of unit "s" consists of thick-bedded, brown-weathering, bluish-gray, medium-grained, metamorphosed lithic sandstone alternating with thin-bedded, dark-gray to black calcareous slate. The unit is well exposed along the Chesapeake and Ohio Railway just west of the State Road 636 underpass. Thick-bedded, gray- to brown-weathered, metamorphosed lithic sandstone (graywacke) interlayered with black calcareous slate is well exposed in the core of a small syncline approximately 0.2 mile (0.3 km) northwest of the underpass (Figure 23). The sandstone (R-6585) has a coarse, fragmental texture with black-slate pebbles greater than 30 mm in length that appear to float in the fine-grained, gray, metamorphosed matrix. Another part of this sequence is exposed along a tributary stream that enters Christians Creek near the sewage-disposal plant approximately 0.4 mile (0.6 km) northwest of the Woodrow

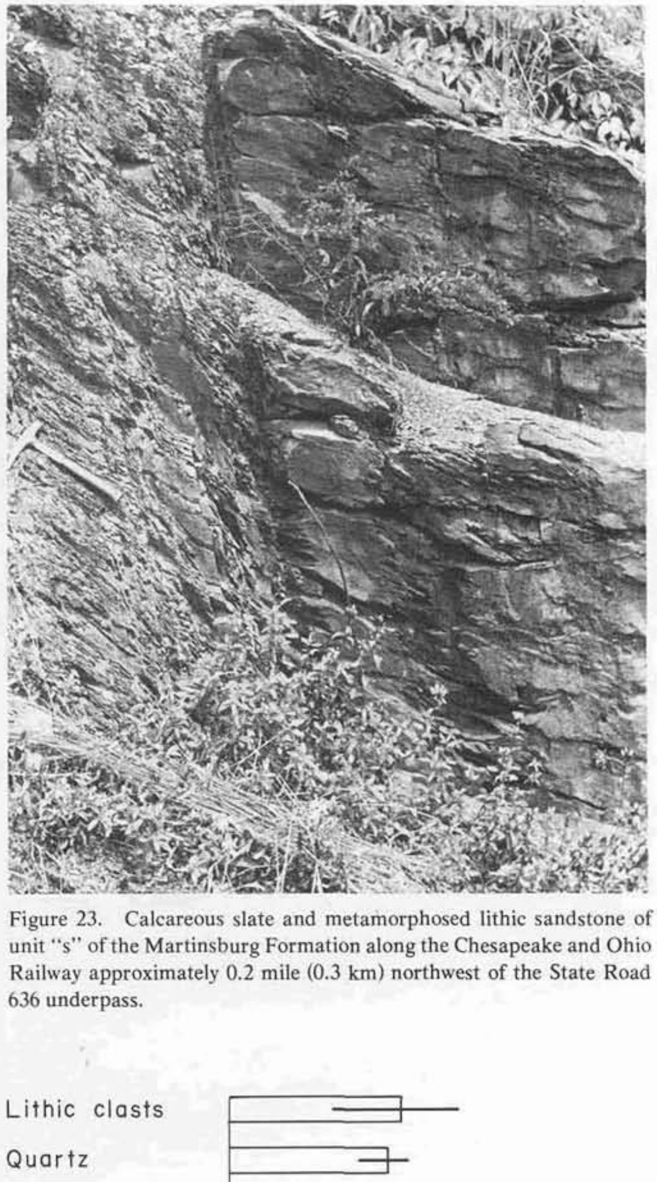


Figure 23. Calcareous slate and metamorphosed lithic sandstone of unit "s" of the Martinsburg Formation along the Chesapeake and Ohio Railway approximately 0.2 mile (0.3 km) northwest of the State Road 636 underpass.

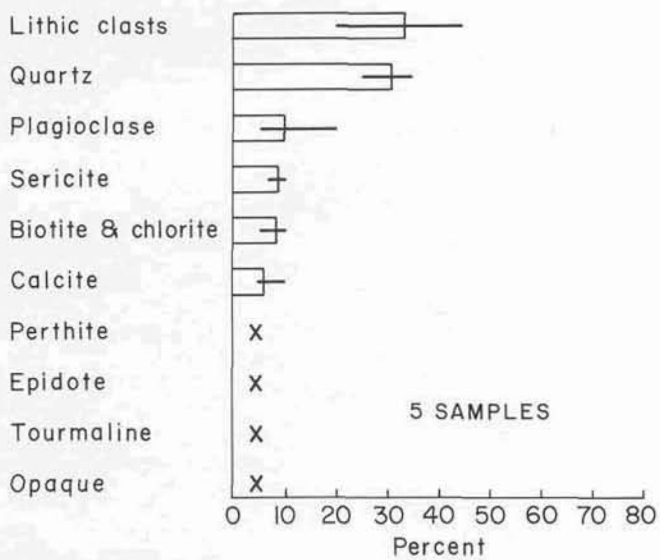


Figure 24. Mineral composition ranges (lines) and averaged estimated composition (bars) of metamorphosed lithic sandstone from the Martinsburg Formation. Minerals in amounts less than 5 percent indicated by x.

Wilson Educational Center. At this locality medium to very thick bedded, bluish-gray, medium-grained lithic sandstone is interstratified with very thin to medium-bedded slate and argillite. Thin sections of the sandstone (R-5543, R-5544, R-6585, R-6586, R-6587) contain about 31 percent quartz, 34 percent rock fragments, 10 percent feldspar, and 25 percent fine-grained, recrystallized matrix consisting of sericite, chlorite, biotite, carbonate, epidote, tourmaline, and pyrite (Figure 24). One linguloid brachiopod was observed in the bottom of a small hollow, approximately 800 feet (244 m) north of the sewage disposal plant west of the Woodrow Wilson Educational Center. The upper contact of unit "s" does not occur within the Waynesboro West quadrangle; the portion of this unit that is present is estimated to be no greater than 300 feet (91 m) thick.

CATACLASTIC ROCKS

Cataclastic rocks consist of medium- to coarse-grained, light- to dark-gray protomylonite, mylonite

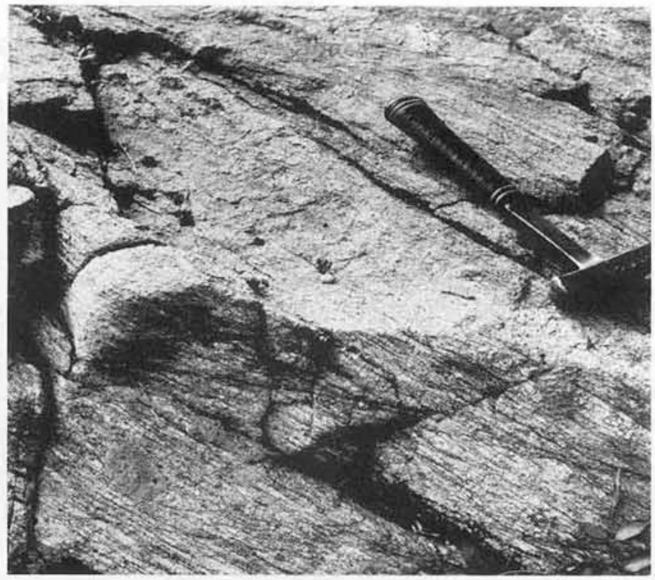


Figure 25. Protomylonite along stream on Mount Armor Farm, about 0.7 mile (1.1 km) east of Avon.

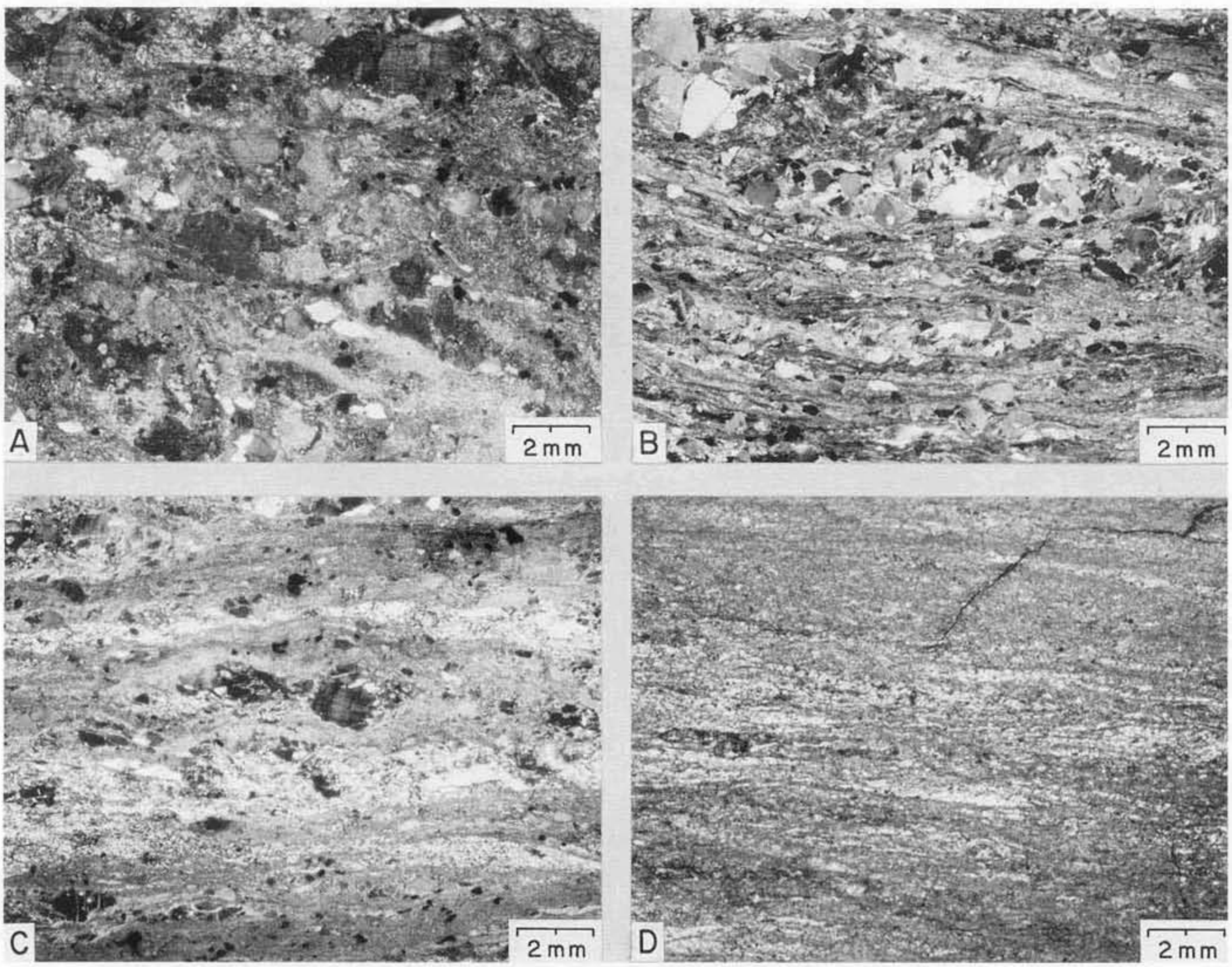


Figure 26. Photomicrograph showing textural gradation between coarser and finer grained cataclastic rocks. A. Mylonitic biotite gneiss (R-6523). B. Protomylonite (R-6526). C. Blastomylonite (R-6533). D. Phyllonite (R-6534). Cross-polarized light.

gneiss with locally prominant interlayers of light- to silvery-gray or dark-gray mylonite schist, blastomylonite, and phyllonite. Protomylonite is the most common rock type in the unit and it is well exposed in rock cliffs for more than a mile along Stockton Creek southeast of U. S. Highway 250 (R-6525, R-6526). Another area of good exposures is along the small stream (R-6527) approximately 0.7 mile (1.1 km) east of Avon.

Protomylonite is distinguished in the field by its well-developed lamination, the abundance of rounded porphyroclasts of feldspar and blue quartz 1 to 5 mm in diameter, which give the outcrop a rough, bumpy surface and its gross similarity to a well-bedded, but metamorphosed, sandstone sequence (Figure 25). The porphyroclasts are within a schistose matrix of finely crushed sericite, quartz, epidote, and ilmenite that comprise less than 50 percent of the rock. The protomylonite . . . "resembles conglomerate or arkose on weathered surfaces . . ." (Higgins, 1971, p. 7) and fluxion structure is visible in outcrop and thin section (R-6527, R-6528, R-6529, R-6530, R-6531).

At some localities the protomylonite is conspicuously interlayered with finer, more schistose cataclastic rocks such as blastomylonite (R-6532, R-6533) and phyllonite (R-6534). Good examples of such interlayers occur in ledges along Yellow Mountain Creek on Rose Hill Farm for a distance of approximately 750 feet (229 m) east from State Road 691. Where the schistose rocks are exposed in saprolite cuts, such as in side ditches along State Road 692 about 0.5 mile (0.8 km) southeast of its intersection with U. S. Highway 250, they resemble phyllitic beds within a layered metasedimentary sequence.

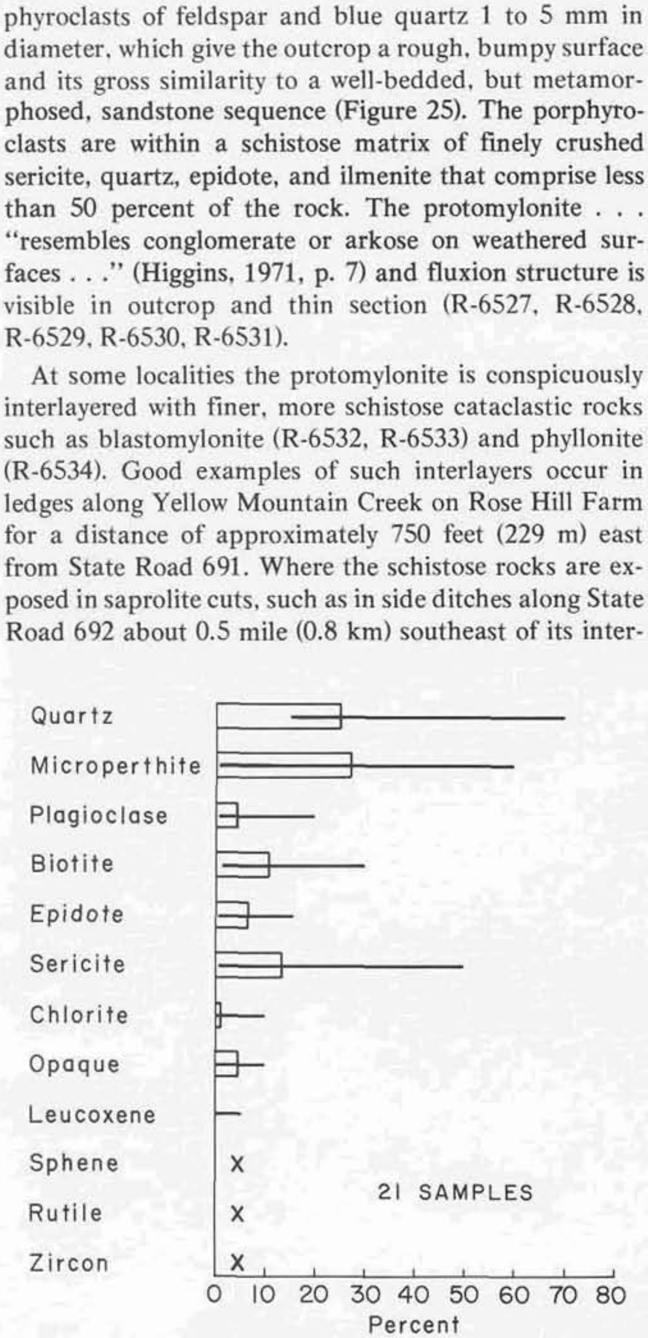


Figure 27. Mineral composition ranges (lines) and averaged estimated composition (bars) of cataclastic rocks. Minerals in amounts less than 5 percent indicated by x.

Phyllonitic layers are also prominantly developed in the cataclastic rocks along the northwestern and southeastern margins of the granodiorite gneiss body that forms Turks Mountain and Round Top. The textural gradation between the coarser, more granular cataclastic gneiss and the finer-grained, more micaceous layers (Figure 26) seems to reflect a progression in the intensity of shearing.

The mineral composition of the cataclastic rocks (Figure 27) is generally that of a granite, and is similar to the composition of the Lovingston mylonitic biotite gneiss (Figure 2). Their mineralogical differences (higher percentages of free quartz, sericite, epidote, and chlorite and lower percentages of free plagioclase and nonaligned coarse biotite in the cataclastic gneiss) suggest transformation of Lovingston into cataclastic gneiss by shearing accompanied by regional retrograde metamorphism in Paleozoic time.

TRIASSIC SYSTEM

Diabase Dikes

Nearly vertical north-northwestward-trending dikes of fine- to medium-grained, dark greenish gray to black diabase have intruded the Precambrian and Paleozoic rocks. Individual dikes are less than 15 feet (5 m) wide and their linear extent is undetermined because of the lack of continuous exposure. Southeast of the Blue Ridge they have been mapped on the basis of a characteristic red clayey soil such as is exposed on the north side of State Road 637, 600 feet (183 m) southeast of Critzers Shop (Plate 1), and by rounded, exfoliated boulders in the residuum. Between rare exposures in the Blue Ridge and the Shenandoah Valley to the northwest the dikes have been traced almost exclusively on the basis of boulders. A good exposure of a thin, fine-grained dike in the Catoctin Formation crops out along Interstate Highway 64 approximately 0.7 mile (1.1 km) northeast of the Albemarle County-Nelson County boundary (Figure 28, Plate 1). A dike in the Elbrook Formation is well exposed on the southeastern side of State Road 782, approximately 0.7 mile (1.1 km) northeast of the road's intersection with State Highway 254 (Figure 29, Plate 2).

The composition of the diabase dikes seems to be generally uniform throughout the area. A sample from the dike along Interstate Highway 64 (R-6562) is fine-grained and consists of narrow labradorite laths that are partly enclosed by augite crystals. A thin section contained minor amounts of olivine and biotite, and showed that veins of serpentine and scattered flakes of chlorite are alteration products. The dikes clearly postdate Paleozoic tectonic events and are considered Triassic or younger in age.

Figure 28. Diabase dike in the Catoctin Formation on the northwest side of Interstate Highway 64, 0.75 mile (1.21 km) east of the Nelson County-Albemarle County boundary.

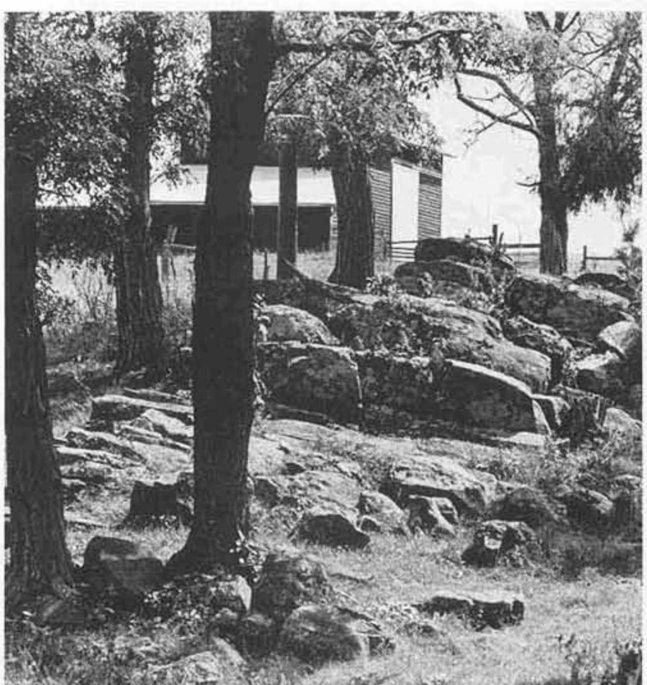


Figure 29. Diabase dike in the Elbrook Formation, viewed from State Road 782 approximately 0.5 mile (0.8 km) northeast of the road's intersection with State Highway 254.

QUATERNARY SYSTEM

The surficial deposits are grouped into five broad categories: (1) high-level terrace and alluvial-fan deposits above maximum flood levels of present drainages, (2) talus deposits composed of unconsolidated material of varying size on and at the base of steep slopes, (3) upland alluvium in steep valleys on each side of the Blue Ridge, (4) lowland alluvium of flood plains along present drainages, and (5) residual soils. Category 5 is described in the section on Environmental Geology.

Terrace and alluvial-fan deposits

The South River and Back Creek flood plains are generally bordered by broad, flat terraces of flood-plain and alluvial-fan deposits older than those along present streams. Terraces northwest of South River consist of older, incised flood-plain deposits, and those southeast of the river are mostly formed from the incised toes of large alluvial fans. The deposits exposed in the terraces are stratified and composed of unconsolidated boulders, cobbles, other gravel, and sand (Figure 30) derived mostly from resistant quartzite strata in the Blue Ridge. The coarser material generally is in a matrix of red clay and silt derived from the weathering of metabasalt and phyllite. Small fans and terraces in the Blue Ridge (Plate

Figure 30. Terrace deposits on Antietam saprolite at Wenonah School in Waynesboro.

2) are composed of coarse material derived from bedrock in the immediate vicinity of the deposits.

