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

GEOLOGY OF THE BERRYVILLE, STEPHENSON, AND BOYCE QUADRANGLES, VIRGINIA

RAYMOND S. EDMUNDSON
W. EDWARD NUNAN

REPORT OF INVESTIGATIONS 34

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

CHARLOTTESVILLE, VIRGINIA
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GEOLOGY OF THE BERRYVILLE, STEPHENSON, AND BOYCE QUADRANGLES, VIRGINIA

By

RAYMOND S. EDMUNDSON [1] AND W. EDWARD NUNAN [2]

ABSTRACT

The Berryville, Stephenson, and Boyce 7.5-minute quadrangles, covering an area of about 150 square miles, are located in northern Virginia, mainly within the Valley and Ridge physiographic province with less than 3 percent of the total area extending into the Blue Ridge. The quadrangles are underlain by bedrock ranging in age from younger Precambrian(?) (Catoctin Formation) through Middle Ordovician (Martinsburg Formation). Paleozoic rocks, exposed along the western slope of the Blue Ridge and adjoining lowlands of the Shenandoah Valley, are assigned to 17 formations and members of which 13 are lithologically distinct to be separately mapped. Cenozoic alluvium and terrace deposits were also mapped.

The major structural features consist of a part of the Massanutten Mountain synclinorium and a small segment on the northwestern limb of the Blue Ridge anticlinorium. The present attitude of the rocks is the result of tectonic transport from the east which produced oversteepened and locally overturned east limbs of synclines and west limbs of anticlines and the easterly dip of low-angle faults. Most of the fold axes trend in a more northerly direction than the general northeasterly strike of the formational outcrop belts resulting in a number of salients and reentrants where the mapped units wrap around the plunging structures. Well-developed cleavage and joints are exposed at many localities.

Crushed stone is produced from high-magnesium dolomite in the Berryville quadrangle and marl from alluvial deposits in the Boyce quadrangle; in the past, limestone and dolomite and shale for building roads have been quarried. Raw materials having the chemical requirements for some of the uses of limestone and dolomite as standardized by various consuming industries, shale potentially useful for brick, tile, and lightweight aggregate, and quartzite potentially useful for high-silica sand are available.

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[2] Former staff member.

INTRODUCTION

The Boyce and Virginia part of the Stephenson and Berryville quadrangles (Plates 1-3) are located in northern Virginia, mostly in Clarke and Frederick counties, but with a small part of the Boyce sheet extending into northern Warren County (Figure 1). The mapped parts of the Berryville and Stephenson 7.5-minute quadrangles are bounded by longitudes 77°52′30″W. and 78°07′-30″W., latitudes 39°07′30″N. and 39°15′N., and by the Virginia-West Virginia state line; the Boyce quadrangle by longitudes 78°00′W. and 78°07′30″W. and by latitudes 39°00′N. and 39°07′30″N. Reference to certain aspects of the geology within the Ashby Gap 7.5-minute quadrangle, based on reconnaissance study, is included in this report since the area affords better exposures of the Lower Cambrian carbonate formations than on the adjoining Berryville and Boyce quadrangles. The study area of about 150 square miles is confined mainly to the Shenandoah Valley with less than 3 percent of the total area extending into the Blue Ridge province.

Shenandoah Valley includes the drainage basins of the Shenandoah River and Opequon Creek, a tributary of the Potomac River, that parallels the Shenandoah and serves as a boundary separating Frederick and Clarke counties in northern Virginia

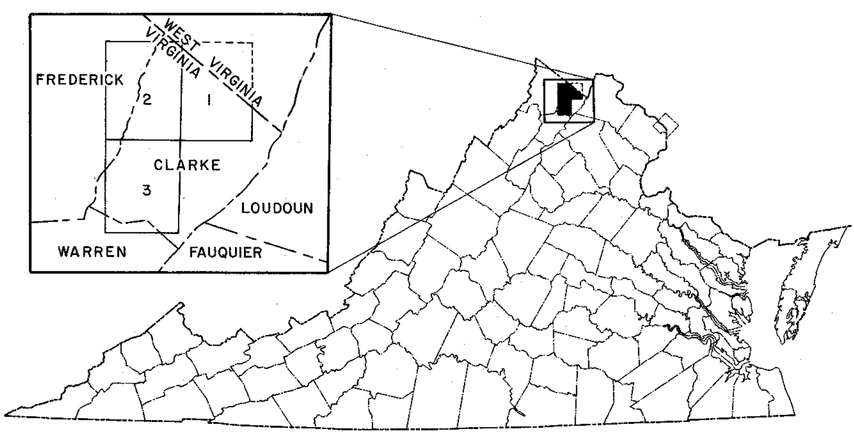

Figure 1. Index map showing location of Berryville (Plate 1), Stephenson (Plate 2), and Boyce (Plate 3) 7.5-minute quadrangles, Virginia.

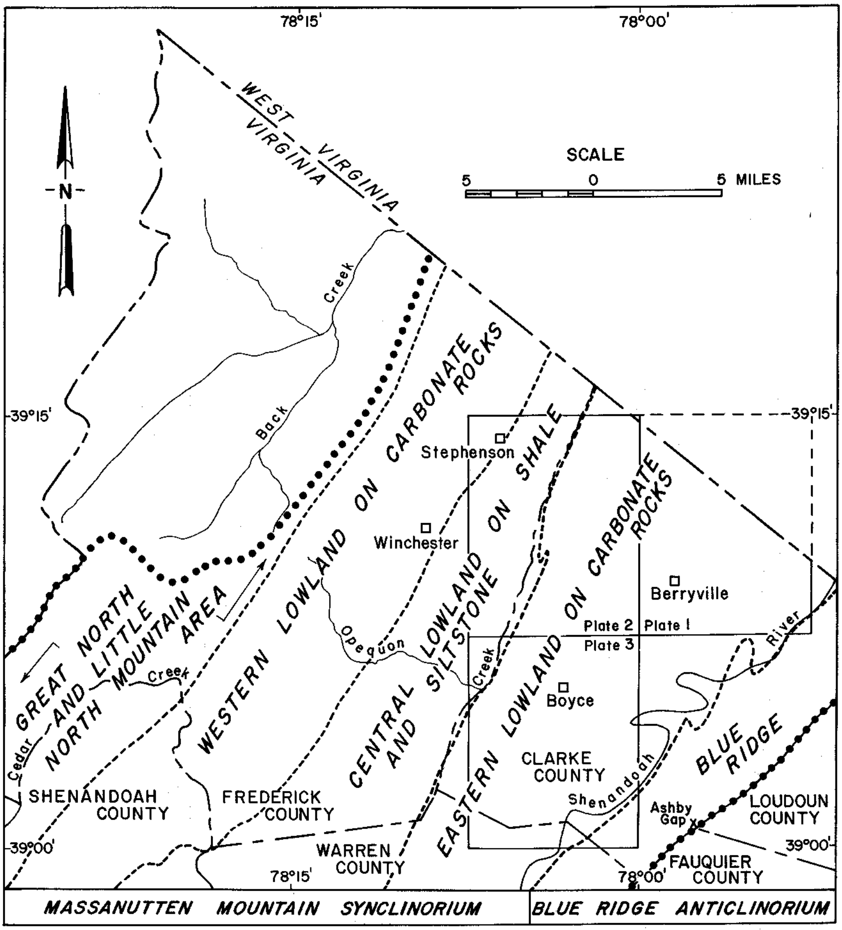

Figure 2. Physiographic subdivisions (modified from Hack, 1965) and major structural elements of the Shenandoah Valley in northern Virginia.

(Figure 2). Shenandoah Valley, with a length of more than 100 miles in Virginia, separates the Blue Ridge province on the southeast from the main part of the Valley and Ridge province of the Appalachian Highlands on the northwest. Specific landforms which serve as the northwestern boundary of "The Valley" in northern Virginia are Little North and Great North mountains. The width of Shenandoah Valley north of the 39th parallel is about 20 miles, but only 12 to 14 miles is within the area of this report. This broad belt is divided into a long central lowland on

Ordovician shale and siltstone that is flanked on the west and on the east by lowlands on Cambrian and Ordovician carbonate rocks (Figure 2).

The lowlands on Cambrian and Ordovician carbonate rocks are characterized as broad, almost flat, belts interspersed with low hills and small discontinuous ridges whose alignment generally reflects the trend of resistant layers of the underlying bedrock. The central lowland, underlain by Ordovician shale and siltstone, has no conspicuous knobs or ridges. It is characterized by high drainage density and interstream surfaces that are flat or smoothly rounded. The lowlands are mostly cleared and in various agricultural uses with apples the dominant crop in portions of the area.

The Appalachian Highlands on the northwest and to the south in Massanutten Mountain are underlain by thick sequences of Silurian clastic rocks. Most of the ridges are underlain by resistant sandstone, whereas the valleys are developed on the softer shales. The Blue Ridge, a bold topographic feature east of the lowlands, can be explained also by the presence of resistant bedrock, including Precambrian(?) metabasalt at and near the crest and beds of Lower Cambrian quartzitic sandstone at intervals along the western flank and foothills. This region is mostly mountainous, forested, and sparsely populated.

The highest elevation, about 1315 feet, is on the Blue Ridge at the southeastern corner of the Boyce quadrangle; the lowest, approximately 365 feet, is on the Shenandoah River at the eastern boundary of the Berryville quadrangle. The highest elevation on the lowlands, approximately 725 feet above sea level, is near the northwestern corner of the Stephenson quadrangle; thus, the relief on the lowlands is about 360 feet and for the study area about 950 feet.

Northern Virginia has a good network of secondary roads that are well maintained. In addition to these roads the facilities for transportation include U. S. Highways 11, 17, 50, and 340; Interstate Highway 81; State Highways 7 and 255; and branch lines of the Baltimore and Ohio, and Pennsylvania, railroads and the Shenandoah Division of the Norfolk and Western Railroad.

In the preparation of this report the results of other investigations, including published and unpublished maps and reports, have been drawn upon freely. The occurrence of iron was mentioned by Holden (1907) and, just south of the map area, manganese-ore deposits, with geologic maps and charts, have been described by Stose and others (1919). Nonmetallic resources which have been tested include raw materials for the manufacture of cement (Bassler, 1909), clay, shale, and related materials (Calver, Hamlin, and Wood, 1961), and limestone and dolomite with regard to their chemical properties (Edmundson 1945) and physical properties (Parrott, 1954). Ground-water resources have been described by Cady (1936). Other geologic studies in the map area or in neighboring regions, which may be applicable here, include those by Cooper and Cooper (1946), Decker (1952), Wilson (1952), Nicholas (1954), Nickelsen (1956), Sando (1956, 1957, 1958), Wood (1962), Page, Burford, and Donaldson (1964), and Wickham (1972).

A comprehensive study of the Appalachian Valley in Virginia was begun by Butts and assistants in 1926 and continued until 1931. The results of these investigations are included in a map and text (Butts, 1933) and a discussion of the stratigraphy, structure, and paleontology (Butts, 1940-41). Plans were formulated in 1936 to have Charles Butts and R. S. Edmundson map the geology of Frederick County; Clarke County, exclusive of the Blue Ridge; and the area north of the 39th parallel in adjoining Warren and Shenandoah counties. Some of the mapping and Butts' discussion of the stratigraphy, supplemented by measured sections and chemical analyses of post-Chilhowee rocks, have been used in two reports: (1) "Industrial limestones and dolomites in Virginia: northern and central parts of Shenandoah Valley" by Edmundson (1945) and (2) "Geology and mineral resources of Frederick County, Virginia" by Butts and Edmundson (1966).

In up-dating the geology for this report and to satisfy the details required by the new 7.5-minute quadrangles the published and manuscript geologic maps cited above and Butts' description of the carbonate rocks in Clarke County were examined and incorporated except for changes in nomenclature, adjustment of formational boundaries, and additions of structural detail. Most of the field work was done by W. Edward Nunan and assistants during the summers of 1970-71. This work included the collection of data used in the revision of earlier investigations, the measurement of stratigraphic sections, and the mapping of the surficial deposits and the older rocks of the Blue Ridge in the southeastern corner of the Berryville and Boyce quadrangles. The senior writer, for health reasons, was unable to take an active part in the field studies but, otherwise, worked closely with Nunan in up-dating the geologic maps and in the preparation of the manuscript. The writers wish to thank Dr. James L. Calver, State Geologist, who authorized the project; Harry W. Webb who made field visits and gave helpful suggestions; and other members of the Virginia Division of Mineral Resources for editing and preparation of the manuscripts and maps for publication. Residents of the area and quarry operators have generously offered information which is incorporated in this report and which is here gratefully acknowledged.

This report, prepared primarily for the residents of the area, includes a description of the different rock types, their structure, and economic resources. The geologic history that gave rise to the present landforms and the origin of the rocks and minerals are discussed briefly. The use of the geologic maps, cross sections, and the descriptions in the text should give a better understanding of the surficial and bedrock resources, the role of geology in varied engineering practices, and serve as a basis for more detailed exploration and testing.

Locations and repository numbers (R-4177) of sampled lithologies are shown on the geologic maps (Plates 1, 2, 3), and samples are on file in the repository of the Virginia Division of Mineral Resources.

STRATIGRAPHY

A part of the Catoctin Formation, composed of Precambrian (?) rocks of volcanic origin, is exposed near the crest of the Blue Ridge in the extreme southeast corner of the Boyce quadrangle (Plate 3). Paleozoic rocks of sedimentary origin exposed along the northwestern slope of the ridge and adjoining lowlands of Shenandoah Valley are assigned to 17 formations and members of which 13 are lithologically distinct to be separately mapped. Measured sections (Appendix) and estimates in the field indicate that the combined thickness of Paleozoic rocks is about 17,000 feet and the map units (Table 1) range from the Lower Cambrian Weverton Formation into the Middle Ordovician Martinsburg Formation. Sand, clay, marl, gravel, and colluvium of

Cenozoic age are present on floodplains and as terrace deposits on many of the upland areas bordering Shenandoah River.

Textural reference to the terrigenous clastic rocks is based on Wentworth's grade scale (1922) and for the carbonate rocks the use of coarse, medium, and fine grained corresponds to the grade limits for gravel, sand, and silt or clay.

PRECAMBRIAN (?) ROCKS

CATOCTIN FORMATION

Within the map area the Catoctin Formation is found only in the extreme southeast corner of the Boyce quadrangle (Plate 3) in a belt which attains a maximum width of approximately 2000 feet. The lower contact of the formation does not occur in the map area. The upper contact is placed at the base of the light-gray metasubarkose of the overlying Weverton Formation.

The Catoctin can be divided into two mappable units, a lower metabasalt member and an upper metatuff member. The lower metabasalt member is partially exposed near the pond at the head of Poplartree Hollow. It consists of fine-grained, even textured, green metabasalt (R-4711), many layers of which are crowded with quartz (R-4712) and epidote-filled amygdules. Epidote veins also occur and much of the metabasalt is epidotized. Volcanic breccia, metatuff, and dusky purple amygdaloidal metabasalts are interbedded with the metabasalt in the adjoining Linden and Front Royal quadrangles, but none of these lithologies have been seen in the Boyce quadrangle. Topographically, the metabasalt member underlies the highest ridges in the map area and forms the backbone of the Blue Ridge to the east.

The exposed lower metabasalt member is at least 370 feet thick and is undoubtedly much thicker. The upper metatuff member is not well exposed in the study area; however, a good exposure can be seen just east of the Boyce quadrangle at the end of State Road 602 in the Ashby Gap quadrangle. Partial exposures and float can be observed along the jeep trail near the headwaters of Poplartree Hollow. The rocks in this unit consist of dusky-purple phyllites (R-4710) with oval, pale-green splotches of muscovite.

Table 1.—Geologic formations in the Berryville, Stephenson, and Boyce quadrangles, Virginia.

Age		Name	Character	Thickness in feet
Cenozoic	Holocene	Alluvium	Dark-gray sandy clay, silt, and clay; calcareous along tributaries to Shenandoah River and Opequon Creek; mollusk shells and pebbles coated with travertine common; some massive deposits of travertine.	0-50±
	—?—	Terrace deposits	Gravels and cobbles, mainly sandstone and quartzite, in sand, silt, and clay matrix; colluvial blocks of greenstone and various lithologies of Chilhowee Group intermixed with alluvial roundstones in proximity to Blue Ridge; mapping generalized.	0-70+
Paleozoic	Ordovician	Martinsburg Formation	Mainly fissile to subfissile clay shale and laminated siltstone; few massive layers of siltstone and medium-thick beds of coarser-grained sandstone occur at several intervals; bluish gray in fresh exposures, but turns yellowish brown on weathering; basal beds are dark-gray to black, calcareous shale with occasional thin layers of metabentonitic clay; upper part eroded from area.	2000+
		Oranda Formation	Drab-gray, argillaceous limestone with intercalated thin siltstones in Stephenson area; east of Opequon Creek, grayish-black, muddy limestone with intercalated black to light-brown, calcareous siltstone and shale; locally at base brownish-black to olive shale with thin layers of pinkish gray, micaceous metabentonitic clay.	0-30
		Edinburg Formation	Cobbly to nodular, dark- to buff-gray limestone with varying proportions of black shale and dense, even-bedded black limestone; minor interbeds of thin brown siltstone and thin metabentonitic clay.	200-550

Age		Name		Character	Thickness in feet
Paleozoic	Ordovician	Lincolnshire Formation		Dark, almost black, fine- to medium-grained limestone; some beds weather to nodular or lenticular slabs; nodules, plates, and stringers of black chert common.	0-100
		New Market Limestone		Mostly bluish- to dove-gray, compact, think-bedded, high-calcium limestone with a lower impure zone that is thinly bedded; locally a few feet of pebble conglomerate at base.	0-130
		Beekmantown Group	Pinesburg Station Dolomite	Predominantly light-gray, fine-grained dolomite; weathers yellowish to drab gray with furrows "butcher-block structures" common; grades into limestones south of State Highway 7; not identified in southern part of Clarke County.	0-400
			Rockdale Run Formation	Interbedded dark bluish-gray, fine-grained limestone and gray, fine- to medium-grained dolomite; ratio of limestone to dolomite greater east of the Massanutten syncline; several distinctive chert zones that form low rounded disconnected ridges and hills; algal structures associated with bioclastic limestone common; dolomite occurs as well-defined beds and as anastomosing rod-like bodies.	2500
			Stonehenge Formation	Laminated, in part siliceously banded, dark-gray, fine-grained limestone; intraformational conglomerates and algal structures common (upper part). Light- to dark-gray, fine- to medium-grained, relatively pure limestone; weathers light bluish gray; occasional bed has tubular-like structures of unknown origin; few thinly laminated limestones with minor amounts of black chert (middle part). Stouf-ferstown Member: fine- to medium-grained limestone with distinctive crinkly siliceous laminae; lenses of coarse-grained, bioclastic limestone common; thickness estimated at 150 to 200 feet (lower part).	700-800

Age		Name	Character	Thickness in feet
Paleozoic	Cambrian	Conococheague Formation	Gray to dark-gray limestone with dolomite and dolomitic limestone; friable-weathering sandstone and sandy chert widespread; silicified algal "heads" common near top; grades down into siliceously banded limestone with beds of intraformational conglomerate common; few beds of limestone, containing well-rounded quartz sand, weather to blocks of friable sandstone (upper part). Ribbon-banded limestone with minor siliceous laminae; light-gray bands are dolomitic; few thicker beds of dolomite (middle part). Big Springs Station Member: interbedded dolomite, magnesian limestone, and limestone; few thin beds of sandy dolomite, brownish-weathering shale, quartzose sandstone, and stringers and nodules of chert (lower part).	2500
		Elbrook Formation	Predominantly limestone with interbeds of dolomite, shale, and siltstone, and an occasional bed of sandstone; much of the limestone and dolomite is banded with argillaceous material and on weathering yields ocherous slabs and thin plates; the more massively bedded impure carbonate rocks weather to a dun color; near middle of formation is a thin zone of varicolored limestone, green to maroon shale, and reddish-brown, fine-grained sandstone; large cryptozoon structures common in upper and lower parts.	2000
		Rome Formation	Argillaceous limestone and dolomite which weather to a yellowish ocherous rock and thicker beds, apparently of purer dolomite, that weather gray; variable amounts of purer bluish-gray limestone, siltstone, mudstone, sandstone, and varicolored fissile shale; many	

Age			Name	Character	Thickness in feet
Paleozoic	Cambrian		Rome Formation	beds, especially near base, contain stringers and nodules of black chert and in the vicinity of Cool Spring is a ridge-making thick lense (?) of light-gray, oolitic chert; most distinctive feature is maroon or reddish-brown shale and siltstone occurring at several intervals.	2200
			Shady Formation	White to bluish-gray, fine- to medium-grained, in part saccharoidal, high-magnesium dolomite (upper part). Bluish-gray limestone with shale partings and interbeds of dolomite; sandstone float near base (lower part). Nowhere in map area is contact with underlying Antietam exposed.	1200
		Chilhowee Group	Antietam Formation	Predominantly silica - cemented, fine- to coarse-grained quartzite and metasubarkose; phyllite partings common; minor sericitic matrix in some sandy beds; many layers stained with iron oxide; maximum thickness unknown due to faulting and alluvial-colluvial cover.	200+
			Harpers Formation	Metagraywacke, metasubarkose, phyllite, and quartzite; quartzites, ranging from 2 to 15 feet thick, occur at several intervals and one unit, nearly 80 feet thick, is mapped (upper part). Phyllite and metagraywacke; rocks weather various shades of grayish green and bluish gray (middle part). Light bluish-gray, sandy phyllite with minor interbeds of fine to medium grained, ferruginous quartzite (lower part).	2200+
			Weverton Formation	Light-gray, massively bedded, quartz conglomerate and quartzite; well-defined cross bedding marked by purple ferruginous bands (upper part). Metagraywacke with pebble size quartz grains; bronze-	400-500

Age		Name		Character	Thickness in feet
Paleozoic	Cambrian	Chilhowee	Weverton Formation	weathering phyllite (middle part). Light-gray, medium- to coarse-grained, thick-bedded metasubarkose with dark streaks of heavy minerals (lower part).	
?	?				
Precambrian (?)			Catoctin Formation	Metamorphosed tuffs: dusky-purple phyllite with oval, pale-green splotches of muscovite; poorly exposed; thickness estimated at 100-300 feet (upper part). Metabasalt: green, fine-grained, even-textured; many layers contain amygdules filled with quartz and epidote; chrysotile and partially replaced quartz-chrysotile veins common; fewer epidote veins; much of greenstone is epidotized (lower part).	500+

This unit occupies topographically low positions between the relatively resistant underlying lower metabasalt and the overlying Weverton Formation.

The upper contact of the upper metatuff member is placed at the base of the overlying Weverton Formation which, in the Boyce quadrangle, is marked by the presence of light gray metasubarkose. This contact is unconformable. The metatuff member is between 100 and 300 feet thick.

CAMBRIAN SYSTEM

CHILHOWEE GROUP

The rocks of the Chilhowee Group in this report area are comprised of three formations, the Weverton, Harpers, and Antietam, and have a probable total thickness of 3200 feet. The oldest rocks (Weverton Formation) are coarse-grained to conglomeratic metasubarkoses and quartzites with subordinate amounts of phyllitic rocks. These grade into a series of metagraywackes (lower Harpers) which in turn grade into quartzite (upper Harpers and Antietam).

Weverton Formation

The Weverton Formation is present in the southeast corner of the Boyce quadrangle (Plate 3) where it is exposed in a belt ranging in width from 800 to 1400 feet. It is also exposed in two anticlinal "noses" west of this belt along the southern boundary of the quadrangle. The Weverton supports the first series of foothills west of the massive Blue Ridge. The lower contact of the formation is placed at the top of the upper metatuff member of the Catoctin Formation, and its upper contact is taken at the top of the highest conglomerate in the upper part of the Weverton.

The Weverton can be subdivided into three lithologic units within the map area. The lower unit consists of light-gray metasubarkose with dark streaks of heavy minerals defining the bedding. The rock is medium to coarse grained and cross-bedding is common. Pink and white quartz grains up to 0.1 inch in diameter occur. This unit is approximately 125 feet thick.

The lower unit of the Weverton is not well exposed in the map area. Incomplete exposures are present on a ridge at the head of Poplartree Hollow, about 400 feet east of the junction of a jeep trail and a private road near the eastern border of the Boyce quadrangle.

The middle unit of the Weverton consists of ferruginous metagraywacke and bronze-weathering phyllite. Pebble-size quartz grains occur in the metagraywacke. The metagraywacke commonly crops out as sharp linear exposures several hundred feet long, standing three or four feet above the ground surface. The phyllite is not well exposed. The thickness of this unit is estimated at 150 feet. The middle part of the Weverton is partially exposed just west of the house located 250 feet east of the junction of the jeep trail and private road on the ridge north of the head of Poplartree Hollow.

The upper part of the Weverton consists of light-gray quartzite with prominent cross-bedding marked by purple ferruginous bands. Most of the beds are conglomeratic with pebbles ranging in size up to 0.5 inch in diameter. The matrix is fine- to medium-grained quartz sand cemented with limonite and quartz. Heavy minerals and feldspars are minor constituents. This rock is massively bedded and well cemented, but becomes friable upon weathering. It forms cliffs up to 50 feet high. Colluvial material derived from this unit masks the lower few hundred feet of the overlying Harpers Formation. One hundred and sixty-two feet of this unit were measured along State Road 602 in the adjoining

Ashby Gap quadrangle. Good exposures of the upper unit are available on all of the ridges mapped as Weverton, but the most accessible are those on the ridge northeast of Poplartree Hollow. They can be reached by State Road 602 in the Ashby Gap quadrangle.

The total thickness of the Weverton Formation is between 400 and 500 feet. This agrees closely with Nickelsen's (1956, p. 249) estimate of 481 feet in the Harpers Ferry area.

Harpers Formation

The Harpers Formation occupies a broad belt averaging about 5400 feet in width in the southeast corner of the Boyce quadrangle (Plate 3). It also occurs in the southeast corner of the Berryville quadrangle (Plate 1). The best exposures of the Harpers are in the beds of Wrights Branch (Section 13) and the stream that flows out of Poplartree Hollow (Section 14) in the Boyce quadrangle. The formation is more susceptible to weathering than are the units above and below it, consequently it underlies the low hills between the bold Weverton and Antietam ridges.

The lower contact of the Harpers with the Weverton is not exposed in the mapped area because several hundred feet of the lower part of the formation are covered by colluvial boulders derived from the upper conglomeratic beds of the Weverton. Chips of bronze-weathering phyllite, ferruginous quartzite, and friable quartzite occur intermixed with the Weverton boulders all the way up the slopes of the Weverton ridges to the first outcrops of the cliff-forming quartzites. In exposures on the railroad tracks east of Front Royal, about 7.5 miles south of Milldale, the lower Harpers rocks are yellowish-gray to grayish-blue sandy phyllites with ferruginous, fine-grained quartzites at the base. The upper contact of the Harpers is placed at the base of a massive, vitreous quartzite in the overlying Antietam Formation.

The Harpers displays a variety of metaclastic rock types and these have been divided into three basic units, a lower member, a middle member, and an upper member. These members are not differentiated on the geologic maps due to inadequate exposures. A quartzite unit in the upper member was mapped and is depicted on the map of the Boyce quadrangle (Plate 3). In the Berryville quadrangle (Plate 1), this unit is not shown separately because structural complications and inadequate exposures make its exact position obscure.