Large alluvial-fan deposits are present between South River and Back Creek southwest of Lyndhurst (Plate 2) and east of South River northeast of Waynesboro (Plate 1). These deposits are similar to those exposed in the terraces, but are of much greater thickness near the foot of the Blue Ridge. Sinkholes and water-filled depressions in these deposits suggest that solution of underlying carbonate strata has formed irregular depressions in the bedrock surface. These bedrock depressions are now filled with alluvial material having a minimum thickness shown by the following drill-hole data. Northeast of Waynesboro near the west foot of the Blue Ridge, stratified sand, clay, and coarse quartzite debris were penetrated to depths of 118.5 feet (36.1 m) and 166.7 feet (50.8 m) in two exploration drill holes located on State Road 619 approximately 1,700 feet (518 m) and 2,100 feet (640 m) respectively, north of the intersection of State Roads 619 and 611. A third exploration drill hole, located on the north shoulder of State Road 621 approximately 600 feet (183 m) west of its eastern terminus, encountered sand, clay, and coarse quartzite debris to a depth of 365.0 feet (111.3 m). At all three sites drilling was terminated due to collapse of the drill-hole sidewalls before bedrock was reached. A domestic water well on the north side of State Road 621 approximately 2,400 feet (732 m) east of its intersection with U. S. Highway 340, was terminated at a depth of 500 feet (152 m) without reaching bedrock (personal communication, Gary Burner, Burner Well Drilling Co., McGaheysville, Virginia, June 1976). Little data are available to sustantiate thickness estimates of the fan deposits southwest of Lyndhurst, but it is probable these materials are at least 75 feet (23 m) thick where underlain by calcareous rocks.

The alluvial-fan deposits along the east foot of the Blue Ridge consist of angular metabasalt and granodiorite gneiss cobbles up to a foot in diameter with a matrix of gravel, sand, and red clay. These deposits range up to 30 feet (9 m) in thickness and are the result of major storms that have flushed debris down the mountain. The resultant deposits are poorly stratified, contain slightly rounded blocks of metabasalt, and have been incised by streams to form terraces.

Talus deposits

Small concentrations of talus occur at the base of almost every escarpment in the Blue Ridge and along the bottom of large excavations made during construction of Interstate Highway 64. Extensive talus fields are present on the west side of the Blue Ridge at the base of steep Antietam quartzite ridges. These unconsolidated deposits consist of cobbles, boulders, and angular quartzite blocks in a sand matrix. Rock fragments range from less than an inch (2.5 cm) to more than 25 feet (8 m) in size and comprise deposits as much as 25 feet thick.

Upland alluvium

Coarse material that has been recently deposited by fluvial transport in the narrow, steep hollows and stream valleys on the flanks of the Blue Ridge consists of angular blocks and slightly rounded cobbles, boulders, and other gravel in a sand matrix. On the west side the upland

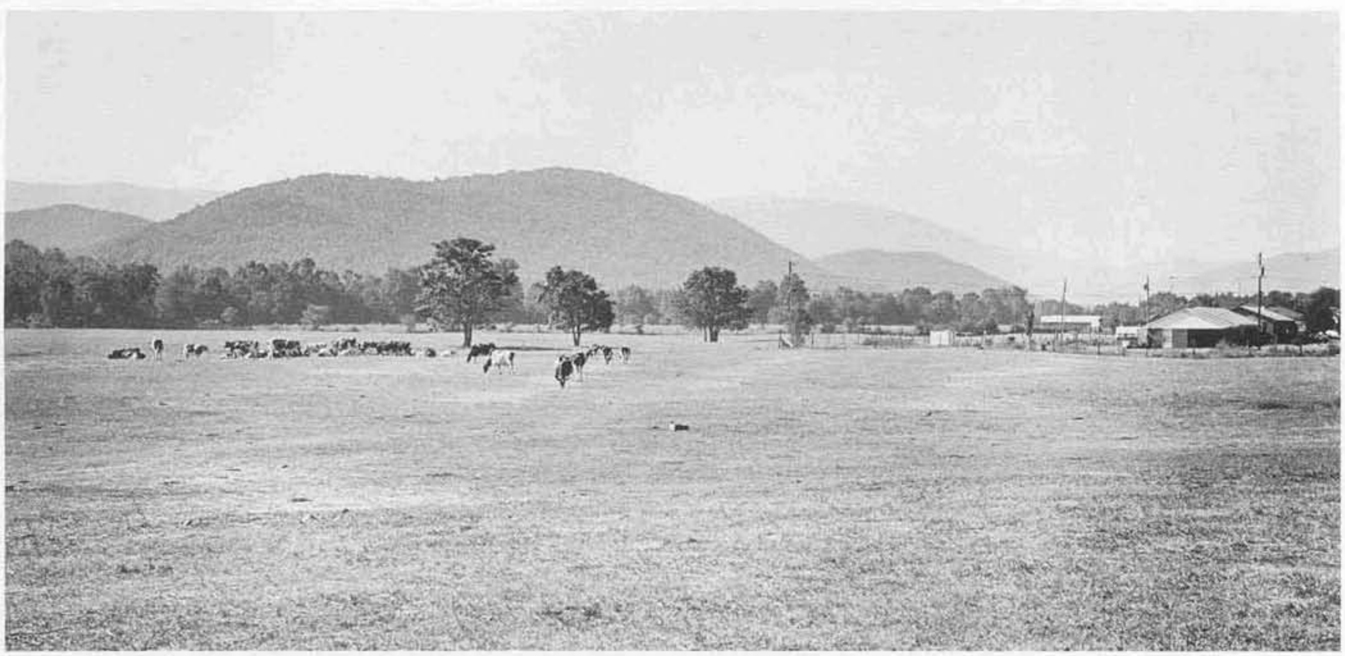


Figure 31. Flood plain of Back Creek; view from bluff approximately a mile east of Lyndhurst.

alluvium is a mixture of quartzite, sandstone, and metabasalt; on the east side the deposits are comprised of metabasalt, phyllite, and gneiss. Downslope fluvial transport and weathering have reduced the size and angularity of the rock material, and near the foot of the Blue Ridge the deposits are as thick as 15 feet (5 m) locally. It is probable that these materials are "flushed out" of the valleys by periodic storms, and the unsorted, outwashed debris is added to the terrace and fan deposits mentioned earlier (Virginia Division of Mineral Resources, 1969; Webb, Nunan, and Penley, 1970). The contact between the upland and lowland alluvium is gradational.

Lowland alluvium

Flood-plain and low-level terrace deposits occur along the South River and Back Creek drainages (Figure 31). These deposits range from 0 to 15 feet (0 to 5 m) in thickness and are composed of gravel, brown-quartz sand and silt, and varying amounts of clay; large quartzite cobble and other gravel beds are commonly present at the base. Smaller lowland alluvial deposits occur along Stockton, Stockton Mill, Andersons, and Williams creeks (Plate 1). Metabasalt and gneiss cobbles are common although sand, silt, and clay comprise the bulk of the deposits.

STRUCTURE

The major geologic structures are the complexly folded west flank of the Blue Ridge anticlinorium and the east flank of the Massanutten synclinorium. Along the east foot of the Blue Ridge (Plate 1) a broad zone of cataclastic gneiss and phyllonite forms a thrust sheet that is bounded on the northwest by the Rockfish Valley fault (Bartholomew, 1977), which separates the cataclastic rocks from metamorphosed plutonic, volcanic, and sedimentary rocks of the Blue Ridge.

A zone of brecciation, faulting, and chaotic structure is present in the Cambrian clastic rocks at the west foot of the Blue Ridge. The western boundary is delineated by the westernmost exposures of the Antietam Formation (Plates 1, 2) and has been interpreted as the trace of a thrust fault in other reports. Whereas a thrust fault may be concealed along this boundary, the apparent stratigraphic displacement and associated fracturing can also be explained as solution and collapse features. Small-scale folds and small-displacement vertical faults are visible in the layered rocks. Joints, cleavage, or schistosity are present in all rock types.

FOLDS

Large-scale folding of the layered rocks can be accurately traced in much of the area. From northwest to southeast across the Waynesboro West and Waynesboro East quadrangles (Plates 1, 2) the southeastward-dipping axial planes of the folds become more gently inclined as the fold forms gradually change from asymmetric to overturned. Large-scale isoclines are present in the Blue Ridge and eastern part of the Shenandoah Valley in all parts of a 4-mile-wide belt of rocks west of the Rockfish Valley fault. Small-scale folds, generally visible only in roadcuts and quarries, appear to mirror the configuration and plunge of the large-scale folds. Small-scale isoclinal folds are exposed in several quarries and borrow pits in the Antietam Formation between Interstate Highway 64 and the northern city limits of Waynesboro (see front cover), in the Harpers and Weverton formations along the Chesapeake and Ohio Railway between U. S. Highway 250 and the north portal of the Blue Ridge Tunnel, and in the Catoctin Formation along Interstate Highway 64 between Rockfish Gap and Newtown at the east foot of the Blue Ridge (Figure 32).

Lower Hemisphere, equal-area projections of the poles to bedding surfaces in the Waynesboro East quadrangle

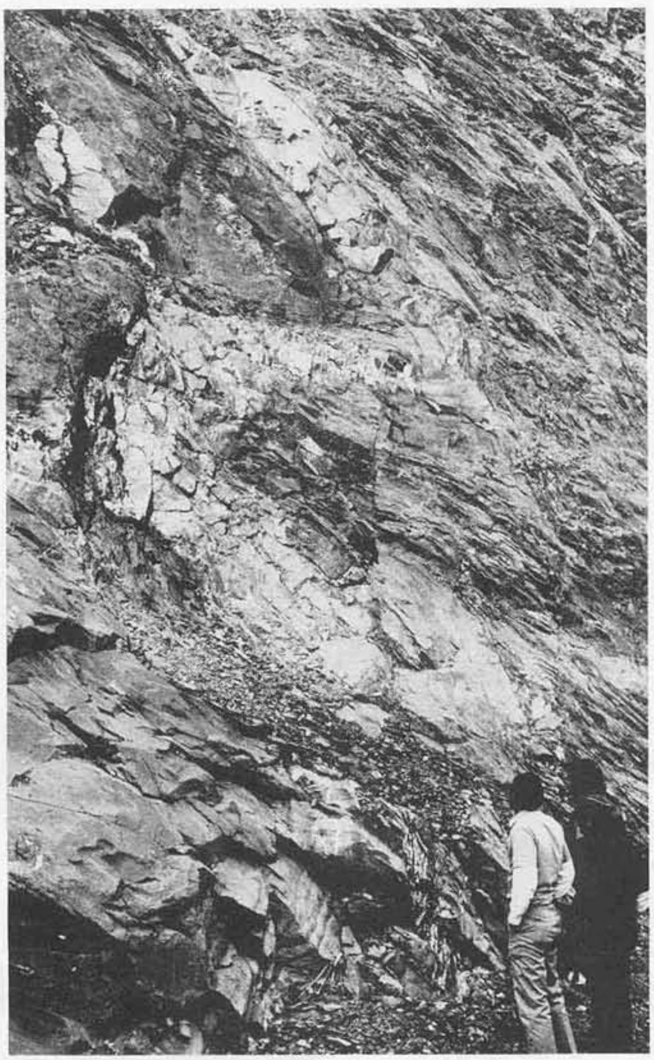


Figure 32. Small-scale fold in the Catoctin Formation along Interstate Highway 64. Fold is delineated by a fractured and partly epidotized metasandstone bed.

(Figure 33, A) show that most beds are gently inclined to the southeast. A similar projection (Figure 33, B) shows that the cleavage is generally more gently inclined to the southeast than the bedding, which implies that the bedded rocks are mostly inverted with their original upper surfaces facing downward to the northwest. These data also show that the fold axes have an 8° plunge to the southwest which corresponds closely to plunge data obtained directly from small-scale folds in the Catoctin and Lower Cambrian clastic rocks. To the southwest the plunge of fold axes is reversed showing a broad transverse downwarping of the fold axes in the Waynesboro area.

The foliation in bedded slate and phyllite is roughly parallel to the axial planes of the folds. The presence of metamorphic biotite in the Lower Cambrian clastic rocks seems to be best developed in the overturned, strongly cleaved, and attenuated fold limbs. The distribution of upright, overturned, and recumbent fold limbs in the two quadrangles is shown in Figure 34.

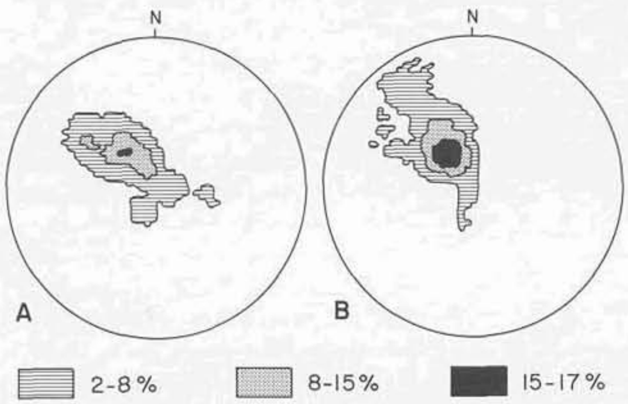


Figure 33. A. Pi diagram for bedding from the Waynesboro East quadrangle. Diagram shows 201 poles to bedding surfaces, machine-plotted and -contoured observations on lower hemisphere of equal-area stereographic net.

B. Pi diagram for cleavage from the Waynesboro East quadrangle. Diagram shows 343 poles to cleavage machine-plotted and -contoured observations on lower hemisphere equal-area stereographic net.

ROCKFISH VALLEY FAULT

A folded low-angle reverse fault, the Rockfish Valley fault, has been traced along the southeast foot of the Blue Ridge and around three windows less than a mile to the southeast (Plate 1). The Pedlar Formation and the unconformably overlying Swift Run and Catoctin formations comprise the footwall of the fault and are exposed in the windows. In the northeasternmost window a syncline containing Catoctin and Swift Run rocks is preserved (Plate 2, cross section A-A'). The upper sheet of the Rockfish Valley fault is comprised of a zone of cataclastic rocks more than 3 miles wide in the Waynesboro East quadrangle. Along the southeast edge of this zone the cataclastic rocks either grade into gneiss of the Lovingston Formation or are in fault contact with it, in which case the cataclastic rocks form the lower sheet of the thrust fault and the Lovingston Formation forms the upper sheet.

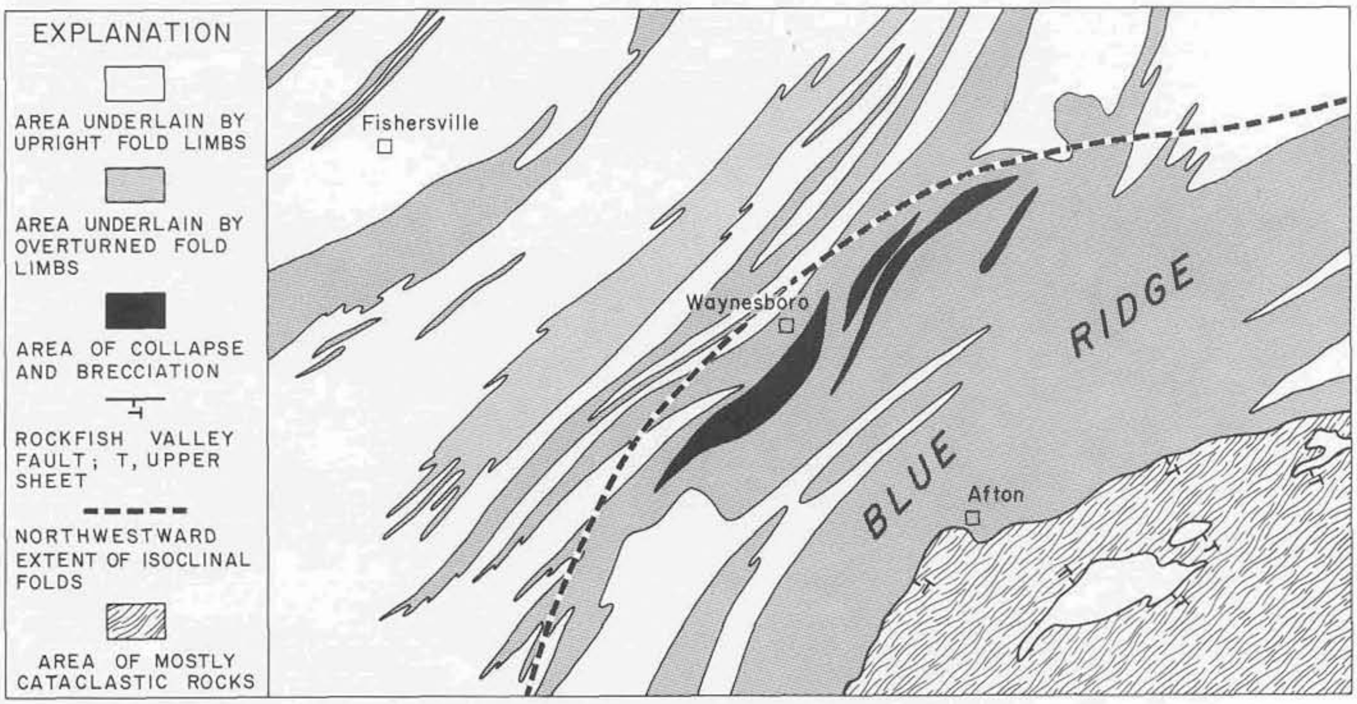


Figure 34. Generalized structural map of the Waynesboro East and Waynesboro West quadrangles depicting the distribution of upright and overturned fold limbs, thrust faults, cataclastic rocks, and areas of collapse and brecciation.

Metamorphic mineral growth in all of the rocks is parallel to the cleavage or shistosity and to the axial planes of the folds showing that metamorphism and folding occurred simultaneously. The cleavage, shistosity, and fold structures in both the upper and lower sheets of the Rockfish Valley fault are discordant with the fault showing that the fault developed toward the end or after the period of folding and metamorphism. Displacement on the Rockfish Valley fault cannot be determined directly as the relationship between the rock bodies separated by the fault is not known. The occurrence of a 4-mile-wide belt of isoclinal folds west of and parallel to the fault suggests that the upper sheet moved at least 4 miles up and over the rocks that now form the Blue Ridge and is responsible for the flattening and attenuation of the folds and the downwarping of the fold axes in the Waynesboro area.

The distribution of the various cataclastic rocks within the Rockfish Valley fault zone is coincident with the relative amount of shear deformation that developed locally. The phyllonites represent areas of greatest rock deformation, principally along the Rockfish Valley fault, and may also mark the trace of subsidiary faults within the cataclastic zone. The cataclastic rocks have two foliations — an older cataclastic schistosity or layering and a younger, crosscutting fracture cleavage. Both foliations have been observed together in outcrop and in rock core from exploration holes.

The generalized geologic and aeromagnetic contour map (Figure 35) generally shows a close relationship between the surficial geology and the magnetic configuration. As the volcanics of the Catoctin Formation are locally magnetite rich and complexly folded, they produce a distinctive pattern of local magnetic highs. The Precambrian gneisses and cataclastic rocks show little magnetic variation in the quadrangles except between Afton and Turks Mountain where a southwestward-plunging positive magnetic anomaly extends from the Catoctin Formation across the Rockfish Valley fault into the area of the cataclastic rocks. This anomaly suggests that this portion of the cataclastic rocks may be underlain by Catoctin volcanics below the Rockfish Valley fault at a shallow depth. The western boundary of the overturned Catoctin is defined by a steep linear magnetic

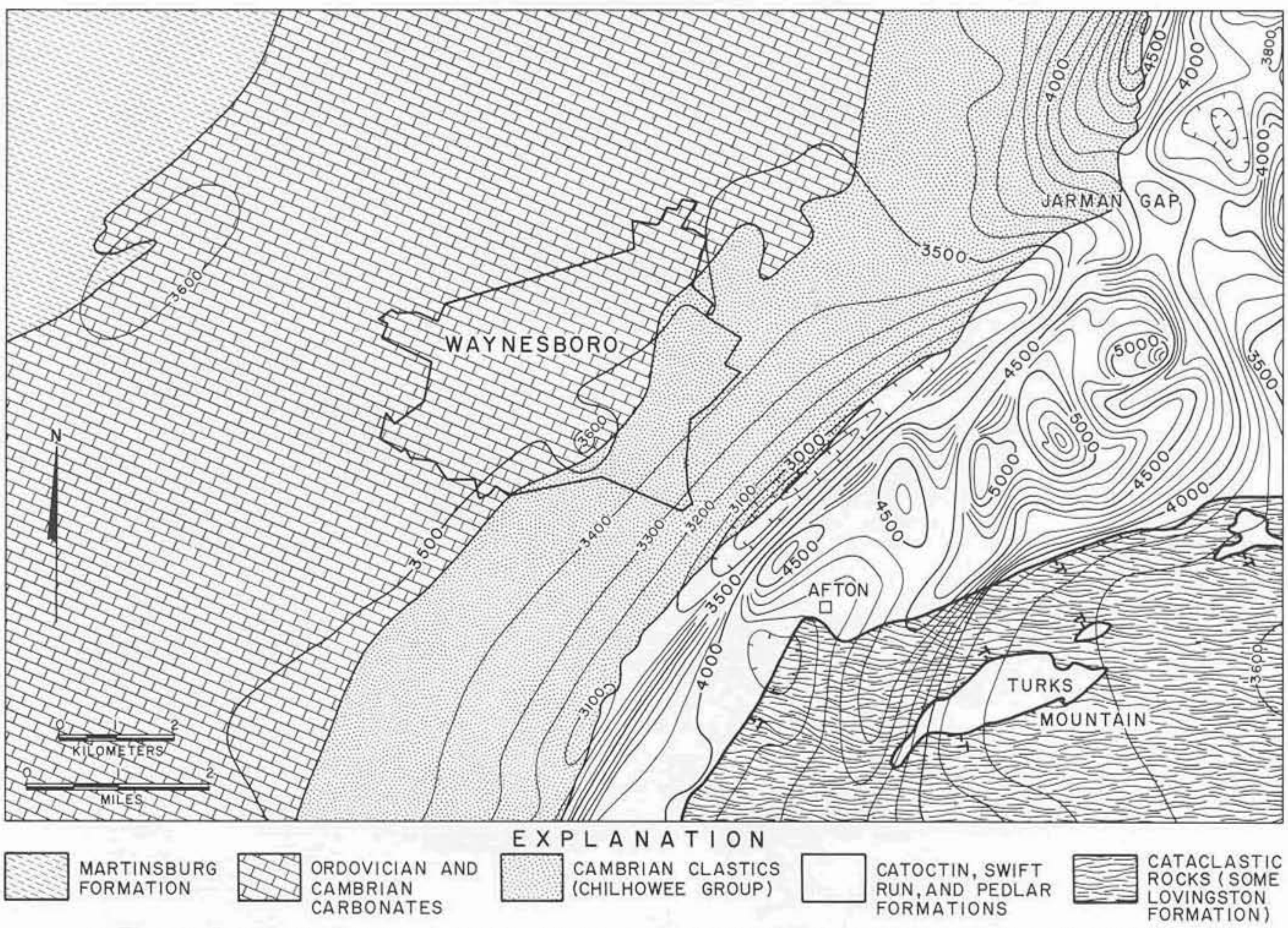


Figure 35. Generalized geologic map of the Waynesboro East and Waynesboro West quadrangles with magnetic contours.

gradient southwest of Jarman Gap where it overlies the Cambrian clastics. North of the gap the gradient slopes gently to the west where the upright Catoctin lies below the Cambrian clastics. The change in character of the magnetic gradient at Jarman Gap reflects the change from the upright fold system to the north to the overturned isoclinal fold system to the southwest.

FRACTURE ZONE

A broad zone of fractured and brecciated quartzite and sandstone of the Antietam and Harpers formations underlies the westernmost foothills of the Blue Ridge south of Sawmill Run. These rocks are situated in an overturned fold limb that has been differentially downdropped along the western margin of the zone, locally placing the Antietam quartzite in contact with the structurally underlying, overturned, maroon phyllite and argillite of the Waynesboro Formation. This contact is concealed beneath Quaternary quartzite and sand sediment at the western foot of the ridges and defines the western boundary of the fracture zone. The eastern boundary is poorly defined but the fracture zone includes all of the Antietam ridges and intervening areas south of Sawmill Run as well as the south crest of Sawmill Ridge. The rocks within the fracture zone are more deeply weathered than their equivalents in upright fold limbs north of Sawmill Run, and except for the quartzite beds they are mostly saprolite where exposed in quarries and borrow pits near Waynesboro. Within much of the zone the axial surfaces of folds, cleavage, and overturned beds are inclined more gently to the southeast than in other areas of these quadrangles (see front cover). Locally, along the west edge of the zone and along the west side of Ramsey Mountain overturned beds are moderately to steeply inclined to the northwest. Brecciation of the quartzites is most intense in these overturned, northwestward-dipping beds.

The contact between the Antietam and Waynesboro formations southwest of Sawmill Run has been interpreted in previous regional studies as a thrust fault (Butts, 1933, 1940-41; Knechtel, 1943; Bloomer and Werner, 1955; Gathright, 1976) or as a normal contact between the Antietam and concealed Shady formations with a parallel fault a short distance to the southeast (Stose and others, 1919). The writers believe the development of the fracture zone is the aftereffect of solution by ground water and not the result of faulting in the tectonic sense. Differential subsidence and gradual collapse of the insoluble quartzite beds structurally overlying a thick carbonate rock unit in an overturned fold limb would account for the anomalous northwesterly inclinations of overturned beds and the chaotic distribution of breccia masses and resistant quartzite ledges. Locally, exploration drill holes substantiate the absence of bedrock to considerable depths in the stratigraphic interval between the Antietam and the Waynesboro formations near Sawmill Run implying the presence of a soluble rock unit at greater depths. This unit, presumably the Shady Formation and possibly carbonate units in the lower Waynesboro Formation, has been locally dissolved to depths of several hundred feet below the surface elevation of Sawmill Run, and more than 100 feet (30 m) below South River in eastern Waynesboro. Interpretive cross sections (Plates 1, 2) that include the overturned fold limb of this major fracture zone are constructed to suggest that a carbonate unit as thick as 1,500 feet (460 m) could have been present between the Antietam and Waynesboro formations. The outlier of Antietam quartzite at Wenonah School in Waynesboro is thought to be an erosional remnant of the collapsed overturned fold limb, and not a klippe.

VERTICAL AND HIGH-ANGLE FAULTS

Local, small-scale vertical faults are characterized by slickensides, brecciation, and minor offset of bedding. They are most common in the fracture zone along the west margin of the Blue Ridge (Plates 1, 2), where most trend to the north or east with the strata generally downthrown on the northwest side. Elsewhere vertical faults have northerly, northwesterly, and westerly trends; some are parallel to or aligned with diabase dikes and may be parts of the regional fracture network along which the magmas were intruded during the Mesozoic Era.

South of Jarman Gap the contact between the lower Cambrian clastics and the Catoctin volcanics may be the trace of a high-angle reverse fault of small displacement. This contact is abnormally straight in an area of complexly folded strata, but the rock sequence across the contact appears to be normal. Locally, the Weverton Formation is very thin, and small-displacement faults may be present at its lower contact on the Chesapeake and Ohio Railway and on Interstate Highway 64. Similarly, a high-angle reverse fault may lie within the Harpers Formation southwest of the Chesapeake and Ohio Railway in Jones Hollow.

JOINTS

Near-vertical joints, which are common in all the rocks, are most apparent in the massive quartzite, dolomite, and metabasalt beds. These fractures are generally transverse to bedding and form large angles with it. The joints are spaced a few inches apart in quartzite beds in the fracture zone along the western Blue Ridge margin. In upright fold limbs, such as on Turk Mountain (Plate 1), joints in the Antietam are 1.0 to 5.0 feet (0.3 to 1.5 m) apart and determine the dimensions of quartzite blocks in the talus.

ECONOMIC GEOLOGY

LIMESTONE AND DOLOMITE

Limestone and dolomite form the bedrock of approximately 50 percent of the surface of the Waynesboro West quadrangle, and about 15 percent of the Waynesboro East quadrangle. The chemical requirements for several uses of limestone and dolomite are listed in Table 2. Chemical analyses of samples in or adjacent to the Waynesboro West quadrangle are given in Table 3.

Limestone that contains more than 95 percent calcium carbonate is termed *high-calcium limestone*, dolomite that has more than 40 percent magnesium carbonate and generally less than 4 percent noncarbonate is called *high-magnesium dolomite*. Limestone that is low in magnesium carbonate and has more than 5 percent noncarbonate (generally silica, alumina, and iron oxide) is *impure limestone* (Edmundson, 1945).

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 furnance)	$MgCO_3$ 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% of $CaCO_3$.
Agricultural dolomite	$CaCO_3$-$MgCO_3$ content should total at least 85%.

Table 3. — Chemical composition of carbonate rocks from localities in or near the border of the Waynesboro West quadrangle (modified after Edmundson, 1945, p. 127).

Location	Formation	Sampled thickness in feet (meters)	$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	Total
Along State Road 795 about 2 miles (3 km) northeast of Fishersville	New Market (limestone)	60 (18)	98.26	0.85	0.29	0.52	0.25	100.17
Half a mile southeast of the intersection of State Roads 635 and 652 about 4 miles (6 km) southwest of Fishersville	Beekmantown (dolomite)	23.8 (7.2)	65.19	31.16	2.68	0.38	0.93	100.34
Along State Road 795 about 1.5 miles (2 km) northwest of Waynesboro	Conococheague (impure limestone)	300 (91)	49.12	35.49	9.26	1.24	4.70	99.81

HIGH-CALCIUM LIMESTONE

Rock units that are potential sources of high-calcium limestone are the Lincolnshire, New Market, and upper 300 feet (91 m) of the Beekmantown formations. The New Market Limestone thins from 60 feet (18 m) at the west edge of the mapped area to less than 5 feet (2 m) at 0.5 mile (0.8 km) northeast of Fishersville; it is absent locally. The rock averages between 96.0 and 98.5 percent $CaCO_3$ and is an excellent potential source of high-calcium limestone where thick enough to quarry. The Lincolnshire Formation contains significant quantities of black, nodular chert that prohibits the full thickness of the formation from being quarried as high-calcium limestone.

The uppermost 300 feet (91 m) of the Beekmantown Formation contains beds of massive, compact, high-calcium limestone similar in composition to the New Market, but it is interbedded with dolomite and is unsuitable for high-calcium purposes. No high-calcium limestone is known to have been quarried for industrial uses in the Waynesboro East or Waynesboro West quadrangles.

HIGH-MAGNESIUM DOLOMITE

Dolomite with varying amounts of impurities is exposed in the upper member of the Elbrook, the upper Beekmantown, and near the base of the Conococheague formations. Available analyses do not show any high-magnesium dolomite.

CRUSHED AND BROKEN STONE

Physical properties are important for rocks used for construction purposes. The most common use of crushed stone is for highway construction. Rocks from portions of all the carbonate and Antietam, Catoctin, and Lovingston formations have a grade A classification for use as highway aggregate (Parrot, 1954). Thus, there is a potential for future development of aggregate sources.

Vulcan Materials Company operated a quarry and crushing plant in the Beekmantown Formation on the north side of Cave Hill (Plate 2) from 1969 to 1972 and produced road-building materials and concrete aggregate for construction of Interstate Highway 64 and for other purposes.

Eastside Quarry operated several quarries at the end of Georgia Avenue about 0.5 mile (0.8 km) east of U. S. Highway 340 in Waynesboro from 1959 to 1970. Weathered and fractured Antietam quartzite was quarried intermittently and sold chiefly for driveways, fill, and other local purposes.

CLAY

Ceramic clays were mined in the Lipscomb area (Plate 2) from 1865 to 1875 (Ries and Somers, 1920). Inclined banding in the pit-mined white clay suggests it may have formed from residuum of the Elbrook Formation. A flood-plain clay, 0.5 mile (0.8 km) southwest of Lipscomb, was reported to have properties making it suitable for the manufacture of brick and drain tile. A similar flood-plain clay was utilized in the manufacture of common brick in Waynesboro. Additional information concerning clay materials and their firing characteristics is given in Ries and Somers (1920) and Calver, Hamlin, and Wood (1961).

SAND AND GRAVEL

The D. M. Conner Sand Company formerly operated at a site 0.5 mile (0.8 km) northwest of Lyndhurst on the northwest side of the South River. Occasional flooding was a problem at this site.

IRON AND MANGANESE

Iron in the form of residual limonite clay was mined for several years near Fishersville (Watson, 1907). Also, the ferruginous sandstone beds of the Harpers Formation were prospected and mined near Waynesboro during the 1800's and until use of the siliceous ore was discontinued in 1905. The average composition of the ore was metallic iron, 38.94 percent; silica, 35.26 percent; phosphorus, 0.38 percent; and manganse, 0.22 percent.

Occurrences of manganese oxides are abundant along the northwest foot of the Blue Ridge, and at one time Augusta County was the most important manganese ore producer in the United States (Watson, p. 246, 1907). Several tracts within the Waynesboro East and Waynesboro West quadrangles were prospected or mined for manganese before 1900. The ore was primarily psilomelene with some manganite, commonly in the form of nodules. The stream valley between Ramsey Mountain and Sawmill Ridge was the site of mining for several years during the 1880's (Stose and others, 1919), and several prospect pits have been observed in brecciated quartzite and alluvial material between Mikes Knob and Ramsey Mountain. Several prospect pits were seen near Inch Branch and in the hollows southwest of Miller Knob (Plate 2); they were probably associated with the Lyndhurst Mine on Back Creek just south of the quadrangle boundary.

HYDROGEOLOGY

by Richard H. DeKay

The occurrence of ground water is largely determined by the geology of an area, and well records provide the basis for an analysis of local hydrogeologic conditions. In this report the detailed geology of the Waynesboro East and Waynesboro West quadrangles is described, but the well records necessary for a thorough analysis of ground-water conditions are not available. Such a comprehensive hydrogeologic study is not within the scope of this report, however, and the tabularized well data are not intended to define the aquifer depth or yield parameters for any of the geologic formations. This is, instead, a summary of ground-water conditions encountered almost exclusively by small-diameter, shallow to moderately deep residential wells that were drilled for small water supplies. Most of these wells are located at sites of convenience to the consumers, and many of the yield figures are estimates provided by drilling contractors.[1]

The writer is indebted to the principal authors of this report for the geologic information utilized and to the water-well drilling contractors who submitted records of their wells to the Virginia Division of Mineral Resources. Among the latter special thanks are extended to Burner Well Drilling, Inc., McGaheysville; Caldwell Well Drilling, Inc., Fishersville; and C. R. Moore Well Drilling Company of Charlottesville. In order to consolidate the results of these random drilling operations it is most expedient to correlate the well data with the rock units penetrated. The rock units in turn have been grouped into three hydrogeologic categories: igneous and metamorphic rocks, clastic rocks, and carbonate rocks.

IGNEOUS AND METAMORPHIC ROCKS

The basalt, granite, and metamorphic rocks differ considerably in lithology but little in primary permeability, which is so small as to be zero for all practical purposes (Davis and DeWiest, 1966). The massive, generally insoluble rocks are brittle under long-term earth stresses, however, and several periods of deformation have produced some regional faulting and considerable local folding and fracturing of the bedrock. In addition to the fractures subsurface openings have been created by sheet structures from erosional unloading, along parted cleavage planes, and from moderate solution activity along some mineralized shear zones. Most of the fractures are steeply inclined and seem to decrease in size and number with depth, the majority being present in the upper 350 feet (107 m) of bedrock; where present the horizontal sheeting occurs at more shallow depths, and cleavage-plane and solution permeability is slight and very localized. Although these characteristics are randomly distributed, the competent nature of the massive rocks keeps the fissures open to moderate depths, imparting a locally exploitable secondary permeability to an otherwise impermeable hydrogeologic terrane.

The depths and yields of wells in these rocks have a fairly wide range (Table 4), much of which is the result of topographic location and proximity to influent drainage. Wells in the cataclastic rocks and Swift Run Formation have the shallowest average depth and largest average yield. In the cataclastic rocks this is due to the intense deformation adjacent to a major fault zone, a relatively thick soil, and low relief at the base of the Blue Ridge where recharge to the sheared rocks is excellent. The Swift Run Formation is a thin rock unit that has been extensively fractured and extends along the lower slopes of the Blue Ridge where runoff waters are intercepted by the open fractures beneath a fairly well-developed soil profile. Wells in the Pedlar and Catoctin formations have a considerably deeper average depth and a much smaller

[1]Additional information or assistance concerning ground-water supplies in these quadrangles may be obtained from the Valley Region office of the State Water Control Board, P. O. Box 268, Bridgewater, VA 22812.

Table 4. — Composite record of reported-depth and estimated-yield data for water wells in igneous and metamorphic rocks in the Waynesboro East and Waynesboro West quadrangles, Virginia.

Rock Unit	No. of wells	Depth in feet (meters)			Yield in gpm (l/m)[1]		
		Minimum	Maximum	Average	Minimum	Maximum	Average
Catoctin Formation	24	46 (14)	1001 (305)	344.1 (105.0)	0 (0)	100+ (379+)	11.1 (42.1)
Swift Run Formation	6	60 (18)	260 (79)	136.3 (41.6)	1 (4)	25 (95)	14.3 (54.2)
Pedlar Formation	15	70 (21)	709 (216)	305.2 (93.1)	0 (0)	30 (114)	8.7 (33.0)
Cataclastic rocks	40	48 (15)	680 (207)	202.5 (61.8)	1 (4)	100+ (379+)	13.1 (49.6)
All units	85	46 (14)	1001 (305)	255.9 (78.0)	0 (0)	100+ (379+)	11.8 (44.7)

[1]Measurement: gpm, gallons per minute; 1/m, liters per minute.

average yield. These more massive and resistant rocks are less deformed, occur at higher elevations where the regional water table is deeper, and are poorly recharged because of thin soils and rapid runoff on steep slopes. In general, the igneous and metamorphic rocks are fairly dependable sources for small quantities of water and may furnish moderate water supplies where wells are located to penetrate multiple fractures in areas of favorable recharge. Otherwise, the mitigating effects of hydrogeologic conditions generally make drilling deeper than 350 feet (107 m) unrewarding and yields greater than 10 gallons (38 liters) per minute the exception rather than the rule.

Few analyses of ground water from these rocks are available, but from them it is indicated the water is generally of good chemical quality — soft, nearly neutral pH, and only slightly mineralized. In areas of mineralized shear zones and from some of the metamorphic rocks moderate amounts of iron and manganese may be present in the water. In most places the soil is well drained and moderately permeable; it is thickest on the cataclastic rocks and Swift Run Formation where installation of septic tanks, drain fields, and other waste-disposal sites is generally acceptable. Even on these rock units, however, and in most places on the Pedlar and Catoctin formations the location of such facilities on steep slopes where the soil is thin or clayey would constitute a potential hazard to the ground-water resevoir. In these areas the leakage of any effluent or leachate can quickly reach the water-bearing fractures that lack natural filtration properties and are therefore not self-cleaning aquifers. A high density of wells should also be avoided as the fractures are not limitless, and sustained pumping of closely spaced wells may lower the local water table. Such a cone of depression is likely to reduce production from some wells and may also accelerate pollution of the ground-water reservoir in areas of unsanitary surface sources.

CLASTIC ROCKS

Siltstone, sandstone, and shale are the predominant lithologies of the clastic rocks, although a few scattered phyllitic, slaty, calcareous, and quartzitic beds are present. With the exception of a few interbedded sandstone, quartzite, and carbonate strata the four clastic rock units are composed of thin-bedded, fine-grained, relatively incompetent rocks that initially may have had a fairly high porosity and a low primary permeability (Walton, 1970). All of these formations have been intensely folded, but fractures are not well developed except in the more massive sandstone and quartzite beds. This poorly developed secondary (fracture) permeability plus the high elevation, steeply dipping strata, and poor recharge conditions of the Weverton and most of the Harpers and Antietam formations are not conducive to large or even moderate ground-water supplies. In the area occupied by the Martinsburg Formation, poor to fair recharge and fewer massive sandstones are factors that reduce its water-bearing potential to that of the other clastic rocks in most places. All four rock units also lack the thick soil cover so necessary for the retention of runoff waters to recharge the underlying bedrock (Trainer and Watkins, 1975).

Wells in the Weverton and Harpers formations have the greatest yield range and highest average yield, but probably only because of their greater depths (Table 5). The predominantly siliceous and argillaceous matrix in these fine-grained rocks limits effective permeability to a secondary type composed mainly of small fractures and

Table 5. — Composite record of reported-depth and estimated-yield data for water wells in clastic rocks in the Waynesboro East and Waynesboro West quadrangles, Virginia.

Formation	No. of wells	Depth in feet (meters)			Yield in gpm (l/m)[1]		
		Minimum	Maximum	Average	Minimum	Maximum	Average
Martinsburg	15	60 (18)	260 (79)	141.6 (43.2)	2 (8)	30 (114)	10.2 (38.7)
Antietam	2	114 (35)	275 (84)	194.5 (59.5)	0 (0)	20 (76)	10.0 (37.9)
Harpers	5	129 (39)	400 (122)	268.2 (81.8)	5 (19)	35 (133)	16.0 (60.6)
Weverton	3	305 (93)	415 (127)	335.0 (102.2)	5 (19)	24 (91)	11.3 (42.8)
All formations	25	60 (18)	415 (127)	196.8 (60.0)	0 (0)	35 (133)	11.5 (43.6)

[1]Measurement: gpm, gallons per minute; l/m, liters per minute.

open bedding or cleavage planes. However, as these incompetent, mica-rich rocks are susceptible to compression by crustal loading, few of the openings extend to depths greater than 250 feet (76 m) below ground surface. Wells in the Antietam and Martinsburg formations are neither as deep nor as productive, but the scarcity of wells in the Antietam and the poor geographic distribution of those in the Martinsburg may not provide an accurate assessment of the water-bearing characteristics of those rock units. Fractures are numerous in the massive Antietam strata but their steep inclination reduces the possibility of interception by a well, and its elevated position and steep slopes result in very poor recharge and a relatively deep water table.

Wells in the Martinsburg Formation are the shallowest of those in the clastic rocks, and reflect the effect of lesser deformation and lower relief. Bedding and cleavage openings are inclined at a shallow angle throughout this rock unit, permitting several to be penetrated by a well bore. However, the relative scarcity of influent streams and brittle rocks reduce the possibility for large yields in most places. In general, these four insoluble clastic rock units lack the necessary combination of favorable hydrogeologic conditions for large or even moderate groundwater supplies, but are dependable sources for yields of less than 15 gallons (57 liters) per minute from depths of less than 250 feet (76 m) in most places.