The lower member of the Harpers consists almost entirely of light bluish-gray sandy phyllite (R-4709) which weathers to bronze flaky phyllite and bronze sandy chips. The sand is very pale orange and occurs disseminated throughout the phyllite. No other rock type was observed in the lower member, but the presence of medium-grained ferruginous quartzite is indicated by float material. About 25 percent of this member is exposed in the map area. The best exposures are in Poplartree Hollow where a partial thickness of 110 feet was measured. The total thickness of the lower member is estimated to be 400 feet.

The middle member of the Harpers consists of various shades of olive, green, and gray phyllite (R-4706, R-4705) and metagraywacke (R-4707, R-4704, R-4708). The rocks weather grayish green to bluish gray. Light reddish brown specks are common on the fresh surfaces of many of the rocks.

The relic detrital framework of the middle Harpers metagraywackes is composed of very fine- to medium-grained sand. The quartz content varies from 60 to 90 percent while the feldspar component ranges from 4 to 34 percent. Rock fragments are rare. Heavy minerals include leucoxene, zircon, tourmaline (frequently with overgrowths), and rutile. Muscovite flakes, many of which are bent and broken, comprise between 1 and 5 percent of the framework.

The matrix content of the middle Harpers rocks is about 70 percent in the phyllites and between 15 and 50 percent in the metagraywackes. Chlorite is abundant and partially replaces muscovite, feldspar, and quartz grains in the framework portion of the rocks. Iron staining is common and quartz cement occurs as syntaxial overgrowths on quartz grains in some of the metagraywackes.

Good exposures of this unit occur in Wrights Branch and up Poplartree Hollow. Partial exposures are present on most of the hillslopes along these stream valleys. Recognition of bedding within this unit is often difficult due to the extensive development of slip cleavage at most outcrops. The thickness of this member is approximately 800 to 1000 feet.

The upper member of the Harpers is distinguished in the field from the middle member by its relatively lighter color and the presence of quartzites. Fresh rocks are various shades of light gray, olive, and grayish blue. Occasional beds of grayish-green, reddish-brown speckled, ferruginous rock occur. The rocks weather shades of pale orange, light brown, and grayish yellow. The strata belonging to the upper member display the widest range of lithologies to be found in the formation. Rocks present include quartzite, metagraywacke (R-4699, R-4713, R-4698, R-4425), metasubarkose (R-4703), and phyllite (R-4702). The quartzite occurs as 2- to 15-foot-thick beds at various intervals interbedded with pelitic beds. A 79-foot-thick body of thin-bedded quartzite (R-4700) occurs at about 650 feet beneath the Antietam along Wrights Branch. This unit is mappable and is responsible for holding up most of Gibson Ridge and the eastern spurs extending northeast and southwest off of The Blue Ball.

The quartzite consists of a framework of fine- to coarse-grained quartz sand cemented by silica as syntaxial overgrowths on the quartz. The larger grains are well rounded and the smaller grains are subangular to poorly rounded. Feldspars do occur and heavy minerals include leucoxene, zircon, and tourmaline.

In the metagraywackes the matrix content ranges from about 35 to 50 percent. It consists of sericite, chlorite, and silt-sized quartz, feldspars, and heavy minerals. The matrix is often iron stained.

The quartz content of the framework fraction of the upper Harpers rocks varies from about 55 percent in the phyllites to 99 percent in the quartzites. Feldspars comprise from less than 1 percent in the quartzites to about 35 percent in some of the metagraywacke and phyllite. Bent and unbent muscovite grains are present in most of the rocks with a content range of between a trace and 6 percent. Rock fragments are rare. Heavy minerals compose up to 2 percent of the framework. Zircon is the most common with tourmaline and leucoxene making up the balance of the heavies.

An unique bed of ferruginous metagraywacke (R-4701) occuring about 1100 feet beneath the base of the Antietam has been used as a marker bed during mapping. It is exposed on the low ridges east of the stream flowing parallel to and east of Gibson Ridge. The upper member is estimated to be between 800 and 1100 feet thick.

The combined thickness of the Harpers Formation is estimated at about 2200 feet. This is less than the thickness measured in Stratigraphic Sections 12 and 13 (Appendix) which indicate a total thickness of about 3200 feet. It is possible that some of the Harpers has been repeated by small-scale folding which was not recognized in the field. Partial overlap of the two sections may also account for the thickness suggested. In view of the foregoing discussion and the reported thicknesses of 1500 to 2000 feet in the Harpers Ferry area (Nickelsen, 1956, p. 251), the estimate of 2200 feet is a reasonable minimum figure for the full thickness of the Harpers.

Antietam Formation

The Antietam Formation is present in the southeast corner of the Boyce quadrangle (Plate 3). A small wedge of Antietam may be present in the Berryville quadrangle (Plate 1) on State Highway 7 about 1400 feet west of the Shenandoah River. The identification of this wedge is questionable and it has been mapped as Antietam Formation and Harpers Formation undifferentiated due to a lack of definitive stratigraphic control and structural complications associated with the northern Blue Ridge border fault.

Lithologies present in the Antietam are primarily silica-cemented, fine- to coarse-grained quartzite and metasubarkose (R-4424). Phyllite partings are common. Silica cement comprises up to 15 percent of the rocks and is often slightly iron stained. It occurs as syntaxial overgrowths on the detrital grains. Minor sericitic matrix occurs in some layers and serves to accentuate the bedding.

In the framework fractions of the rocks, the quartz content varies from about 95 percent in the quartzites to approximately 75 percent in the feldspathic rocks. Feldspars comprise from approximately 4 percent of the quartzites to about 20 percent of the metasubarkoses. Rock fragments and muscovite are less than 1 percent each. Several unbent muscovite flakes occur. Heavy minerals include well-rounded zircon and tourmaline and comprise between 2 and 3 percent of the framework. In general, the sand in the quartzose rocks is coarser and better rounded than is the sand in the feldspathic ones.

The base of the Antietam is placed at the lowest, ledge-forming, vitreous quartzite above the interbedded quartzite and pelitic beds of the upper Harpers. The upper contact is not exposed in the mapped area. The Antietam is in fault contact with the younger Shady Formation in the Boyce quadrangle.

The total thickness of the Antietam is not known. A minimum of 200 feet was estimated for that part of the formation present on the west flank of Gibson Ridge (Plate 3) but it is undoubtedly much thicker in some portions of the Boyce quadrangle. On The Blue Ball and in the vicinity of Venus Branch the outcrop belts suggest a thickness of as much as 800 feet. This is probably extreme and the excessively wide outcrop belt may be due to repetition of parts of the Antietam by unrecognized tight folding and minor faulting. Good exposures of the Antietam can be seen on Gibson Ridge, The Blue Ball, and in Venus Branch in the Boyce quadrangle.

SHADY FORMATION

The Shady Formation, a thick mass of carbonate rock of mostly high-magnesium dolomite (Table 4) in the upper two-thirds of the section and impure limestone with interbeds of dolomite in the lower part, overlies quartzite of the Antietam Formation. It follows closely Shenandoah River from the Virginia-West Virginia boundary in a southwesterly direction across Clarke County and into Warren County where it is terminated by faulting. This belt is modified locally by folding which is reflected by a sinuous outcrop pattern. Much of the belt is concealed by thick residuum and locally blanketed by terrace and colluvial deposits. Exposures of the Shady within the map area occur in the southeastern parts of the Berryville and Boyce quadrangles (Plates 1, 3). Some of the accessible localities of parts of the Shady (R-4163) are within the Marvin Chapel anticline and associated minor folds which form a broad salient that is crossed by State Highway 7 about midway between Webbtown and Shenandoah River (Appendix, Section 2), in the Stuart M. Perry, Inc. quarries along the southern boundary of the Berryville quadrangle; it also occurs in a broad salient and reentrant on the west side of Shenandoah River northeast of Castlemans Ferry Bridge (Plate 1). The sinuous boundary between the Shady and Rome formations in the vicinity of Cool Spring clearly demonstrates the presence of two folds plunging in a more northerly direction than the northeasterly trend of the map units. The synclinal fold (Figure 3) on the east displays high-magneium dolomite (Appendix, Section 1) which is overlain by oolitic chert. These resistant beds form a low ridge where they wrap around the axis of the northeasterly-plunging Cool Spring anticline. Similar beds, interpreted as defining the base of the overlying Rome Formation, have not been observed at other localities in Clarke County, but the persistence of black oolitic chert closely overlain by maroon shale may represent approximately the same interval along strike to the southwest. Incomplete exposures of the Shady have been observed in the southeastern part of the Boyce quadrangle along the steep bluff on the north side of Shenandoah River due west of White Horse Rock and along Wolfe Marsh Run near the southern boundary of the map area (Plate 3).

Within the adjoining Ashby Gap quadrangle the Shady is well displayed at several localities. An almost continuous exposure of the upper part of the Shady dolomite is in a steep bluff along Shenandoah River, beginning 0.8 mile south of Lockes Landing and extending eastward for about 2200 feet. Although all of the beds along this traverse (Edmundson, 1945) have a southeasterly

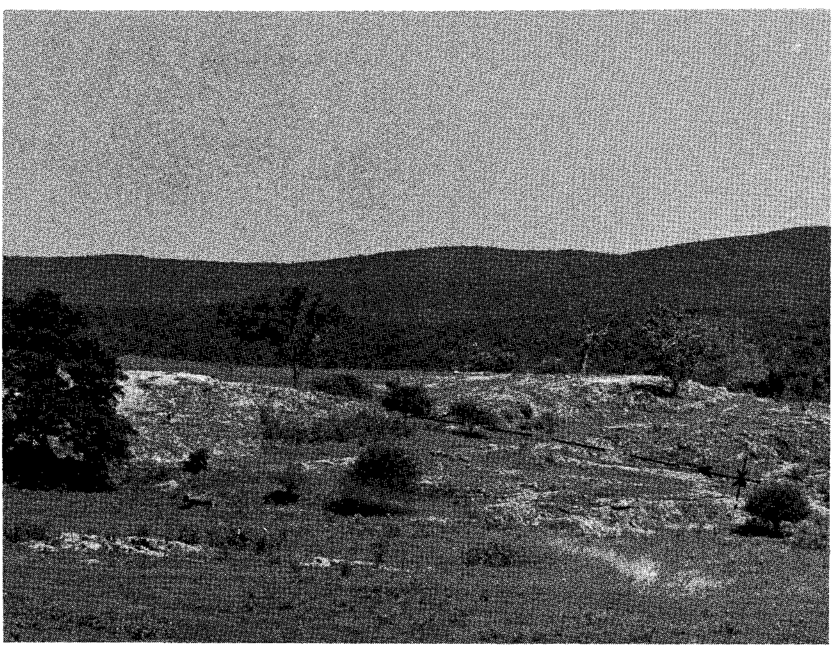

Figure 3. Syncline displaying high-magnesium dolomite in upper part of the Shady Formation about 0.2 mile southeast of Cool Spring and 1.5 miles northeast of Castlemans Ferry Bridge.

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dip, the occurrence of Rome lithologies east and west of the Shady indicate repetition by an anticline overturned in a northwesterly direction. Perhaps the true thickness of the rocks in this exposure is about 600 feet (Appendix, Section 15). A fairly complete section of the Shady, also in the Ashby Gap quadrangle, is along Dog Run about 2 miles due south of State Highway 7 and extending westward, up section, from a point 0.35 mile west of State Road 621. West of the Antietam Formation at this locality is a covered interval of about 150 feet containing sandstone blocks and shale chips of questionable age. Continuing to the west the lower part of the Shady consists of about 300 feet of blue limestone, with yellow shale partings up to 0.5 inch thick, and interbeds of dolomite. The upper part of the Shady is about 800 feet thick and consists predominantly of very light- to bluish-gray, fine- to medium-grained dolomite. Near the top of the formation are a few thin beds of very dark-gray, fine-grained limestone. The prominent chert zone in the base of the Rome was not exposed along the line of the section, but is well displayed along the strike of the belt to the southwest. This chert zone, which occurs about 25 feet beneath the first maroon shales in the Rome, has been used in placing the top of the Shady. Although some uncertainty exists regarding the top and bottom of the formation, the thickness is estimated to be about 1200 feet.

The only fossils found in the Shady in Clarke County are *Salterella conulata* Clark (Fossil identified by E. L. Yochelson, personal communication, 1973). These conical-shaped gastropods are plentiful in the lower part of the dolomite member along Dog Run. *Salterella pulchella* Billings was reported by Butts (1942) to be abundant in the uppermost beds of the Shady-Tomstown at Millville, West Virginia, which is about 11 miles northeast of Clarke County. To the southwest in Wythe County, Virginia, a considerable assemblage of fossils occur in the Shady, including *Archeocyathus, Kutorgina cingulata, Nisusia festinata,* and *Olenellus* sp. These fossils indicate that the Shady Formation is of Lower Cambrian age.

ROME FORMATION

The Rome Formation crops out in a belt that ranges in width from about 0.5 to more than 2 miles. The formation boundaries defining this belt have a zigzag pattern due to the many overlapping folds. As with the other thick carbonate formations of

Cambrian and Ordovician age in northern Virginia there are no completely exposed sections. Partial exposures, representing lithologies at different stratigraphic intervals within the Rome, are in the fields south and east of Wickliffe Church between the Taylor Hill syncline and the Cool Spring anticline, at Marvin Chapel, along Wheat Spring Branch and its tributaries (Plate 1), and along the south side of Shenandoah River at Calmes Neck. Fairly good exposures are along Dog Run and in the triangularly shaped synclinal area on the south side of Shenandoah River southeast of Lockes Landing (Ashby Gap quadrangle) and on the Boyce quadrangle (Plate 3), mostly within the middle and upper parts of the formation, in the bed of Wolfe Marsh Run between the Shenandoah River and Smith Hollow, at Lovers Leap 0.5 mile southwest of Bethel, and along Spout Run southwest of Calmes Neck.

The Rome is a heterogeneous formation throughout its extent in the Appalachian region. Argillaceous limestone and dolomite which weather to a yellowish ocherous rock and thicker beds, apparently of more pure dolomite, that break down on weathering to gray, angular fragments occur at intervals throughout the

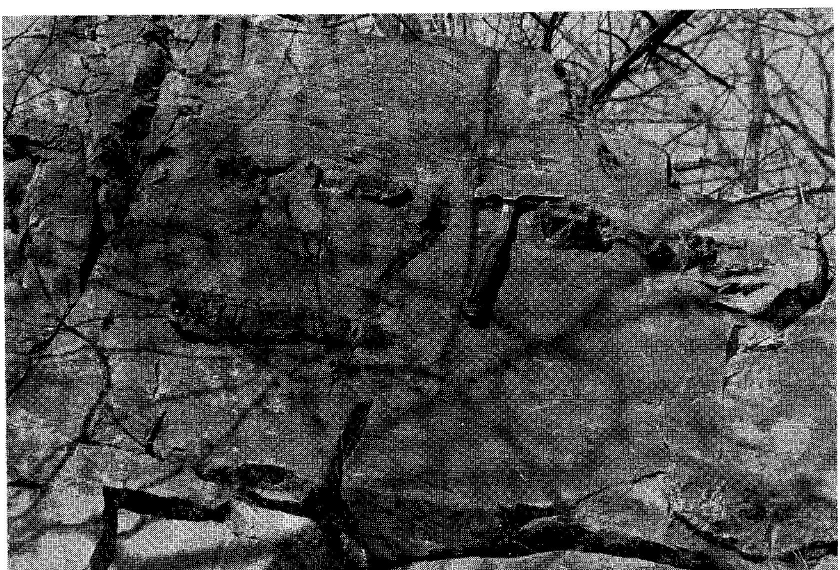

Figure 4. Nodules of black chert in laminated dolomite near base of the Rome Formation along south bluff of Shenandoah River at Calmes Neck.

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Figure 4. Nodules of black chert in laminated dolomite near base of the Rome Formation along south bluff of Shenandoah River at Calmes Neck.

full thickness of the formation. In addition there are beds of apparently pure limestone, fine- to medium-grained sandstone, and varicolored shale and mudstone. Many of the carbonate rocks contain stringers and nodules of black chert (Figure 4) and in the vicinity of Cool Spring (Plate 1) there is a lense-shaped mass of light-gray oolitic chert near the base of the formation.

The most distinctive feature for the identification of the Rome is red, perhaps best described as a maroon or deep reddish-brown shale or mudstone. At Marvin Chapel, 1.5 miles northeast of Webbtown (Plate 1), Butts (1942) refers to an 145-foot exposure of shale, mainly yellowish, but containing three intercalations of maroon shale with an aggregate thickness of about 65 feet. He concludes that this section probably is a representative example of the manner of occurrence and relative thicknesses of the maroon beds of the Rome in northern Virginia.

Incomplete exposures allow only broad generalizations regarding the distribution of the different lithologies within the Rome Formation. The lower part of the formation consists of very dark-gray, fine- to medium-grained dolomite interbedded with light-gray, fine-grained limestone and dolomite and a few sandstone beds up to 5 feet thick. Maroon shales occur near the base and are usually separated from the underlying Shady by a few feet of limestone containing nodules and stringers of black oolitic chert. Since maroon shales occur above but within a couple hundred feet of the light-gray, oolitic chert (Figure 5) at Cool Spring, it is probable that this siliceous rock and associated shales, may occupy the same position in the sections as the black oolitic chert along strike to the southwest. Locally within the lower part is very impure, gnarly, weathering limestone and maroon shale, perhaps 100 feet thick, which make strong riffles where crossed by Shenandoah River.

The upper part of the Rome, estimated at more than three-fourths of the total thickness is characterized by an increase in the maroon shale content, the presence of green shales, and more rusty-weathering sandstones (R-4158) and chert than in the lower part. Dolomite and limestone appear to comprise only about 50 percent of the rock in the upper part of the section; however, it is most likely that much of the yellowish ochreous mudrock and shale have been derived from argillaceous limestone or dolomite through loss of their calcareous content by weathering. The inter-

Figure 5. Light-gray, oolitic chert near base of the Rome Formation about 0.3 mile northeast of Cool Spring.

calations of maroon or green shale, normally 3 to 4 feet thick but ranging up to about 35 feet at Marvin Chapel, and abundant chert and beds of sandstone appear to be concentrated high in the upper part of the Rome on the Berryville quadrangle, especially near Webbtown. Lesser amounts of sandstone and chert have been found on the Boyce quadrangle.

West of the Shenandoah River and about 0.5 mile north of Wolfe Marsh Run (Plate 3) the least width of the outcrop belt is about 2800 feet. Using this width and the available attitude of the rocks the thickness is calculated to be about 2200 feet, and that is taken as the probable thickness of the formation.

The only fossils found in the Rome in Clarke County are algal structures. These forms are abundant in certain limestone beds (Figure 6) within the upper part of the formation and a few specimens of silicified cryptozoon(?) float (R-4182), consisting mainly of doubly terminating quartz crystals, have been noted on the surface overlying bedrock near the base of the Rome. A diagnostic Lower Cambrian fossil (*Olenellus*) occurs in an ocherous bed associated with maroon shale near Indian Rock, Virginia.

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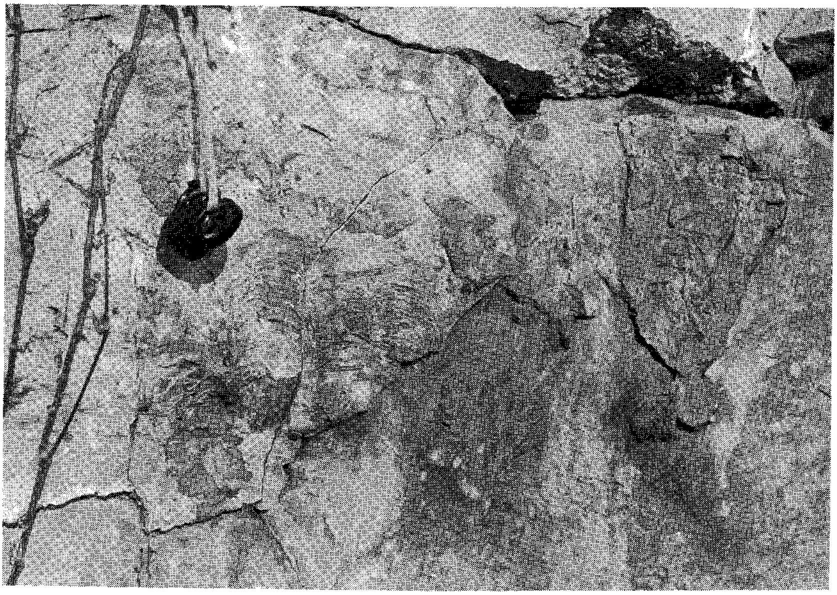


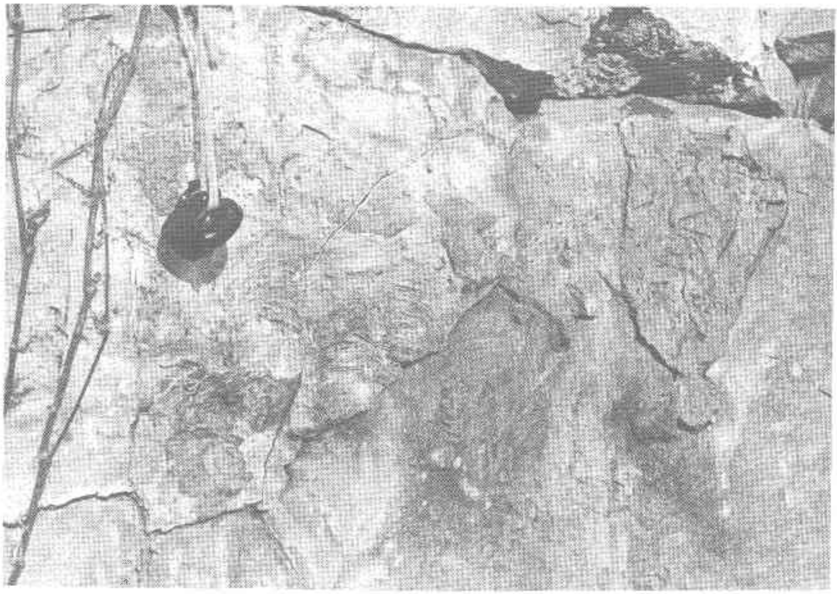
Figure 6. Algal (cryptozoon) limestone layer in the upper part of the Rome Formation along south side of Shenandoah River at Calmes Neck.

The same genus occurs in similar rocks south into northern Georgia and northern Alabama, where the containing beds are in the Rome Formation in its type region.

ELBROOK FORMATION

The Elbrook crops out in a belt 0.4 to 1.5 miles wide and takes on a pattern in conformity with the structure of the underlying Rome Formation. There are relatively good exposures along Long Marsh Run near the Virginia-West Virginia boundary, along State Road 608 between Webbtown and Marvin Chapel, and on the east limb of the Calmes Neck anticline where it is crossed by Craig Run about 1.5 miles southeast of Berryville (Plate 1). Measurement of substantial parts of the Elbrook have been examined on the eastern flank of the Milldale syncline along Wolfe Marsh Run east and west of State Road 624 and to the southwest along Borden Marsh Run (Plate 3). A part of the section along Borden Marsh Run is on the adjoining Linden quadrangle.

The Elbrook is predominantly limestone and dolomitic limestone with lesser amounts of dolomite, shale, siltstone, and an



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The Elbrook is predominantly limestone and dolomitic limestone with lesser amounts of dolomite, shale, siltstone, and an occasional bed of sandstone. The carbonate layers vary from a few inches to more than 2 feet in thickness. Much of what appears as relatively pure, fine-grained, bluish-gray limestone (R-4156) contains argillaceous and sandy laminae which, owing to a slight difference in color brought out by weathering, give the layers a ribbon-banded appearance (Figure 7). On complete decalcification the argillaceous bands yield ocherous slabs and shale-like debris that is not distinguishable from similar material in parts of the underlying Rome Formation. The problem of separating the two units becomes even more difficult at certain localities where the impure carbonates of the Elbrook are interbedded with siltstones and fine-grained sandstones. An approximate boundary can be determined where exposures are adequate to display maroon or green shales that commonly occur near the top of the Rome.

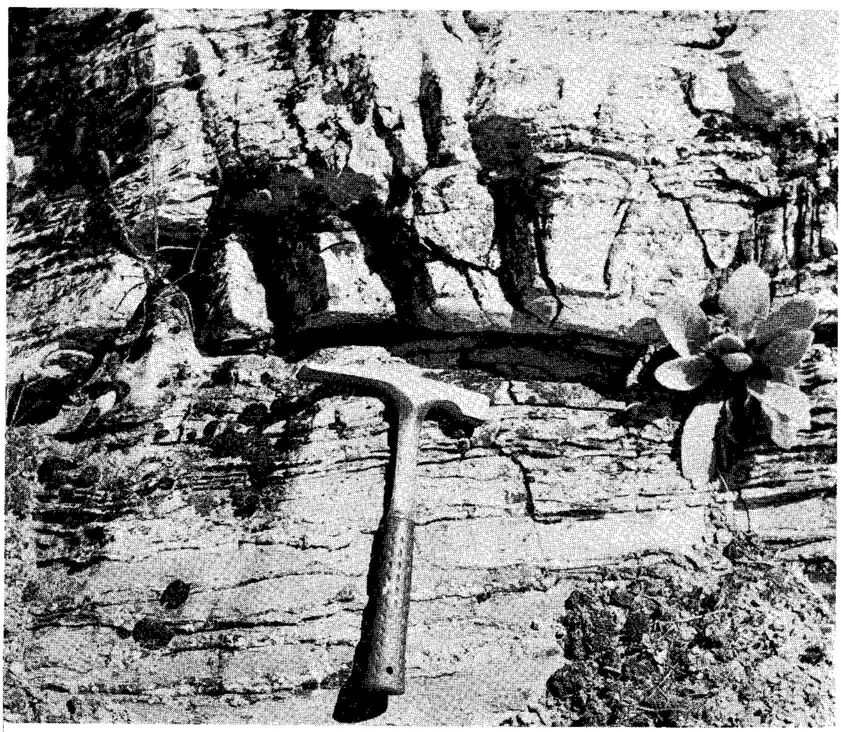

Figure 7. Banded limestone with thicker interbeds of dolomite in upper part of the Elbrook Formation along Craig Run about 1.5 miles southeast of Berryville.