Owners and drillers of wells in the Weverton, Harpers, and Antietam formations disclose a diverse quality of water from these rock units. Water from homogeneous, quartzose sandstone and quartzite is generally of good chemical quality, but may be turbid when the matrix is of argillaceous or calcareous composition. In heterogeneous sandstone and siltstone the water is more mineralized and locally contains moderate quantities of iron and manganese. Water from shale and phyllitic rock that comprises most of the Harpers and Martinsburg formations is moderately to highly mineralized and moderately hard. Iron is the most common contaminant in these waters, which are also acidic in places where sulfide minerals occur in the bedrock. In areas of more calcareous strata, the water is moderately hard to hard, and locally there may be turbidity problems with the water from any of these formations.

In most places that are underlain by these clastic rocks the sandy soil is very shallow, permeable, and well-drained — conditions that impose moderate to severe restrictions on septic tanks, drain fields, and other waste-disposal facilities, depending on steepness of slope and thickness and acidity of soil. In a portion of another quadrangle underlain by these rock units (Rader and Biggs, 1975) the quality of ground water has been endangered where effluent and leachate from septic tanks and waste-disposal sites has permeated the shallow water-filled fractures. In rocks of this type with poor natural-filtration properties, such a situation may rapidly pollute the near-surface ground-water reservoir (Ecolsciences, 1974). This condition may be accelerated by the continuous pumping of several wells in a small area. The creation of a cone of depression in such an area will not only induce infiltration of contaminants from nearby unsanitary surface sources but may also reduce production from some of the smaller-yield, shallow wells.

CARBONATE ROCKS

Bedrock between the western foothills of the Blue Ridge and Fishersville includes eight rock units that are predominantly of carbonate lithology (Plate 2). For the purpose of this report two of these formations (Lincolnshire and New Market) are considered as a single unit because of their lithologic similarity, thinness, and scarcity of well data. None of the carbonate rocks in Virginia are composed of pure limestone or dolomite (Edmundson, 1945) and some, such as the Conococheague, Elbrook, and particularly the Waynesboro formations, contain appreciable amounts of interbedded sandstone and shale; however, many of these noncarbonate interbeds contain a soluble matrix that increases their otherwise poor permeability. The limestone and dolomite are thin-bedded to massive and have been considerably folded in most areas resulting in the development of fractures and joint systems. Most of these rocks show the effects of solution activity on their channeled, weathered surfaces, especially in the development of numerous sinkholes. Dense, crystalline and undeformed carbonate rocks have very low permeabilities (Davis and DeWiest, 1966), but fracture openings and their enlargement by solution activity has created a secondary permeability that makes wells of large yield possible. These openings are generally widely spaced and steeply inclined, however, resulting in many wells of low yield and relatively few shallow water-bearing zones. Statistics for 12 deep, highly-productive wells completed for municipal and industrial supplies are so different from those for residential and farm wells that they are discussed separately and included in the carbonate well data (Table 6) as footnote 2.

The average total depth of wells in six of the eight carbonate formations varies only 70 feet (21 m), the exception being the combined Lincolnshire and New Market formations for which the anomalous, shallow average may be the result of inadequate (2 wells) data. However, their relatively steep inclination, moderate surface elevation, and poor recharge conditions are sufficient reason why these shallow wells have the lowest average yield for wells in the eight formations. Productivity from the Chepultepec and Shady formations is also low, although the wells in them are considerably deeper. Not much is known of the hydrogeologic conditions for the Shady

Table 6. — Composite record of reported-depth and estimated-yield data for water wells in carbonate rocks in the Waynesboro East and Waynesboro West quadrangles, Virginia.

Formation	No. of wells	Depth in feet (meters)			Yield in gpm (l/m)[1]		
		Minimum	Maximum	Average	Minimum	Maximum	Average
Lincolnshire-New Market	2	150 (46)	200 (61)	175.0 (53.4)	4 (15)	6 (23)	5.0 (19.0)
Beekmantown	31	60 (18)	400 (122)	245.6 (74.9)	0 (0)	200 (758)	25.1 (95.1)
Chepultepec	2	200 (61)	260 (79)	230.0 (70.2)	5 (19)	8 (30)	6.5 (24.6)
Conococheague	19	63 (19)	500 (152)	271.6 (82.8)	0 (0)	100 (379)	18.7 (70.9)
Elbrook[2]	33	71 (22)	500 (152)	201.6 (61.5)	1 (4)	60 (227)	14.3 (54.2)
Waynesboro[2]	16	150 (46)	378 (115)	242.1 (73.5)	10 (8)	60 (227)	25.3 (95.9)
Shady	6	125 (38)	500 (152)	240.0 (73.2)	0 (0)	12 (45)	5.3 (20.1)
All formations	109	60 (18)	500 (152)	234.5 (71.2)	0 (0)	200 (758)	18.8 (71.3)

[1]Measurement: gpm, gallons per minute; l/m, liters per minute.

[2]Exclusive of 12 deep, public and industrial water wells drilled near the contact of the Waynesboro and Elbrook formations; composite statistics for these wells are:

Depth range in feet (meters): 163 (50) to 784 (239), Average 478 (146)

Yield range in gpm (l/m): 320 (1,213) to 1,557 (5,901), Average 700 (2,653)

Formation as a large portion of a well bore penetrates only the thick alluvium and residual soil that covers the bedrock. As these rocks are thought to be intensely deformed in an area of excellent recharge, it is possible that deeper wells may be considerably more productive. Relatively slight deformation, a thin soil cover, and only fair drainage are considered the reasons for only small yields from wells in the Chepultepec Formation. As was the case for the Lincolnshire and New Market formations, however, inadequate well data may misrepresent their water-bearing potential, as these limestone units are the most pure and hence the most soluble of the carbonates in this area.

Wells in the other four formations are typical of those in carbonate rocks — erratic in depth and yield but with moderate averages for each. Wells in the Elbrook Formation have the shallowest average depth and lowest average yield of this group, showing only that its secondary permeability is better developed at shallower depths than in the other formations. About 40 percent of the wells for which data is available, however, are located in the lower (eastern) portion of the formation, most of which is at low elevations, covered by alluvium, and adjacent to South River. As the rocks are highly fractured and recharge is excellent, solution activity has enlarged near-surface openings to make small yields readily available at shallow depths. It is likely deeper wells in the lower Elbrook will furnish considerably larger quantities of water. Drainage and soil cover for the upper Elbrook are not as favorable nor are the rocks as deformed as those in the lower portion of the formation. As a result, recharge and solution activity are reduced and the wells are somewhat deeper and lower in yield.

Wells in the Conococheague Formation are the deepest of those in the carbonate formations, a condition that is largely the result of higher relief and steeply inclined strata. Because a relatively thick soil cover is generally developed on this unit and poorly cemented sand strata occur within it, the Conococheague Formation is usually an excellent source for ground-water supplies wherever it is fractured and well recharged. In this quadrangle, however, the steepness of the strata, relatively thin soil, and poor drainage in most areas has reduced its productivity, although it remains a fairly reliable source for wells of small to moderate yield from moderate depths.

Farm and residential wells in the Beekmantown and Waynesboro formations have almost identical depth and yield statistics that together are the most favorable for any rock units in these quadrangles (Table 6). Fair drainage and a relatively thick soil on the soluble, fractured, brittle rocks of the Beekmantown are responsible for the success of most wells that penetrate it. The degree of solution activity along bedding and fractures in this rock unit is evidenced in Blue Hole, a cavernous opening in near-vertical limestone west of Cave Hill. In 1966 a turbine test pump was installed and 1,410 gallons (5,344 liters) per minute pumped for 75 hours with only 14.3 feet (4.3 m) of drawdown. Wells in the Waynesboro Formation, however, owe their success to the superior recharge to fractured carbonate and interbedded detrital rocks. Hydrogeologic factors seem so favorable for wells in this formation that it is surprising the wells are as deep and the yields as small as they are. As yields for the residential wells in this unit are initial estimates, it is likely that pump tests would reveal most of the estimates are low. In general, wells in the carbonate rocks have the most favorable average depth and yield statistics of the three categories (Table 7), but have a higher percentage of failures due to the inconsistent distribution of fracture and solution openings.

Back Creek and South River flow northeastward along the foothills of the Blue Ridge from Lyndhurst to the northeast side of Waynesboro near the contact of the Waynesboro and Elbrook formations (Plate 2). As a result of intense folding that inverted the rocks in most of this area, fracturing and cleavage of the carbonate and interbedded detrital strata has been developed to a high degree. Covering the broken, well-bedded, and soluble rocks is a thick cover of alluvial deposits that is partially saturated by Back Creek and South River as well as by the considerable runoff from the Blue Ridge. In this extremely favorable hydrogeologic environment 12 deep, large-diameter wells were drilled at selected sites for the purpose of obtaining large supplies of ground water for public and industrial use. The results of these drilling operations are summarized in Table 6, footnote 2, that shows the wells average 478 feet (146 m) in depth and 700 gallons (2,653 liters) per minute in yield. This is one of the better examples in western Virginia of the high ground-water potential of an area where properly located and constructed wells penetrate rocks on which all the favorable hydrogeologic criteria are superimposed. Although such areas are relatively few, the economic exploitability of ground water from them is amply demonstrated by these wells near Waynesboro.

The quality of ground water from the carbonate formations generally is moderately hard to hard from calcium and magnesium mineralization, water from limestone being harder than that from dolomite or interbedded detrital rocks. However, water from the detrital strata is frequently turbid, and moderately high in iron, silica, and sulfate; in some areas moderate amounts of sodium and nitrate are also present (Cady, 1936). In most places in this area of low relief these rocks are covered by a fairly deep, well-drained soil that generally contains a substantial amount of silty clay that has only moderate permeability. In the more elevated areas the soil is thinner, more sandy, and better drained. Moderate restrictions are placed on the installation of septic-tank, drain-field, and waste-disposal facilities in these soils, but the main concern is the presence of sinkholes and the sudden development of new ones. The open sinkholes provide easy and direct access of contaminants to the ground-water reservoir, and their interconnection with subsurface solution cavities and rock fractures permits rapid transmission of pollutants for greater distances than in unconsolidated or permeable rocks (Todd, 1959). Sustained and heavy pumping of new wells may also de-

Table 7. — Composite record for 219 water wells in the Waynesboro East and Waynesboro West quadrangles, Virginia, grouped according to the lithologic category in which they were drilled.

Category	No. of rock units	No. of wells	Depth in feet (meters)			Yield in gpm (l/m)[1]		
			Range	Average	Most[2]	Range	Average	Most[2]
Carbonate[3]	8	109	60-500 (18-152)	235 (72)	60-300 (18-91)	0-200 (0-758)	18.8 (71.3)	0-20 (0-76)
Clastic	4	25	60-415 (18-127)	197 (60)	60-250 (18-76)	0-35 (0-133)	11.5 (43.6)	0-15 (0-57)
Igneous and metamorphic	4	85	46-1001 (14-305)	256 (78)	46-350 (14-107)	0-100+ (0-379+)	11.8 (44.7)	0-10 (0-38)

[1]Measurement: gpm, gallons per minute; l/m, liters per minute.

[2]Most common (approximately 75 percent) depth and yield ranges of completed wells.

[3]Exclusive of 12 deep, public and industrial wells of large yield.

water near-surface cavities, thus causing the collapse of overlying strata some distance from the well. Because of these environmental hazards, the location of wells relevant to unsanitary surface sources and existing structures should be selected with care in carbonate terranes.

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.

An increasing, more affluent, and mobile population in an era of economic growth has led to more intensive development of land within Virginia. To a significant extent it is the characteristics of the subsurface earth materials that determine how land can be most effectively and safely utilized. As factors other than geology commonly initiate need and influence use for a given piece of land, the availability of geologic data to planners and developers is of primary importance.

Areas with similar geologic factors that affect land modification in the Waynesboro East and Waynesboro West quadrangles were evaluated on the basis of lithology, slope stability, erodibility, and response to excavation. From this evaluation 14 environmental geology units were formed and are discussed sequentially as related to bedrock age and are tabulated in the explanations of Plates 1 and 2. Modified-land, rockfall, and karst areas are described as special units involving land modification.

The geologic units on Plates 1 and 2 are guides to land units with similar environmental and physical properties. However, as some of these units vary internally, *a detailed evaluation of individual sites by professional personnel is recommended.* The maps and the report which follow should be of use to planners, developers, and conservationists in making decisions concerning the long-range use of land within these two quadrangles.

UNIT 1

Unit 1 consists of the Lovingston Formation, the cataclastic rocks, and the soil and residuum developed on them in a belt about 3 miles (5 km) wide along the southeastern foot of the Blue Ridge. The gently rolling topography consists of low linear ridges parallel to the trend of cleavage in the bedrock or at nearly right angles to it along prominent joint (fracture) directions. Slopes along the tops of the ridges are generally less than 5 percent; along their margins adjacent to stream valleys the slopes range from 10 to 15 percent, and incised banks adjacent to some streams are locally steeper than 15 percent.

Bedrock consists of highly deformed, massively layered to highly schistose granitic gneiss that locally contains quartz veins. Outcrops are most common along major streams, but bedrock is also moderately well exposed on the rolling uplands. This is probably due to differential weathering that causes the more massive, resistant gneisses to stand out in relief above the less resistant schistose rocks. Outcrops in stream valleys are generally resistant ledges; along some streams, such as Stockton Creek and Haynes Branch, rock cliffs have been formed. Upland outcrops are generally ledge or pavement types that may occur just below the land surface over significant areas. Most of the bedrock in this unit is hard and requires blasting and removal of boulders with heavy machinery.

The gneissic layering of the more resistant rock types (Figure 29) consists of lenticular bodies of interlocking crystalline quartz and feldspar between layers of finely ground and altered minerals, including mica. These mica-rich layers commonly represent significant zones of weakness along which the rock has previously been broken, and they should be considered as potential slip planes. Excavations that involve high rock walls where cleavage is inclined toward the excavation should be benched or cut back to slopes equal to or less than that of the cleavage inclination.

Thick to very thick, well-drained, red, clay-rich soils are most commonly developed on this unit; thinner, more granular, brown-colored soils are exposed only along slopes and near outcrops. A yellowish-brown, sandy,

[1]Additional data on forestry, regional planning, soils and water may be obtained from the following agencies: (1) Virginia Division of Forestry, P. O. Box 3758, Charlottesville, VA 22903; (2) for Albemarle and Nelson counties, Thomas Jefferson Planning District Commission, 701 East High Street, Charlottesville, VA 22901; for Augusta County, Central Shenandoah Planning District Commission, P. O. Box 1337, 119 West Frederick Street, Staunton, VA 24401; (3) Soil Conservation Service, U. S. Department of Agriculture, P. O. Box 10026, Richmond, VA 23240; (4) State Water Control Board, P. O. Box 268, Bridgewater, VA 22812.

silty-clay surface layer about 10 inches (25 cm) thick is commonly present on flatter ground, but most shallow excavations encounter the red clayey subsoils. Because the soil and subsoil range from 8 feet (2 m) to as much as 50 feet (15 m) thick on most broad ridgetops, excavation during dry weather is not difficult; sticky mud problems may be encountered during wet weather. The excessive clay content may impose limitations on some types of construction, such as installation of septic-tank drainage fields for sewage disposal in the moderately permeable subsoil. Also, as the clay has a moderate shrink-swell potential and may be relatively plastic and compressible, heaving or subsidence of concrete slabs and foundations may occur if the underlying subsoil becomes saturated.

Soil stabilization through the use of soil cement may be required for roads and streets in which the subsoil is used as a base for bituminous pavement. Inclined embankments that have been stripped of vegetation may be subject to rapid erosion and resultant siltation problems in nearby streams. Inadequately drained steep cuts in the subsoil and in saprolite may be subject to sloughing or slump failure. Despite engineering limitations due to soil properties, the gently sloping, flat-topped ridges on unit 1 appear to be the most suitable areas southeast of the Blue Ridge in the Waynesboro East quadrangle for solid waste disposal sites. The location of such a facility on the middle of a broad ridge on the unit's deep and relatively impermeable soil would prevent extensive movement of contaminated water or leachate developed in the fill and would isolate it from the ground-water reservoir. Negative factors, such as moderate shrink-swell clay that might lead to cracking of compacted cover material, resulting infiltration and leaching, and poor workability in wet weather, would require careful engineering of drainage and roads to maintain an economic sanitary landfill.

Current use of land underlain by this unit is almost wholly agricultural (predominantly pasture) with much of the remainder in woodland; a few orchards are present on some steeper slopes, especially along the southeast foot of the Blue Ridge. Recommended nonfarm use of this land includes limited residential development carefully following restrictions on waste disposal imposed by soil conditions and on local ground-water supplies.

UNIT 2

Unit 2 consists of granodiorite and granite gneiss of the Pedlar Formation and the soil and residuum developed on them. The unit forms isolated ridges and rounded hills southeast of the Blue Ridge. Slopes are generally steep (greater than 15 percent) except for small areas on hilltops.

The bedrock is either a massive, coarse-grained, dark greenish gray granodiorite gneiss or a light-gray granite gneiss that occurs only in one area on the southeast slope of the Blue Ridge northeast of Greenwood. Outcrops are mostly large, massive, very resistant ledges that generally require blasting or large, partially exfoliated boulders that can only be removed by heavy machinery. In places on the margins of the isolated bodies southeast of the Blue Ridge the granodiorite gneiss has a cleavage similar to that found in the cataclastic gneiss discussed in unit 1. Joints are generally widely spaced, nearly vertical, and contribute to the formation of large boulders. The principal occurrence of this unit is bounded on its southeast side by the Rockfish Valley fault.

Soil and residuum range from 2 to 6 feet (1 to 2 m) in thickness. Hillslopes may have only 12 inches (30 cm) of soil, the top of which is generally very dark brown and stony; on more gentle slopes the subsoil is locally as thick as 36 inches (91 cm) and may contain some silty clay.

Steepness of slope and the shallow and stony nature of the soil severely limit most types of construction on unit 2. Although the soil may have a moderate to high permeability, the proximity of hard bedrock to the surface greatly restricts the use of septic-tank drainage fields and causes most of the area to be unsuitable for construction of sanitary landfills. It is suggested that current land use, which consists predominantly of woodland with some pastures and orchards on the gentler slopes, is the most favorable land use for unit 2.

UNIT 3

Unit 3 contains soil and residuum developed on schist and metamorphosed sandstone of the Swift Run Formation in a narrow belt that trends northeasterly across the Waynesboro East quadrangle along the southeast slope of the Blue Ridge (Plate 1). From the eastern quadrangle boundary southwest to U. S. Highway 250 and in the area southwest from Afton most of the unit occurs on slopes steeper than 15 percent; southwest of U. S. Highway 250 to State Road 750 slopes of 10 to 15 percent are most common. The bedrock is well exposed and slopes have a relatively high density of outcrops that consist of moderately to steeply inclined ledges, generally developed along the cleavage. From the eastern quadrangle boundary to the vicinity of Afton the predominant rock type is tan, greenish- and silvery-gray mica schist or phyllite with thin beds of metamorphosed sandstone; southwest of Afton there are more massive metamorphosed sandstone beds. Joints are numerous but widely spaced. Cleavage represents a potential slip surface, and where it is inclined into excavations the excavation should be benched or cut back to slopes equal to or less than the inclination of the cleavage. Bedrock near the surface may be rippable except for the massive metamorphosed sandstone beds southwest of Afton.

The soil cover ranges from less than 5 to 40 feet (2 to 12 m) in thickness and is generally well-drained, consisting of inorganic, micaceous silts and clays. Thinner soils on the steeper slopes generally contain less clay and more mica-schist fragments and angular quartz gravel in the subsoil, imparting a moderate to good permeability and lower shrink-swell potential than the silt- and clay-rich soils on gentle slopes. Construction is severely limited by steep slopes over most of the unit. Where slopes are not steep there are moderate restrictions for construction of septic-tank drain fields, buildings with basements, and local roads and streets because of the moderate permeability and shrink-swell potential of the silt and clay subsoils. Over much of unit 3 erosion may be severe if the soil is disturbed on steep slopes.

The present land use within unit 3 is predominantly woodland, with orchards on some slopes and small, gently sloping areas in pasture. Fairly dense residential development has occurred at Newtown, with less dense development in the Greenwood and Afton areas.

UNIT 4

Unit 4 consists of residual soil on the eastern slope and crest of the Blue Ridge that is underlain by schistose metabasalt, tuffaceous metamorphosed sandstone, and epidosite of the Catoctin Formation. Closely spaced jointing and a southeastward-dipping cleavage pervade these rocks (Figure 36). The well-drained soils range from 3 to 6 feet (1 to 2 m) in thickness except on the upper portions of ridges where they are generally less than 3 feet (1 m) thick or absent.