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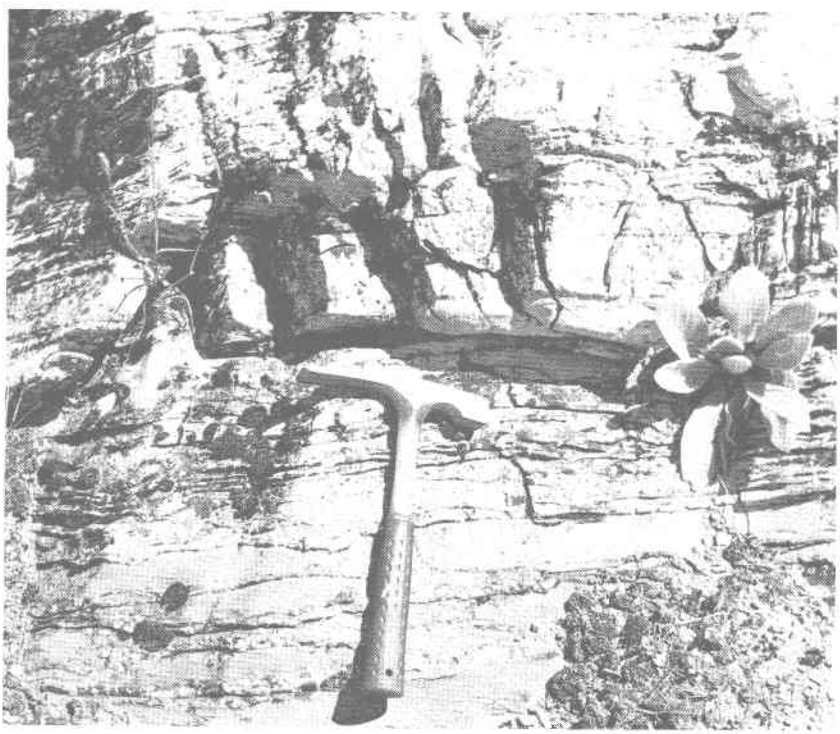


Figure 7. Banded limestone with thicker interbeds of dolomite in upper part of the Elbrook Formation along Craig Run about 1.5 miles southeast of Berryville.

Four general zones appear to have different arrangement of lithologies but without boundaries separating one zone from another. The lower 400 to 500 feet of the Elbrook, although partly covered, seems to be very shaly and silty as seen in weathered exposures near Webbtown (Plate 1) and along and north of Wolfe Marsh Run (Plate 3). Scattered exposures of relatively fresh impure limestone with minor amounts of impure dolomite, which weather yellowish-tan (R-4152), crop out near the axis of the Calmes Neck anticline southeast of Berryville. Exposures within this interval north of Wolfe Marsh Run and along the road leading down Borden Marsh Run southeast of Milldale are mostly impure gray dolomite. Above this zone is a unit, approximately 150 feet thick, that appears to be composed largely of light-gray, saccharoidal dolomite. However, siltstone and shale fragments are abundant as float, thus suggesting that they were derived from beds that are now concealed by the residuum.

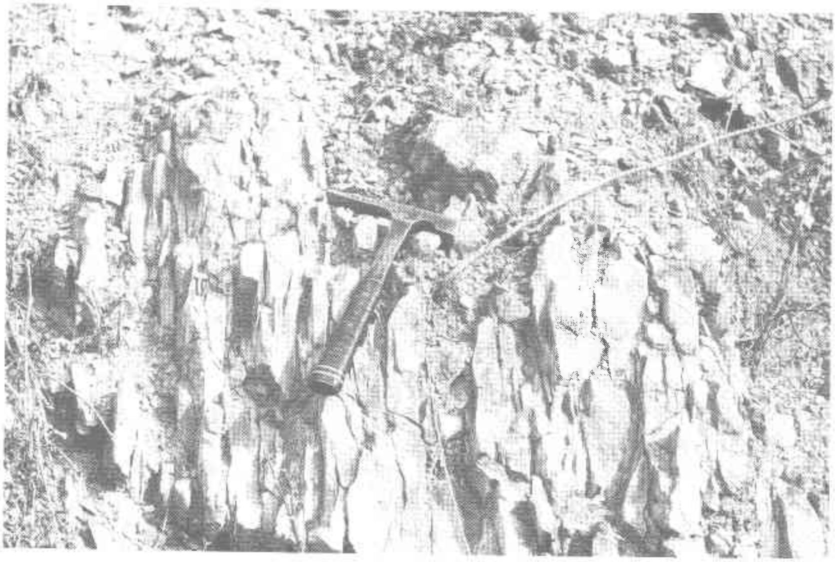
The light-colored zone is overlain by 600 to 700 feet of multicolored ribbon-banded limestone, fine- to medium-grained, sandy and shaly dolomites, calcareous and noncalcareous shales, and siltstones. Most of these lithologies are displayed in the vicinity of Milldale (Appendix, Section 12). There are places where the shale units are 10 feet or more thick. This assemblage of rocks, comprising the middle part of the Elbrook, contains a relatively thin zone of green and/or maroon shale, mudstone (R-4157), sandstone, and sandy carbonates. One or more or these lithologies, resembling the underlying Rome, has been found at several localities in Clarke and Warren counties and appears to occupy a constant stratigraphic position. The best display of the zone which was seen in the map area is near the crest of the Calmes Neck anticline along State Road 613 about 600 feet southwest of Craig Run. Other exposures on the Berryville quadrangle are just west of State Road 608 about 1 mile northeast of Webbtown, along State Highway 7 about 0.5 mile west of Webbtown, and along State Road 608 about 600 feet southeast of Dog Run. On the Boyce quadrangle this zone has been observed near the junction of State Roads 624 and 626 (Figure 8), along State Road 622 about 400 feet east of its junction with State Road 624, and near the axis of the Stone Bridge anticline at the southern edge of the Boyce quadrangle 0.5 mile east of State Road 658.

The uppermost part of the Elbrook west of Milldale (Plate 3) is about 600 feet thick as determined from the width of the belt

Figure 8. Impure limestone with clayey seams near middle of the Elbrook Formation along State Road 624 about 300 feet east of its junction with State Road 626. Bedding, parallel with hammer head, is cut by vertical cleavage.

and an assumed average dip of 60 degrees. The rocks are predominantly light- to dark-gray, fine- to medium-grained dolomite which weathers yellowish to dark brownish gray. Shaly dolomites which weather dark rusty brown are conspicuous near the top of the unit. Scattered throughout are fine-grained, medium- to bluish-gray limestone with laminae of argillaceous limestone or dolomite which weather yellowish gray. The slight difference in color, brought out by weathering, between the relatively pure and argillaceous laminae gives a banded appearance. Although the weathered appearance of most of the rocks in this section suggest that they are dolomites, the evidence is not conclusive since strongly argillaceous limestones will also weather to a dun color. For the purpose of comparison see the description of the rocks (Appendix, Section 3, Units 1-31) from the northern part of the map area (Plate 1).

The thickness of the Elbrook cannot be accurately measured, but, along and south of State Highway 7 about 1.5 miles east of Berryville, where the outcrop is narrowest and the dip nearly vertical the possible maximum thickness is about 2000 feet.



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Stromatolites, probobly composed of cryptozoa, were noted at several localities along the outcrop belt of the Elbrook and were particularly well-developed as flattened cabbage-shaped colonies up to 3 feet in diameter in the limestones north of Milldale and along Craig Run. There is no evidence here regarding age, since no other fossils have been collected from the Elbrook and the algal structures have a wide geologic range. However, during the survey of Frederick County (Butts and Edmundson, 1966, p. 18) a few fossils were collected from the lowermost beds of the Elbrook west of the Massanutten syncline. Trilobite remains identified as *Glyphaspis* and *Glossopleura* are genera of Middle Cambrian age. Wilson (1952, p. 304-305) reports that: "Several of the common Dresbachian, Upper Cambrian, genera range down into the Elbrook. . . ." On the basis of fossils reported from nearby regions, it may be assumed that the Elbrook within the area of this report is of Middle and lower Upper Cambrian age.

CONOCOCHEAGUE FORMATION

The Conococheague, which overlies the Elbrook Formation, derives its name from Conococheague Creek, Franklin County, Pennsylvania, where it was named by Stose (1908, p. 701) as the Conococheague Limestone. The name is amended in this report to include two changes: (1) the lower 100 to 200 feet is designated the Big Spring Station Member (Wilson, 1952, p. 307-308) and (2) the crinkly-weathering siliceous limestones at the top of the Conococheague, originally considered uppermost Cambrian, are now known to be of Early Ordovician age and were assigned by Sando (1958, p. 839) to the Stoufferstown Member of the Stonehenge Formation. The Big Spring Station and Stoufferstown members have not been mapped in this report, but their presence has been established provisionally at several localities. In the case of the Stoufferstown the Cambrian-Ordovician boundary at the base of this member has been lowered 150 to 200 feet.

The Conococheague occupies a belt that ranges in width from about 0.85 mile at the southwestern corner of the Boyce quadrangle (Plate 3) to more than 2.5 miles from the vicinity of Berryville northeastward to the Virginia-West Virginia boundary (Plate 1). Although exposures seem adequate in this broad area, any attempt to make detailed descriptions of the rock sequence

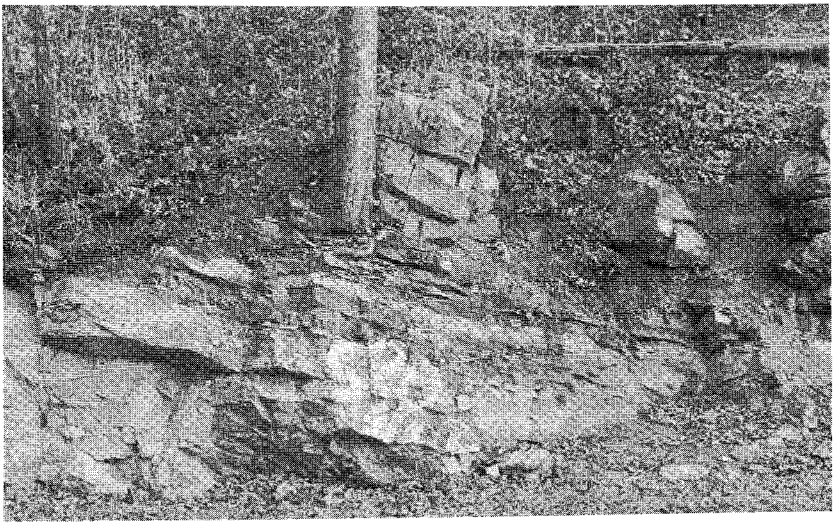

Figure 9. Banded limestone (light-colored) and impure dolomite with intercalated thin layers (hammer head on 9-inch bed) and lenses of friable-weathering sandstone in the lower part of the Big Spring Station Member of the Conococheague Formation along north side of State Road 723 in Millwood.

and thickness determinations are not rewarding, since parts of the Conococheague are repeated by at least eight folds. In many exposures it is very difficult to determine the attitude of the rocks because of well-developed fracture cleavage.

Some of the best exposures in the northern part of the area are in the open fields on both sides of U. S. Highway 340 about 1.5 miles north of Berryville, along the same highway about 1 mile southwest of Gaylord, and along Craig Run south and southeast of Berryville (Plate 1). To the southwest on the Boyce quadrangle (Plate 3) partial exposures are east and west of U. S. Highway 340 north of Briggs, along State Road 620 north of Millwood, along and north of State Road 622, about 1 mile northwest of Bethel, and along the upper reaches of Wolfe Marsh Run and Borden Marsh Run, especially in the vicinity of Stone Bridge.

The boundary between the Elbrook and the Big Spring Station Member of the Conococheague is placed just below the first appearance of medium- to coarse-grained, friable-weathering sandstone. In the nothern part of the area (Plate 1) these basal sandstones appear to be thinner and less numerous than to the southwest on the Ashby Gap and Boyce (Plate 3) quadrangles.

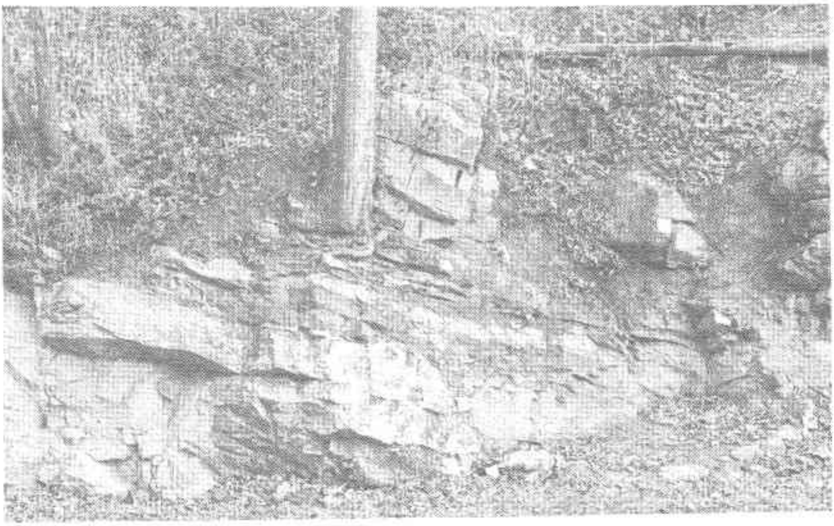

Figure 9. Banded limestone (light-colored) and impure dolomite with intercalated thin layers (hammer head on 9-inch bed) and lenses of friable-weathering sandstone in the lower part of the Big Spring Station Member of the Conococheague Formation along north side of State Road 723 in Millwood.

and thickness determinations are not rewarding, since parts of the Conococheague are repeated by at least eight folds. In many exposures it is very difficult to determine the attitude of the rocks because of well-developed fracture cleavage.

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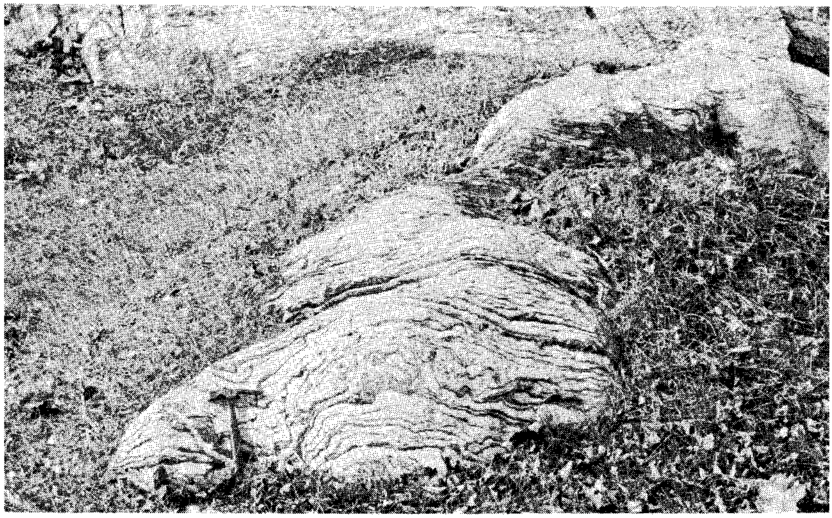
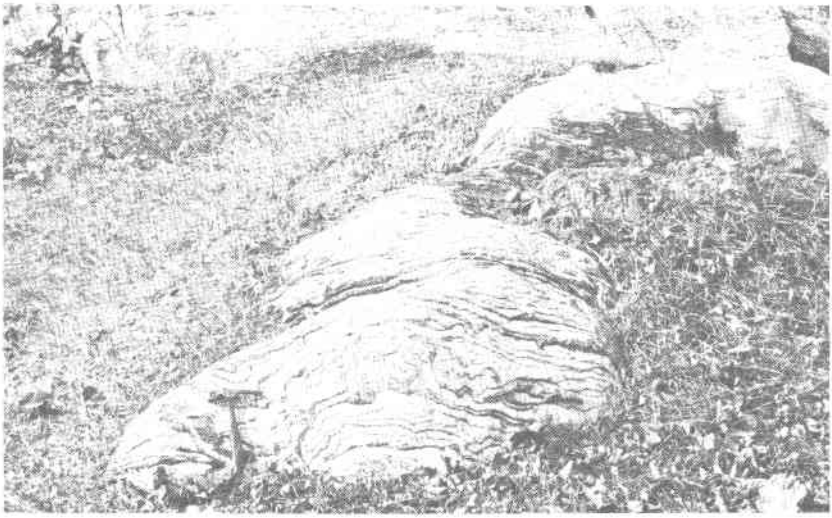


Figure 10. Limestone with crinkly siliceous laminae and chert (at hammer handle) in the Conochocheague Formation along west side of U. S. Highway 340 about 0.8 mile northwest of Briggs.

In addition to the sandstones the lower 100 to 200 feet of the Conococheague differs from the overlying parts of the formation in containing a larger percentage of dolomite and dolomitic limestone (Figure 9). Above these beds, tentatively assigned to the Big Spring Station Member of the Conococheague, are 500 to 600 feet of carbonates consisting predominantly of ribbon-banded limestones with minor amounts of siliceous laminae. The light-gray bands in the limestone, which weather light bluish gray, are thought to contain more magnesian than the host rock. A few beds of dolomite, weathering light gray and pale yellow, occur in this interval.

The upper part of the Conococheague is composed mainly of 600 to 800 feet of limestone characterized by siliceous banding which grades upward into 500 to 700 feet of limestone with interbeds of dolomite and abundant sandstone near the top. Some of the siliceous laminae in the lower part of the unit occur as plate-like sheets and other beds contain laminae which are very irregular or crinkly and, because of their greater resistance to weathering, tend to stand out in relief on the surfaces like ribbing or fluting (Figure 10). In addition to the siliceous banding, many of the limestone beds contain intraformational conglomerates (Figure 11), up to 18 inches thick, that are lense shaped. Sand-



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Above the siliceous limestones are gray to dark-gray limestones with interbeds of light- to dark-gray dolomite and dolomitic limestone. The limestones weather light bluish gray, the dolomites light gray and pale yellow. Most of the rocks are fine grained. Siliceous banding is present in some of the beds, but is not conspicuous as in the underlying interval. Friable weathering sandstones (R-4148) crop out occasionally and the wide distribution of float indicates that sandstone is abundant in the upper few hundred feet of the Conococheague. In the top of the formation the sandstone (sandy chert) is cemented by silica and from Pyle-

Figure 11. Intraformational limestone conglomerate and crinkly siliceous laminae in the Conococheague Formation east of U. S. Highway 340 in the vicinity of Pigeon Hill.

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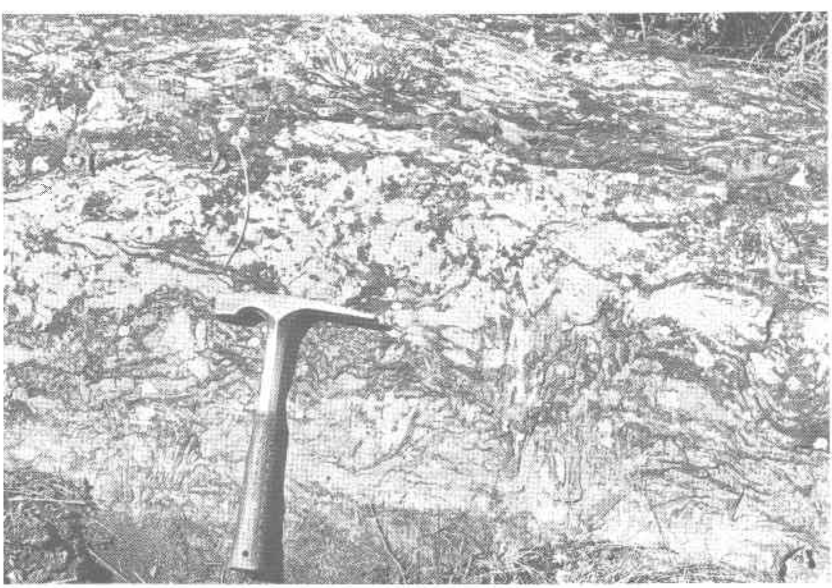

Figure 11. Intraformational limestone conglomerate and crinkly siliceous laminae in the Conococheague Formation east of U. S. Highway 340 in the vicinity of Pigeon Hill.

town north to West Virginia a number of silicified algal(?) structures (R-3920, R-4171) have been noted at this interval.

Sandstone, the best criterion for the identification of the Conococheague, may be examined along State Road 644 at the west end of Stringtown, near the Virginia-West Virginia boundary about 1 mile northwest of Gaylord, several exposures of beds 1 to 3 feet thick along U. S. Highway 340 and State Road 617 between Boyce and Briggs, around the Pyletown anticlinal salient and the Horsepen Spring synclinal reentrant west of State Road 624 about 2 to 3 miles southeast of White Post, along State Road 658 (R-4181) between Stone Bridge and the Clarke County-Warren County boundary. Sandstone with siliceous cement, some displaying algal structures, is well displayed along State Road 633 about 1 mile north of Old Chapel, on a prominent hill about 1.3 miles northwest of Briggs (Figure 12), and along State Road 639 about 1 mile northwest of Lewisville (R-3920).

The Conococheague is estimated to be about 2300 feet thick in the southern part of the area (Plate 3), but it may be thicker in the north, especially between Stringtown and Gaylord (Plate 1). In preparing the cross sections an average thickness of about 2500 feet is assumed.

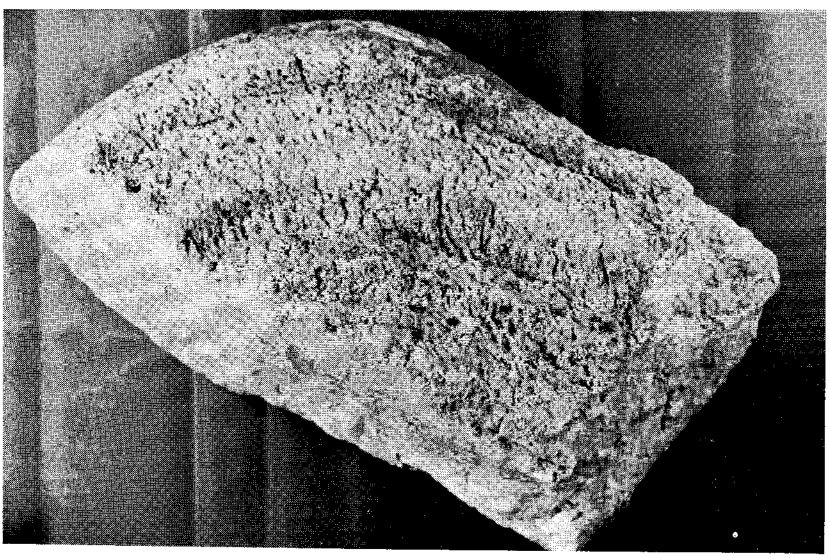

Figure 12. Cryptozoon chert, 100-200 feet below top of the Conococheague Formation, on prominent hill 1.3 miles northwest of Briggs.

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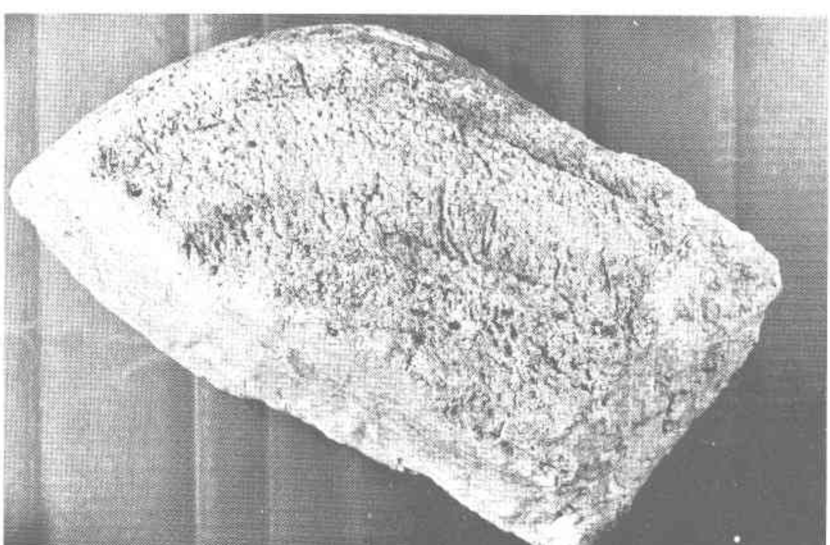

Figure 12. Cryptozoon chert, 100-200 feet below top of the Conococheague Formation, on prominent hill 1.3 miles northwest of Briggs.

No fossils, except for algal structures, have been found in the Conococheague within the area of this report. *Tellerina wardi,* regarded as of Upper Cambrian age, has been found in the formation at two localities in Frederick County (Butts and Edmundson, 1966, p. 21). Wilson (1952, p. 308) reports that trilobites of all three Upper Cambrian stages are present in a section of the Conococheague near Winchester, Virginia.

ORDOVICIAN SYSTEM

BEEKMANTOWN GROUP

The nomenclature of Lower Ordovician rocks used in this report will follow Sando's (1956, p. 935) proposal for the section in Maryland, namely that the Beekmantown be raised from formation to group status and include three formations which are, in ascending order, Stonehenge Formation, Rockdale Run Formation, and Pinesburg Station Dolomite. With reference to the Cambrian-Ordovician boundary, Sando (1957, p. 16) stated: "The occurrences of *Symphysurina* and *Clelandia* about 30 feet below the top of the formation proves the Early Ordovician age of at least this part of the Conococheague. The lithologic break separating the Conococheague from the Stonehenge does not, therefore, coincide with the boundary between the Cambrian and Ordovision systems." Later Sando (1958, p. 839) proposed the name, Stoufferstown Member of the Stonehenge Limestone, to include the beds originally mapped as upper Conococheague in Maryland.

Subsequent studies by Wood (1962, p. 36-48) along the west side of the Massanutten syncline in northern Virginia show that this member, containing *Symphysurina,* ranges in thickness from about 30 to 100 feet and Page, Burford, and Donaldson (1964) in the Martinsburg area, West Virginia, report a thickness of 100 to 200 feet.

Stonehenge Formation

The Stonehenge crops out in the northwestern corner of the Stephenson quadrangle (Plate 2) and in a belt, 1000 to 1200 feet wide, east of White Post and Boyce (Plate 3) and west of Berryville (Plate 1). The outcrop is sinuous due to overlapping folds and one diagonal fault.

The Stoufferstown Member at the base of the Stonehenge consists of fine- to medium-grained limestone with distinctive crinkly siliceous laminae in the northern part of Clarke County and west of the Massanutten syncline in Frederick County (Plates 1, 2). In the southern part of the study area siliceous laminae are present, but they occur mostly as thin sheet-like partings that do not comprise a significant part of the rock. Lense-shaped, coarse-grained bioclastic limestones are common and well exposed at Horsepen Spring (Plate 2). Fossils include fragments of cephalopods, brachiopods, gastropods, and pelmatozoans. The pelmatozoan stems are abundant and minute, the largest diameter being less than one millimeter.

The best exposure for measuring the thickness of the Stoufferstown Limestone Member, containing abundant crinkly siliceous laminae, is along State Road 672 about 2.5 miles west of Clearbrook, Frederick County (Edmundson, 1945, p. 33). Here the limestone with crinkly siliceous laminae has a thickness of 140 feet and the overlying banded limestone unit is 67 feet thick. By following this belt to the southwest for about 0.5 mile it is within a few hundred feet of the northwest corner of the Stephenson quadrangle (Plate 2). Other partial exposures of the Stoufferstown (R-4178) which are resistant enough to make a rather conspicuous terrace at places along its outcrop are north and south of U.S. Highway 50 about 1.2 miles southeast of Waterloo, from the vicinity of Pyletown northeast to Chapel Run (Plate 3), and near the Virginia-West Virginia boundary in the northwestern part of the Berryville quadrangle (Plate 1). Since precise boundaries are nonexistent, it is assumed that the thickness of the Stoufferstown is 150 to 200 feet in northern Virginia.

The top of the Stonehenge is placed at the base of the first bed of dolomite in the Rockdale Run Formation. Beds overlying the Stoufferstown consist of 500 to 600 feet of fine- to medium-grained, light- to dark-gray relatively pure limestone (R-4175). Many beds are 3 to 4 feet thick and weather light bluish gray. Interbedded with these limestones are occasional beds which have tubular structures (R-4172) of unknown origin dispersed through them in a random manner. One type of tube is about 0.1 inch in diameter and about 1 inch in length. They occur in light-gray, fine-grained limestone and appear to be composed of the same material as the host rock, thus they are only recognized by their slightly lighter-colored periphery. The other type of tubular structure occurs in dark-gray, fine-grained limestone. These tubes, up to 0.3 inch in diameter, several inches long, and frequently curved, are filled with gray coarse-grained carbonate that weathers in prominent relief on the rock surfaces. There are also some intercalations of thinly bedded limestones with minor amounts of black chert.

The top of the Stonehenge consists of laminated, in part siliceously banded, dark-gray, fine-grained limestone which weathers blue gray. North of Horsepen Springs and west of the junction of State Roads 657 and 636 is a zone of highly siliceous limestone which resembles the rock that is generally in the Stoufferstown Member of the Stonehenge. Interbedded with these highly siliceous zones are beds of conglomerate with the pebbles composed of siliceous limestone and measuring up to 4 inches in diameter. Algal structures are common in the upper part of the Stonehenge.

In addition to the algal structures, *Finkelnburgia* cf. *F. bellatula* are abundant 1.5 miles southwest of White Post and in the vicinity of Horsepen Spring (R-4173), Clarke County; a good collection of the same species (Butts, 1942) was made 1000 feet southwest of Success, Warren County. Characteristic, curved cephalopods, probably *Dakeoceras,* are widely distributed at this horizon in Clarke County and are particularly well displayed along the outcrop belt west of Sugar Hill and southeast of Boyce. A few poorly preserved gastropods, commonly filled with calcite, and resembling *Ecculiomphalus* have been observed at several localities.

Rockdale Run Formation

The Rockdale Run-Stonehenge boundary is placed arbitrarily just beneath the first occurrence of dolomite in the section. Dark chert nodules, which weather to light-gray, sandy chert (R-3922), occur in the dolomite layer and a low disconnected ridge is commonly developed along the outcrop. Where this interval is covered, an approximate boundary is assumed on the lowland side of the ridge which generally contains chert float. The top of the Rockdale Run Formation is placed at the top of the highest limestone sequence beneath the Pinesburg Station Dolomite where this lithology is recognized in the section and, in turn, the top of the Pinesburg Station Dolomite is placed below the New Market Limestone. This relationship is well displayed along the western side of the Massanutten syncline in the Stephenson area and on the east in Clarke County from the vicinity of State Highway 7 northeastward into West Virginia. In a southwesterly direction dolomite becomes less conspicuous and near the southern border of the Stephenson quadrangle and on the adjoining Boyce quadrangle the Rockdale Run Formation, consisting mainly of limestone but with interbeds of dolomite, is closely overlain by the New Market Limestone. For these reasons the Rockdale Run Formation and Pinesburg Station Dolomite are undifferentiated and mapped as a single unit on the Berryville and Stephenson quadrangles, whereas only the Rockdale Run Formation appears in the legend on the Boyce quadrangle.

The Rockdale Run Formation occupies a belt 1 mile wide northwest of Stephenson and about 3.5 miles wide along the Virginia-West Virginia boundary in the northeastern part of the Stephenson quadrangle and the adjoining northwestern part of the Berryville quadrangle. The narrowest part of the belt is in the vicinity of Boyce (Plate 3) where the distance measured at right angle to the strike from the top of the Stonehenge to the base of the New Market, since the Pinesburg Station Dolomite is not recognized, is about 1 mile. Excellent exposures of parts of the formation may be seen in the fields north of U. S. Highway 340 between White Post and Double Tollgate and northwest of the highway between White Post and Waterloo. Equally good exposures can be seen north of State Highway 7 and especially in the fields north and south of State Roads 656 and 761.

The Rockdale Run in the Stephenson area (Appendix, Section 5) is partly covered. The available exposures show that it is composed of bluish- to dove-gray, fine-grained limestone with interbeds of mottled and laminated dolomitic limestone and gray, fine- to medium-grained dolomite. An estimate based on several incompletely exposed sections in Frederick County indicates that the ratio of limestone or magnesian limestone to dolomite is about 3 to 1. East of the Massanutten syncline, the formation is predominantly limestone with only minor amounts, probably less than 10 percent, of dolomite. Fresh exposures of limestone generally are medium to bluish gray and weather to lighter shades. The texture is mainly fine grained or aphanic, but many layers show a mechanical origin and are coarser grained. The dolomite occurs as distinct beds, 6 inches to 4 feet thick, and as laminations and anastomosing networks of irregular rodlike bodies in the limestone. This general arrangement of lithologies appears to be repeated at several intervals within the upper 200 to 300 feet of the Rockdale Run Formation in the southern part of the mapped area (Appendix, Section 11), and in the state quarry on the adjoining Stephens City quadrangle. The well-defined beds of dolomite are fine to medium grained (R-3924) and commonly display "butcher block" type of weathering, whereas the dolomite forming the anastomosing bodies is coarse grained. Fresh exposures are light gray and weather to various shades of gray, yellowish tan, and pale yellow.

Small algal structures, commonly associated with sandy bioclastic limestone have been noted at several stratigraphic positions in the study area (Figure 13). Larger algal heads, 3 to 6 inches in diameter, have been observed at a few localities (Appendix, Section 11). Chert occurs sparingly throughout the formation, but is sufficiently concentrated near the base (R-3922), 1000 to 1200 feet above the base (R-4180), and from 500 to 800 feet below the top to locally form low, rounded, disconnected ridges and hills. The basal chert is light gray and

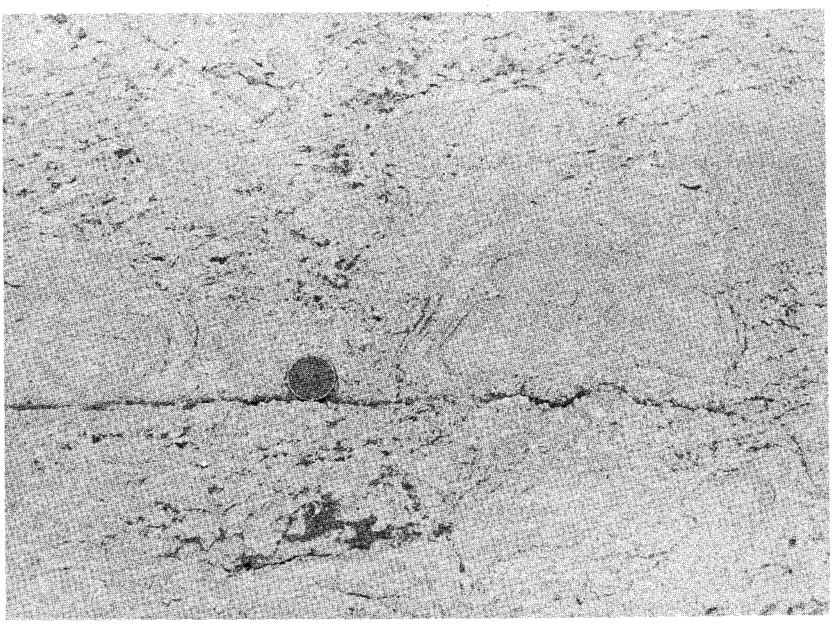

Figure 13. Concentric algal structures in bioclastic limestone of the Rockdale Run Formation along State Road 632 and about 1 mile north of State Highway 7.

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Figure 13. Concentric algal structures in bioclastic limestone of the Rockdale Run Formation along State Road 632 and about 1 mile north of State Highway 7.

commonly sandy, and float material has been observed at many localities throughout the area within 100 to 200 feet above the top of the Stonehenge Formation. The middle zone, 1000 to 1200 feet above the base of the formation, consists of black, sandy chert nodules in bluish-gray limestone. Accessible places to observe this cherty zone are along State Road 644 at the western boundary of the Boyce quadrangle, on the north side of U. S. Highway 340 about 0.5 mile west of White Post (R-4180), and along State Road 635 about 1 mile northwest of Stringtown (Plate 1). About 300 feet above this cherty zone are several hundred feet of predominantly light bluish-gray limestone (R-4179) with many layers showing well-developed algal structures and containing the greatest number of *Ceratopea* observed in Clarke County. The upper cherty zone begins about 650 feet below the New Market Limestone near the southern boundary of the Stephenson quadrangle. It consists of a few 3- to 6-inch thick beds of black stromatolitic chert and abundant black chert nodules, up to 3 inches thick, which occur throughout a limestone-dolomite sequence of 132 feet (Appendix, Section 11, unit 6). The full extent of these resistant beds has not been checked in the field, but since they form low linear ridges (Figure 19, E), they have served a useful purpose in defining the structure between the Waterloo syncline and the Pyletown anticline on the Stephenson quadrangle mainly south of State Highway 7.

No locality was found within the study area where the thickness of the Rockdale Run Formation could be determined. The width of outcrop of the Rockdale Run and Stonehenge formations along cross section C-C′ near the southern boundary of the Stephenson quadrangle (Plate 2) is 7400 and 2300 feet respectively. The Stonehenge has an average thickness of about 750 feet at this locality; thus, if the degree of folding that expands the outcrop belt of the Stonehenge is maintained in a northwesterly direction, the thickness of the Rockdale Run would be about 2400 feet.

The Rockdale Run Formation contains many layers of limestone which are abundantly fossiliferous, but the fossils are so firmly incorporated in the rock as to be unavailable for study and certain identification. They generally appear in section only on weathered rock surfaces or as fragments in bioclastic limestone (Figure 13). The lower part of the section (Nittany division of Butts, 1942) is characterized by a few specimens of *Lecanospira* cf. *L. compacta* and a few layers crowded with distorted brachiopod shells that appear to be *Diaphelasma pennsylvanicum.* Gastropod shells, commonly shown in section and filled with white calcite, are probably species of *Ecculiomphalus* and *Hormotoma.* The upper part (Bellefonte division of Butts, 1942) of the formation is characterized by *Ceratopea,* the operculum of some unidentified gastropod, which is distributed throughout, but is particularly abundant in the rather pure limestones near the middle of the section. Of the gastropods, *Hormotoma* cf. *H. gracilens* and cf. *H. artemesia* are the most common. A few specimens of *Orospira* were found and flat forms like *Ophileta* and *Ecculiomphales* occur, but their identification is questionable. The most abundant fossils are algal structures, ranging from less than 0.9 to several inches in diameter, and scattered at intervals throughout the formation.

Pinesburg Station Dolomite

The upper part of the Pinesburg Station Dolomite is exposed in the vicinity of Stephenson, within the Wadesville anticline, along the Baltimore and Ohio Railroad east of Swimley, and at many localities in the open fields north of State Highway 7. Apparently the dolomite thins in a southwesterly direction east of the Massanutten syncline. On the west limb of the Stones Chapel syncline (Plate 2), where crossed by State Road 657, the New Market Limestone is underlain by about 100 feet of dolomite and then followed in normal sequence by bluish-gray limestone. Near the southern boundary of the Stephenson quadrangle (Appendix, Section 11), within the Boyce quadrangle (Plate 3), and on the adjoining Stephens City quadrangle the Pinesburg Station is absent and the uppermost part of the Beekmantown Group consists largely of limestone with some interbeds of dolomite.

The Pinesburg Station Dolomite is dark to light gray (R-4171) on fresh surfaces, but weathers very light gray to flesh colored. Most of the beds are fine grained, a few medium grained, and many show cross-hatching furrows ("butcher-block structures") produced by differential weathering. Chert is not abundant but within the Wadesville anticline a few layers contain white chert nodules, averaging 0.5 inch in diameter.

Along the Baltimore and Ohio Railroad east of Swimley there is about 385 feet of Pinesburg Station Dolomite exposed, and in the vicinity of Stephenson (Appendix, Section 5) 353 feet has been measured. Both of these exposures are covered at the base. In Section 7 the traversed distance could accommodate about 600 feet of rock, but since the section is about 50 percent covered and at least two limestone beds about 1 foot thick occur near the middle of the section, it is most likely that the Pinesburg Station-Rockdale Run boundary lies within the covered interval. Perhaps 300 to 400 feet would be a reasonable estimate of the thickness in the northern part of the area. A combined thickness of about 2700 feet is assumed for the Rockdale Run and Pinesburg Station formations in the interpretive cross sections.

NEW MARKET LIMESTONE

The New Market Limestone succeeds the Pinesburg Station Dolomite or the Rockdale Run Formation and is overlain by dark-gray commonly cherty limestone of the Lincolnshire Formation. It crops out in a very narrow band along the northwestern side of the Massanutten syncline near Stephenson and parallel with U.S. Highway 11. This belt is offset by a diagonal fault south of Hiatt Run and north of Freyco (Plate 2). East of Opequon Creek the New Market and associated younger lower Middle Ordovician limestones are so complexly folded and faulted that some of the mapping (Plates 1-3) may be subject to different structural interpretations. East of the main folded belt, dominated by the Wadesville anticline, are two faulted outliers (Stones Chapel and Waterloo synclines). A third folded and faulted structure involving the New Market and associated units is along the Baltimore and Ohio Railroad at the West Virginia line about 0.5 mile east of Swimley. At this locality the New Market is repeated three times within a distance of a few hundred feet across the strike. The evidence is not conclusive, but this structurally deformed belt may be a part of the Stones Chapel syncline (Plate 2). The New Market has been identified at many localities within these outlying belts, but in the southern part of the Stephenson quadrangle and in the northern part of the Boyce quadrangle the exposures are generally poor and at a few localities the New Market and/or Lincolnshire appear to be very thin or even missing from the section. For these reasons the New Market and Lincolnshire in the eastern belts are not differentiated on the geologic maps.

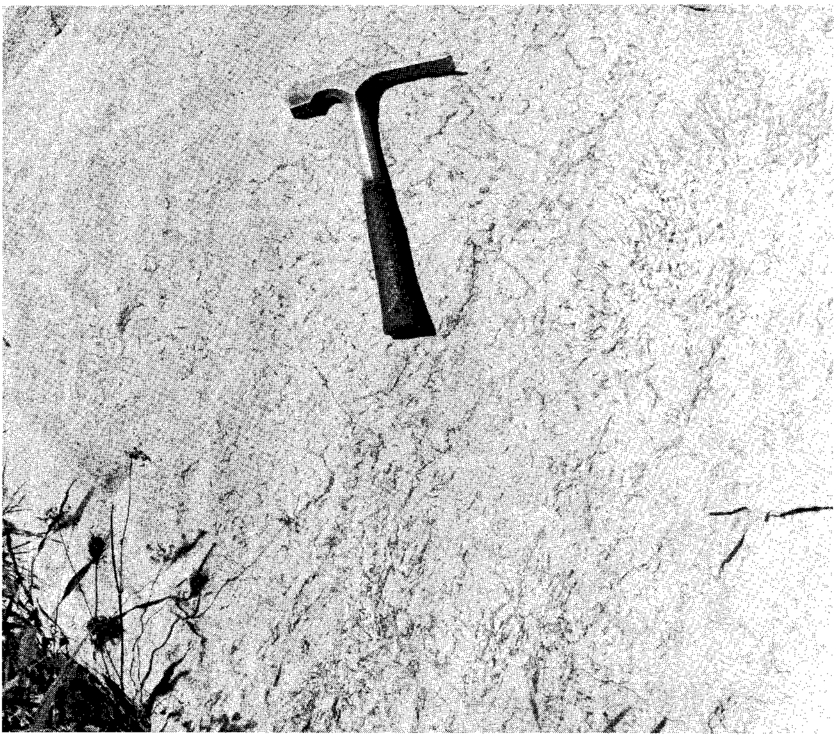

Figure 14. Dove-colored New Market Limestone with gastropods and corals along State Road 761 about 0.35 mile east of Opequon Creek.

The distinctive characteristics of the New Market Limestone (R-4170) are compact very fine-grained texture, conchoidal fracture, and bluish- to dove-gray color (Figure 14). The formation is usually thick bedded in the upper part and commonly shows thin films of chalk-like material on weathered surfaces. At most localities the formation may be divided into two parts: an upper division including more than half of the total thickness, containing about 97 to 98 percent calcium carbonate; and a lower zone containing thin-bedded, slightly impure layers. Locally, a few feet of limestone-pebble conglomerate occurs at the base. This basal conglomerate and marked variations in thickness within short distances along the strike suggest that the New Market was deposited on an irregular surface at the top of the Beekmantown Group.

The thickness of the New Market west of the Massanutten syncline throughout the Shenandoah Valley in Virginia is, with

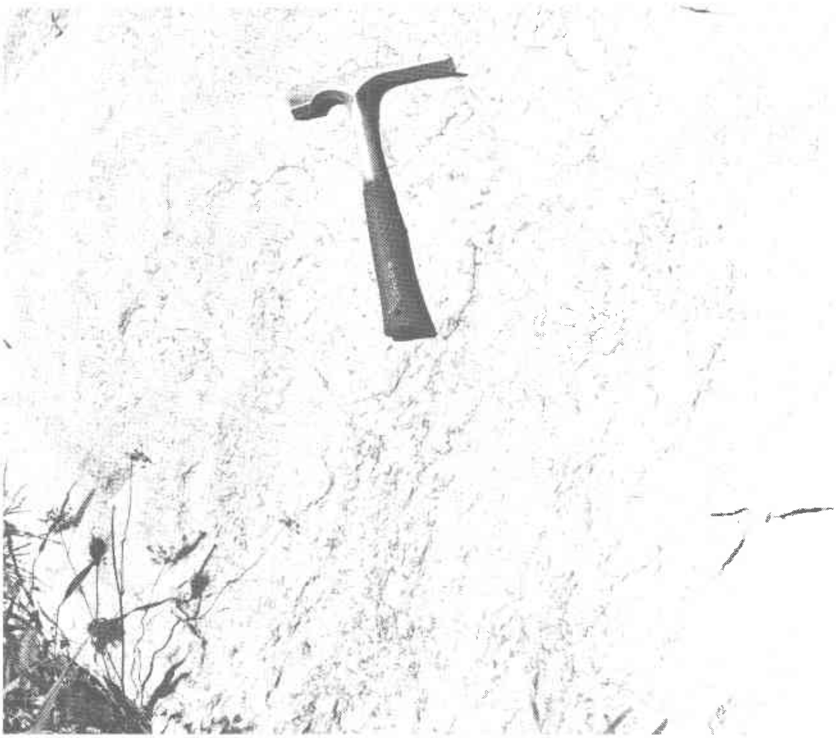

Figure 14. Dove-colored New Market Limestone with gastropods and corals along State Road 761 about 0.35 mile east of Opequon Creek.

The distinctive characteristics of the New Market Limestone (R-4170) are compact very fine-grained texture, conchoidal fracture, and bluish- to dove-gray color (Figure 14). The formation is usually thick bedded in the upper part and commonly shows thin films of chalk-like material on weathered surfaces. At most localities the formation may be divided into two parts: an upper division including more than half of the total thickness, containing about 97 to 98 percent calcium carbonate; and a lower zone containing thin-bedded, slightly impure layers. Locally, a few feet of limestone-pebble conglomerate occurs at the base. This basal conglomerate and marked variations in thickness within short distances along the strike suggest that the New Market was deposited on an irregular surface at the top of the Beekmantown Group.

The thickness of the New Market west of the Massanutten syncline throughout the Shenandoah Valley in Virginia is, with few exceptions, much greater than in the eastern belts. Measurements in the Stephenson area (Appendix, Sections 4, 5) show that the thickness varies from about 70 to 120 feet. In Clarke County the maximum thickness is about 67 feet at a locality 0.3 mile east of Opequon Creek and 200 feet north of State Road 761 (Appendix, Section 7). Apparently this thickness is maintained for only a short distance to the north and south along strike, since in the vicinity of Wadesville (Appendix, Section 6) the possible maximum thickness is not more than 35 feet and to the south along State Road 660, about 0.5 mile east of Opequon Creek, the thickness is estimated at 20 feet. Several measurements in the complexly folded belts north and south of State Highway 7 and U. S. Highway 50, and in the faulted synclinal areas, show thicknesses that vary from less than 15 feet to a maximum of not more than 50 feet.

The fossils that have been observed in the New Market within the map area are mainly sections of large gastropods. The most abundant forms suggest *Trochonemella;* others seem to be *Lophospira.* Another significant fossil, *Tetradium syringoporoides,* (Figure 14), is present in outcrop along State Road 663 (Appendix, Section 5) and just north of State Road 761 (Appendix, Section 7).

LINCOLNSHIRE FORMATION

The New Market Limestone within the study area, is succeeded, with no known interruption of deposition, by the Lincolnshire Formation. Along the west side of the Massanutten syncline the top of the Lincolnshire is placed within a few feet of the first occurrence of siltstone in the Edinburg, which is commonly associated with cobbly to shaly weathering, dark-gray limestone. East of the syncline the boundary is placed below the first occurrence of dense, black limestone with abundant shaly partings, since the siltstones are higher in the section.

The Lincolnshire crops out within a narrow sinuous band, contiguous with the underlying New Market, that is repeated by folding east of Opequon Creek and locally disarranged by faulting on both limbs of the Massanutten syncline. It has been observed also at several localities within the Stones Chapel and Waterloo synclines.

The Lincolnshire (R-4168) is an easily recognizable formation in northern Virginia. It is dark-gray, in places almost black, fine- to medium-grained limestone. Beds range from about 2 to 4 inches thick and many of the layers tend to be nodular or made of irregular, lenticular slabs. On close examination parts of the formation appear to be bioclastic limestone with fragmental fossils comprising most of the rock. At a few localities the rock contains pink partings and thin clay seams along the irregular bedding surfaces. Another distinctive feature of the Lincolnshire in most areas is the occurrence of abundant nodules, plates and stringers of black chert (Figure 15). The chert commonly weathers out on the surface and affords a means of tracing the formation where there are no exposures of bedrock. At localities where chert is not prominently developed (Appendix, Section 6), or if the chert is omitted from the sample, the rock contains about 97 percent calcium carbonate (Table 4).

The Lincolnshire is 50 to 100 feet thick west of the Massanutten syncline and averages about 80 feet (Appendix, Section 5) in the Stephenson area (Plate 2). East of Opequon Creek the maximum thickness observed was about 85 feet (Appendix, Sec-

Figure 15. Dark-gray bioclastic limestone and black chert in the Lincolnshire Formation along State Road 761 about 0.35 mile east of Opequon Creek.

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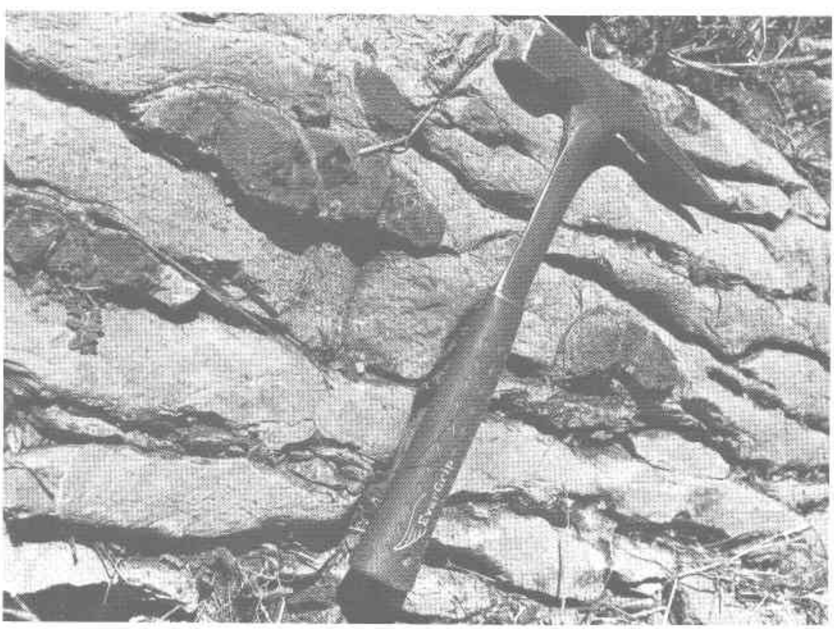


Figure 15. Dark-gray bioclastic limestone and black chert in the Lincolnshire Formation along State Road 761 about 0.35 mile east of Opequon Creek.

tion 6) at a locality 300 feet north of the Baltimore and Ohio Railroad at Wadesville. Along the same belt, about 500 feet southeast of Wadesville, the thickness is about 50 feet. About 200 feet north of State Road 761 and 0.3 mile east of Opequon Creek the thickness is about 60 feet (Appendix, Section 7). Along State Road 660 about 1000 feet east of its intersection with State Road 645 and at another locality 600 feet north of State Highway 7 and 0.3 mile west of State Road 660 the Lincolnshire is very thin or missing from the section. Near the southern boundary of the Stephenson quadrangle in the Waterloo syncline the exposures are adequate to determine a thickness of 10 feet on the western limb and about 14 feet on the eastern limb (Appendix, Section 11). Exposures of abundantly cherty limestone and residual chert float, where bedrock is covered, are in the relatively large area at the south end of the Wadesville anticline just north of Dry Marsh Run, along State Road 645 and 0.6 mile north of State Highway 7, and near the top of a low ridge east of State Road 645.

Fossils identified by Butts (1942) from the Lenoir Limestone (Lincolnshire Formation of this report) in Clarke County include *Strophomena* cf. *S. tennesseenis* Williard, ramose bryozoans suggesting *Stenopora* or *Dekayella,* and crinoid stems. In up-dating this report the present writers have identified tentatively *Mastopora ovoides,* coarse-ribbed brachiopods suggesting *Dinorthis,* and abundant *Girvanella.* For a larger number of fossils collected from this horizon the reader is referred to lists cited in the report on Frederick County (Butts and Edmundson, 1966).

EDINBURG FORMATION

The Edinburg Formation includes about 550 feet of beds above the Lincolnshire Formation and below the Oranda Formation in Frederick and northern Clarke counties (Appendix, Sections 7, 8). Where the Oranda is not recognized the top of the Edinburg is placed just below the first sandy shales at the base of the Martinsburg Formation.

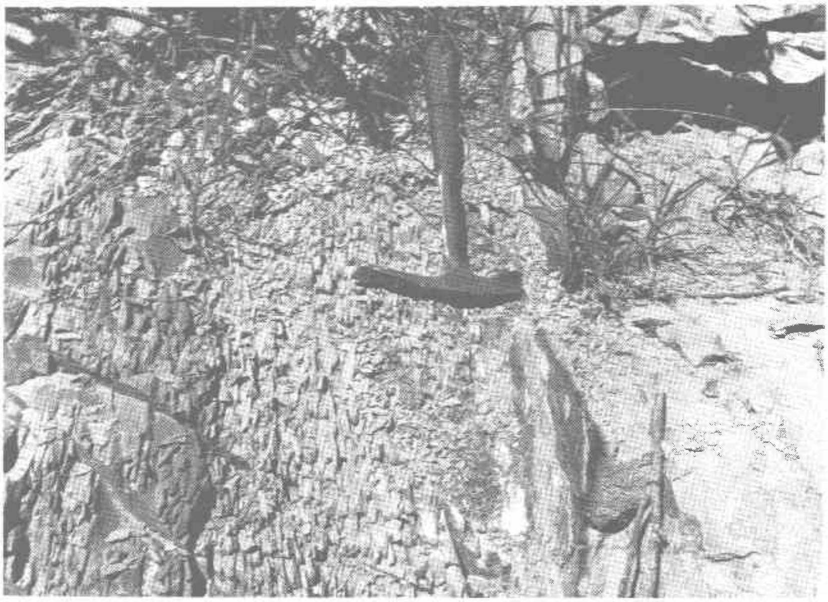
The Edinburg on the west side of the Massanutten syncline crops out in a band, about 800 feet wide, in the Stephenson area and in general paralleling U. S. Highway 11. There are no fully exposed sections in this area (Plate 2), but several incomplete exposures indicate that about 70 percent of the unit consists of cobbly to nodular, dark- to buff-gray limestone with shaly partings ("Lantz Mills facies" of Cooper and Cooper, 1946, p. 78, 95-96) and the remaining parts of the section, occurring as units of variable thickness intercalated within the cobbly beds, are composed mainly of dense, even bedded, black limestone and partings of black shale ("Liberty Hall facies" of Cooper and Cooper, 1946, p. 78, 95-97). Although not observed in the Stephenson area (Plate 2), a layer of siltstone, approximately 3 feet thick, and several thin metabentonites commonly occur near the base of the formation. This resistant bed, named by Butts and Edmundson (1966, p. 31) as the Tumbling Run sandstone, is a valuable horizon marker for several miles north and south of the type area in northern Shenandoah County. A similar bed, supposed to be the same, crops out in Frederick County and forms a low ridge about 1 mile west of Stephens City and in the eastern environs of Winchester (Edmundson, 1939, p. 99-104).