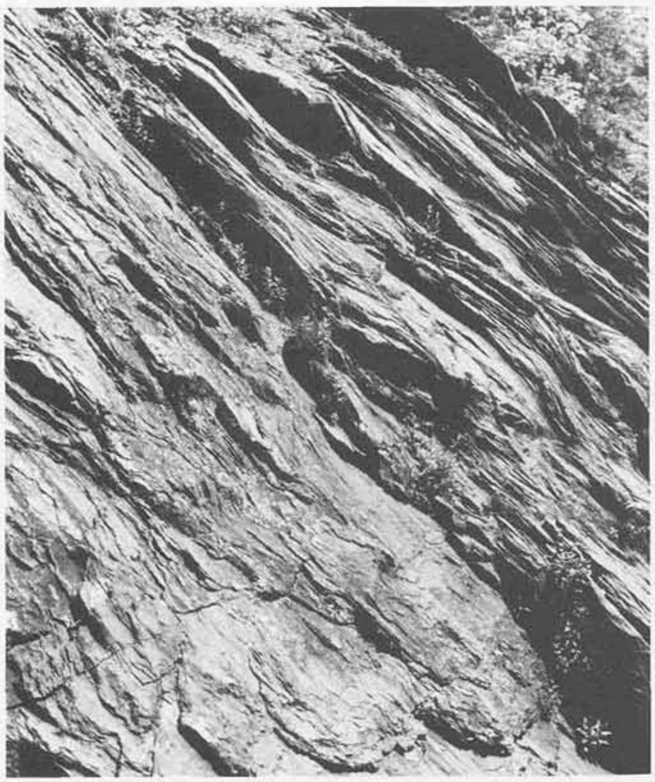


Figure 36. Cleavage in the Catoctin Formation associated with environmental geology unit 4 along Interstate Highway 64 near Skyline Drive.

Permeability of the soils is generally moderate, and the shrink-swell potential is low. Good building sites exist on the stable gentle slopes where the drainage is also adequate for installation of septic-tank drainage fields. Deep cuts remain stable if oriented perpendicular to cleavage and if loose joint blocks are removed during construction. The likelihood of ground creep, minor slides, and rockfalls during excavation is greater on moderate to steep slopes.

Depth to bedrock, slope, and rocky soils are the major restricting factors in land use. Recommended use of land is for farming, pasture or woodland, and residential development in limited areas.

UNIT 5

Unit 5 is underlain by quartzite, metamorphosed conglomerate, and phyllite of the Weverton Formation. Deep (4 to 8 feet or 1 to 2 m), well-drained, rocky soils are predominant on the moderate to steep slopes, but rock outcrops are common on very steep slopes. The soil has a moderate permeability and a low to moderate shrink-swell potential. Construction is extensively limited by the rockiness on steep slopes; on gentle slopes there are only moderate limitations for the construction of homesites with basements, septic-tank drainage fields, streets, picnic areas, and campsites. Artificial cuts are subject to rockfalls and slides.

UNIT 6

Unit 6 is underlain by phyllite and quartzite beds of the Harpers Formation on the west slope of the Blue Ridge. Thin (1.0 to 1.5 feet or 0.3 to 0.5 m), excessively drained soils are predominant on the steeply sloping convex ridges. Bedrock is rarely exposed on natural slopes and is generally rippable near the surface except where quartzite and ferruginous sandstone are present. Artificial cuts are very susceptible to erosion, and slough into piles of slaty talus (Figure 37). Soil permeability varies from moderate to high, and its shrink-swell potential is low. Severe restrictions exist for most types of construction except on the few slopes of less than 15 percent grade. Recommended use of the land is for pasture or woodland.

UNIT 7

Unit 7 is underlain by metamorphosed sandstone, quartzite, and interbedded phyllite of the Antietam Formation on the west slope of the Blue Ridge. The slopes are commonly steep, and the excessively drained, stony, gravelly soils grade upslope into rock fields (Figure 38) with bedrock commonly exposed on ridge crests. The permeability of the soil is high, and its shrink-swell

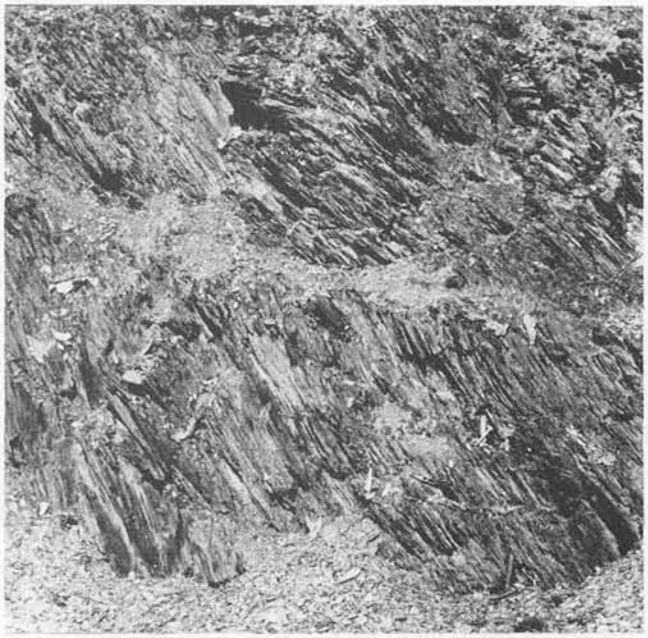


Figure 37. Weathered Harpers phyllite associated with environmental geology unit 6. Artificial cuts in this unit are very susceptible to erosion and weather into piles of slaty talus.

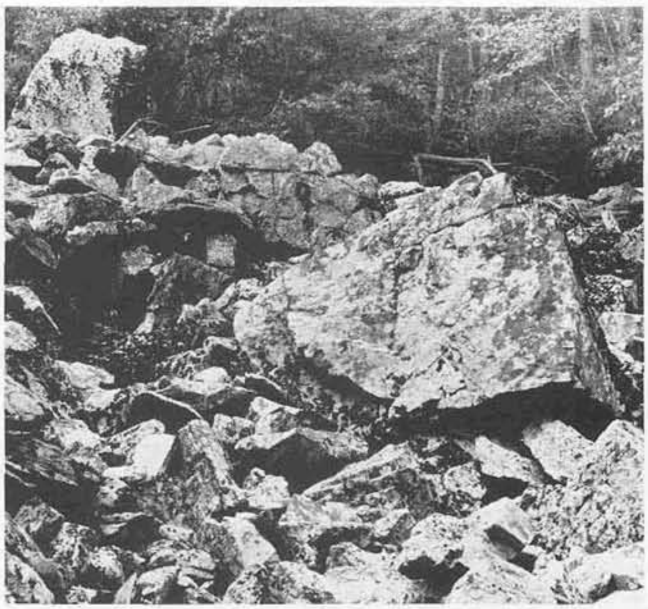


Figure 38. Talus on the western slope of the Blue Ridge. Excessively drained soils of environmental geology unit 7 grade upslope into rock fields.

potential is low to moderate. Soil creep occurs on most slopes, and excavation may cause slumps or landslides. Solution subsidence may be an important factor along the western edge of the unit near the concealed contact with the Cambrian carbonate formations. Steep slopes and the stony, shallow soil limit most farm, urban, and recreational uses for this unit. Most of the land is woodland, though some of the less steep and stony areas are residential in the eastern portion of Waynesboro.

UNIT 8

Unit 8 consists of soils, residuum, and bedrock associated with the carbonate rocks of the Shady, Waynesboro, Elbrook, Conococheague, Chepultepec, Beekmantown, New Market, and Lincolnshire formations (Plates 1, 2). This wide belt of carbonates underlies most of Waynesboro and the area as far west as Fishersville and is characterized by a gently rolling topography with most slopes less than 10 percent. Exceptions to the general topography are the sandstone ridges of the Conococheague Formation and the rounded chert hills of the Beekmantown Formation, where slopes range from 10 to 20 percent.

Except for the concealed Shady Formation about which little information is available, deep, well-drained soils occur on all slopes, but are most prevalent on the more gentle ones where depth to bedrock may be as much as 12 feet (4 m). A more rocky soil is present where limestone outcrops are less than 10 feet (3 m) apart on steep slopes and hilltops. A more sandy, well-drained soil covers the steeper ridges and knolls of the Conococheague Formation, formed in residuum from underlying sandstone (Plate 2). Conical hills and low ridges in the Beekmantown Formation are commonly covered with chert debris derived from massive chert beds in the middle portion of the formation. Caves, sinkholes, and other karst phenomena are most abundant near these zones of sandstone and chert.

Throughout unit 8 low to moderate slopes are stable except for a minor amount of soil creep; appreciable soil creep and severe erosion of distrubed areas may occur on steep slopes. It is suspected that a pinnacled bedrock profile exists beneath the soil covering portions of this unit resulting in significant changes in depth to bedrock over horizontal distances of less than 10 feet (3 m).

Although there are many attractive construction sites on the gentle slopes with deep residual soils, most of the deep soils have a substantial clay subsoil that has a moderate permeability and a moderately high shrink-swell potential. These soil conditions place restrictions on sewage- and waste-disposal facilities, and the possibility of sudden collapse of the ground surface or differential subsidence in pinnacled bedrock areas requires careful engineering of major structures. It should be emphasized that areas of carbonate bedrock are particularly sensitive to man-induced environmental stresses and that the ground-water reservoir, which generally transcends individual property boundaries, is especially susceptible to contamination from surface sources in sinkhole or karst areas.

Except for Waynesboro and the immediate suburban area, the dominant current land use is agricultural. The rolling areas are predominantly used for pasture whereas some steeper slopes and hilltops are used for woodland or orchard.

UNIT 9

Unit 9 consists of soil, saprolite, residuum, and bedrock associated with highly deformed calcareous slate, interbedded argillite, and argillaceous limestone of the lower and middle portions of the Martinsburg Formation (Plate 2, Omb, units "c" and "a"). There are two parallel belts of unit 9 separated by a central ridge of unit 10 northwest of Fishersville. The land of unit 9 is highly dissected and forms slopes with gradients of 5 to 20 percent south of U. S. Highway 250. Slopes are generally steeper north of U. S. Highway 250, such as in the valley of Meadow Run.

Soils are mainly a mixture of thin (1.0 to 1.5 feet or 0.3 to 0.5 m), excessively drained material and slightly thicker (2.5 to 4.0 feet or 0.8 to 1.2 m), well-drained clayey material. The permeability ranges from moderate to high, and the shrink-swell potential is low except where clay layers occur in the subsoil.

Low to moderate slopes are usually stable but runoff increases with the proportion of slate in the bedrock. Runoff is greatest on steep slopes, and severe erosion can be expected if the soils are disturbed. Deep, artificial cuts should be oriented perpendicular to the trend of cleavage (Figure 21) whenever possible in order to minimize sloughing.

The more gently rolling areas south of U. S. Highway 250 seem to have better construction sites, although more recent residential development has taken place on land with relatively steep slopes along Meadow Creek. The Woodrow Wilson Educational Center, the town of Fishersville, and the development along Meadow Creek are the only major areas of nonagricultural land use on this unit. Gentle slopes and bottomland are used as crop land, and the steeper slopes are mostly pastureland.

Shallow soil, clay subsoil, and the possibility of the formation of solution channels and sinkholes on interbedded limestone place severe restrictions on drainage-field waste-disposal systems and possible sanitary landfill sites.

UNIT 10

Calcareous slate and interbedded sandstone and argillite in the upper portion of the Martinsburg Formation (Plate 2, Omb, unit "s", Figure 23) constitute the bedrock associated with this unit in two areas northwest of Fishersville. One area encompasses a continuous northeastward-trending ridge crest, and the other a flat-topped ridge and bluffs along Christians Creek. Slopes along the ridge crest and the bluffs along Christians Creek exceed 20 percent grade at many places; the only large area of gentle slopes is occupied by the Woodrow Wilson Educational Center. The major factors limiting use of the land are the shallowness (10 to 40 inches or 25 to 102 cm) and droughtiness of the soil and the steep slopes. Slaty soil overlying fractured slate is shallow and has a low shrink-swell potential; sandy soil overlying slate and thin interbedded sandstone is deeper, has a few clay subsoils, and a moderate shrink-swell potential. Both soil types are acidic, and permeability ranges from moderate to moderately good. Erosion is a serious problem on slopes greater than 10 percent due to rapid runoff. Slope stability is a function of the intersection of bedrock cleavage with slope angle and direction, and care should be taken when developing artificial cuts. Building sites are generally good, but the shallow soils and rapid runoff place restrictions on the type and density of waste-disposal facilities. Recommended uses include woodland, pasture, and small grain crops.

UNIT 11

Unit 11 consists of diabase dikes and the residual soils derived from them. These long, narrow bodies of dark, dense, igneous rock have been injected into nearly vertical fractures in older rocks during Triassic time. Southeast of the Blue Ridge these resistant rocks generally crop out only along stream valleys and in deep artifical cuts, but rounded boulders formed by spheroidal weathering are commonly found in the residuum.

Soil and weathered rock from the dikes can be excavated by heavy machinery, but the larger boulders may require blasting to remove them from deep excavations. The plastic clay subsoil associated with deeply weathered dikes is sticky and very slippery when saturated, making it hard to work during wet weather. It has a high shrink-swell potential and may have very slow percolation, imposing moderate to severe limitations for septic-tank waste-disposal systems.

Most of the dikes are narrow enough to be avoided at any particular site, but sloughing and seepage problems may occur near their contacts with adjacent rocks when exposed in road cuts or highwall embankments in thick residuum.

UNIT 12

Unit 12 consists of the upland terrace and alluvial-fan deposits on both sides of the Blue Ridge. The upland terraces along South River and Back Creek (Figure 28) represent ancestral alluvial deposits consisting of well-sorted and stratified cobbles and other gravel, sand, and clay. The surficial 1.5 to 3.0 feet (0.5 to 0.9 m) of these terraces is commonly fine, sandy loam with predominantly clay or gravel subsoil, and it is well suited for agricultural purposes. Permeability is moderate to high and the shrink-swell potential is generally low, both depending on clay content. Building sites are generally good, but sloughing and slides may occur in deep artificial cuts if the soil is wet or the toe of a gravelly slope is disturbed. Severe restrictions exist for solid- and liquid-waste disposal due to the rapid movement of water through the terrace gravels and their superposition over carbonate rocks in most areas. An on-site inspection is recommended prior to any construction.

The small terrace deposits in Robinson and Jones hollows and the large fan deposits at the western foot of the Blue Ridge are usually a mixture of ancestral alluvial and colluvial material. The local upslope rock type determines to a large extent the physical properties of the soil, which generally consists of coarse, 1-inch to 6-foot (3-cm to 2-m) rock fragments in a matrix of sand and clay. Steepness of slope, stoniness, and variable permeability of the soil limit the use of land on unit 12. If the toes of these fans are disturbed, earth movement (creep under normal conditions and slides under saturated conditions) is virtually assured. Recommended use of this land is for woodland and recreational purposes.

Alluvial fans on the east side of the Blue Ridge are a mixture of outwashed and weathered clays, sands, and gravels from greenstone and granodorite of the Blue Ridge. Bedrock is normally greater than 5 feet (2 m) below the surface. There is a great variation in both shrink-swell potential and permeability of the deposits, which is proportional to the amount of clay present. Restrictions on septic-tank drainfields and construction sites are generally moderate, but some planning and engineering will be required prior to disturbance of the terrace materials. Severe restrictions are generally limited to areas in which the soil has a high clay content or where the slopes are steep.

UNIT 13

Unit 13 consists of talus deposits and upland alluvium along each side of the Blue Ridge. The talus deposits are fields that contain angular blocks of rock with very little soil matrix, and they are generally on steep slopes with ledges and sparse vegetation; rockfalls are common. The valley deposits of upland alluvium contain rounded boulders and finer gravel, sand, and associated sandy soil; they are generally wet and commonly have lush vegetation. These unconsolidated materials have high permeability, and they are subject to downslope creep under normal rainfall conditions; during periods of high rainfall, landslides are likely to occur. If the toe of moderate or steep slopes in this material is excavated, earth movements may take place.

Steep slopes and stoniness limit both farm and nonfarm uses. Some pastureland and orchards have been developed along the sides of valleys, but most of the area is used for woodland or recreation.

UNIT 14

Unit 14 consists of lowland alluvial flood-plain and lower terrace deposits that are extensive west of the Blue Ridge along South River, Back Creek, the lower parts of Inch Branch, Sawmill Run, and Robinson and Jones Hollows (Figure 28). On the east side of the Blue Ridge, flood plains are well developed in the Linkinghole Creek, Stockton Creek, and Moormans River drainages. Less extensive alluvial deposits are present along Andersons, Stockton Mill, Williams, and Yellow Mountain creeks.

The alluvial soil is well-drained silt loam or fine sandy loam which contains scattered clay lenses that have somewhat poor drainage. Upstream in the hollows and on steep slopes these deposits become coarser, grading into the gravels, cobbles, and boulders of unit 13. Depth to bedrock varies from 5 to more than 30 feet (2 to 9 m). Natural slopes are rarely greater than 5 percent, except where the stream gradient itself is nearly 5 percent. If left undisturbed, the unit is relatively stable; in the lowlands excavations are subject to slides and sloughing, and on the few steep slopes any disturbance increases the danger of landslides.

Throughout the unit the shrink-swell potential is low and permeability is high, except in clays. Periodic flooding places severe restrictions on construction of any sort. The flooding, however, replenishes these soils in nutrients and makes the alluvial land excellent for most agricultural purposes.

MODIFIED LAND

Areas that have undergone extensive modification by man through grading, which has resulted in large cuts and fills at construction or solid-waste disposal sites, have been delineated on Plates 1 and 2 as modified land. Significant portions of the natural soil horizons, subsoil, or bedrock may have been removed, redeposited, and compacted by heavy machinery at another location within a given site. No generalizations as to the physical properties or distribution of material can be made in these areas without a detailed on-site survey of existing soil and rock conditions.

ROCKFALLS

Areas of actual or potential rockfalls are located along several steep slopes in the Blue Ridge, in deep roadcuts along Interstate Highway 64, and along South River and Stockton Creek. These rockfalls and small areas that are related to abandoned quarry operations and steep artificial cuts are shown on Plates 1 and 2. Rockfall is defined in this report as an area subject to relatively free-falling rock debris at the base of or on steep slopes. The upper portion of many talus deposits contain rockfall areas not shown on Plates 1 and 2. Construction at or near the base of steep slopes where known rockfalls occur is extremely hazardous.

KARST LAND

Sinkholes are common in unit 8, are present in the western portions of units 12 and 14, and may develop near large-producing water wells in those areas. Sinkholes greater than 20 feet (6 m) in diameter and karst land characterized by numerous sinkholes, disappearing streams, and cave openings are plotted on Plates 1 and 2.

The potential is large for ground-water pollution in all limestone areas, particularly in areas of karst land, due to the underground network of solution channels associated with sinkholes and caves. The sinkholes provide a primary conduit for ground-water recharge, and any activity that contaminates or interfers with this recharge may affect the quality of ground water.

REFERENCES

American Geological Institute, 1972, Glossary of geology: Washington, Am. Geol. Inst., 858 p.

Bartholomew, M. J., 1977, Geology of the Greenfield and Sherando quadrangles, Virginia: Virginia Division of Mineral Resources Publication 4, 43 p.

Bloomer, R. O., and Werner, H. J., 1955, Geology of the Blue Ridge region in central Virginia: Geol. Soc. America Bull., vol. 66, p. 579-606.

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

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

Cady, R. C., 1936, Ground-water resources of the Shenandoah Valley, Virginia: Virginia Geol. Survey Bull. 45, 137 p.

Calver, J. L., Hamlin, H. P., and Wood, R. S., 1961, Analyses of clay, shale, and related materials — northern counties: Virginia Division of Mineral Resources, Mineral Resources Report 2, 194 p.

Davis, S. N., and DeWiest, R. J. M., 1966, Hydrogeology: New York, John Wiley and Sons, Inc., 463 p.

Ecolsciences, Inc., 1974, Environmental assessment of the proposed sewerage facilities for the town of Front Royal, Virginia: open-file report, town of Front Royal.

Edmundson, R. S., 1945, Industrial limestones and dolomites in Virginia: northern and central parts of Shenandoah Valley: Virginia Geol. Survey Bull. 65, 195 p.

Gathright, T. M., II, 1976, Geology of the Shenandoah National Park, Virginia: Virginia Division of Mineral Resources Bulletin 86, 93 p.

Hack, J. T., 1965, Geomorphology of the Shenandoah Valley, Virginia and West Virginia, and origin of the residual ore deposits: U. S. Geol. Survey Prof. Paper 484, 84 p.

Herz, Norman, 1969, The Roseland alkalic anorthosite massif, Virginia, *in* Origin of anorthosite and related rocks: New York State Mus. and Sci. Service Mem. 18, p. 357-367.

Higgins, M. W., 1971, Cataclastic rocks: U. S. Geol. Survey Prof. Paper 687, 97 p.

Hillhouse, D. N., 1960, Geology of the Piney River-Roseland titanium area, Nelson and Amherst counties, Virginia: Doctoral, Virginia Polytech. Inst.

Knechtel, M. M., 1943, Manganese deposits of the Lyndhurst-Vesuvius district, Augusta and Rockbridge counties, Virginia: U. S. Geol. Survey Bull. 940-F, p. 163-198.

Nelson, W. A., 1962, Geology and mineral resources of Albemarle County: Virginia Division of Mineral Resources Bulletin 77, 92 p.

O'Neill, B. J., Jr., 1964, Atlas of Pennsylvania's mineral resources — pt. 1, Limestones and dolomites in Pennsylvania: Pennsylvania Geol. Survey, 4th Ser., Bull. M50, 40 p.

Parrot, W. T., 1954, Physical test results of the Virginia highway statewide aggregate survey: Virginia Department of Highways, 68 p.

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

Rader, E. K., and Biggs, T. H., 1975, Geology of the Front Royal quadrangle, Virginia: Virginia Division of Mineral Resources Rept. Inv. 40, 91 p.