The Edinburg Formation crops out in a complexly folded and faulted belt east of Opequon Creek, in two narrow outliers (Stones Chapel and Waterloo synclines) east of the main folded belt lying in general between State Highway 7 and U. S. Highway 50, and in a small folded and faulted belt east of Swimley at the Virginia-West Virginia boundary. The rocks exposed in these belts show marked variations in lithology. Along the northwest limb of the Wadesville anticline from the north boundary of the Stephenson quadrangle southwest to the general vicinity of Dry Marsh Run there is an alternation of Lantz Mills and Liberty Hall with the cobbly weathering limestones (R-4167) more abundant in the upper 100 feet. Three shaly siltstones (R-4165) associated with thin beds (R-4166) of metabentonite (Figure 16) have been described from localities along and just south of State Road 671 (Appendix, Sections 7, 8). Farther south in the vicinity of State Highway 7 the Edinburg is mainly the Liberty Hall consisting of interbedded black and gray limestone layers, 2 to 4 inches thick, in regular succession that gives the impression of rhythmical deposition; black shales which weather yellowish gray; and scattered calcareous siltstones which weather brownish gray. A few slightly nodular layers and an occasional bed of fossil fragments have been observed in this broad expanse of the Edinburg which is repeated by folding east of Opequon Creek. In the southern part of Clarke County and in the vicinity of Riverton, Warren Coun-

Figure 16. About 55 feet below top of the Edinburg Formation along State Road 761 and 0.2 mile east of Opequon Creek (Appendix, Section 7, Units 9 and 10). The sequence up section (from right to left) includes dark-gray limestone, 0.5 inch of black chert (at hammer head) derived from leaching of 3-4 inches of metabentonitic clay, and 3 feet of hackly weathering siltstone and shale.

ty, the Edinburg is entirely Liberty Hall with black shale more abundant than black limestone (Cooper and Cooper, 1946, p. 78). On the east limb of the Wadesville anticline, where examined north of State Road 660 (Appendix, Section 9), the Edinburg, like the exposures in the southern part of the county, is composed largely of the Liberty Hall.

In the narrow belts referred to as the Stones Chapel and Waterloo synclines (Plates 2, 3) the exposures are generally poor and the bedrock deeply weathered. The Edinburg appears to be the Liberty Hall and the width of outcrop, especially in the Waterloo syncline, suggests a thickness of not more than 200 feet. However, the evidence for the Martinsburg Formation shown as occupying the median part of the fold is not conclusive, thus the Edinburg may be thicker than shown on the geologic maps. Based on measurements (Appendix, Sections 7-9) and estimates, the Edinburg varies in thickness from about



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200 to 550 feet and probably averages 400 to 500 feet throughout most of the area.

Along the west limb of the Massanutten syncline in Frederick County, the Edinburg is equivalent to beds described by Butts as the Chambersburg Limestone, exclusive of the relatively thin "*Christiania*" bed at the top of the formation. In Clarke County the Chambersburg Limestone, so far as the evidence of *Mastopora* goes, is present only in a narrow area in the northwest corner of the county and near the north end of a narrow synclinal strip of Martinsburg that crosses State Highway 7 at Section 10 (Appendix) about 0.5 mile east of Opequon Creek. According to Butts, the Chambersburg and older Athens Formation are in sequence in northwestern Clarke County, but are so much alike in lithologic character that it has not been possible to locate a boundary between them, except possibly for a distance of 3 to 4 miles north of Dry Marsh Run. Along this line is a thin, laminated, fine-grained sandstone which, in general character and stratigraphic position, corresponds to the Tumbling Run sandstone that approximately marks the base of the Chambersburg Limestone in Frederick and Shenandoah counties. If it is the same sandstone, as thought probable by Butts, it is the only discovered marker between the Athens and Chambersburg formations in Clarke County.

Perhaps additional work should be done on siltstones of the Edinburg before considering them as valid stratigraphic markers. For example, measured sections (Edmundson, 1945, p. 179; Cooper and Cooper, 1946, p. 93-94; Appendix, Section 7, this report) along the west limb of the Wadesville anticline in the vicinity of State Road 761 show three prominent siltstones within the Edinburg. Of special interest at this locality is abundant *Mastopora* in limestone below the second siltstone from the top of the section; thus, based on the known distribution of *Mastopora*, the uppermost siltstone probably would not be correlative with the Tumbling Run sandstone.

The Athens (Liberty Hall of this report) fauna (Butts, 1942) from outcrops in Clarke County and near Riverton, Warren County, includes *Cryptograptus tricornis, Discellograptus sextans, Didymograptus sagitticaulis, Diplograptus foliaceus, Echinosphaerites* sp., *Rhinidictya* several sp., *Diplotrypa*(?) sp., *Stictoporella*(?) sp., *Resserella* sp., *Lingula nympha, Paterula* sp., *Sowerbyella* sp., *Calliops* sp., *Robergia major, Ampyxina* *scarabeaus, Dionide contrita* (?), *D. holdeni, Arthrorachis elspethi, Cybele* sp., *Tretaspis reticulata, Bronteopsis gregaria, Encrinurus* (?) sp., *Ceraurus* (?) sp., and *Eridoconcha* sp. Additional Athens graptolites have been reported by Decker (1952, p. 72) from a rather limited outcrop of shale along the south side of State Highway 7 (formerly U. S. Highway 340), 4.6 miles west of Berryville. Evidence for an age equivalent to the Chambersburg Limestone (Butts, 1942) for the limestones which crop out in the northwestern part of Clarke County are *Christiania trentonensis, Mastopora pyriformis,* and *Corineorthis* (?) sp. Other forms in the faunule are *Oxoplecia* sp., *Receptaculites* sp., and *Streptelasma* (?) sp.

ORANDA FORMATION

The Oranda Formation is probably continuous along the western limb of the Massanutten syncline in Frederick County, although it is nowhere fully exposed in the Stephenson area (Plate 2). Cooper and Cooper (1946, p. 92) describe a poorly exposed section of Oranda, about 3 miles north of the Stephenson quadrangle, as being composed of 30 feet of drab-gray, argillaceous limestone with intercalated thin siltstones. Scattered exposures of thin beds of dark-colored shale, siltstone, and argillaceous limestone, lying above limestone-bearing *Mastopora*, have been observed near the boundary of the Martinsburg Formation along State Roads 749, 664, and 761 in the Stephenson area. Farther southwest parts of the formation are exposed in the bluff on the north side of Hiatt Run about 500 feet east of Milburn Cemetery, along the southeast side of a low ridge 0.5 mile southwest of Hiatt Run, and along State Road 662 about 1000 feet north of its junction with State Road 661.

Beds, provisionally identified as Oranda, have been examined on the west limb of the Wadesville anticline at the crossing of State Road 761 and in a complexly folded area on the east limb of the structure along State Highway 7. Along State Road 761, about 1.7 miles southwest of Wadesville, the interval at the top of the Edinburg (Appendix, Section 7) is partly covered on both limbs of a minor syncline that includes a narrow strip of Martinsburg shale in the trough of the fold. Beneath the Martinsburg on the west limb is an exposure of about 6 feet of medium-grained, impure, shaly limestone and on the east limb is a covered interval of 20 or more feet with abundant shale and limestone chips in a brownish-colored residuum similar to that developed on siltstones and shales. Along State Highway 7, about 0.6 mile east of Opequon Creek (Appendix, Section 10) beds tentatively referred to the Oranda include about 23 feet of dark-colored shale, brown siltstone, impure limestone, and a thin layer of micaceous bentonitic clay at the base.

The full extent of the Oranda is not known in northern Virginia, thus it is included with the underlying limestone and mapped as the "Edinburg and Oranda Formations". It has not been identified on the Boyce quadrangle or in any of the outlying synclinal areas on the Stephenson and Berryville quadrangles. The possibility exists that the Oranda may undergo a change in facies and extend much farther south along the eastern side of the Massanutten syncline. Cooper and Cooper (1946, p. 86-89) suggest the possibility that it may be represented by the 8-foot sandstone with granulated fossils, just above the Edinburg near Riverton, Warren County, Virginia. They also believe that it is possibly represented in the lower part of the thick succession of sandy shales which have been identified as Martinsburg, particularly on the east side of the Massanutten syncline between Riverton and U. S. Highway 50 east of Staunton.

The chief guide fossil *Reuschella "edsoni"*, has not been identified in Clarke County, but some of its associates, including *Christiania, Oxoplecia,* and graptolites, are common.

MARTINSBURG FORMATION

The Martinsburg Formation is the youngest consolidated rock within the mapped area, but since erosion has removed an unknown amount of the section, no determination of thickness is possible. Page, Burford, and Donaldson (1964) have described the formation as 2000 to 3000 feet thick in the Martinsburg region. The lower boundary is placed above calcareous siltstone and argillaceous limestone of the Oranda Formation, where recognized in the section; otherwise, there is no satisfactory evidence for determining a precise boundary at the base of the Martinsburg. The boundary, under these conditions, is arbitrarily drawn below the first occurrence of dark-gray to black, calcareous shales which are relatively free of any associated siltstones. In weathered exposures these basal shales, 100 to 150 feet thick, are generally yellow to tan with indistinct bedding.

The Martinsburg occupies a belt 3.5 miles wide, along the median part of the Massanutten syncline (Plates 2, 3), lying in general between Stephenson, Frederick County, and Opequon Creek, but in places extending almost a mile across the creek into Clarke County. In addition to this broad belt, there are five outlying, narrow synclinal bands of Martinsburg that are disarranged locally by minor faults. In the broad outcrop belt the Martinsburg, except for the basal part, varies from a fissile to subfissile clay-shale (R-1704, R-651) to a thinly laminated rock composed of exceedingly fine quartz particles in a clay matrix and can be described as a siltstone or fine-grained sandstone. There are a few massive layers of siltstone, apparently without laminations, and medium-thick beds of coarser-grained sandstone. The main body of the Martinsburg is bluish gray in fresh exposures but changes to a brownish color on weathering, due to the oxidation of the ferruginous constituents in the shale.

The basal dark-gray to black shales may be seen at many localities along the west side of the Massanutten syncline in the Stephenson area, east of Opequon Creek, and in the outlying narrow synclinal belts. Exposures of the main body of the Martinsburg are especially good along U. S. Highway 50, State Road 657, and State Highway 7. Along State Highway

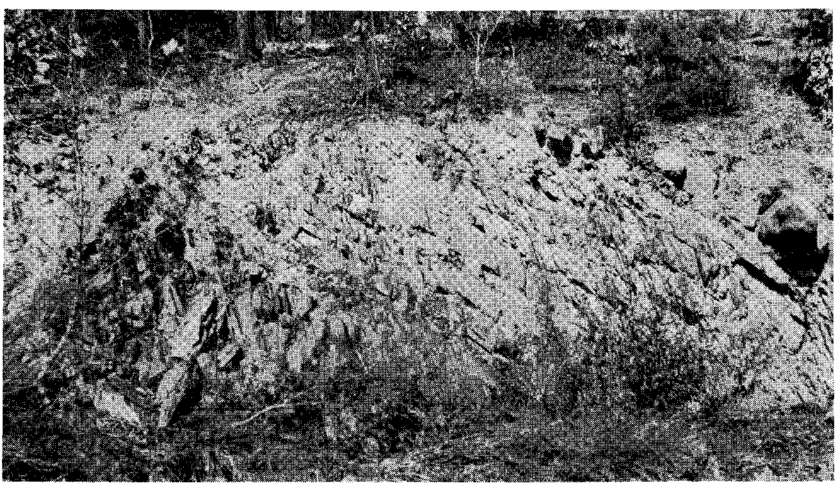

Figure 17. Asymmetrical anticline, cut by steeply inclined fracture cleavage, in shale and siltstone of the Martinsburg Formation along State Highway 7 (old location) about 0.7 mile west of Opequon Creek.

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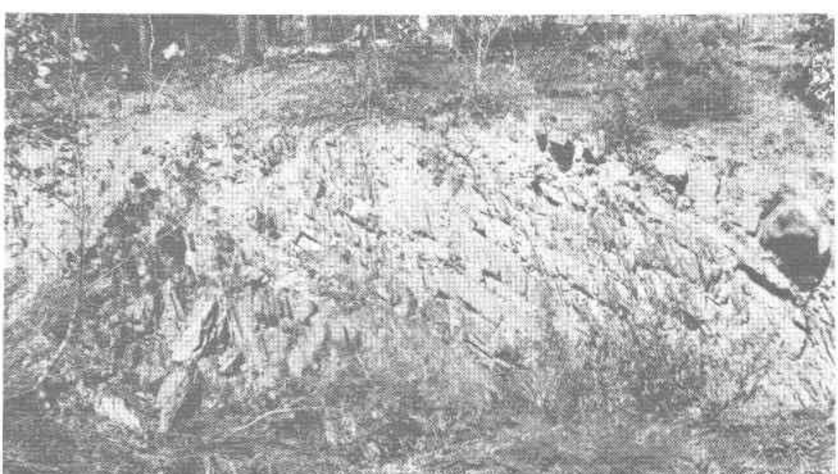

Figure 17. Asymmetrical anticline, cut by steeply inclined fracture cleavage, in shale and siltstone of the Martinsburg Formation along State Highway 7 (old location) about 0.7 mile west of Opequon Creek.

7, about 0.7 mile west of Opequon Creek, is a typical exposure of Martinsburg shale and siltstone displaying an asymmetrical anticline cut by fracture cleavage (Figure 17). The extensive lowland underlain by the Martinsburg within the Massanutten syncline is characterized by low rounded hills, high drainage density, and a thin residual mantle with abundant shale chips. The contrast in land forms between the shale area and the bordering lowlands on carbonate rocks is distinctive and the separation of these subdivisions can be accomplished within a few hundred feet from a study of aerial photographs and 1:24,000-scale topographic maps.

No fossils, except graptolites, have been collected from the Martinsburg within the area of this report. The graptolites are represented by species of *Diplograptus,* probably *D. amplexicaulis, Climacograptus* sp., and *Corynoides gracilis.*

CENOZOIC SURFICIAL DEPOSITS

The Martinsburg clastics are the youngest thoroughly stratified rocks remaining in the area after erosion in which all younger rocks have been removed. The most extensive surficial material is the residual mantle, or residuum, which was formed by weathering of the underlying bedrock. In a few places the structure of the underlying bedrock is preserved, but more commonly it is structureless material. Other surficial deposits are alluvial roundstones on many of the uplands, some more than 200 feet above the present stream level; angular to subangular colluvial gravels intermixed with the alluvial materials adjacent to the Blue Ridge; and alluvial deposits that occupy all of the flood plains along the major streams and as narrow bands along many of their tributaries.

In up-dating the geologic maps a distinction was made between the alluvial bottom lands that were mapped as *Alluvium;* and the alluvial roundstones, in places intermixed with angular colluvium, that were mapped as *Terrace Deposits.* Although the boundary showing the distribution of alluvium is approximate, there is more field data available than for the delineation of the terrace deposits. For this reason the distribution of the terrace deposits on the geologic maps should be considered highly generalized. No attempt was made to map the residual mantle, but its development and its relationship to the underlying bedrock is described briefly.

TERRACE DEPOSITS

Gravels occur on many of the ridges and hills adjacent to the Shenandoah River and some smaller tributary streams in the Berryville and Boyce quadrangles. These deposits are irregularly shaped and discontinuous, and they overlie rocks of Lower and Middle Cambrian age. The surfaces on which the deposits lie are irregular and in places the Cambrian rocks project through the gravels. The exact boundaries of the deposits are obscure due to erosion and slumping. It is also impossible to determine the true thickness, since there are no known deep excavations or drill cores to supply the subsurface information.

In general, the gravels appear to be confined to the approximate width of the meander belt of Shenandoah River. Within the Berryville quadrangle the gravels, although occurring as discontinuous patches, are displayed in an eastern and western belt which are separated from each other by a distance of about 2400 feet (Plate 1). The eastern belt is between 600 and 1200 feet wide and extends in a southwesterly direction along the uplands which border the west side of the Shenandoah River; the western belt is approximately 1000 feet wide and extends from the vicinity of Wheat Spring Branch southwestward into the Ashby Gap quadrangle.

West of the Shenandoah River and near the southern boundary of the Boyce quadrangle, gravel is abundant on an upland as high as the 670-foot level. East of the river and Hardin Island (Plate 3) two alluvial terraces can be identified. The sandy sediment that forms Hardin Island and the adjoining narrow flood plain is terminated on the east by a gently sloping surface that is covered with alluvial roundstones intermixed with angular to subangular gravels. This surface, ranging in elevation from about 450 to 500 feet above sea level, is regarded as the younger of the two terraces and gives the appearance that it was formed when Shenandoah River shifted its channel and disturbed the original continuity of the alluvial apron at the western base of the Blue Ridge. The older terrace begins near where Venus Branch enters the Boyce quadrangle and extends in a northwesterly direction to Shenandoah River, and is crossed by State Road 638 about 1000 feet south of the Warren County-Clarke County boundary. This surface is more dissected than the lower terrace and contains more colluvial material because of its proxmity to resistant rocks of the Blue Ridge.

The alluvial gravels consist mainly of sandstone and quartzite, and their only possible sources were Silurian sandstones in Massanutten Mountain on the south and in Little North Mountain on the west and from Cambrian quartzites of the Blue Ridge on the east. In the alluvial aprons adjacent to the Blue Ridge, angular to subangular colluvial gravels, consisting of the Catoctin greenstone and various lithologies from the Chilhowee Group, are intermixed with the alluvial roundstones. The coarse fraction of the terrace deposits consists mainly of small cobbles 2.5 to 5 inches in diameter; lesser amounts of small boulders, 1.5 feet in diameter, and an occasional large boulder, up to 3 or 4 feet in diameter. The matrix enclosing the gravels consists of varying proportions of sand, silt, and clay. On some of the upland areas there appears to be a greater concentration of cobbles on the surface than is found in exposed vertical sections. Perhaps this means that most of the fine sediments has been eroded from the upper part of the section.

There are very few exposures of bedrock in the area supporting alluvial terraces, except where the Shenandoah River and its tributaries cut across the northeasterly trend of the rocks. Sufficient control does exist, however, to show that the Shady, Rome, and Elbrook formations underly the terrace deposits at the west foot of the Blue Ridge. Since these carbonate formations, especially the Rome and Elbrook, are impure, a considerable thickness of residuum may separate the terrace gravels and bedrock.

In Smith Hollow, near the southern boundary of the Boyce quadrangle (Plate 3) and about 1500 feet south of the highest terrace deposit, bedrock is exposed at the 600-foot level, thus, under the most favorable conditions, the thickness of residuum and terrace material is about 70 feet. The combined thickness of residuum and gravels northeastward from Lovers Leap to Calmes Neck is estimated at less than 10 feet near Old Bethel Church, 60 to 70 feet along U. S. Highway 50 about 0.3 mile northwest of Byrd Bridge (Figure 18) and possibly more than this thickness in the prominent hill 0.2 mile southeast of where State Road 621 crosses Spout Run.

ALLUVIUM

Alluvial deposits occupy many of the flood plains along tributary streams that comprise the Shenandoah River and Opequon

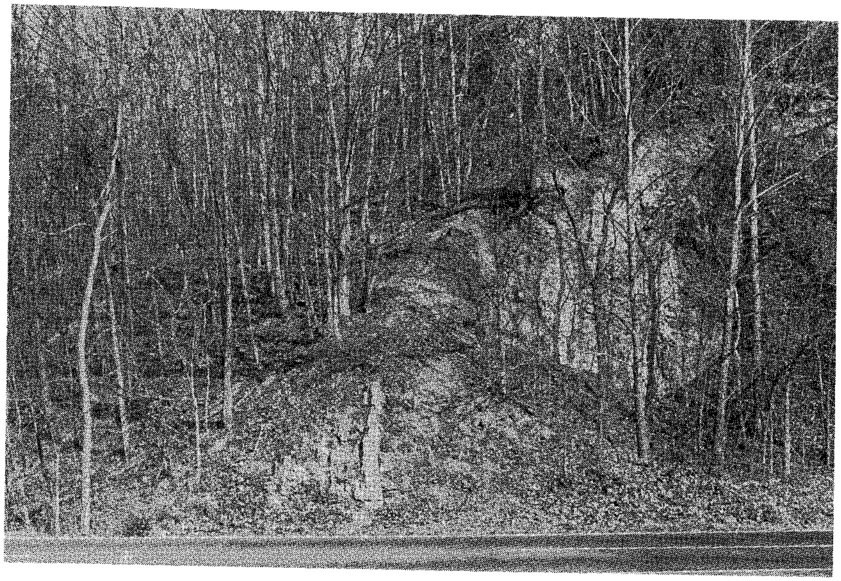

Figure 18. Shale and siltstone of the Rome Formation overlain by terrace deposits along north side of U. S. Highway 50 about 0.3 mile northwest of Byrd Bridge. (Color pattern for terrace deposits on Plate 3 should be extended southward to include most of the symbol showing vertical beds of this locality).

Creek drainage basins and become more extensive along the master streams. In areas of thick residuum or where blanketed by terrace deposits the best exposures of bedrock are commonly in the narrow stream channels that are bordered by flood plains.

The sediments within the flood plains are primarily dark-gray fine sand, slit, and clay. Along the eastward-flowing tributaries to the Shenandoah River, which traverse carbonate bedrock, and along both sides of the river the alluvial material is calcareous. Fresh water mollusk shells and travertine-coated pebbles are common, and locally, in many of the stream beds there are massive deposits of travertine. Some of the best exposures of the alluvial deposits in the Shenandoah River drainage basin are along Spout Run between Millwood and the Shenandoah River and along Chapel Run in the northeastern corner of the Boyce quadrangle (Plate 3). The alluvial deposits are estimated to be 30 to 50 feet thick along the Shenandoah River.

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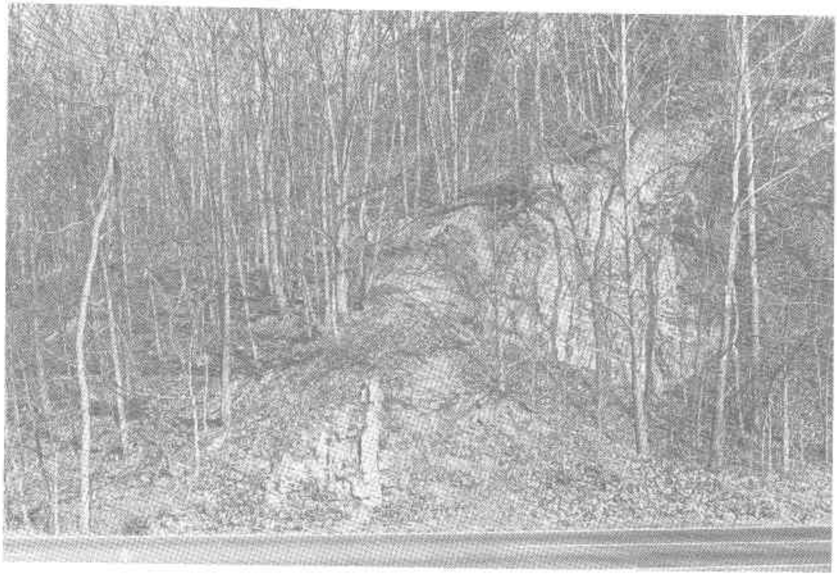

Figure 18. Shale and siltstone of the Rome Formation overlain by terrace deposits along north side of U. S. Highway 50 about 0.3 mile northwest of Byrd Bridge. (Color pattern for terrace deposits on Plate 3 should be extended southward to include most of the symbol showing vertical beds of this locality).

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In the Opequon Creek drainage basin all of the valley floors of eastward-flowing streams are covered by dark gray sand and clay. Along most of the streams the calcareous content is similar to that observed within the Shenandoah River drainage basin. The only extensive alluvial deposits noted along westward-flowing Opequon tributaries are along Dry Marsh Run in the central part of the Stephenson quadrangle (Plate 2). On the east side of State Road 635 this deposit has been excavated for agricultural use and abundant fresh water mollusk shells can be collected. The alluvial deposits along Opequon Creek may range up to 30 feet in thickness.

RESIDUAL MANTLE AND LANDFORMS

The residual mantle is the most widespread and because of various agricultural uses, the most valuable economic resource. Only soil scientists are qualified to classify and map these materials, thus the following discussion will include examples showing the relation of residual mantle to landforms and kind of bedrock. Observations within the map area seem to be in accord with the findings of Hack (1965, p. 48-49) who offers the following explanation:

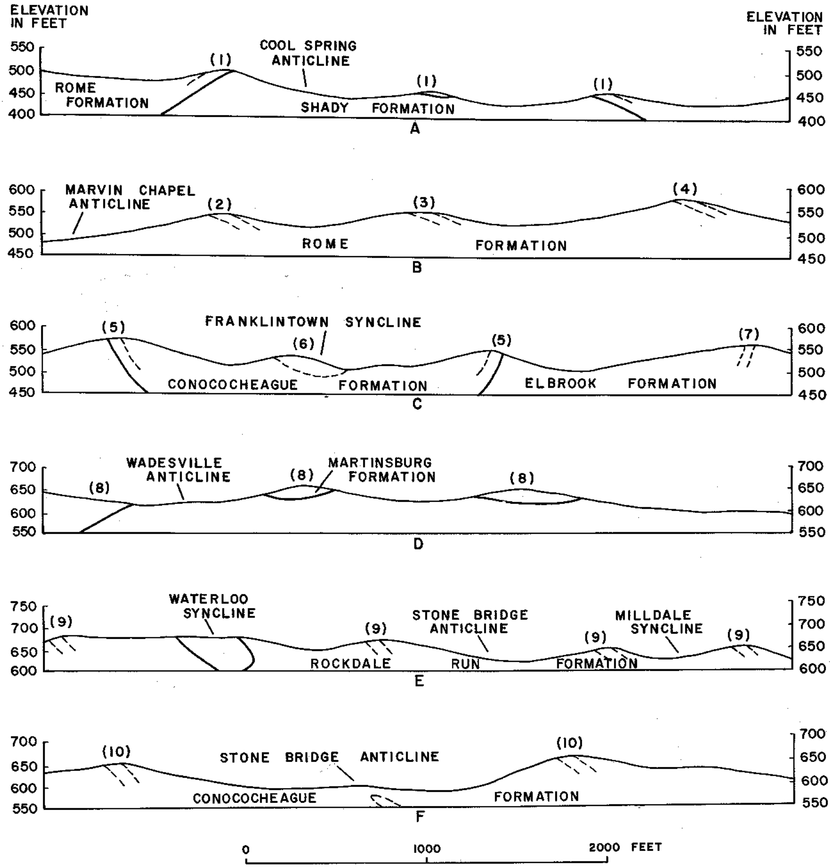
"All the rocks are subject to both mechanical and chemical weathering, but the rates of the two kinds of weathering differ. In mountain areas like the Blue Ridge, quartzites are subject to chemical weathering, but the rate is slow and the rocks stand in rugged relief. As a result, they are exposed to mechanical weathering, and much of the material in the mountains is carried off by creep and by streams in the form of coarse blocks. In the lowland areas, mainly because of the kind of rock present, chemical weathering is more rapid than mechanical weathering and produces fine-grained residues that can be carried off on gentle slopes. Small amounts of resistant material in the rock, like chert or sandstone, weather more slowly and, like the quartzite in the mountains, form blocks that are mixed with or blanket the fine-grained material. . . . The amount of inert residue in the rock is not the factor that controls the accumulation of residuum. The most important factors are the size, toughness, and rate at which the fragments of residue can be broken up."