__________ 1976, Geology of the Strasburg and Toms Brook quadrangles, Virginia: Virginia Division of Mineral Resources Rept. Inv. 45, 104 p.

Ries, Heinrich, and Somers, R. E., 1920, The clays and shales of Virginia west of the Blue Ridge: Virginia Geol. Survey Bull. 20, 118 p.

Schwab, F. L., 1970, Origin of the Antietam Formation (late Precambrian-Lower Cambrian), central Virginia: Jour. Sed. Petrology, vol. 40, no. 1, p. 354-366.

__________ 1971, Harpers Formation, central Virginia — A sedimentary model: Jour. Sed. Petrology, vol. 41, no. 1, p. 139-149.

Stose, G. W., and others, 1919, Manganese deposits of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, 166 p.

Swett, Keene, and Smit, D. E., 1972, Paleogeography and depositional environments of the Cambro-Ordovician shallow-marine facies of the North Atlantic: Geol. Soc. America Bull., vol. 83, p. 3223-3248.

Todd, D. K., 1959, Ground-water hydrology: New York, John Wiley and Sons, Inc., 336 p.

Trainer, F. W., and Watkins, F. A., Jr., 1975, Geohydrologic reconnaissance of the upper Potomac basin: U. S. Geol. Survey Water-Supply Paper 2035, 68 p.

Virginia Division of Mineral Resources, 1963, Geologic map of Virginia: Virginia Division of Mineral Resources, scale 1:500,000.

Virginia Division of Mineral Resources, 1969, Natural features caused by a catastrophic storm in Nelson and Amherst counties, Virginia: Virginia Minerals, Special Issue, 20 p.

Walton, W. C., 1970, Groundwater resource evaluation: New York, McGraw-Hill Book Company, 664 p.

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

Webb, H. W., Nunan, W. E., and Penley, H. M., 1970, Road log — Storm-damaged areas in central Virginia: Virginia Minerals, vol. 16, no. 1, p. 1-10.

GLOSSARY[1]

(The definition of a particular word is that pertaining to this report and not to its possible multiple uses.)

argillite — A compact rock derived from mudstone or shale that has been weakly metamorphosed and lacks the cleavage of a slate or the crenulations of a phyllite.

cataclastic — Pertaining to the structure produced in a rock by the action of severe mechanical stress during dynamic metamorphism. Characteristic features include the bending, breaking, and granulation of the minerals in the rock.

cleavage — The property or tendency of a rock to split along secondary, aligned fractures, or other closely spaced, planar structures or textures, which are produced by deformation or metamorphism.

cone of depression — A depression in the potentiometric surface of a body of ground water that has the shape of an inverted cone around a well from which water is being withdrawn.

dynamothermal metamorphism — A common type of regional metamorphism involving the effects of directed pressures and shearing stresses as well as a wide range of confining pressures (3 to 10 kilobars) and temperatures (400°C to about 800°C).

foliation — A general term for a planar arrangement of textural or structural features in any type of rock; most commonly applied to metamorphic rock.

gneiss — A foliated rock formed by regional metamorphism in which bands or lenticles of granular minerals alternate with bands or lenticles in which minerals having flaky or elongate prismatic habit are predominant.

hydrogeology — The science that deals with subsurface waters and related surface waters as dictated by the geologic environment.

influent stream — A stream that contributes water to (recharges) the ground-water reservoir.

joint — A surface of actual or potential fracture or parting in a rock, without displacement.

karst — A type of topography that is formed over limestone, dolomite, or gypsum by dissolving or solution, and that is characterized by closed depressions or sinkholes, caves, and underground drainage.

lithology — The description of rocks, especially in hand specimens and in outcrops, on the basis of such characteristics as color, structure, mineralogic composition, and grain size.

loam — A rich, permeable soil composed of a friable mixture of relatively equal and moderate proportions of clay, silt, and sand particles, and usually containing organic matter (humus) with a minor amount of gravelly material. It usually implies a fertile soil, and is sometimes called topsoil, in contrast to subsoils which contain little or no organic matter.

mylonite — A microbreccia with fluxion structure produced by the extreme granulation and shearing of rocks during dynamic metamorphism.

permeability, primary — The original capacity of a geologic formation to transmit fluids through interconnected pore spaces.

permeability, secondary — The transmission of fluids through physical (fractures) or chemical (solution) openings developed after a rock was formed.

phyllite — A metamorphosed rock (originally mudstone or shale) formed by regional metamorphism and intermediate in metamorphic grade between slate and mica schist.

phyllonite — A rock that macroscopically resembles a phyllite but that is formed by mechanical degradation (mylonitization) of initially coarser rocks.

porosity — A measure of interstices in a rock expressed as the percentage of void space to the total rock mass.

residuum — The mantle of material formed in place by the decomposition and disintergration of rocks and the consequent weathering and loss of volume of the mineral materials. The original structures of the rock are partially preserved in much of it, but in some areas the residuum is chaotic in structure or completely structureless.

saprolite — A soft, earthy, clay-rich, thoroughly decomposed rock formed in place by chemical weathering of igneous and metamorphic rocks. It often forms a thick (as much as 300 feet or 91 meters or more) layer or cover that perserves almost intact the structure of the original material and which has undergone little or no loss of volume as a result of weathering. The color is commonly some shade of red or brown.

schist — A strongly foliated crystalline rock formed by dynamic metamorphism which can be readily split into thin flakes or slabs due to the well-developed parallelism of more than 50 percent of the minerals present, particularly those of elongate prismatic or lamellar habit, e.g. hornblende, mica.

shrink-swell potential — An indication of the volume change to be expected of a soil material with changes in moisture content. Shrink-swell causes much damage to building foundations, roads, and other structures.

talus — An accumulation of rock fragments of any size or shape (usually coarse and angular) derived from and lying at the base of a cliff or steep rock slope.

xenoblastic — Said of a mineral of low form energy which has grown during metamorphism without the development of its characteristic crystal faces and the texture produced thereby.

[1] Definitions predominantly adapted from American Geological Institute (1972).

APPENDIX

ROAD LOG

The following road log is a guide to important geologic features visible along or near highways in or adjacent to the Waynesboro East and Waynesboro West 7.5-minute quadrangles. Distances between points of interest, as well as cumulative mileage, are shown. *Permission should be obtained from the owner before entering and collecting any samples from private property; failure to obtain such permission violates trespass laws and is punishable under law.*

Cumulative miles (km)	*Distance*	*Explanation*
0.0 (0.0)	0.0 (0.0)	Begin road log a mile east of Waynesboro East quadrangle at intersection of U. S. Highway 250 and State Road 824, approximately 0.4 mile (0.6 km) west of the Interstate Highway 64 bridge over U. S. Highway 250. Proceed east on State Road 824.
0.6 (1.0)	0.6 (1.0)	Pass Virginia Department of Highways and Transportation maintenance facility on right (west) side of State Road 824.
0.95 (1.53)	0.35 (0.56)	Cross bridge over Stockton Creek and park at borrow pit on left (east) side of State Road 824.
		STOP 1. Quarry on right side of State Road 824 (Crozet 7.5-minute quadrangle). Enter quarry area through gate in fence just south of bridge after obtaining permission to go on to quarry property, and walk approximately 300 feet (91 m) in a westerly direction along Stockton Creek. Lovingston mylonitic biotite gneiss quarry face on left (south). Cataclastic gneiss with felsic veins or stringers that contain blue quartz is exposed in the bottom of the small stream flowing out of the quarry near its confluence with Stockton Creek. Similar veins in the gneiss along Stockton Creek, 160 feet (49 m) west of the western edge of the quarry, are more discordant and have been folded. Return to vehicle, turn around, and return to U. S. Highway 250 by way of State Road 824.
1.9 (3.1)	0.95 (1.53)	Intersection of U. S. Highway 250 and State Road 824; turn left (west) onto U. S. Highway 250.
2.0 (3.2)	0.1 (0.2)	Cataclastic gneiss with interlayered phyllonite exposed at entrance to Patricia Anns Country Store.
2.5 (4.0)	0.5 (0.8)	Pass entrance to campground on left. Water-well drill cuttings from this locality show interlayered cataclastic gneiss and phyllonite.
3.0 (4.8)	0.5 (0.8)	Enter Waynesboro East quadrangle.
4.0 (6.4)	1.0 (1.6)	Pass Lebanon Presbyterian Church on right (north) side of U. S. Highway 250.
4.2 (6.8)	0.2 (0.3)	Turn right (north) onto State Road 796 and continue west, downhill parallel to U. S. Highway 250.
4.3 (6.9)	0.10 (0.16)	*STOP 2.* Exposure of granodiorite gneiss of the Pedlar Formation in driveway just uphill from Stockton Creek. Rock is medium to coarse grained, slightly foliated, and characteristically bluish to greenish gray on fresh surfaces. The large weathered blocks with thin, yellow to light-gray rinds are typical of most exposures in the area. The granodiorite gneiss is part of a small body that occurs on each side of Stockton Creek but cannot be traced for any significant distance. Return to vehicle and retrace route on State Road 796 to U. S. Highway 250.

Cumulative miles (km)	Distance	Explanation
4.4 (7.1)	0.10 (0.16)	Turn right (west) on U. S. Highway 250 from State Road 796.
4.5 (7.2)	0.10 (0.16)	Cross Stockton Creek.
4.6 (7.4)	0.10 (0.16)	Granodiorite gneiss of the Pedlar Formation exposed in low ledges on south side of Stockton Creek, approximately 240 feet (73 m) north of U. S. Highway 250. A thin section of a sample from this locality (R-6538) contains fibrous amphibole pseudomorphs after pyroxene, a general characteristic of the granodiorite gneiss. Continue west on U. S. Highway 250.
4.9 (7.9)	0.3 (0.5)	Boulders of cataclastic rocks exposed in the flood plain of Stockton Creek on right (north) side of U. S. Highway 250.
5.1 (8.2)	0.2 (0.3)	Recross Stockton Creek.
5.6 (9.0)	0.5 (0.8)	Intersection of U. S. Highway 250 and State Highway 6; turn left (south) on State Highway 6.
6.1 (9.8)	0.5 (0.8)	*STOP 3.* Intersection of State Highway 6 and State Road 803; pull off road onto right shoulder at intersection. Phyllonite, a schistose rock derived from intense shearing of the cataclastic rock unit, is exposed in roadcuts. The phyllonite seems to completely surround a large, relatively unsheared body of granodiorite gneiss forming Turks Mountain and Round Top, two hills visible to the south. It marks the trace of the Rockfish Valley fault around the hills. Core data from drill holes show the phyllonite is interlayered in the cataclastic rock unit. Continue in a southwesterly direction along State Highway 6.
6.4 (10.3)	0.3 (0.5)	Turn left (southeast) onto State Road 637 at Critzers Shop.
7.1 (11.4)	0.70 (1.13)	*STOP 4.* Weathered exposures of granodiorite gneiss in roadcuts on the south slope of Turks Mountain. The rock is similar to that at Stop 2, and the dark-greenish masses between the large feldspar blasts are amphibole pseudomorphs of pyroxene. Orange to yellow saprolite and soil are typical on more gentle slopes developed on this rock unit. Turn around and return to State Highway 6. Gap between Turks Mountain and Round Top occurs along the trace of a diabase dike.
7.8 (12.6)	0.7 (1.1)	Turn right (northeast) from State Road 637 onto State Highway 6 at Critzers Shop.
8.6 (13.8)	0.8 (1.3)	Turn left (northwest) onto U. S. Highway 250; pass Rockfish Gap Country Store on right.
8.8 (14.2)	0.2 (0.3)	Turn left (west) onto State Road 750. Park on left shoulder about 300 feet (91 m) west of intersection.
		STOP 5. Ledges of cataclastic rocks in bottom of Stockton Creek on left (south) side of State Road 750. Three varieties of cataclastic rocks can be seen at this stop, all of which have well-developed schistosity. The fine-grained, greenish-gray mica schist with feldspar lumps is blastomylonite. Coarser-grained, "gritty"-textured rocks are protomylonite and mylonite gneiss. The cataclastic rocks seem to have been derived by intense shearing, primarily from Lovingston gneiss. Continue in a northwesterly direction along State Road 750.
9.2 (14.8)	0.3 (0.5)	Pass outcrops of cataclastic gneiss in stream on left (south side of Stockton Creek).

Cumulative miles (km)	*Distance*	*Explanation*
9.5 (15.3)	0.3 (0.5)	Cross contact (Rockfish Valley fault) between cataclastic rocks and Swift Run metasedimentary rocks, which are exposed on a small orchard road on the right side of State Road 750, just northwest of the contact line.
10.0 (16.1)	0.5 (0.8)	Pass intersection with State Road 637; continue uphill on State Road 750 along which there are discontinuous exposures of the Swift Run Formation.
10.6 (17.0)	0.6 (1.0)	At the intersection of State Road 750 and State Highway 151 turn right (north) uphill around the Afton Post Office and into parking area between the post office and the Chesapeake and Ohio Railway; park in east end of lot.
10.7 (17.2)	0.1 (0.2)	*STOP 6.* Swift Run Formation. Walk to the northeast along railroad spur to the point where the spur intersects the main line; turn to the left (southwest) and walk through deep cuts in the Swift Run Formation that range from light grayish green sericite schist to whitish-weathering, metamorphosed sandstone beds. Two cleavages, one steeply dipping and one more gently dipping, can be seen in these cuts. Bedding is visible at a few locations below overhanging ledges, and is manifested as subtle color banding and as a change in grain size from one band to another. Return to intersection of railroad tracks and follow spur back to parking area.
10.8 (17.4)	0.1 (0.2)	Turn right onto State Highway 151.
11.3 (18.2)	0.5 (0.8)	Turn left onto U. S. Highway 250 and continue uphill toward the crest of the Blue Ridge at Rockfish Gap.
12.3 (19.8)	1.0 (1.6)	Pass prominent exposures of the Catoctin Formation on right (north) side of U. S. Highway 250; scenic view of Rockfish Valley on the left (south) side of U. S. Highway 250.
12.6 (20.3)	0.3 (0.5)	Turn right on entrance ramp to Skyline Drive.
12.7 (20.4)	0.1 (0.2)	Turn right on Skyline Drive, crossing bridge over Interstate Highway 64. Pass intermittent exposures of the Catoctin Formation along right side of Skyline Drive.
13.5 (21.8)	0.8 (1.3)	Stop at entrance station to Shenandoah National Park. Leave rock hammers in car as collecting samples in the park is prohibited by law. Continue northeasterly on Skyline Drive noting outcrops of the Catoctin Formation along the way.
15.8 (25.4)	2.3 (3.7)	Pass McCormick Gap Overlook on left (map elevation 2,455 feet).
18.1 (29.0)	2.6 (4.2)	Pass Beagle Gap Overlook on right.
18.5 (29.8)	0.4 (0.6)	*STOP 7.* Park at Appalachian Trail crossing in Beagle Gap (map elevation 2,490 feet). Cross stile over fence on northeast side of Skyline Drive and follow Appalachian Trail across field to slope of Calf Mountain. Ascend in a northerly direction along Appalachian Trail. Trail traverses through slope breccia derived from the Catoctin Formation. About 0.3 mile (0.5 km) from Skyline Drive leave trail and continue traverse toward northwest to the southwest summit (map elevation 2,910 feet) of Calf Mountain. About 500 feet (152 m) above the trail cross a bench that seems to follow a flow-on-flow contact in the Catoctin Formation. Above this bench on the summit are low outcrops of metamorphosed sedimentary breccia within the Catoctin. The rocks at the higher elevations on Calf, Bear Den, and Scott mountains appear to be situated on the nearly horizontal upright limb of an overturned anticline; the lower elevations are on the southeastward-dipping overturned limb. Return to cars and continue to the north along Skyline Drive.

Cumulative miles (km)	*Distance*	*Explanation*
19.2 (30.9)	0.7 (1.1)	Turn left into Calf Mountain Overlook; turn around and proceed southwesterly along Skyline Drive.
25.2 (40.6)	6.0 (9.7)	Entrance station; continue to the southwest, crossing over Interstate Highway 64 and U. S. Highway 250.
26.0 (41.8)	0.8 (1.3)	Turn right onto State Road 610, continue northwesterly past Howard Johnsons to intersection with U. S. Highway 250.
26.2 (42.1)	0.2 (0.3)	Turn left (north) onto U. S. Highway 250 west.
26.3 (42.3)	0.1 (0.2)	Pass under Interstate Highway 64 bridge and park on right shoulder just west of bridge. *STOP 8.* Exposures on east side of U. S. Highway 250 are the uppermost metasedimentary unit of the Catoctin Formation. Interlayers of greenstone, metamorphosed arkose, purple metatuff, and fine-grained phyllitic metasedimentary rocks are exposed for approximately 1,300 feet (396 m) along the highway. Primary sedimentary features in these rocks show repetitive isoclinal fold limbs; the axial surfaces of the folds have a dip toward the southeast roughly parallel to cleavage. After examining these outcrops return to cars and continue down the mountain (north) along U. S. Highway 250.
26.8 (43.1)	0.5 (0.8)	Pass motel on right.
26.9 (43.2)	0.1 (0.2)	*STOP 9.* Pull off road onto right shoulder beyond second motel entrance. Thick section of metasedimentary rocks of the Catoctin Formation is exposed in the eastern (right) face of the roadcut, and the uppermost metabasalt unit is exposed in the western (left) face. After examining outcrops, continue to the northwest along U. S. Highway 250.
27.2 (43.7)	0.3 (0.5)	Purple phyllitic metatuff unit at the top of the Catoctin Formation is well exposed along the highway ditch.
27.9 (44.9)	0.5 (0.9)	*STOP 10.* Turn left into gravel parking area. Exposures on the north side of U. S. Highway 250 are in the Weverton Formation, which includes sericitic phyllite, iron-rich metamorphosed sandstone, thin-quartzite layers, and quartz pebble conglomerate. Continue west on U. S. Highway 250.
28.2 (45.4)	0.3 (0.5)	Ferruginous quartzite of the Harpers Formation on the right (north) side of U. S. Highway 250.
28.4 (45.7)	0.2 (0.3)	*STOP 11.* Park on shoulder of U. S. Highway 250, just east of Chesapeake and Ohio Railway overpass; walk up road to railroad tracks and then west along Chesapeake and Ohio Railway for about 1,300 feet (396 m). Note seemingly isoclinally folded, metamorphosed ferruginous sandstone layers of the Harpers Formation exposed in embankment near railroad bridge. The metamorphosed sandstone is interlayered with light-gray phyllite and sandy phyllite. In the western end of the exposures (Figure 10) phyllite is the predominant lithology (middle Harpers). Return to car and proceed northwest along U. S. Highway 250.
28.7 (46.2)	0.3 (0.5)	Enter City of Waynesboro.
30.5 (49.1)	1.8 (2.9)	Turn right at intersection onto U. S. Highway 340.
30.8 (49.6)	0.3 (0.5)	Turn right onto quarry access road immediately after passing beneath Chesapeake and Ohio Railway bridge.

Cumulative miles (km)	*Distance*	*Explanation*
31.3 (50.4)	0.5 (0.8)	Continue along access road parallel to tracks and past abandoned quarry office buildings. (During wet weather this unsurfaced road may be impassable.)
31.6 (50.8)	0.3 (0.5)	Pass large brecciated mass of Antietam quartzite on left.
31.8 (51.2)	0.2 (0.3)	*STOP 12.* Harpers Formation. Park cars at Chesapeake and Ohio Railway sign near end of quarry face and walk eastward along the railroad right-of-way. The upper part of the Harpers Formation, a phyllite sequence with thin- to medium-bedded metamorphosed sandstone layers, is exposed in the first cut along the north side of the railroad. Cleavage in these rocks has a more gentle dip than the southeastward-dipping strata, showing that the rocks are overturned. Toward the east the bedding dips become more gentle to a point where they are horizontal and seem to be completely inverted, as shown by Z-shaped minor folds and the cleavage-bedding relationships. Farther to the east bedding has a westward dip and a second, steeply southeastward-dipping joint system becomes recognizable. These fractures are thought to be related to the collapse and westward rotation of the overturned fold limb following solution of the underlying Shady Formation. Return to the end of the abandoned Antietam quarry that was originally operated by the Chesapeake and Ohio Railway for ballast stone. The shattered and brecciated Antietam quartzite required little or no blasting to quarry. Turn around and return to U. S. Highway 340.
32.4 (52.1)	0.6 (1.0)	Turn left onto U. S. Highway 340.
32.7 (52.6)	0.3 (0.5)	Intersection between U. S. Highways 340 and 250; continue south on Delphine Avenue (State Road 624).
33.0 (53.1)	0.3 (0.5)	Turn left onto 11th Street. Drive to end of 11th Street and turn right onto borrow-pit entrance road.
33.3 (53.6)	0.3 (0.5)	*STOP 13.* Park at chain gate on entrance road and walk uphill to borrow pit. Saprolite of the upper Antietam Formation is exposed in quarry face. Rock consists of thin metamorphosed sandstone beds interlayered with phyllite and argillite. Folds displayed in these beds have axial surfaces that have a gentle dip to the west (Figure 14) and are locally down-dropped to the west along small-displacement vertical faults. It is thought that the visible structures mirror the larger scale structures in the Blue Ridge. Return to vehicles and retrace route to Delphine Avenue via 11th Street.
33.5 (53.9)	0.2 (0.3)	Turn right on Delphine Avenue (State Road 624) and continue to its intersection with U. S. Highway 250.
33.8 (54.4)	0.3 (0.5)	Turn left onto U. S. Highway 250.
33.9 (54.6)	0.1 (0.2)	Pass beneath Norfolk and Western Railway.
34.0 (54.7)	0.1 (0.2)	Turn right onto U. S. Highway 250-340 Bypass.
34.4 (55.4)	0.4 (0.6)	Waynesboro Fire Department on left.
34.6 (55.7)	0.2 (0.3)	Turn right onto North Wayne Avenue, continue one block and park by the Chesapeake and Ohio Railway.