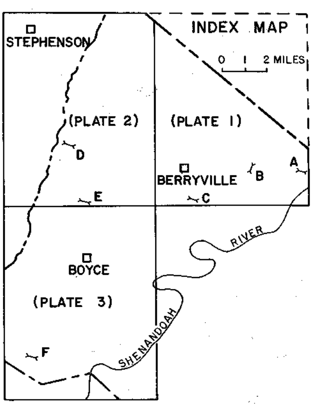
The residuum is very thin on the Martinsburg Formation within the Massanutten syncline, except in the alluvial areas along the streams. On the upland regions the weathered bedrock is exposed on the surface or its presence at shallow depths is indicated by chips of shale and siltstone strewn over the surface. Because of its greater resistance to chemical weathering than the subjacent limestones the Martinsburg commonly forms low ridges where it occupies the troughs of narrow synclines east of Opequon Creek (Figure 19-D).

The New Market, Lincolnshire, Edinburg, and Oranda formations, are restricted to narrow belts east of Opequon Creek and in the vicinity of Stephenson west of the Massanutten syncline. The residuum is generally thin, estimated at only a few feet, and with numerous ledges that crop out on the surface. A low ridge commonly develops above the thicker siltstones (Edmundson, 1939) of the Edinburg and the cherty beds of the Lincolnshire. The summits of these low ridges are generally strewn with fragments of the chert or siltstone even if there are no exposures of the underlying bedrock.

Thick residuum is generally lacking on the formations of the Beekmantown Group, except above the cherty beds (Figure 19-E) that occur at a few horizons within the Rockdale Run Formation.

Residuum is more widespread and generally thicker on the Cambrian carbonates than on any of the Ordovician formations. Impure constituents in the Conocoheague form low, disconnected ridges (Figure 19-C, F), which are traceable for considerable distances in parts of the area. There are few exposures of bedrock, but the presence of sandstone blocks or slabs of siliceous limestone and chert scattered over the surface along the crest of the ridges serves a useful purpose in geologic mapping. The Conococheague is underlain by the Elbrook Formation, exposures of which are generally poor, except in deep roadcuts and along ravines that have penetrated below relatively thick residuum. Of special significance is a low, discontinuous ridge developed near the middle of the formation. The bedrock responsible for this landform is a thin zone of green and/or maroon shale and brown to maroon sandstone (Figure 19-C). The Rome Formation, like the overlying Elbrook, is largely concealed by a relatively thick residual mantle and on the uplands near the Shenandoah River by terrace deposits. West of the terrace deposits there are three indistinct low ridges at intervals within the belt mapped as Rome which owe their origin to resistant lithologies (Figure 19-A, B).





EXPLANATION

(1) LIGHT-GRAY, OOLITIC CHERT, MAROON SHALE, AND IMPURE CARBONATES.

(2) IMPURE LIMESTONE, DOLOMITE WITH QUARTZ SAND, AND DRUZY QUARTZ.

(3) MAROON SHALE, BROWN SILTSTONE AND MUDSTONE; FEW THIN BEDS OF FINE-GRAINED SANDSTONE.

(4) MAROON AND GREEN SHALE, BROWN SILTSTONE, IMPURE DOLOMITE, AND CHERTY ALGAL LIMESTONE.

(5) COARSE-GRAINED, CALCAREOUS SANDSTONE AND IMPURE CARBONATES.

(6) LIMESTONE WITH CRINKLY SILICEOUS LAMINAE.

(7) GREEN AND MAROON SHALE AND FINE-GRAINED SANDSTONE.

(8) YELLOW TO BROWNISH-GRAY SHALE, MUDSTONE, AND SILTSTONE.

(9) MINOR DOLOMITE; FEW BEDS CONTAIN QUARTZ SAND INTERBEDDED WITH LIMESTONE CONTAINING ALGAL STRUCTURES AND CHERT.

(10) CHERT, SOME FINE-GRAINED SANDSTONE, ARGILLACEOUS DOLOMITE, AND SILICEOUS LIMESTONE.

Figure 19. Generalized profiles showing relationship of landforms to resistant parts of the underlying bedrock.

The oldest carbonate unit in Shenandoah Valley is the Shady Formation of Lower Cambrian age. Much of the belt is concealed by terrace and colluvial materials due to its proximity to Shenandoah River and the steep western slope of the Blue Ridge. The absence of diagnostic landforms suggests that there are no resistant beds in the formation.

STRUCTURE

The major structural framework consists of the northwestern part of the Blue Ridge anticlinorium and the Massanutten Mountain synclinorium (Figure 2). The present attitude of the layered rocks is related to compressive forces which produced tectonic transport from the east accompanied by folding of the strata into a series of anticlines and synclines and local disruption of the normal sequence by faulting. Most of the fold axes trend in a more northerly direction than the general northeasterly strike of the rocks. This produces a number of salients and reentrants as the rocks wrap around the generally northward-plunging structures and the formational boundaries in-

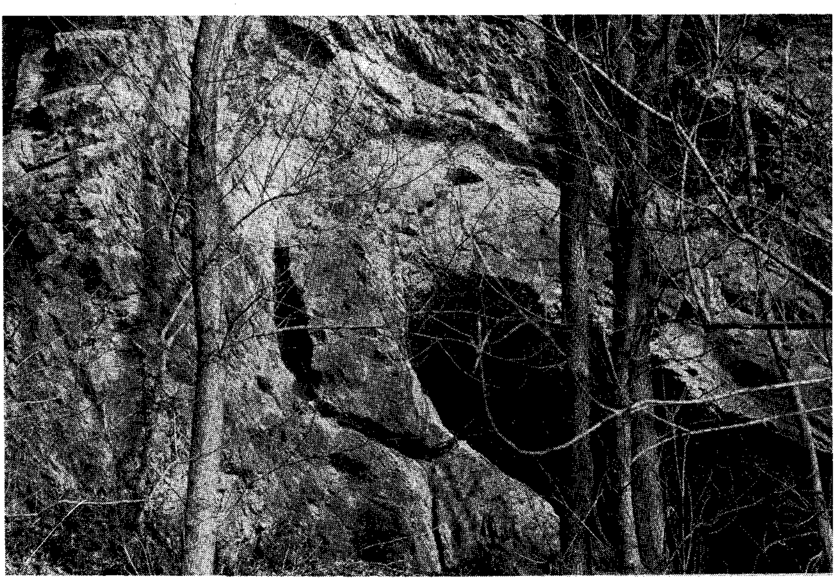


Figure 20. Dolomite and shale of the Rome Formation along north side of Shenandoah River east of Lovers Leap (Plate 3). Rocks of the anticline, overturned in a northwesterly direction, are cut by cleavage dipping steeply to the southeast.

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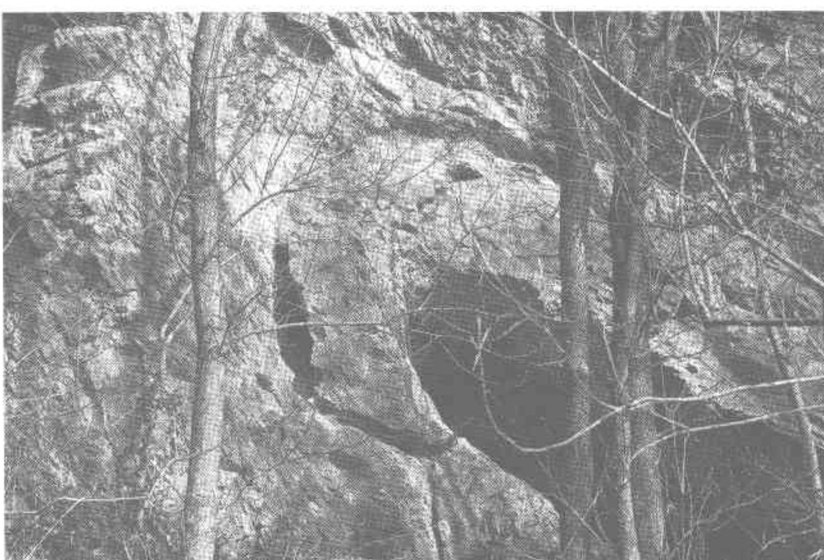


Figure 20. Dolomite and shale of the Rome Formation along north side of Shenandoah River east of Lovers Leap (Plate 3). Rocks of the anticline, overturned in a northwesterly direction, are cut by cleavage dipping steeply to the southeast.

volved show a distinct zigzag pattern (Plates 1-3). The style of many of the structures produced in response to the tectonic transport from the east is shown by the oversteepened and locally overturned east limbs of synclines and west limbs of anticlines (Figure 20) and by the easterly dip of the low-angle faults. High-angle faults, some cutting across the strike of the rocks, and well-developed cleavage (Figure 17) and joints are exposed at many localities.

BLUE RIDGE ANTICLINORIUM

The Blue Ridge anticlinorium (Espenshade, 1970, p. 199) in northern Virginia, roughly along the 39th parallel, consists of a core of older Precambrian gneisses which are flanked on the limbs by younger Precambrian(?) rocks of sedimentary and volcanic origin. The northwestern limb of the fold is roughly coincident with the Blue Ridge — a bold topographic feature that serves as a natural boundary for the Paleozoic rocks of the Valley and Ridge province to the northwest. The eastern limb of the fold is in the Piedmont province and in northern Virginia the younger Precambrian(?) rocks are bounded on the east by downfaulted Triassic basins filled mostly by nonmarine sedimentary rocks with lesser amounts of volcanic rocks.

RLUE RIDGE AND WESTERN FOOTHILLS

Within the area of this report a small part of the northwestern limb of the anticlinorium is represented in the Blue Ridge Highlands where the Catoctin Formation occurs at and near the crest and Chilhowee rocks, displaying several northeasterly-plunging minor folds, are exposed on the northwestern flank and in the foothills (Plate 3).

Faults are informally referred to as the *Blue Ridge border faults* in this report because the total extent of these faults and their relationships to other faults that occur at various localities along the west foot of the Blue Ridge in northern Virginia are not known. The southern fault enters the Boyce quadrangle (Plate 3) from the south at a locality about 800 feet east of Shenandoah River and then trends in an easterly direction forming a deep reentrant where it crosses Venus Branch. From this locality it trends in a northeasterly direction to the east boundary of the quadrangle. The fault apparently dies out in the western portion of the adjoining Ashby Gap quadrangle somewhere south of Calmes Neck. Along most of this distance there are good exposures of the Antietam or upper part of the Harpers, both ridge-making formations, east of the fault trace except for limited exposures east of Hardin Island where the overridden rocks are covered by gravel, colluvium, and flood-plain alluvium. However, exposures and attitudes of the rocks on the north side of Shenandoah River east of Lovers Leap, at the mouth of Long Branch, and about 1 mile southwest of Byrd Bridge suggest that the basal Cambrian clastics are thrust upon the Shady Formation. Brecciated quartzite in front of the thrust fault crops out in two areas: (1) at the base of a steep bluff along the north side of Shenandoah River in the vicinity of White Horse Rock and (2) beginning near the southern boundary of the Boyce quadrangle and extending in a southwesterly direction into the adjoining Linden quadrangle. These breccias are interpreted as detached fault slices, or klippen, since they are composed of material similar to the fragmented Antietam quartzites, commonly found along the fault trace, and appear to overlie unconformably the younger Shady Formation. Both areas are separated from the trace of the fault by flood-plain alluvium which has a width of 750 feet at White Horse Rock and 1600 feet along the southern boundary of the Boyce quadrangle. Similar detached slices of breccia, derived from the Antietam Formation, have been recognized by Wickham (1972, p. 755) in the Front Royal area.

The northern Blue Ridge border fault enters the Berryville quadrangle (Plate 1) from the south at a point about 500 feet west of Shenandoah River and extends in a northeasterly direction for approximately 2000 feet. Northeastward from this locality it is covered by flood plain alluvium and its maximum northerly extent is unknown. The fault was traced southward into the adjoining Ashby Gap quadrangle for about a mile and a half.

The units present in the hanging wall adjacent to the fault are the Harpers and Antietam(?) formations. Most of the exposed rocks are of Harpers lithologies, but one large body of quartzite, strongly suggestive of Antietam types, was observed in excavations for the new location of State Highway 7, just west of its junction with State Road 603. These Chilhowee rocks are thrust over dolomites in the Shady Formation.

MASSANUTTEN MOUNTAIN SYNCLINORIUM

The Massanutten Mountain synclinorium includes the bedrock structures underlying Shenandoah Valley. From the vicinity of Strasburg, Shenandoah County, to Massanutten Peak southeast of Harrisonburg, Rockingham County, a distance of about 45 miles, Massanutten Mountain is underlain by thick Silurian sandstones and appears as a single bold ridge when viewed from the adjacent valley floor. However, the structure is not a single symmetrical trough, but is affected by several subordinate anticlines and synclines. Farther northeast, including the area of this report, the synclinorium includes the bedrock structures of three lowlands (Figure 2). These physiographic subdivisions (Hack, 1965) include a long central lowland underlain by Ordovician shale and siltstone that is flanked by a western and an eastern lowland on Cambrian and Ordovician carbonate rocks. Specific landforms which define "The Valley" and closely approximate the boundary of the synclinorium in northern Virginia are Little North Mountain on the northwest and the Blue Ridge province on the southeast.

Axial traces of selected folds, including those assigned local names, are shown on Plates 1-3 by dashed lines. Due to generally poor exposures, the mapping of many of the traces as being persistent throughout the study area is interpretive and subject to revision. In many instances the symmetry of a fold will change from upright to overturned and may show a reversal in the direction of plunge within a few hundred yards along the trend of the structure. Axial traces are clearly defined (1) where exposures are adequate to map salients and reentrants or (2) where exposures are incomplete but the configuration of landforms reflects the distribution of resistant parts (Figure 19) of the underlying bedrock.

CENTRAL LOWLAND ON SHALE AND SILTSTONE

Massanutten syncline, marking the trough of the synclinorium, is a complex structure involving a thick sequence of Martinsburg clastic rocks. The width of the outcrop belt, along a traverse from Stephenson southeastward to Opequon Creek, is about 3 miles (Plate 2). The location of the synclinal axis is provisional, since no faunal or lithologic criteria were found to justify more than an approximation. Minor folding on a scale too small to map was observed along all of the traverses, and many of the flexures, especially in the eastern half of the belt, are overturned in a northwesterly direction. An important structure throughout the belt is well-developed fracture cleavage (Figure 17).

WESTERN LOWLAND ON CARBONATE ROCKS

The western lowland, underlain by deformed Cambrian and Ordovician carbonate rocks, is approximately 5 miles wide in Frederick County (Butts and Edmundson, 1966, Plate 1). It is bounded on the southeast by the lowland on the Martinsburg Formation and on the northwest by Little North Mountain. About 2.5 square miles of this broad belt is included in the northwestern sector of the Stephenson quadrangle (Plate 2). Although this is a relatively small part of the western lowland, an almost complete section of Ordovician carbonate rocks is represented.

The general northeasterly trend in the Stephenson area of the lower Middle Ordovician formations (New Market, Lincolnshire, Edinburg, and Oranda) is interrupted by minor folds and faults. Two folds are well displayed (Plate 2, Section A-A′) east of U. S. Highway 11 and north of State Road 664. Both folds, a syncline flanked on the east by an anticline, plunge in a southwesterly direction. The axial trace of the anticline is located near the junction of the spurline with the Baltimore and Ohio Railroad at Freyco. Rocks comprising the west limb of the fold have not been recognized along the northern boundary of the Stephenson quadrangle. Here the Pinesburg Station Dolomite occupies the median part of the anticline and appears to be in fault contact with the Edinburg Formation. This fault is known to extend in a southwesterly direction for at least 0.5 mile, since the New Market Limestone is terminated abruptly just north of State Road 749.

The main belt of the lower Middle Ordovician limestones, averaging 1200 feet wide, extends from the northern boundary of the Stephenson quadrangle southwestward for a distance of 2.5 miles to where it is truncated by faulting as it wraps around the axis of an anticline plunging to the southwest. This fault, believed to be a high-angle type, extends in a north-northeasterly direction for about 2 miles, passing near the junction of U. S. Highway 11 and State Road 761. Large quantities of brecciated New Market Limestone occur along the fault at a locality between Hiatt Run and State Road 663. The New

Market-Pinesburg Station boundary, west of the fault, begins in an open field 0.25 mile north of U. S. Highway 11 and extends in a southwesterly direction to the western boundary of the map area. Near the southwestern end of this belt is a syncline which is a complementary structure to the anticline east of the fault.

EASTERN LOWLAND ON CARBONATE ROCKS

The eastern lowland on carbonate rocks ranges in width from about 7 miles along U. S. Highway 50 to more than 10 miles along State Highway 7. It is bounded on the west by the Martinsburg Formation and on the east by clastic rocks of the Chilhowee Group at the west foot of the Blue Ridge. A complexly folded and faulted belt closely parallels Opequon Creek from the vicinity of Wadesville (Plate 2) southwestward to the western boundary of the Boyce quadrangle (Plate 3) about 2 miles northwest of White Post. North of State Road 657 this structural complex is dominated by the *Wadesville anticline*, a well-defined fold whose axial trace can be mapped with reasonable accuracy from the northern boundary of the Stephenson quadrangle southwestward for 6.5 miles to the vicinity of Isaac Run. The anticline, with the Pinesburg Station Dolomite occupying the limbs of the fold, is a doubly plunging structure with the reversal taking place somewhere in the vicinity of State Road 761. The continuity of the fold is interrupted along Dry Marsh Run by a cross fault which has shifted the axial trace, south of the fault, in a westerly direction 0.2 of a mile. The east limb of the anticline along and north of State Highway 7 is modified by at least four minor folds and three faults. The belt of lower Middle Ordovician limestones (New Market-Oranda) south of State Road 657 for a distance of 3 miles, is narrow and the structure is interpreted as an overturned monocline faulted upon the Martinsburg Formation. The belt widens southwest of State Road 644 and displays several minor folds and faults (Plate 3).

The lower part of the Martinsburg Formation, east of the complexly folded and faulted belt along Opequon Creek, is poorly exposed in two narrow parallel belts *(Stones Chapel* and *Waterloo synclines)*, separated by limestones and dolomites of the Beekmantown Group. Associated with these synclines are the *Lost Corner anticline* and two unnamed folds on the west and the *White Post anticline* about midway between the two synclines. Lower Middle Ordovician limestones wrap around the axis of the northeasterly plunging Stones Chapel syncline 0.25 mile south of State Road 723 and approximately 1 mile northeast of Lost Corner. Both limbs of the fold, except for minor faulting near the southwestern end, are maintained in a northeasterly direction to the vicinity of State Road 620 where the limestones forming the east limb are gradually eliminated from outcrop by impinging against a fault. From a locality 0.7 mile east of Old Salem Church northeastward to where the limestones on the west limb are terminated by faulting, the structure is a monocline with steep southeasterly dip and bounded on the east by a thrust fault. The attitude of rocks in the fault block near the northeastern end of the structure and where limestones of the same age are exposed east of Swimley suggest that the axial trace of the Stones Chapel syncline is continuous throughout this part of the area. The eastern outliner (Waterloo syncline) extends from a locality 0.3 mile north of State Road 657, where it is terminated by a fault on the northwest side, southwestward to a locality 1 mile northwest of Boyce (Plates 2, 3). Minor faulting has been postulated on both sides of the structure for a short distance north and south of the boundary between the Stephenson and Boyce quadrangles, since rocks of Beekmantown age are in contact with the Edinburg Formation. Along the west limb of the syncline, about 0.3 mile north of the southern boundary of the Stephenson quadrangle, the exposures are adequate to determine that the combined thickness of the New Market and Lincolnshire is about 25 feet and the thickness of the Edinburg is estimated to be not more than 200 feet. On the eastern limb near the northeastern end of the syncline the New Market and Lincolnshire appear to be missing and dolomite is closely overlain by the Edinburg. Minor faulting and thinning by compression during orogeny may explain these anomalies or the role of sedimentation, favored by the present writers, may be responsible for some of the stratigraphic discontinuities observed here and at other localities within the complexly folded belt east of Opequon Creek.

The Elbrook-Conococheague boundary, located below the first occurrence of coarse-grained sandstone in the section, defines three northeasterly plunging folds in the southern part of the Boyce quadrangle (Plate 3) by forming two prominent salients, the *Stone Bridge* and *Pyletown anticlines,* separated by a deep reentrant, the *Milldale syncline.* In a northeasterly direction, along U. S. Highway 340 between Waterloo and Boyce, the broad outcrop belt of the Stonehenge Formation shows at least four folds within a distance of 0.5 mile across the strike, thus the selection of the correct axial trace for each of the above named structures is questionable.

The *Horsepen Spring* syncline is responsible for a deep reentrant of the Elbrook-Conococheague boundary along State Road 622 about 1 mile northwest of Old Bethel Church. Four minor folds, extending 2 to 3 miles north and south of the boundary between the Stephenson and Boyce quadrangles, have been identified between the Horsepen Spring syncline and the Pyletown anticline. The axial trace of the syncline is terminated by impinging against a diagonal fault north of State Road 657 and then after an offset of about 1600 feet in a northerly direction its northeasterly course is continued on the east side of the fault.

The diagonal fault is interpreted as extending from near the southern boundary of the Stephenson quadrangle northeastward across the northwestern part of the Berryville quadrangle (Plate 1) to connect with a fault shown on the West Virginia state geologic map (West Virginia Geological and Economic Survey, 1968). The mapping of the fault at certain localities is speculative, since the rocks show no recognizable differences in lithology across the assumed position of the fault. One or more of the following criteria used in locating the trace of the fault include breccia (R-3918), gouge (Figure 21), intensely deformed beds, local changes in the attitude of the rocks, and a break in continuity of landforms underlain by cherty beds.

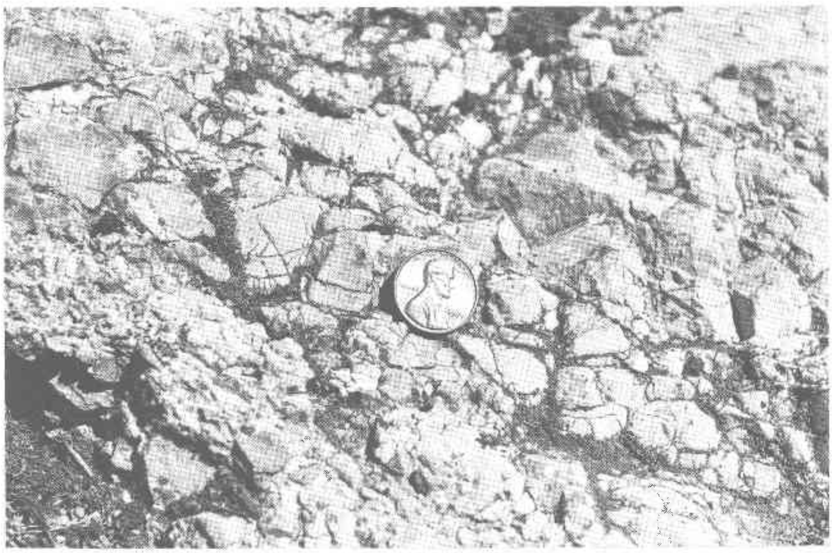
The *Webbtown syncline,* near the middle of the Berryville quadrangle (Plate 1), is selected arbitrarily as a reference fold, since the exposures are adequate to locate the axial trace in the vicinity of Webbtown and to the northeast and southwest for a distance of several miles. Beginning about 1.5 miles northeast of Webbtown and extending to the Virginia-West Virginia boundary corrobative evidence for mapping the axial trace includes linear ridges developed on sandstones in the lower part of the Conococheague and to the southwest similar landforms are developed on resistant beds within the Elbrook Formation. In an easterly direction from Webbtown to Cool Spring near the eastern boundary of the Berryville quadrangle (Plate 1)

Figure 21. Gouge and breccia in fault zone about 2 miles southeast of Swimley and 0.3 mile north of State Road 640.

are the *Marvin Chapel anticline, Taylors Hill syncline, Cool Spring anticline,* and at least 10 unnamed minor folds.

Sufficient evidence exists to postulate a high-angle fault that is crossed by State Highway 7 about 1600 feet east of the junction of State Road 621. The fault extends almost due north for at least 1 mile and is crossed by Wheat Spring Branch at a locality 0.75 mile south of Marvin Chapel. North of State Highway 7 the Shady Formation which should be present on the west limb of the Marvin Chapel anticline is not exposed at the surface. Instead there are rocks typical of the lithologies occurring several hundred feet above the base of the Rome Formation. The eastern boundary of the carbonate rocks along cross section B-B′ (Plate 1) are terminated by a low-angle fault along the eastern slope of a low rounded hill just west of a broad floodplain bordering Shenandoah River. At this locality and to the south near the western approach to Castleman Ferry Bridge brecciated quartzite, probably a part of the Antietam Formation, has been thrust upon dolomite of the Shady Formation.

The Cool Spring anticline and a gently plunging shallow syncline along the southeast side represent the most easterly



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The Cool Spring anticline and a gently plunging shallow syncline along the southeast side represent the most easterly folds involving carbonate rocks within the map area (Plate 1). The axial traces of the folds trend in a southwesterly direction but, due to terrace deposits on the uplands and floodplain alluvium near Shenandoah River, their southwestern limits are unknown.

The Taylors Hill syncline, a name derived from a prominent landform on the adjoining Ashby Gap quadrangle, and its associated minor folds is compementary to the Marvin Chapel anticlinal complex on the west. At the southern boundary of the Berryville quadrangle it is a relatively simple downwarp with only two minor folds on its east limb. However, near Wheat Spring Branch the axial trace appears to bifurcate with one prong forming a deep reentrant shown by the Elbrook-Rome boundary 0.5 mile northeast of Bethel Church and the eastern prong repeating a small part of the Elbrook at the Virginia-West Virginia boundary 0.4 mile northeast of Wickliffe.