Cumulative miles (km)	*Distance*	*Explanation*
		STOP 14. Clastic beds in the upper Waynesboro Formation are exposed along the railroad east of the Florence Avenue bridge; dolomite in the lower Elbrook Formation occurs west of the bridge. The Waynesboro Formation includes maroon, green, tan, and yellow argillite and phyllite with interbedded metasiltstone and metasandstone. The coarser beds under the bridge contain well-preserved ripple marks, mud cracks, and cross-bedding, all of which show the beds are overturned. Several beds at this locality contain fossil impressions of the brachiopods *Acrotreta buttsi* and *Kutorgina*. The lower Elbrook Formation exposed northwest of the bridge contains ribbon-banded dolomite and dolomitic limestone. The ribbon banding is formed by alternating dolomite and limestone. Approximately 160 feet (49 m) west of the bridge some red argillite is interlayered with the dolomite and limestone. Return to vehicle, turn around, and retrace route to U. S. Highway 250 Bypass via Wayne Avenue.
34.7 (55.8)	0.1 (0.2)	Turn right onto U. S. Highway 250 Bypass.
35.4 (57.0)	0.7 (1.1)	Intersection of U. S. Highways 340 and 250; turn right onto U. S. Highway 250.
36.8 (59.2)	1.4 (2.3)	Turn left onto State Road 1022 (Bookerdale Road) at crest of hill.
37.3 (60.0)	0.5 (0.8)	Cross trend of diabase dike (boulders exposed in field adjacent to building on right.
37.6 (60.5)	0.3 (0.5)	*STOP 15.* Conococheague Formation is exposed on the left (southeast) side of Bookerdale Road. This is the typical light gray weathering limestone that has a ribbon-banded character due to tan to buff dolomite laminae, or thin (20 mm) interbeds. A well-developed cleavage cuts across the bedding in these outcrops, and locally there has been some transposition of the bedding in small Z-shaped cleavage folds. Much of the irregularity of lamination is probably due to differential compaction or other soft-sediment deformation.
37.8 (60.8)	0.2 (0.3)	End of State Road 1022; turn around and return to U. S. Highway 250.
38.8 (62.4)	1.0 (1.6)	Turn right onto U. S. Highway 250.
39.5 (63.6)	0.7 (1.1)	Intersection with Oakland Parkway, continue along U. S. Highway 250.
40.2 (64.7)	0.7 (1.1)	Turn right onto U. S. Highway 340.
40.9 (65.8)	0.7 (1.1)	Turn left onto Lovers Lane.
41.3 (66.5)	0.4 (0.6)	*STOP 16.* Park at barrier on left side of road and walk along sewer line paralleling South River. Exposures of the Elbrook Formation occur along bank of South River on sewer line right-of-way to south. First exposures, 160 feet (49 m) south of the barrier, consist of dark-gray crystalline dolomite, with algal stromatolites. Purplish-weathering, kinked, laminated phyllite occurs farther to the south along the river. Return to vehicle and proceed along Greenway Circle to Meadowbrook Lane; turn right on Meadowbrook Lane.
41.7 (67.1)	0.4 (0.6)	Turn left onto Northgate Avenue.

Cumulative miles (km)	*Distance*	*Explanation*
42.1 (67.8)	0.4 (0.6)	Turn left onto U. S. Highway 340.
43.1 (69.4)	1.0 (1.6)	Cross over Interstate Highway 64; continue west on U. S. Highway 340.
46.2 (74.4)	3.1 (5.0)	Turn right onto State Road 635.
47.4 (76.3)	1.2 (1.9)	*STOP 17.* Park on shoulder of State Road 635. Exposures of Chepultepec limestone in pastureland on both sides of road. On the east side are gently dipping ledges of massive, gray limestone with thin, serrated laminae and black chert nodules. Cleavage is well developed in these rocks, and there are many thin, white veins of calcite. Coiled cephalopods in outcrops northeast of the pond on the east side of the road. Continue along State Road 635.
47.7 (76.8)	0.3 (0.5)	Beekmantown Formation exposed in field on right (north). Intersection with State Road 643; turn right on State Road 635.
48.3 (77.8)	0.6 (1.0)	Exposure of Lincolnshire and New Market limestones on right (northeast).
48.7 (78.4)	0.4 (0.6)	Intersection with State Road 608 at edge of quadrangle; turn right (northeast) onto State Road 608.
48.8 (78.5)	0.1 (0.1)	*STOP 18.* Exposures of basal Martinsburg slate in roadcut along State Road 608. This slate is light-gray to tan on weathered exposures, and black on fresh exposures. The slate here is calcareous, has a well-developed phyllitic sheen due to fine, crystalline mica along cleavage, and a prominent crenulation in addition to bedding-cleavage intersections on cleavage surfaces. The graptolite *Climacograptus* is found here. Continue northeast on State Road 608.
49.4 (79.5)	0.6 (1.0)	Cross Interstate Highway 64.
49.9 (80.3)	0.5 (0.8)	Turn right (southeast) onto State Road 627 to Tinkling Springs churchyard.
50.1 (80.6)	0.2 (0.3)	*STOP 19.* Pull off on right beside house across from church. Lincolnshire limestone exposed beside the house is dark gray and weathers to medium gray. It is coarse grained, bioclastic, and very recrystalline. Coiled cephalopods approximately 10 to 15 mm in diameter can be seen on the irregular bedding surfaces. Trilobite fragments and bryozoan debris comprise a large percentage of the rock. At this locality the Lincolnshire Formation appears to project upwards through Martinsburg slate on the crest of a minor anticline. The original structure may have been a small bryozoan patch reef surrounded by muddy shoals. Return to State Road 608.
50.3 (81.0)	0.2 (0.3)	Turn right (northeast) onto State Road 608, then turn left (northwest) onto State Road 636.
51.2 (82.4)	0.9 (1.5)	*STOP 20.* Park on right (northeast) side of road at base of hill. Limestone in the "a" unit of the Martinsburg Formation is exposed on right (northeast) side of State Road 636 opposite farm road. The flaggy, bedded limestone is black on freshly broken surfaces, weathers light-gray, and has a characteristic blocky jointing. The irregularly spaced beds are 1.5 to 6 cm thick and within the beds is a fine, regular lamination. Flat pebble conglomerate beds and mud-slump features have also been observed in side ditches along this road. Slaty beds occur above and below this limestone. Continue to the northwest along State Road 636.

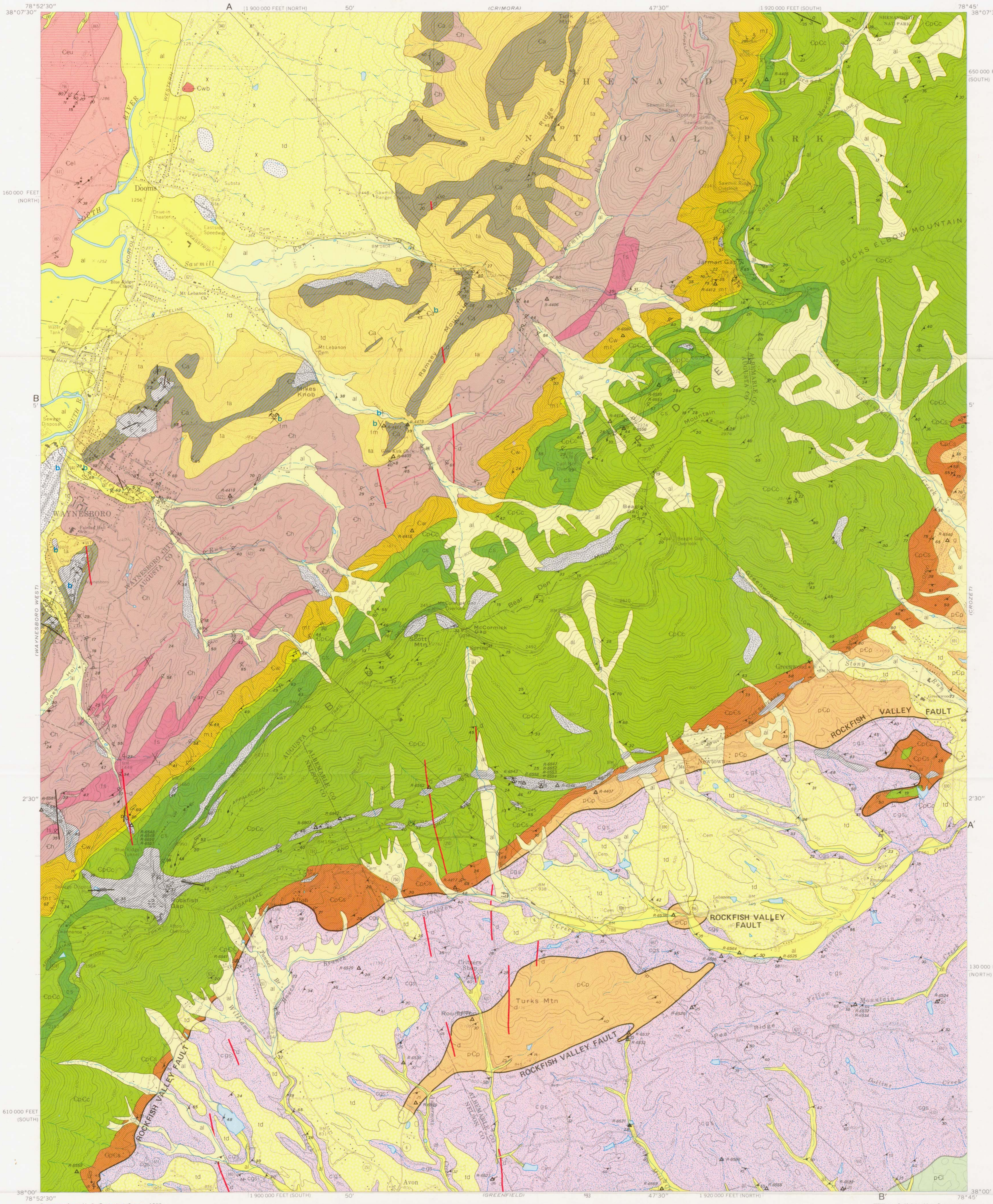
Cumulative miles (km)	Distance	Explanation
51.6 (83.0)	0.4 (0.6)	*STOP 21.* Martinsburg Formation, unit "s." Stop just east of Chesapeake and Ohio Railway overpass and walk south along railroad to exposures of interlayered slate and metamorphosed lithic sandstone. Massive sandstone beds form a small syncline at this locality. Slate chips, and quartz and feldspar clasts can be seen in the coarse-grained rocks. Return to vehicle and continue to the northwest along State Road 636.
51.9 (83.5)	0.3 (0.5)	Enter Stuarts Draft quadrangle.
53.1 (85.5)	1.2 (1.9)	Turn right (east) at intersection with U. S. Highway 250, passing roadcuts in the Martinsburg.
53.9 (86.9)	0.8 (1.3)	Reenter Waynesboro West quadrangle.
54.9 (88.4)	1.0 (1.5)	Turn left (north) on State Road 642.
55.7 (89.6)	0.8 (1.3)	Turn left (north) on State Road 794 and proceed downhill.
56.2 (90.5)	0.5 (0.8)	*STOP 22.* Park on right shoulder of road. Martinsburg slate is exposed on left (west) across creek. Interbedded, dark-gray to black slate and light-tan to buff, calcareous argillite are typical of the middle (unit "a") Martinsburg Formation. Bedding has dips steeply to the southeast and cleavage is slightly less steep, showing the tops of beds are to the west and upside down. The slate is well crystallized, as verified by X-ray analyses which show the presence of calcite, quartz, muscovite, chlorite, albite, and epidote(?). This is a characteristic greenschist-facies metamorphic mineral assemblage, and X-ray analyses of slate from the basal ("c" unit) Martinsburg give similar results. Continue along State Road 794 to first driveway.
56.7 (91.2)	0.5 (0.8)	Turn around in driveway and proceed southeast on State Road 794.
57.7 (92.9)	1.0 (1.6)	Turn right (southwest) onto State Road 642.
58.5 (94.2)	0.8 (1.3)	Turn left (southeast) onto U. S. Highway 250.
59.4 (95.6)	0.9 (1.5)	Turn left (northeast) onto State Road 608 in Fishersville.
60.0 (96.5)	0.6 (1.0)	*STOP 23.* Turn left onto State Road 608 at intersection with State Road 796 and park on shoulder of road. The Beekmantown Formation is exposed as ledges in the field northeast of the intersection. The upper contact of the Beekmantown with Lincolnshire limestone is exposed along State Road 608, approximately 300 feet (91 m) northwest of the intersection. The upper part of the Beekmantown consists of thick, interbedded dolomite, limestone, and burrowed dolomitic limestone. The limestone resembles New Market Limestone but occurs stratigraphically below it and is separated from it by an unconformity at some localities; no New Market Limestone was recognized at this locality. The uppermost dolomite in the Beekmantown is overlain by coarse, gray, bioclastic limestone of the Lincolnshire Formation. The contact between the Lincolnshire and Martinsburg formations can be traced across State Road 608 approximately 600 feet (183 m) northwest of the intersection. Return to car and continue along State Road 608 to red barn on left (west).

Cumulative miles (km)	*Distance*	*Explanation*
60.3 (97.0)	0.3 (0.5)	Turn around and return to intersection of State Roads 608 and 796.
60.7 (97.7)	0.4 (0.6)	Turn left (northeast) on State Road 796.
63.0 (101.4)	2.3 (3.7)	Enter Fort Defiance quadrangle.
64.2 (103.3)	1.2 (1.9)	Turn right (southeast) on State Highway 254.
64.6 (103.9)	0.4 (0.6)	Reenter Waynesboro West quadrangle.
65.3 (105.1)	0.7 (1.1)	Turn left (northeast) on State Road 782.
66.0 (106.2)	0.7 (1.1)	*STOP 24.* Diabase dike exposed in trees on right (southeast) side of State Road 782 weathers to boulders that stand up in relief over the bedrock (Elbrook Formation). Turn around in drive on left and return to the southwest toward State Highway 254.
66.7 (107.3)	0.7 (1.1)	Turn left (southeast) on State Highway 254.
67.2 (108.1)	0.5 (0.8)	*STOP 25.* Upper Elbrook Formation exposed on southeast side of intersection with State Road 799. The Elbrook here is a thin- to medium-bedded dolomite with characteristic cross-hatched weathering. The weathered surface is yellowish brown and gray, and fresh rock is dark gray.
69.2 (111.3)	2.0 (3.2)	Continue southeast on State Road 254 to Waynesboro city limits.

END OF ROAD LOG

INDEX

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



Base map from U. S. Geological Survey, 1973
Waynesboro East Quadrangle, 7½-minute series

GEOLOGIC MAP OF THE WAYNESBORO EAST QUADRANGLE, VIRGINIA

Geology by Thomas M. Gathright II, William S. Henika and John L. Sullivan III

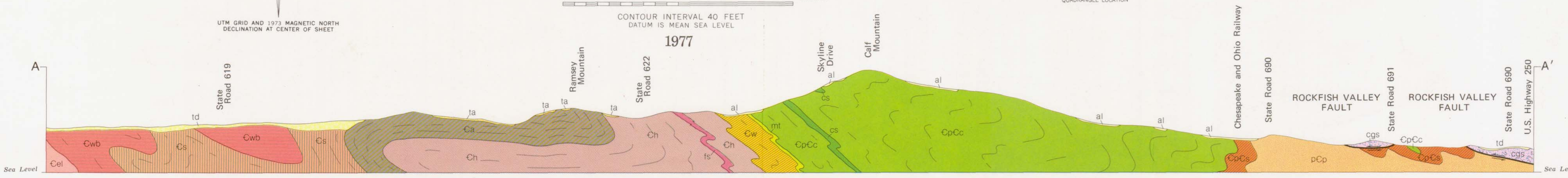
SCALE 1:24 000

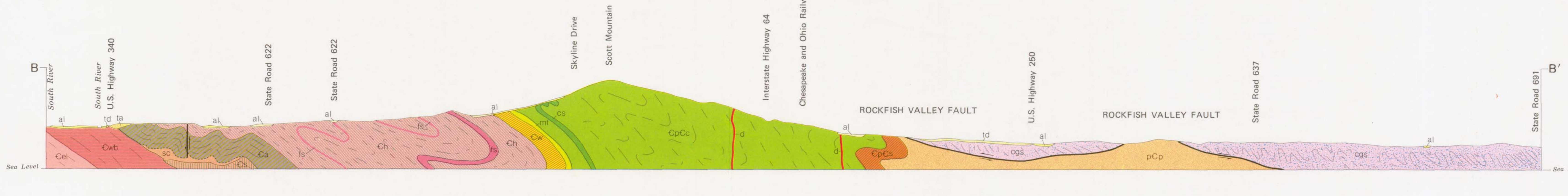
UTM GRID AND 1973 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL

1977

QUADRANGLE LOCATION





EXPLANATION

Age	Symbol	ROCK CHARACTERISTICS	GEOLOGIC AND ECONOMIC FACTORS AFFECTING LAND MODIFICATION
QUATERNARY	al	Alluvium: *Flood-plain and low level terrace deposits of sand and silt overlying silty clay and gravel; large cobbles present.*	Alluvium periodically flooded; cuts and excavations subject to sliding and sloughing; flooding restricts nonfarm uses. (Unit 14 in text.)
	al	Alluvium: *Sand, cobbles, rounded boulders, and angular blocks along upland streams.*	Block fields and debris-filled valleys on the Blue Ridge subject to creep, slides, and local rockfalls. Droughtiness, steep slopes, and mass movement limit agricultural and nonfarm uses. (Unit 13 in text.)
	ta	Talus deposits: *Cobbles, boulders, and angular blocks in a sand matrix.*	
	td	Terrace and alluvial-fan deposits: *High-level terrace and alluvial-fan deposits of gravel and sand in a red clay matrix.*	Older, upland sediments of variable permeability; artificial cuts subject to creep and sloughing. Characteristics of underlying bedrock may greatly influence environmental response of terrace deposits to man-induced stress. (Unit 12 in text.)
	sc	Sandy clay: *Sand, clay, and coarse quartzite debris. (in cross-section B-B' only.)*	Suspected to occur locally beneath unit 7.
TRIASSIC	d	Diabase dikes: *Dark greenish-gray to black diabase.*	Weathers into large, rough-surfaced, round boulders and bright-red clay. Difficult to excavate. (Unit 11 in text.)
CAMBRIAN	Ꞓeu, Ꞓel	Elbrook Formation: Ꞓeu, upper member, *characteristically orangish-yellow weathering, gray to dark-gray crystalline dolomite with phyllitic and slaty interbeds; some thin interbeds of dark-gray algal limestone.*	Moderately deep, well-drained soils, somewhat shaly. Small sinkholes are common. (Unit 8 in text.)
		Ꞓel, lower member, *laminated to thin-bedded, pale-green phyllite and slaty dolomite; interbeds of laminated, fine-grained, buff to light-gray weathering, light- to dark-gray dolomite. Laminated red phyllite occurs locally.*	Shallow, shaly, clay soils with moderate permeability and moderately high shrink-swell potential. Extensive karst areas. (Unit 8 in text.)
	Ꞓwb	Waynesboro Formation: *Gray, brown, green, and red argillite and phyllite with interbeds of laminated to thin-bedded, light- to dark-gray dolomite and limestone, and tan, fine-grained, thin- to thick-bedded sandstone.*	Extreme variation in depth to bedrock where terrace deposits are present. Sinkholes common, particularly in overlying terraces. Soil thicknesses highly variable. (Unit 8 in text.)
	Ꞓs	Shady Formation: *(In cross sections only.)*	Suspected zone of solution and collapse at the west foot of the Blue Ridge. (Unit 8 in text.)
	Ꞓa, q	Antietam Formation: *Thin-bedded, tan to white, metamorphosed, feldspathic sandstone, interlayered with green and pink, laminated phyllite and argillite (upper part). Massive, fine-grained, white to light-gray,* Skolithos-*bearing vitreous quartzite (lower part).* q, *thick prominent quartzite ledge.*	Mountain land with shallow, stony, and sandy soils that grade upslope into rock fields and outcrop. High permeability and low to moderate shrink-swell potential. Creep and slides. (Unit 7 in text.)
	Ꞓh, q, fs	Harpers Formation: *Green to bluish-gray, quartz-chlorite-sericite phyllite, with thin to massive interbeds of grayish-green to bluish-gray metamorphosed sandstone.* q, *light-tan, prominent quartzite.* fs, *zone of metamorphosed, ferruginous sandstones.*	Mountain land with thin, excessively drained soils; rippable bedrock near surface. Low to moderate permeability and low shrink-swell potential. Artificial cuts are susceptible to erosion and sloughing. (Unit 6 in text.)
	Ꞓw	Weverton Formation: *Light-brown weathering, green quartzose phyllite; thick, coarse-grained, reddish-purple, metamorphosed, ferruginous sandstone and light-gray, pebble quartzite. Laminated green or dark purplish-gray phyllite locally at base.*	Shallow, excessively drained, rocky soil. Moderate permeability and low to moderate shrink-swell potential. Creep and sloughing are common on steep slopes. (Unit 5 in text.)
	mt, cs, ꞒpꞒc	Catoctin Formation: *Fine-grained, dark greenish gray chlorite-epidote-albite schist and actinolite-chlorite-albite schist; amygdaloidal metabasalt, epidosite, epidote-quartz breccia, and greenish-gray metatuff.* mt, *mottled, greenish-purple, phyllitic metatuff.* cs, *light-green medium- to coarse-grained, metamorphosed, lithic sandstone and phyllite.*	Mountain land, with well-drained, rocky, red clay soils. Moderate permeability and low shrink-swell potential. Pervasive joints and cleavage throughout. (Unit 4 in text.)
	ꞒpꞒs	Swift Run Formation: *Medium- to coarse-grained, light- to greenish-gray, tan-weathering quartz-sericite schist and quartz-sericite-chlorite schist; some schistose, metamorphosed, lithic sandstone.*	Mountain land with well-drained micaceous-clay soils of variable depth. Steep slopes, especially those parallel to cleavage, are subject to creep and slides. (Unit 3 in text.)
PRECAMBRIAN	pꞒp, g	Pedlar Formation: *Dark bluish- to greenish-gray, coarse-grained, massive to sheared, granodiorite gneiss.* g, *light-gray, greenish-gray, or pink, very coarse grained, porphyritic, massive to sheared, granite gneiss.*	Mountain land, characterized by steep slopes, scattered massive ledges, and shallow, stony, well-drained soils. Severe restrictions on most construction, solid-waste disposal, and septic-tank drainfield sites. (Unit 2 in text.)
	pꞒl	Lovingston Formation: *Dark-gray, medium-grained, massive to foliated granitic gneiss and mylonitic biotite gneiss.*	Uplands, characterized by low, linear, parallel ridges, moderate to gentle slopes, and locally thick clay soils. Moderate restrictions on construction, solid-waste disposal, and septic-tank drainfield sites in areas of thin soils. (Unit 1 in text.)
	cgs	Cataclastic rocks, altered from precambrian rocks in Paleozoic time: *Dark to light-gray, medium- to coarse-grained suite of protomylonite, mylonite, phylonite, blastomylonite and mylonite gneiss derived from the Lovingston Formation.*	

OTHER LAND–MODIFICATION FACTORS

Modified land: *Extensive cut and fill due to grading.*

Rockfalls: *Areas of actual or potential rockfalls or slides not included in talus deposits.*

Karst land: *Areas of known or potential sinkhole development, subsidence, and cave openings.*

x Sinkhole.