Folding of Chilhowee rocks on the Ashby Gap quadrangle, which plunge in a northeasterly direction, probably are responsible for the Marvin Chapel anticline and the superimposed minor folds on the eastern and western limbs. Exposures of bedrock along Wheat Spring Branch and its tributaries offer good control for the location of the axial traces of the two folds on the east limb of the Marvin Chapel anticline. In a westerly direction, especially in the broad belt south of State Highway 7 and east of Webbtown, there are very few exposures of bedrock and the mapping of the axial traces of the minor folds in this area is interpretive.

From Webbtown to the western boundary of the Berryville quadrangle the named folds, from east to west, are the *Gaylord anticline, Franklintown syncline, Calmes Neck anticline, Lewisville syncline, Pigeon Hill syncline, Berryville anticline, Carter Hall syncline*, and *Millwood anticine*. The presence of low linear ridges and rounded hills developed above resistant beds in the Big Spring Station Member at the base of the Conococheague Formation are well-displayed along the flanks and axial position of the Millwood anticline and Carter Hall syncline north of U. S. Highway 50, the Berryville anticline and Pigeon Hill syncline east of Briggs, the Calmes Neck anticline and Franklintown syncline southeast of Berryville, and the Gaylord anticline at the state boundary north of U. S. Highway 340. Other landforms developed on highly siliceous beds and sandstones at higher stratigraphic levels in the Conococheague have been used with success in determining the structure at many localities. A few of the better examples include siliceous sandstones near the top of the Conococheague which form distinct ridges on both limbs of the Millwood anticline north and south of State Highway 7 and along State Road 639 on the west limb of the Carter Hall syncline. Calcareous sandstones in the Conococheague can be traced, mainly by sandstone blocks strewn over the surface, southwest of Lewisville along the west side of State Road 641 to where they wrap around the axis of the northeasterly-plunging Lewisville syncline, then northeastward forming a distinct salient around the axis of the Calmes Neck anticline, and finally forming a deep reentrant as the beds wrap around the axis of the Franklintown syncline (Plate 1).

GEOLOGIC HISTORY

The greater Appalachian province extends from Newfoundland southwestward to central Alabama where it is concealed by younger sediments of the Gulf Coastal Plain. The width of this province along the 39th parallel, beginning with the Cincinnati Arch in southern Ohio and extending eastward to the Fall Line in northern Virginia, is about 400 miles. Physiographic provinces along this traverse, from west to east, are the Appalachian Plateaus, Valley and Ridge, Blue Ridge, and Piedmont. East of the Fall Line is the Atlantic Coastal Plain.

Around the middle of the 19th century geologists James Hall and J. D. Dana recognized that Paleozoic sediments in the Appalachian Mountains (Valley and Ridge Province) were formed in a narrow linear belt and suggested that deposition took place at about the same rate as the trough was subsiding. Hall observed also that these rocks had a thickness much greater than the relatively undisturbed Paleozoic section in the upper Mississippi Valley and concluded, therefore, that folded mountains throughout the world should coincide with similar troughs containing the thickest sediments. Dana, about 100 years ago, introduced the name "geosynclinal" for the Appalachian trough. According to this classical concept the geosyncline was separated from the Atlantic by a positive area (Appalachia) which was the source of most of the sediments. This pioneer work in the Appalachians laid the foundation for subsequent studies which are continuing today at an accelerated pace. The reader interested in the results of much current work and many of the unsolved Appalachian problems is referred to "Studies of Appalachian Geology: Central and southern." This book published in 1970 (New York, Interscience Publishers) contains 25 papers which are grouped in four sections, one dealing with the stratigraphy and sedimentation of the Valley and Ridge and Appalachian Plateaus; another with the structure and tectonics of the same region; a third with the geology of the Blue Ridge and the Reading Prong; and a last section on the Piedmont.

The area described in this report, (Plates 1-3) covers a very small part of the Blue Ridge and the easternmost section of the Valley and Ridge province in northern Virginia. It does not include detailed studies of certain aspects of the geology that are basic for a meaningful discussion of the geologic history. Therefore, reference to the work of other writers will be made to give credit for facts or inferences utilized in the following summary of the birth and development of the greater Appalachian province.

Owens (1970, *citing* Drake and others, 1959) introduces his discussion of the Atlantic Coastal Plain by referring to published geophysical and drillhole data that show the basement, consisting of Piedmont-type rocks, contains a series of arches and troughs which reflect late diastrophic events in the central and southern Appalachians. More specifically, the results of these geophysical investigations show two troughs separated by a ridge in the basement near the junction of the continental shelf and slope along the continental margin of eastern North America. The shelf trough is reported to be filled with as much as 17,000 feet of shallow-water sediments, and under the slope and rise there is even a greater thickness of sediment which contains features suggestive of a deep-water origin. These writers suggest that the Appalachian geosyncline during its early stages of development may have had a configuration much like that of the present eastern margin of North America. Brown (1970) develops this hypothesis with an interpretation of the sedimentary record in the Piedmont and Blue Ridge of Virginia and offers some possible approximate correlations with lower Paleozoic rocks in the eastern part of the Valley and Ridge province. The following outline of the geologic history, only slightly modified after Brown, postulates that in earlier Precambrian time the basement rocks were exposed in a mountainous region on the northwest and extended in a southeasterly direction beneath the sea. The submerged part of the basement was considered to have the configuration of a fairly deep trough close to the land and separated from the open sea to the east by a low ridge. A basic assumption for the development of the rock record is that various parts of the region were subject to episodic uplift, basin downwarping, and locally accompanied by igneous activity that varied in intensity from time to time.

By the close of Precambrian time the westward advancing seas had eroded the eastern part of the mountainous region and a great thickness of eugeosynclinal graywacke and pelitic sediments had accumulated in relatively deep water in the downwarp basin of the Piedmont. Some sediment was supplied also to the trough from an easterly direction by a slowly rising ridge. A thinned northwestern edge of the graywacke and pelitic sediments, commonly only a few feet thick in the Blue Ridge of northern Virginia, lies unconformably upon the basement. In the waning stage of Precambrian time and probably continuing into the Cambrian was a great period of volcanic activity with lavas and tuffs (Catoctin Formation) covering wide areas in Virginia and in neighboring states to the northeast. In northern Virginia the volcanic rocks with some interbeds of sediments crop out in two belts, one on each limb of the Blue Ridge anticlinorium. The volcanic rocks on the west limb, coinciding with the Blue Ridge, lie on the basement rocks or on a few feet of graywacke and pelitic sediments, where recognized in the section, and below the Lower Cambrian clastic rocks of the Chilhowee Group. Feeder dikes for the Catoctin and other dikes that formed gabbro sills and ultramafic bodies in the eugeosynclinal sediments of the Piedmont are related to this episode in geologic history.

In Lower Cambrian time the stage is set for the accumulation of a vast thickness of miogeosynclinal sediments which later formed the bedrock of the Valley and Ridge province. Due to subsidence in the eugeosyncline and to a lesser extent in the miogeosyncline the shelf is widened westward. Chilhowee rocks are deposited on the shelf, partly upon the basement and partly upon Catoctin, with some of the finer material transported eastward beyond the edge of the shelf. Near the end of Lower Cambrian time the shelf had been cut far westward and subsidence had produced a shallow trough near the eastern edge of the shelf. Deposits on the shelf include a western thinning of the Chilhowee rocks overlain by the Shady Formation, mostly dolomite; and a heterogeneous mixture of carbonates, shales, and siltstones of the Rome Formation. At the close of this stage filling had caught up with downwarping and a widespread tidal-flat existed in the miogeosyncline. Sediments, from easterly and westerly sources, continued to form in the eugeosyncline and granodiorite which intrudes these sediments may have been emplaced at this time or somewhat later.

By middle Ordovician time several thousand feet of carbonate rocks, mainly shallow-water deposits of biogenic origin, had formed in the miogeosyncline and minor amounts of carbonate overlain by detrital sediments had been deposited in the eugeosyncline. In this eastern belt there had been a recurrence of submarine volcanism and some compression and uplifting of the lowlands which was a source of muds and fine sands that were transported westward to interfinger with calcareous sediment in the miogeosyncline. Perhaps the muddy and silty facies of the lower Middle Ordovician carbonates may have formed in this manner. In late Ordovician time the miogeosynclinal trough had deepened to a level where deepwater conditions prevailed and sediments from an easterly source accumulated to form the flysch facies (McBride, 1962) of the Martinsburg Formation, which is the youngest consolidated bedrock preserved in the map area (Plates 2, 3). Younger rocks of the Paleozoic era, representing many thousands of feet of sediments, once existed in the region, but have been removed subsequently by erosion.

Toward the end of the Paleozoic era, downwarping of the Appalachian basin ended and upward movements began, which were accompanied by enormous pressures from the southeast. As a result of this lateral pressure, perhaps extending into post-Paleozoic time, the rocks of the Appalachian trough were folded, faulted, and uplifted into a positive area. This profound tectonic episode is commonly referred to as the "Appalachian Revolution." However, tectonic activity in the Appalachian chain which left an imprint on the character, structure, and distribution of the rocks is not limited to the Appalachian Revolution. The earliest recorded event in northern Virginia, in excess of one billion years (Tilton and others, 1960), was deformation of granitic rocks which formed gneisses that are exposed in the core of the Blue Ridge anticlinorium. Evidence for a later tectonic event may be found in the Piedmont of central Virginia. Here muds containing fossils of Ordovician age, which later become slate, are overlain unconformably (?) by conglomeratic schists. Brown (1970, p. 347), concludes that this unit "must be as young as upper Ordovician, and it may well be lower Silurian—perhaps the product of rapid erosion promoted by Taconic uplift of some sort to the northwest." The rocks in the Blue Ridge province, including gneiss, metabasalt of the Catoctin, and the phyllitic beds of the Chilhowee, contain minerals indicative of the greenschist metamorphic facies. Espenshade (1970, p. 209) states that "The effects of middle Paleozoic metamorphism are evident in all pre-Triassic rocks of the anticlinorium." Generally, the intensity of deformation and the grade of metamorphism decreases in a northwesterly direction across the Blue Ridge and Valley and Ridge provinces. Post-Paleozoic tectonic activity includes (1) the Triassic downfaulted basins in the Piedmont that are filled with sedimentary and volcanic rocks and (2) post-Triassic movements which are recorded largely by unconsolidated Mesozoic and Cenozoic sediments of the Atlantic Coastal Plain.

Post-Paleozoic geologic history, beginning with the first dry land in the folded Appalachians and continuing to the present time, has been chiefly land sculpture and the formation of surficial deposits. How landforms evolved in the Appalachians, beginning with the geographic cycle or peneplain concept, has been a subject considered by many able investigators for more than eighty years. Alternate theories to explain landscape have been proposed by some geologists. Hack (1965) gives a review of earlier work concerning geomorphic processes and landform development in the Shenandoah Valley and an alternate explanation, the equilibrium concept of landscape. In this study (Hack, 1965, p. 1) "it is assumed that the erosion and downwasting of the central Appalachians were continuous and uninterrupted by periods of baseleveling."

ECONOMIC GEOLOGY

Crushed stone is produced from dolomite in the Berryville quadrangle and marl from alluvial deposits in the Boyce quadrangle; in the past, limestone and dolomite, and shale for building roads have been quarried. Raw materials within the study area having the chemical requirements for some of the uses of limestone and dolomite as standardized by various consuming industries (Table 2), shale potentially useful for brick, tile, and lightweight aggregate (Table 5), and quartzite potentially useful for high-silica sand are available.

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

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

INDUSTRIAL LIMESTONE AND DOLOMITE

Carbonate rocks of potential industrial use are arbitrarily subdivided into *high-calcium limestone,* containing more than 95 percent calcium carbonate, and *high-magnesium dolomite,* containing more than 40 percent magnesium carbonate and generally less than 4 percent noncarbonates. Since the noncarbonate constituents, chiefly silica, alumina, and iron oxides, are important for certain uses, *impure limestone* is used to describe those formations which are commonly low in magnesium carbonate or contain more than 5 percent noncarbonates. Chemical analyses (Edmundson, 1945) and physical test data (Parrott, 1954) from selected localities in northern Virginia are shown in Tables 3 and 4.

HIGH-CALCIUM LIMESTONE

High-calcium limestone (Table 3) includes the New Market Limestone, exclusive of impure layers commonly developed near the base; locally a part of the Lincolnshire Formation in areas where it is relatively free of chert; and layers, generally only a few feet in thickness, interbedded with magnesian limestone and dolomite of the Rockdale Run Formation.

The New Market west of the Massanutten syncline crops out in a narrow band extending northeastward across the northwestern corner of the Stephenson quadrangle (Plate 2). Measurements at two localities (Appendix, Sections 4, 5) along this belt indicate that the thickness varies from 67 to 118 feet and one chemical analysis of 88 feet of rock described in Section 4 shows a calcium carbonate content of 97.44 percent. Additional analyses along this belt, north and south of the Stephenson area, have been published by Edmundson (1945, p. 38-39). One locality along Clearbrook Run, 0.1 mile northeast of the northern boundary of the Stephenson quadrangle, displays about 130 feet of New Market Limestone that shows a calcium carbonate content of 98.02 percent.

The thickness of the New Market east of the Massanutten syncline throughout the Shenandoah Valley in Virginia is, with few exceptions, much less than in the western belts. In Clarke County the maximum thickness observed is 67 feet at a locality north (Appendix, Section 7) and south (Edmundson, 1945, p. 176) of State Roard 761. Only the upper 39 feet at this locality appears to meet the specifications for high-calcium limestone. Apparently the thickness cited along State Road 761 is maintained for only a short distance to the north and south along the strike, since in the vicinity of Wadesville (Appendix, Section 6) the possible maximum thickness is not more than 35 feet and to the south along State Road 660, about 0.5 mile east of Opequon Creek, the thickness is estimated at 20 feet. On the east limb of the Wadesville anticline at the crossing of State Road 661 the thickness is about 65 feet, but only the upper 30 feet appears to be of good quality. The thickness of the New Market Limestone at several localities from the general vicinity of State Highway 7 southwestward to U. S. Highway 50 is estimated to be between 15 and 30 feet. Although these exposures are inadequate for precise determination of thickness and for representative sampling,

Table 3.—Chemical composition of carbonate rocks from selected localities in northern Virginia (modified after Edmundson, 1945, p. 38, 40, 187-188).

Formation and Location	Geologic Section No.	Geologic Section Unit.	Thickness in feet	$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	Total
New Market: about 500 feet east of U. S. Highway 11 and 0.4 mile NE of railroad station at Stephenson.	4	3	88	97.44	1.24	0.22	0.08	0.82	99.80
New Market: along Clearbrook Run about 0.4 mile SE of Clearbrook and 0.1 mile NE of the northern boundary of the Stephenson quadrangle.	—	—	130	98.02	0.97	0.04	0.04	0.52	99.59
New Market: about 1000 feet south of State Road 761 and 1.7 miles SW of Wadesville.	8	2	39	96.78	1.12	0.28	0.08	0.90	99.16
New Market: along State Road 657 about 1.5 miles east of Opequon Creek.	—	—	45	98.15	0.92	0.16	0.08	0.78	100.09
Lincolnshire: about 200 yards north of State Road 668 and 100 yards NW of Wadesville.	6	3	85	97.01	1.29	0.40	0.08	0.88	99.66
Edinburg: about 100 yards north of State Road 669 and 0.7 mile SE of Rest. Section about 2.5 miles north of the Stephenson quadrangle.	—	—	391	90.89	2.58	5.18	0.34	1.26	100.25
Shady, upper: about 0.25 mile NW of Shenandoah River and 1.5 miles NE of Castlemans Ferry bridge.	1	3	40	54.82	43.74	0.64	0.52	0.28	100.00
	1	2	40	54.02	42.51	1.54	0.44	0.36	98.87
	1	1	150	54.22	42.53	1.58	0.68	0.64	99.65
Shady, within upper: about 0.3 mile north of State Highway 7 and 3.5 miles SE of Berryville.	2	2	96	57.02	42.45	0.12	0.32	0.08	99.99

Formation and Location	Geologic Section No.	Unit.	Thickness in feet	$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	Total
Shady, upper: in north bluff of Shenandoah River beginning on the west about 0.8 mile south of Lockes Landing.	15	5-6	242	54.82	42.24	1.50	0.44	0.60	99.60
	15	1	200	54.92	42.44	0.96	0.56	0.64	99.52
Stonehenge, upper: about 0.2 mile south of U. S. Highway 340 and 1 mile SW of Boyce.	—	—	125	89.77	3.53	6.67	0.41	0.94	101.32
	—	—	125	93.43	2.97	4.94	0.54	0.29	100.00
Rockdale Run, lower: along State Road 639 about 3.5 miles north of Berryville.	—	—	300	92.10	3.60	5.32	0.32	0.55	101.89
	—	—	150	90.63	3.30	4.37	0.95	0.87	100.12
	—	—	150	85.09	4.37	8.55	0.56	0.75	99.32
Rockdale Run, middle: about 1000 feet north of U. S. Highway 340 and 0.75 mile NW of White Post.	—	—	100	92.17	2.08	4.52	0.12	0.86	99.75
Pinesburg Station, upper: about 0.5 mile SW of intersection of U. S. Highways 50 and 522 and 0.5 mile south of Winchester. Average of three samples each about 350 feet.	—	—	350	54.41	40.05	5.34	0.49	0.69	100.98

it is thought that there are no large deposits of high-calcium limestone in this area. The best exposed section of the New Market, east of the main folded belts, is along the west limb of the Stones Chapel syncline where it is crossed by State Road 657. Here 45 feet of rock shows a calcium carbonate content of 98.15 percent.

It is known that the Lincolnshire Formation in Shenandoah Valley, at localities where the section is relatively free of chert and shaly partings, will meet the specifications of high-calcium limestone. Generally, the formation is impure and this description applies to its occurrence within the area of this report, except for a locality (Appendix, Section 6) in the vicinity of Wadesville. The southwestward extent of this relatively pure Lincolnshire is unknown because of poor exposures. The upper part of the Rockdale Run Formation along State Road 646, about 1.5 miles northwest of White Post, contains units of high-calcium limestone (Edmundson, 1945, p. 185) interbedded with magnesium limestone and dolomite. Field studies indicate that sampled units, 50 feet or more thick, contain less than 95 percent calcium carbonate.

HIGH-MAGNESIUM DOLOMITE

By arbitrarily setting the specifications for high-magnesium dolomite as a rock containing more than 40 percent magnesium carbonate and generally less than 4 percent noncarbonates, every analysis of the upper part of the Shady Formation in Clarke County (Edmundson, 1945, p. 188) would meet these requirements (Table 3). It is also probable that the Pinesburg Station Dolomite may meet these specifications within the northern and northwestern parts of the Stephenson quadrangle (Plate 2), but no chemical analyses are available. Several chemical analyses from this interval in Frederick County (Butts and Edmundson, 1966, p. 104) contain more than 40 percent magnesium carbonate, one contains less than 3 percent noncarbonates, and four exceed but closely approach the maxima for noncarbonates.

The Shady Formation, although rather remote from railroad transportation, is a potential reserve of large tonnage of high-magnesium dolomite. This evaluation is based on test data from one or more samples from several localities; thus, it is recommended that detailed exploration, sampling, and tests should be carried out to prove any particular locality for commercial development. The Shady, although not fully exposed within the study area, is estimated to have a thickness of about 1200 feet. Much of the belt mapped as Shady is covered by surficial deposits, except north of State Highway 7 and in steep bluffs bordering Shenandoah River at several localities within the Ashby Gap quadrangle where the meandering river has cut across the southwesterly trend of the rocks. The character and composition of the uppermost part of Shady dolomite, well displayed in a shallow syncline southeast of Cool Spring, are described in Section 1 (Appendix). Exposures of dolomite, probably within the upper third of the formation, are well displayed in the Stuart M. Perry quarries along the southern boundary of the Berryville quadrangle and near the crest of a broad anticline about 0.3 mile north of State Highway 7 and 3.5 miles east of Berryville (Appendix, Section 2). An almost continuous exposure of the upper part of the Shady is in the north bluff of Shenandoah River beginning about 0.8 mile south of Lockes Landing and extending in an easterly direction for about 2000 feet. Near the middle of this exposure is the axis of an anticline, which is overturned in a northwesterly direction. The character and composition of the overturned limb which dips steeply to the southeast are given in Section 15 (Appendix).

IMPURE LIMESTONE

Impure limestone formations include the Stonehenge, the Lincolnshire at most localities, and the Edinburg. Other relatively impure limestones which are interbedded with dolomites are referred to under "Crushed and broken stone."

The Stonehenge crops out in the northwest corner of the Stephenson quadrangle and in a belt, 1000 to 1200 feet wide, across the mapped area east of White Post and Boyce and west of Berryville. Where the outcrop is narrowest the thickness, including the Stoufferstown Member at the base, is estimated to be about 800 feet. The average of two analyses (Table 3) from the upper part of the Stonehenge, which crops out in a broad area about 1 mile southwest of Boyce, contains 91.60 percent calcium carbonate, 3.25 percent magnesium carbonate, and 5.80 percent silica. Rock of a similar appearing character, although not sampled, is displayed about 0.5 mile northeast of Boyce, and at a locality 1 mile southwest of White Post.

The Lincolnshire, except in the vicinity of Wadesville (Appendix, Section 6), appears to contain relatively large quantities of chert throughout Clarke County and conspicuous, but lesser amounts, of chert in the Stephenson area. The Edinburg is composed of variable lithologies. West of the Massanutten syncline it is composed mainly of cobbly to nodular, buff-weathering limestone (Lantz Mills) with tongues of black limestone and black shale (Liberty Hall). East of Opequon Creek in the northwestern part of the county the ratio of Liberty Hall to Lantz Mills in the Edinburg is about 2 to 1. The amount of shale and argillaceous limestone increases in a southwesterly direction and in the southern part of Clarke County the Edinburg is all Liberty Hall. The Edinburg was not sampled for chemical analyses within the area of this report, but near the Virginia-West Virginia boundary (Edmundson, 1945, p. 30) the full thickness of the formation along the same belt that is mapped through the Stephenson area contains 90.89 percent calcium carbonate and 5.18 percent silica. In areas where Liberty Hall is dominant, the carbonate content is lower and the insoluables range from about 10 to more than 20 percent.

CRUSHED AND BROKEN STONE

Stone used as an aggregate in highway construction and maintenance is classified into grades A, B, and C on the basis of three physical properties: abrasion loss, absorption, and specific gravity. According to Gooch, Wood, and Parrott (1960, p. 2-3), "The most important physical property is the abrasion loss, which is determined by the Los Angeles Abrasion Test. . . . For Grade A classification, the loss must be between 0 and 35% for Grade B between 35 and 43%, and for Grade C between 43 and 50%.

"Grade A and B aggregate are utilized for aggregate base course, soil aggregate surface course, bituminous concrete, Portland cement, surface treatment, stabilization aggregate, or crusher run. Grade C is used for soil aggregate surface course and stabilization aggregate."

Absorption, expressed as percentage, is the difference in weight of a sample submerged in water for 24 hours divided by the oven dry weight. According to Gooch, Wood, and Parrott (1960, p. 3): "Any aggregate that absorbs over 1 to 1.5 percent of water is considered questionable and should be subjected to a soundness test." With regard to specific gravity, the method used by the Virginia Department of Highways is the bulk specific gravity (Saturated Surface Dried).

It is significant that parts of all of the carbonate formations, Chilhowee quartzites, and the Catoctin greenstone, although varying in lithologic character from place to place, have grade A classification. Physical test results of a statewide aggregate survey for use in locating potential sources of coarse aggregate are available in Parrott (1954). Table 4 is a compilation from Parrott's report showing about half of the prospects cited from Clarke County. Changes in stratigraphic nomenclature were made to be consistent with the units described in this report.

Large amounts of aggregate are currently being produced from the Shady Formation near the southern boundary of the Berryville quadrangle about 0.5 mile southwest of the junction of State Highway 7 and State Road 612 by Stuart M. Perry Company, Inc. No samples were collected for chemical analyses, but the stone appears to be high-magnesium dolomite similar to that described in Section 2, (Appendix).

T. M. Gathright and P. G. Nystrom of the Virginia Division of Mineral Resources supplied the writers with a memorandum report (January 12, 1973) on the structure and mineralization of the quarry. Recent operation has extended the working face in a north-northeasterly direction across a high-angle cross fault with slikensides on fractured faces suggesting that the relative movement across the fault zone was down to the south. A tectonic breccia is present on the west wall of the quarry along the fault trace and is composed of dark-gray, fine-grained, dolomite clasts in a coarse-grained, light-gray, dolomite matrix (possibly a recrystallized fault gouge). Solution cavities are present along the fault trace and to the south the rocks are strongly jointed for 100 to 150 feet.

Mineralization within the quarry is largely restricted to (1) the zone of brecciation and (2) along bedding planes and fracture surfaces of the rocks adjacent to the fault zone on the north. The breccia clasts in the fault zone have surface coatings of very fine-grained pyrite and calcite, and very small pyrite grains are disseminated throughout the breccia matrix. The thinly bedded dolomites of the north block are medium gray and fine grained

Table 4.—Physical tests of aggregate samples from selected localities in Clarke County, Virginia (modified after Parrott, 1954, p. 39-40).

Formation	Latitude	Longitude	Specific Gravity	Absorption	Los Angeles Loss		Soundness
					Abrasion	Grading	
Shady	39°07′48″	77°55′00″	2.85	0.18	20.0	A	OK
Rome	39°06′12″	77°57′48″	2.64	0.38	21.2	A	OK
Conococheague	39°01′24″	78°05′48″	2.73	0.14	20.9	A	OK
Conococheague	39°02′18″	78°05′12″	2.69	0.47	29.8	A	OK
Conococheague	39°06′24″	78°00′42″	2.72	0.28	20.7	A	OK
Stonehenge	39°07′30″	78°01′48″	2.67	0.73	20.0	A	OK
Stonehenge	39°05′18″	78°04′24″	2.71	0.25	26.8	A	OK
Rockdale Run	39°07′48″	78°02′36″	2.69	0.28	26.5	A	OK
Rockdale Run	39°09′42″	78°02′12″	2.70	0.49	19.4	A	OK
Rockdale Run	39°12′12″	77°59′48″	2.71	0.14	25.2	A	OK
New Market	39°08′54″	78°03′06″	2.73	0.06	21.9	A	OK
New Market	39°10′42″	78°03′24″	2.69	0.39	28.8	A	OK
Edinburg	39°10′42″	78°04′24″	2.71	0.27	23.7	A	OK
Chilhowee qtz.	39°01′18″	78°01′30″	2.63	0.10	25.8	A	OK

with stringers and pods of white, very coarse-grained dolomite that define bedding. Pyrite, barite, ankeritic dolomite and finely crystalline quartz are localized in the white, coarse-grained dolomite of the stringers and pods, and along cleavage fractures and in the white, coarse-grained dolomite matrix of small zones of brecciation. Barite box-work with some masses ranging up to six inches in diameter occur in the saprolite or residual soil in a solution cavity along the eastern wall of the quarry. Barite fracture fillings up to several inches in thickness appear to occur in bedrock adjoining the solution cavity, but this occurrence could not be verified due to its position high on the vertical quarry face.

In addition to the bedrock mineralization a thin gossan, consisting of irregular crystalline and botryoidal goethite and limonite, lies on the residual soil, or in the top of it, and below the thin remnant of an old terrace deposit. Many quartz crystals up to 1 inch in length and quartz crystal masses occur with the gossan and in the residual soil.