CONTACTS

Exposed or approximate

Indefinite contact along collapse breccia zone (in cross section B-B' only)

FOLDS

Direction and angle of plunge of minor anticline

Direction and angle of plunge of minor syncline

Direction and angle of plunge of minor fold showing strike and dip of axial plane

Direction and angle of plunge of minor fold showing strike and dip of axial plane and symmetry of fold

FAULTS

Black line where exposed or approximate; gray line where covered or inferred; U, upthrown side, D, downthrown side, T, upper sheet; arrows indicate direction of relative movement

BRECCIA

b Collapse breccia

ATTITUDE OF ROCKS

Strike and dip of beds

Strike and dip of overturned beds

Strike of vertical beds

FOLIATION

Strike and dip of schistosity

Horizontal schistosity

Strike of vertical schistosity

LINEATION

Direction and angle of plunge of rodding, boudinage, and crinkle folds

Direction, angle of plunge, and symmetry of crenulation

Direction and angle of plunge of mineral lineation, streaks, and grooves

MINE, QUARRY, AND PROSPECTS

Abandoned mine or quarry

Crushed stone (quartzite) quarry

fm Iron and manganese mine

Prospect

f Iron

m Manganese

fm Iron-manganese

SAMPLE LOCATIONS

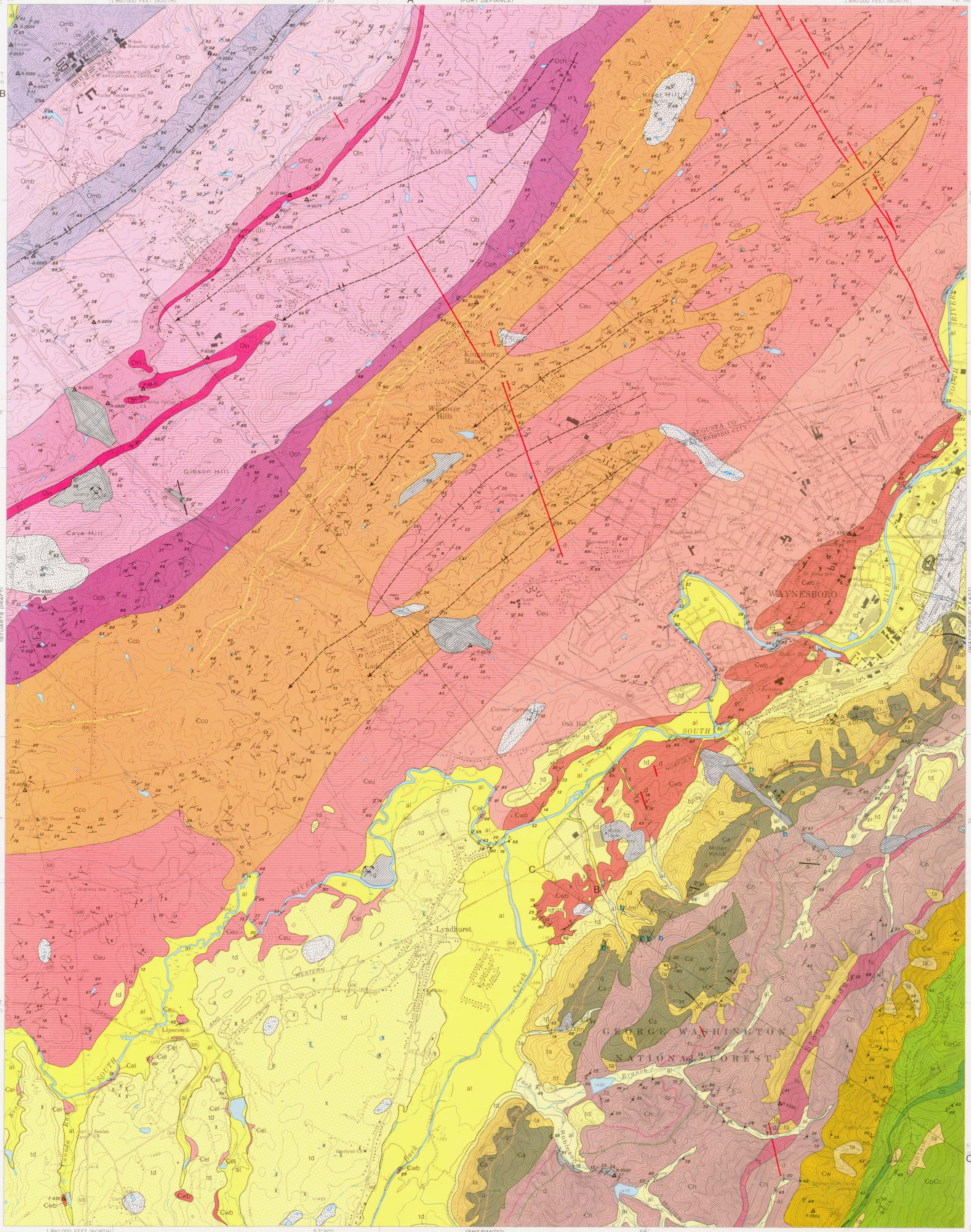
R-4414 R, repository number of sample

CROSS SECTION DESIGN:

1. No vertical exaggeration.
2. Subsurface structure interpreted from surface measurements.
3. Thickness of terrace deposits, colluvium, 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

PUBLICATION 3
WAYNESBORO WEST QUADRANGLE
PLATE 2



Base map from U. S. Geological Survey, 1973
Waynesboro West Quadrangle, 7½-minute series

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GEOLOGIC MAP OF THE WAYNESBORO WEST QUADRANGLE, VIRGINIA

Geology by Paul G. Nystrom, Jr.

UTM GRID AND 1973 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

QUADRANGLE LOCATION

1977

EXPLANATION

ROCK CHARACTERISTICS / GEOLOGIC AND ECONOMIC FACTORS AFFECTING LAND MODIFICATION

	Unit	Rock characteristics	Geologic and economic factors affecting land modification
QUATERNARY	al	Alluvium: *Flood-plain and low level terrace deposits of sand and silt overlying silty clay and gravel; large cobbles present.*	Alluvium periodically flooded; cuts and excavations subject to sliding and sloughing; flooding restricts nonfarm uses. (Unit 14 in text.)
	al	Alluvium: *Sand, cobbles, rounded boulders, and angular blocks, in upland stream valleys.*	Block fields and debris-filled valleys on the Blue Ridge subject to creep, slides, and local rockfalls. Droughtiness, steep slopes, and mass movement limit agricultural and nonfarm uses. (Unit 13 in text.)
	ta	Talus deposits: *Cobbles, boulders, and angular blocks in a sand matrix.*	
	td	Terrace and alluvial-fan deposits: *High-level terrace and alluvial-fan deposits of gravel and sand in a red clay matrix.*	Older, upland sediments of variable permeability; artificial cuts subject to creep and sloughing. Characteristics of underlying bedrock may greatly influence environmental response of terrace deposits to man-induced stress. (Unit 12 in text.)
	sc	Sandy clay: *Sand, clay, and coarse quartzite debris, (in cross sections A-A' and C-C' only)*	Suspected zone of solution and collapse, to occur locally beneath unit 7.
TRIASSIC	d	Diabase dikes: *Dark greenish-gray to black diabase.*	Weathers into large, rougn-surfaced, round boulders and bright-red clay. Difficult to excavate. (Unit 11 in text.)
ORDOVICIAN	Omb (s, a, c)	Martinsburg Formation: s, *alternating thick-bedded, bluish-gray, brown-weathering, medium-grained, metamorphosed lithic sandstone and thin-bedded, dark-gray calcareous slate.*	Shallow, shaly, acidic soil overlying slate and metamorphosed sandstone. Cuts subject to sliding and sloughing. (Unit 10 of text.)
		a, *very thin to medium-bedded, dark-gray calcareous slate alternating with tan-weathering argillite and dark-gray argillaceous limestone.* c, *black, graptolitic slate; very rare argillite lamelli.*	Shallow, residual soils overlying calcareous slate, interbedded argillite, and argillaceous limestone. Shallow cover subject to severe erosion on denuded slopes. (Unit 9 in text.)
	Oln	Lincolnshire Formation: *Dark-gray, medium-grained, medium- to thick-bedded limestone with abundant black nodular chert and thin, irregular pink or brown partings. A gray, coarsely crystalline, bioclastic limestone is present locally.* New Market Limestone: *Dove-gray, massive, micritic limestone.*	Shallow soils developed on hills, locally cherty soil and high shrink-swell clay. Sinkholes are common. (Unit 8 in text.)
	Ob	Beekmantown Formation: *Interbedded dove-gray, micritic limestone and thick-bedded, fine- to medium-grained, light-gray dolomite (upper part). Massive beds of light-gray and dark-gray dolomite with interbedded chert (middle part). Interbedded dark-gray, laminated limestone and gray, medium- to coarse-grained, thick-bedded dolomite (lower part).*	Deep, well-drained clayey soils on gentle slopes. Moderate permeability and moderately high shrink-swell potential. Conical hills are underlain and covered by massive chert. Large sinkholes and caves are common. (Unit 8 in text.)
	Och	Chepultepec Formation: *Dark-gray to bluish-black, fine-grained, thick-bedded cherty limestone with a few thin interbeds of orangish-yellow weathering, gray dolomite. Siliceous laminae are abundant in the lower part.*	Generally deep, clayey soils on gently rolling terrain; small sinkholes common. (Unit 8 in text.)
CAMBRIAN	Ꞓco (s)	Conococheague Formation: *Dark-gray, fine-grained, algal limestone alternating with ribbon-banded limestone, thinly laminated limestone, and light-brown weathering, laminated to thick-bedded dolomite.* s, *light-tan to brown, medium- to coarse-grained sandstone occurs as thin beds in the lower part and as thicker, more persistent beds in the middle part.*	Generally shallow clayey soils, moderate permeability. Sinkholes and caves are well developed at or near sandstone beds. Soil is sandy, deeper, and more permeable downslope from the sandstone beds. (Unit 8 in text.)
	Ꞓeu	Elbrook Formation: Ꞓeu, upper member, *characteristically orangish-yellow weathering, gray to dark-gray crystalline dolomite with phyllitic and slaty interbeds; some thin interbeds of dark-gray algal limestone.*	Moderately deep, well-drained soils, somewhat shaly. Small sinkholes are common. (Unit 8 in text.)
	Ꞓel	Ꞓel, lower member, *laminated to thin-bedded, pale-green phyllite and slaty dolomite; interbeds of laminated, fine-grained, buff to light-gray weathering, light- to dark-gray dolomite. Laminated red phyllite occurs locally.*	Shallow, shaly, clay soils with moderate permeability and moderately high shrink-swell potential. Extensive karst areas. (Unit 8 in text.)
	Ꞓwb	Waynesboro Formation: *Gray, brown, green, and red argillite and phyllite with interbeds of laminated to thin-bedded, light- to dark-gray dolomite and limestone, and tan, fine-grained, thin- to thick-bedded sandstone.*	Extreme variation in depth to bedrock where terrace deposits are present. Sinkholes common, particularly in overlying terraces. Soil thicknesses highly variable. (Unit 8 in text.)
	Ꞓs	Shady Formation: *(In cross sections only.)*	Suspected zone of solution and collapse at the west foot of the Blue Ridge. (Unit 8 in text.)
	Ꞓa (q)	Antietam Formation: *Thin-bedded, tan to white, metamorphosed, feldspathic sandstone, interlayered with green and pink, laminated phyllite and argillite (upper part). Massive, fine-grained, white to light-gray,* Skolithos-*bearing vitreous quartzite (lower part).* q, *thick, prominent quartzite ledge.*	Mountain land with shallow, stony, and sandy soils that grade upslope into rock fields and outcrop. High permeability and low to moderate shrink-swell potential. Creep and slides. (Unit 7 in text.)
	Ꞓh (q, fs)	Harpers Formation: *Green to bluish-gray, quartz-chlorite-sericite phyllite, with thin to massive interbeds of grayish-green to bluish-gray metamorphosed sandstone.* q, *light-tan, prominent quartzite.* fs, *zone of metamorphosed, ferruginous sandstones.*	Mountain land with thin, excessively drained soils; rippable bedrock near surface. Low to moderate permeability and low shrink-swell potential. Artificial cuts are susceptible to erosion and sloughing. (Unit 6 in text.)
	Ꞓw	Weverton Formation: *Light-brown weathering, green quartzose phyllite; thick, coarse-grained, reddish-purple, metamorphosed, ferruginous sandstone and light-gray, pebble quartzite. Laminated green or dark purplish-gray phyllite locally at base.*	Shallow, excessively drained, rocky soil. Moderate permeability and low to moderate shrink-swell potential. Creep and sloughing are common on steep slopes. (Unit 5 in text.)
PRECAMBRIAN(?)	ꞒpꞒc (mt, cs)	Catoctin Formation: *Fine-grained, dark greenish gray chlorite-epidote-albite schist and actinolite-chlorite-albite schist; amygdaloidal metabasalt, epidosite, epidote-quartz breccia, and greenish-gray metatuff.* mt, *mottled, greenish-purple, phyllitic metatuff.* cs, *light-green medium- to coarse-grained, metamorphosed, lithic sandstone and phyllite.*	Mountain land, with well-drained, rocky, red clay soils. Moderate permeability and low shrink-swell potential. Pervasive joints and cleavage throughout. (Unit 4 in text.)

OTHER LAND–MODIFICATION FACTORS

Modified land: *Extensive cut and fill due to grading.*

Rockfalls: *Areas of actual or potential rockfalls or slides not included in talus deposits.*

Karst land: *Areas of known or potential sinkhole development, subsidence, and cave openings.*

x Sinkhole.

CONTACTS

Exposed or approximate

Indefinite contact along collapse breccia zone (in cross sections A-A' and C-C' only)

FOLDS

Anticline—trace; direction of plunge

Syncline—trace; direction of plunge

Overturned syncline—trace; direction of plunge

FAULTS

Black line where exposed or approximate; gray line where covered or inferred; U, upthrown side, D, downthrown side, T, upper sheet; arrows indicate direction of relative movement

BRECCIA

b Collapse breccia

ATTITUDE OF ROCKS

45 Strike and dip of beds

50 Strike and dip of overturned beds

Strike of vertical beds

FOLIATION

20 Strike and dip of schistosity

QUARRIES AND PROSPECTS

Abandoned quarry

q Crushed stone (quartzite)

ls Crushed stone (limestone and dolomite)

qp Quartzite and phyllite

g Sand and gravel

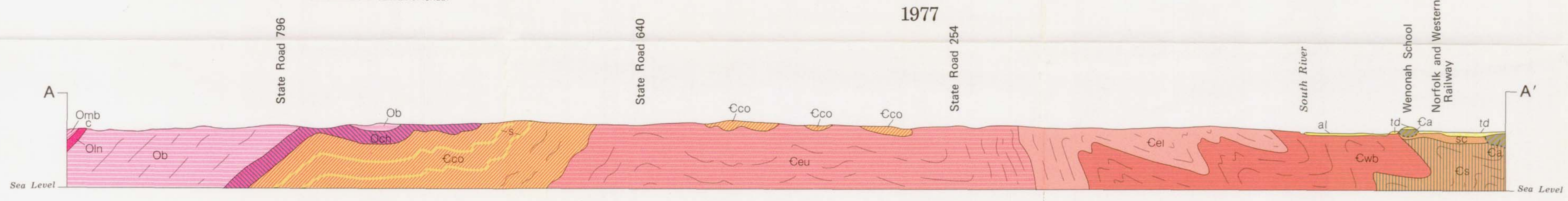
fm Prospect

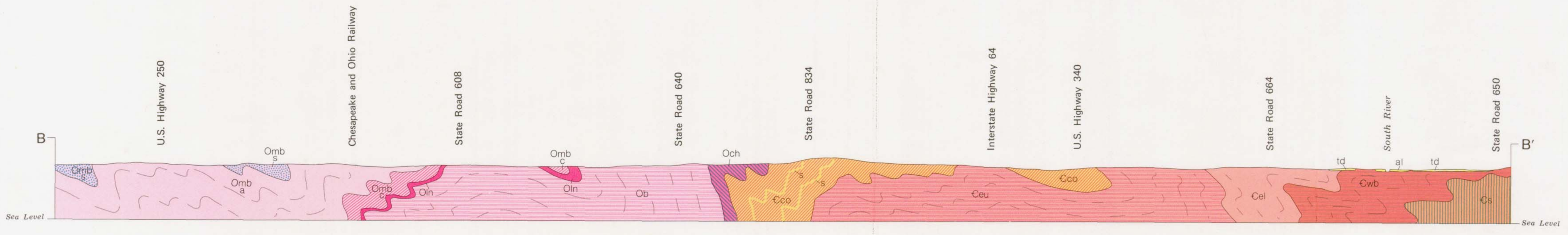
Iron-manganese

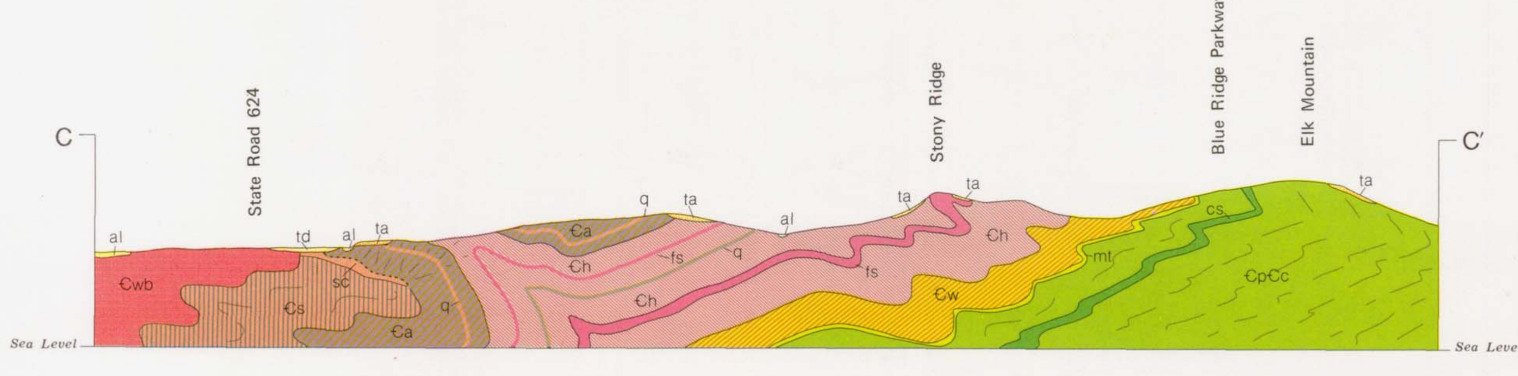
SAMPLE LOCATIONS

R-6572 R, repository number of sample

F-934 F, repository number of fossil sample







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