Although the mineralization at this locality amounts to only a fraction of a percent of the rock body and has no potential commercial value its occurrence in and adjacent to a fault is of interest since the mapping of cross faults, even of small displacement, could be the locus of other, possibly significant mineralization.

The Salem Stone Corporation quarry, now inactive, is located north of State Road 663 about 1 mile west of the railroad station at Stephenson (Appendix, Section 5). The aggregate produced was limestone and dolomite from near the middle of the Rockdale Run Formation. Portable plant was utilized at the site to produce crushed stone for local road construction.

MARL

Available chemical analyses of travertine or calcareous tufa, where free from contamination, show more than 97 percent of calcium carbonate. Generally, the marl that occupies the flood plains of streams is intermixed with variable amounts of fine sand and clay and the calcium carbonate content ranges from about 65 to 94 percent with the magnesium carbonate less than one percent. Most of the impurities are silica and organic matter.

Deposits of calcareous marl have been extensively quarried from open pits on the west side of Shenandoah River at Calmes Neck. Currently, marl is being produced for agricultural use by J. C. Digges and Sons from a locality along Chapel Run about 0.5 mile southeast of Briggs (Plate 3).

Much of the alluvium that occupies the flood plains along the eastward-flowing tributaries to Shenandoah River and Opequon Creek is composed of calcareous sandy clay. Freshwater mollusk shells and rounded pebbles coated with travertine are common, and massive deposits of travertine have been observed in many of the stream beds. Perhaps the best place to observe marl within the Shenandoah River drainage basin is along Spout Run between Millwood and Shenandoah River (Plate 3). Calcareous marl appears to be widespread along Dry Marsh Run which is a westward flowing tributary to Opequon Creek (Plate 2). This deposit, containing abundant fresh-water mollusk shells, has produced marl from an open pit on the east side of State Road 635.

It is thought that the belts mapped as alluvium may contain marl deposits of commercial importance. The maps should be used as a guide in selecting localities for more detailed geologic investigation and testing.

CEMENT MATERIALS

Portland cement is produced by burning a finely ground artificial mixture, consisting essentially of about three parts of limestone to one part of clay or shale. In this ratio it is assumed that the limestone is nearly pure calcium carbonate and the clay or shale is siliceous (preferably 2.5 to 3 times as much silica as alumina plus iron oxide). Specifications also restrict the magnesia content to not more than 6.3 percent (Table 2). The burning takes place in a specially designed rotary kiln at temperatures which will produce incipient fusion. The clinker resulting from this calcination is then ground to a fine powder which will react with water to form a rock-like mass.

Among the potential raw materials for the manufacture of Portland cement are limestone from the New Market, Lincolnshire and Edinburg formations and shale from the Martinsburg Formation. The carbonate units crop out in narrow belts adjacent to the Martinsburg Formation along the northwestern limb of the Massanutten syncline in the Stephenson area and are in close proximity to the Baltimore and Ohio Railroad (Plate 2). The same units are widely distributed east of Opequon Creek in Clarke County (Plates 2, 3), although the New Market has less thickness and the Edinburg appears to contain a larger percentage of argillaceous material. According to Bassler (1909, p. 73-74), "The middle Ordovician limestones exposed along the eastern edge of the Massanutten syncline are crossed by the railroad in Clarke County at but a single locality. This is at Wadesville in the northwestern corner of the county. However, for a short distance north of this place the line of outcrop of these limestones is not far from the railroad, and to the south and west for 1.5 miles the two parallel each other, so that this county affords an abundance of suitable limestones within short distances of transportation facilities." In indicating advantageous sites, such as the Wadesville area, Bassler (1909, p. 66) "means simply to imply that the cement rock and pure limestone deposits occur at the places mentioned, and that transportation facilities are at hand. Whether good cement can be made from the raw materials found at these places is a matter which can be determined only by experimentation on a commercial scale. The argillacoues limestones, in many instances, have a composition very similar to good cement materials of other regions, but this does not necessarily indicate that they also will make first-class cement."

CLAYS, SHALES, AND RELATED MATERIALS

Tests and determinations of properties required to evaluate the potential ceramic and nonceramic uses of raw materials in the northern counties of Virginia have been published by Calver, Hamlin, and Wood (1961). Within the study area one sample of shale and interbedded thin layers of siltstone shows a potential use for lightweight aggregate and the other sample, consisting of shale and mudstone and interbedded thin layers of fine-grained sandstone, shows a potential use for common brick and tile (Table 5). Both samples were collected from the Martinsburg Formation (Plate 2, Nos. R-651, R-1704) which occupies a belt, about 3.5 miles wide, lying in general between Stephenson and Opequon Creek, but in places extending almost a mile across the creek into Clarke County. The Martinsburg contains an enormous volume of rocks, but Calver, Hamlin, and

Table 5. — Potential uses of clay materials from the Stephenson quadrangle, Virginia (compiled from Calver, Hamlin, and Wood, 1961).

Location	Formation	Sampled Interval	Potential Use
Junction of State Roads 600 and 664, about 2.5 miles southeast of Stephenson (repository number R-651).	Martinsburg	Composite sample of 245 feet of weathered shale and mudstone, and thin layers of interbedded, fine-grained sandstone.	Common brick and tile
Southwest side of State Road 660 about 6 miles northwest of Berryville and 0.5 mile northwest of the intersection of State Road 660 and 645 (repository number R-1704).	Martinsburg	Composite sample of about 30 feet of weathered shale and a few interbedded thin layers of siltstone.	Lightweight aggregate

Wood (1961, p. 3) in their introduction emphasize that: ". . . the evaluation remarks are based on test data determined on one or two samples from each locality. Detailed exploration, sampling and tests should be carried out to prove any particular locality for commercial development."

HIGH-SILICA SAND

The Antietam Formation is composed primarily of silica cemented, fine- to coarse-grained quartzite and metasubarkose with minor phyllite partings. Good exposures of parts of the formation, including vitreous quartzite, can be seen on Gibson Ridge, The Blue Ball, and in Venus Branch. In Clarke County, Harris (1972a, p. 11) refers to an exposure of the Erwin Quartzite (Antietam Formation of this report) on the south end of Gibson Ridge 0.1 mile east of State Road 638 (Plate 3). This locality was not selected for analysis, but in an open-file report Harris (1972b) concludes that the "rock material would be extremely difficult to crush for use as high-silica sand."

The results of studies by Harris (1972a) along the same belt of rocks southwest of the Boyce quadrangle (Plate 3) show that a composite sample of the raw material from the upper 47 feet of the Erwin Formation in Page County contains 97.8 percent SiO_2 and 99.6 percent when beneficiated. Hand samples from the lower part of the Page County section and from a locality in Rockingham County contain 99.3 percent SiO_2.

IRON ORE

Mines and prospects, including oxides of manganese and iron, have been described from many localities along the northwest foot of the Blue Ridge in northern Virginia (Stose and others, 1919; King, 1943). However, there is no record of any manganese production within the area of this report and only one reference to the production of a small amount of iron ore.

Holden (1907, p. 430) reports that iron ore in the form of "limestone limonite" occurs in a number of places a short distance west of the Shenandoah River. Some of this ore is reported to have been mined and hauled to the Shannondale furnace in Jefferson County, West Virginia. Residents of the area report that ore was mined for about one year around 1900 from a locality about 1.5 miles north of Castlemans Ferry and 5 miles east of Berryville. This operation, known as the Berryville mine, produced ore which was hauled to a furnace at Riverton, Warren County. So far as known there has been no production in this area since about 1900.

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APPENDIX

STRATIGRAPHIC SECTIONS

The lithologic descriptions and thicknesses of the exposed rock units within the map area are described as stratigraphic sections 1 through 14. The section numbers are the same as the locality numbers shown on the geologic maps (Plates 1-3). Section 15 is on the adjoining Ashby Gap quadrangle.

Section 1: Cool Spring

About 0.2 mile SE of Cool Spring and 1.5 miles NE of Castleman Ferry Bridge, Clarke County (Plate 1); modified after Edmundson (1945, p. 180).

		Thickness Feet
Shady Formation (upper 230± feet)		
3	Dolomite, light-gray to white, fine- to medium-grained; covered at the top; SiO_2, 0.64; Fe_2O_3, 0.52; Al_2O_3, 0.28; $CaCO_3$, 54.82; $MgCO_3$, 43.74; total, 100.00	40
2	Dolomite, light- and bluish-gray, fine grained. Analysis of units 2 and 3, sampled thickness 80 feet: SiO_2, 1.54; Fe_2O_3, 0.44; Al_2O_3, 0.36; $CaCO_3$, 54.02; $MgCO_3$, 42.51; total, 98.87	40
1	Dolomite, dark-gray, fine-grained; in part brecciated and veined with white dolomite; partly covered; SiO_2, 1.58; Fe_2O_3, 0.68; Al_2O_3, 0.64; $CaCO_3$, 54.22; $MgCO_3$, 42.53; total, 99.65	150±

Section 2: Webbtown

On east limb of Marvin Chapel anticline about 0.4 mile north of State Highway 7 and 1.4 miles east of Webbtown, Clarke County (Plate 1); modified after Edmundson (1945, p. 181).

Shady Formation (within upper part, 368 feet)		
4	Dolomite, bluish-gray, fine-grained; partly covered	53
3	Dolomite, bluish-gray; gnarly weathering	34
2	Dolomite, white to light-gray and cream-colored, fine- to medium-grained; few saccharoidal beds; SiO_2, 0.12; Fe_2O_3, 0.32; Al_2O_3, 0.08; $CaCO_3$, 57.02; $MgCO_3$, 42.45; total, 99.99	96
1	Dolomite, dark-gray; in part brecciated and veined with white dolomite; covered at base	185

Section 3: Craig Run

Begins on east limb of Calmes Neck anticline about 2 miles SE of the County High School in Berryville and extends in a northwesterly direction

	Thickness Feet
paralleling Craig Run to the vicinity of State Road 613, Clarke County (Plate 1); measured by W. E. Nunan.	
Conococheague Formation (lower 375 feet)	
58 Limestone, medium-gray, medium-grained, weathers gray to pinkish gray; siliceous laminae near top	17
57 Covered	35
56 Limestone, dark-gray, fine- to medium-grained; weathers light gray with grayish-brown laminae	59
55 Dolomite, medium light-gray, fine-grained, cross-laminated; weathers yellowish gray	3
54 Limestone, medium-gray, medium-grained; weathers bluish gray; siliceous laminae in upper part; poorly exposed in lower part	29
53 Limestone, dark-gray, medium-grained; weathers medium-gray; beds 2 feet thick	18
52 Limestone, dark-gray, medium-grained; weathers medium light gray with yellowish-gray dolomitic ribbons; chert nodules common and 3-inch thick chert bed at base	12
Big Springs Station Member (202 feet)	
51 Limestone, medium-gray, medium-grained, cross-bedded; at top is 3- inch thick bed of very sandy dolomite that weathers to a yellowish-orange sand	4
50 Limestone, medium-gray, fine-grained; weathers light gray with minor yellowish-gray dolomitic bands	14
49 Dolomite, dark brownish-black, fine- to medium-grained; weathers rusty brown	2
48 Limestone, medium dark-gray, fine-grained; weathers light gray with yellowish-gray dolomitic banding	10
47 Shale, dark-gray; weathers brownish gray; partly covered	9
46 Limestone with thin intercalations of dolomitic limestone; ribbon banded; limestone is light gray, fine grained; weathers light bluish gray; dolomitic limestone is very light gray, medium grained; weathers yellowish gray; near middle is a 1.5-foot thick bed of cross-laminated, medium-gray, fine-grained dolomite	9
45 Dolomite with interbeds of dolomitic limestone; medium to light gray, medium grained	5
44 Covered	9

	Thickness Feet
43 Dolomite, dark-gray, medium-grained; weathers rusty orange; contains coarse sand grains	2
42 Shale, dark-gray; weathers brownish gray	3
41 Limestone with interbeds of dolomite; limestone, light-gray, fine-grained; weathers light bluish gray; dolomite, light-gray, fine- to medium-grained; weathers light gray	15
40 Covered	6
39 Dolomite, dark-gray, medium-grained; weathers brownish to light yellowish gray; about 50 percent covered	27
38 Limestone, light-gray, fine- to medium-grained; weathers light bluish gray; contains chert nodules 13 feet from top; at base is 1-foot thick bed of light-gray, medium-grained dolomite	21
37 Covered	20
36 Limestone with interbeds of dolomitic limestone; ribbon banded; limestone is light gray, fine grained; weathers light bluish gray; dolomitic limestone is medium light gray, medium grained; weathers medium gray	9
35 Dolomite, light-gray, fine-grained	5
34 Dolomite, dark-gray, medium-grained; weathers brownish gray	6
33 Limestone, light-gray, fine-grained; weathers light bluish gray	24
32 Sandstone, light-gray to pale-yellow, coarse-grained, well-sorted, cross-bedded; on weathering the rock becomes brown and friable	2
Elbrook Formation (upper 761 feet)	
31 Dolomite with interbeds of limestone; dolomite, light-gray, medium-grained; weathers very light gray; limestone, medium-gray, fine-grained; weathers light bluish gray; about 80 percent covered	76
30 Dolomite, dark-gray, fine-grained; weathers rusty brown; contains 2-foot thick bed of light-gray, fine grained limestone near middle	52
29 Limestone, medium-gray, fine-grained; weathers light bluish gray; interbeds of impure limestone or dolomite with abundant argillaceous laminae; ribbon banded; weathers yellowish gray; few layers contain dolomite-pebble conglomerates; gymnosolenid stromatolites in basal bed	47
28 Scattered exposures of light-gray, medium-grained dolomite; weathers light gray to pale orange	42

		Thickness Feet
27	Dolomite, olive-green, medium-grained; weathers pink to yellowish brown	3
26	Covered	25
25	Dolomite, light-gray, fine-grained, laminated; contains chert nodules	2
24	Covered	4
23	Limestone, medium-gray, fine-grained; weathers light bluish gray; interbeds of very thin layers of argillaceous limestone or dolomite; weathers yellowish gray; ribbon banded	8
22	Dolomite, medium-gray, fine-grained; weathers light gray with very light-gray banding	6
21	Dolomite, very dark-gray, medium-grained, saccharoidal, laminated; weathers light gray; contains thin beds of intraformational conglomerate	6
20	Covered	42
19	Limestone, medium-gray, fine-grained; weathers light bluish gray; interbeds of thin layers of impure limestone or dolomite; weathers very light gray, ribbon banded; near middle are thicker beds of light- to dark-gray, fine- to medium-grained dolomite that weathers yellow to brownish gray	37
18	Dolomite, light-gray, fine-grained, weathers pale yellow	3
17	Limestone, light-gray, fine- to medium-grained; weathers light bluish gray; siliceous partings	26
16	Dolomite, dark-gray, medium-grained; weathers brownish gray	1
15	Limestone, medium-gray, fine-grained; weathers light bluish gray; interbeds of very thin layers of argillaceous limestone or dolomite; weathers yellowish gray; ribbon banded	3
14	Limestone, medium-gray, medium-grained; weathers light gray; interbeds of medium-gray, fine-grained dolomite; weathers light gray; contains a few thin beds of brownish-black shale; about 70 percent covered	44
13	Limestone, dark-gray, fine-grained, shaly; weathers medium gray	4
12	Mostly covered; medium-gray, medium-grained limestone with interbeds of light-gray, medium-grained dolomite near middle	57
11	Limestone, medium-gray, fine-grained, laminated; weathers light gray; some layers contain granule-size dolomite clasts; interbeds of dolomite that weathers very light gray	33
10	Limestone, medium-gray, fine-grained; weathers light bluish gray; interbeds of very thin layers of argillaceous limestone or dolomite; weathers yellowish-gray; ribbon banded	9

		Thickness Feet
9	Limestone, light-gray, fine-grained; weathers very light-gray; contains abundant stringers of dolomite which weather pale yellow and brownish gray; lower part, intermittent exposures of brownish gray-weathering dolomite and medium-gray limestone	40
8	Covered	34
7	Dolomite, light-gray, fine-grained; weathers pale yellow to light gray	3
6	Dolomite, light-gray, medium-grained; interbeds of medium-gray, fine-grained limestone; weathers light bluish gray; contains stromatolite structures	10
5	Limestone, light-gray, fine-grained; weathers light bluish gray	4
4	Mostly covered; scattered exposures of limestone and dolomite	117
3	Limestone, medium-gray, fine-grained; weathers light bluish gray; interbeds of very thin layers of argillaceous limestone or dolomite; weathers yellowish gray; ribbon banded	4
2	Covered	14
1	Limestone, medium-gray, medium-grained; covered at base	5

Section 4: Stephenson

About 500 feet east of U. S. Highway 11 and 0.4 mile NNE of railroad station at Stephenson, Frederick County (Plate 2); modified after Edmundson (1945, p. 25).

New Market Limestone (118 feet)

3	Limestone, dove-gray, compact, thick-bedded; SiO_2, 0.22; Fe_2O_3, 0.08; Al_2O_3, 0.82; $CaCO_3$, 97.44; $MgCO_3$, 1.24; total, 99.80	88
2	Limestone, dove- to bluish-gray, compact to fine-grained	30

Pinesburg Station Dolomite (upper part)

1	Dolomite, gray, fine-grained	335+

Section 5: Hiatt Run

Units 4-8 were measured along Hiatt Run and State Road 663 about 1000 feet east of U. S. Highway 11; line of traverse offset 1500 feet NE along strike of rocks and then continued northwesterly to inactive quarry near Interstate Highway 81, Frederick County (Plate 2); measured by W. E. Nunan.

Lincolnshire Formation (82± feet)

		Thickness Feet
8	Covered, abundant medium-grained limestone float	41±
7	Limestone, dark-gray, medium-grained; weathers gray; contains rusty-orange seams on fresh surfaces; fossils include pelmatozoan stems, *Mastopora* cf. *M. ovoides,* and brachipods	29
6	Covered	12±

New Market Limestone (67 feet)

5	Limestone, dove-gray, extremely fine-grained; beds up to 3 feet thick; weathers light bluish gray; contains sections of large gastropods and a significant coral, *Tetradium syringoporoides,* which is easily recognized on weathered surfaces as clear calcite "eyes"	43
4	Limestone, dove-gray, extremely fine-grained; contains drab-colored, muddy laminations in lower part with limestone-pebble conglomerate at base	24

Pinesburg Station Dolomite (352+ feet)

3	Dolomite, dark- to light-gray, fine- to medium-grained; beds up to 3 feet thick; covered at base	352+

Rockdale Run Formation (upper 1345± feet)

2	Partly covered; about equal amounts of intermittent limestone and dolomite outcrops	850±
1	Limestone, dove-gray, fine-grained; interbeds of mottled and laminated dolomitic limestone and gray to very light-gray, fine- to medium-grained dolomite; contains several fossiliferous zones; section ends in inactive quarry	495±

Section 6: Wadesville

About 800 feet NE of the crossing of State Road 661 and the Baltimore and Ohio Railroad at Wadesville, Clarke County (Plate 2); modified after Edmundson (1945, p. 176).

Lincolnshire Formation

3	Limestone, dark-gray, medium-grained; SiO_2, 0.40; Fe_2O_3, 0.08 Al_2O_3, 0.88, $CaCO_3$, 97.01; $MgCO_3$, 1.29; total, 99.66	85

New Market Limestone (35 feet)

2	Limestone, dove-gray, compact	20
1	Limestone, light-gray, compact, impure; weathers yellowish gray	15

Pinesburg Station Dolomite

Section 7: Opequon Creek

A

Composite section about 1.3 miles SSW of Wadesville, Clarke County. Units 8-13 measured along State Road 761 about 1000 feet east of Opequon Creek; units 5-7 offset along strike about 700 feet south of road; and units 1-4 begin at barn 200 feet north of road (Plate 2); measured by W. E. Nunan.

		Thickness Feet
	Martinsburg Formation (lower 10 feet)	
13	Shale, dark-gray, calcareous; weathers buff with dark-gray to rusty-brown bands; covered at top	10
	Oranda (?) *Formation* (20± feet)	
12	Covered; brownish-colored residuum with shale and limestone chips; within this interval on west limb of narrow syncline is about 6 feet of medium-grained, shaly limestone	20±
	Edinburg Formation (554± feet)	
11	Limestone, dark-gray, fine-grained; abundant yellow to buff siliceous partings; beds 3 inches to 1 foot thick weather to cobbly blocks; abundant *Mastopora pyriformis*	52
10	Siltstone (R-4165) and shale; olive colored when fresh; shale weathers light yellowish brown; thin deeply weathered, yellowish-orange bentonitic clay (R-4166) at base	3
9	Limestone (R-4167), dark-gray, fine- to medium-grained; beds 3 inches to 1 foot thick; buff weathering siliceous partings; black crust of silica, 0.5 inch thick, at top of unit; abundant *Mastopora pyriformis*	16
8	Siltstone and shale; olive to dark-gray; hackly weathering; 1 foot of bentonitic clay at base; separated from underlying limestone by a crust of black silica	10
7	Limestone, dark-gray, fine- to medium-grained; contains buff siliceous bands; beds 3 inches to 1 foot thick; about 30 percent covered	263
6	Limestone, black, fine-grained; some thin calcareous shale partings; abundant fragments of brachiopods, gastropods, trilbites, and crinoid stem plates; few beds contain pyrite crystals about 1 mm in diameter	180
5	Covered	30
	Lincolnshire Formation (60 feet)	
4	Limestone, dark-gray, granular; few thin, black chert layers and nodules becoming more abundant in lower part; abundant fossil fragments with a few layers crowded with *Girvanella*	60

	Thickness Feet
New Market Limestone (67 feet)	
3 Limestone, dove-gray, fine-grained; weathers light bluish gray with clear calcite "eyes"; beds 3 inches to 3 feet thick; contains large gastropods and corals (*Tetradium syringoporides*)	38
2 Covered; this interval about 1000 feet south of State Road 761 contains dove-gray, compact, thinly laminated, impure limestone with thin limestone-pebble conglomerate at base (Edmundson, 1945, p. 176)	29
Pinesburg Station Dolomite	
1 Dolomite, dark- to light-gray, fine- to medium-grained; weathers very light gray; few layers contain white chert nodules, averaging 0.5 inch in diameter; two limestone beds, about 1 foot thick, and separated by a paced distance of 60 feet occur near middle of section; about 50 percent covered; thickness uncertain; may include a part of the underlying Rockdale Run Formation	610±

Section 8: Opequon Creek

B

About 1000 feet south of State Road 761 and 1.4 miles SW of Wadesville, Clarke County (Plate 2); modified after Edmundson (1945, p. 176, 179).

Edinburg Formation (530± feet)	
12 Limestone, black, nodular-weathering; may contain Oranda Formation in upper part	72±
11 Siltstone, dark-gray; weathers brown; partly covered	3
10 Limestone, shaly, cobbly weathering	16
9 Siltstone and shale	10
8 Limestone, black, irregularly bedded; brown partings	145
7 Limestone, black, buff weathering, cobbly	35
6 Limestone, black; shaly partings; a few feet of shaly siltstone at base	56
5 Limestone, black, cobbly weathering; shaly partings	47
4 Limestone, black, compact, thin-bedded	146
Lincolnshire Formation (58 feet)	
3 Limestone, dark bluish-gray, granular, sparsely cherty	58
New Market Limestone (68 feet)	

		Thickness Feet
2	Limestone, dove-gray, compact: SiO_2, 0.28; Fe_2O_3, 0.08; Al_2O_3, 0.90; $CaCO_3$, 96.78; $MgCO_3$, 1.12, total, 99.16	39
1	Limestone, gray, compact, impure; thin conglomerate at base	29

Pinesburg Station Dolomite

Section 9: Dry Marsh Run

Begins at the top of the Lincolnshire Formation on the SE slope of a low rounded hill 200 feet north of State Road 660 about 1800 feet east of its junction with State Road 635 and 0.5 mile north of Dry Marsh Run, Clarke County (Plate 2); modified after Butts (1942).

Edinburg Formation (403± feet)

12	Mostly covered; few exposures of black and dark-gray limestone with gray shale partings; thickness estimated	80+
11	Siltstone and shale	10
10	Limestone, black, fine-grained, shaly; partly covered; thickness estimated	170±
9	Siltstone	2
8	Limestone, black, fine-grained, shaly	60
7	Siltstone	2
6	Limestone, shaly	3
5	Limestone, dark-gray, fine-grained; *Helicotoma* identified south of State Road 660	40
4	Shale	1.5
3	Limestone, shaly	1.5
2	Limestone, black to dark-gray, fine-grained; few shale partings; contains *Homotelus* and *Dionide*	13
1	Covered interval; abundant chert float; thickness estimated	20±

Lincolnshire Formation

Section 10: State Highway 7

Begins in the lower part of the Martinsburg Formation, 0.63 mile east of Opequon Creek, and extends westerly along the north side of the eastbound lane of State Highway 7 for approximately 1000 feet, Clarke County (Plate 2); measured by W. E. Nunan.

Martinsburg Formation (lower 162 feet)

9	Shale, light-gray, yellow, pale-green, light-brown; weathers buff to pale orange; some layers are calcareous; several thin beds of bentonitic clay	98

		Thickness Feet
8	Shale, dark-gray, calcareous; few interbeds of thin, bright-orange, noncalcereous shale; both shales weather pale orange; graptolites abundant	64
Oranda(?) Formation (28 feet)		
7	Limestone, grayish-black, fine-grained, muddy	1
6	Siltstone and shale, interbedded, black to light-brown, calcareous; contains graptolites	24
5	Shale, brownish-black to olive-black, noncalcareous; pinkish-gray, micaceous bentonitic clay at base	3
Edinburg Formation (upper 186 feet)		
4	Limestone, dark-gray, medium- to coarse-grained, cobbly weathering; composed laregly of pelmatozoan fragments and bryozoan colonies; beds 4 to 8 inches thick	5
3	Limestone, grayish-black, fine-grained; contains numerous fractures filled with white calcite; beds 4 to 8 inches thick	25
2	Limestone, dark-gray, fine-grained; contains interbeds of brownish-gray siltstone; pale-orange bentonitic clay at base	33
1	Limestone, dark-gray, fine-grained; contains numerous fractures filled with white, coarse-grained calcite; few thin beds of bentonitic clay in the upper 14 feet; covered at base	123

Section 11: Old Salem Church

Begins at the Waterloo syncline, about 1.5 miles N. 80°E. of Old Salem Church, and extends southeasterly to the axis of the Stone Bridge anticline, Clarke County (Plate 2); measured by W. E. Nunan.

Edinburg Formation (lower 39 feet)		
15	Shale, brownish-black; weathers to pale-orange chips	5
14	Partly covered; limestone, black, fine-grained; weathers gray; interbeds of black shale; brownish-gray siltstone float	34
Lincolnshire Formation (14 feet)		
13	Partly covered; limestone, dark-gray, coarse-grained; few beds composed largely of fossil fragments	14
New Market Limestone (51 feet)		
12	Limestone, medium-gray, fine-grained; weathers light gray; beds 2 inches to 2 feet thick; laminated in lower part; contains *Tetradium* corals, which are expressed on smooth rock surfaces as clear calcite "eyes", and large high-spired gastropods	45

	Thickness Feet
11 Limestone-pebble conglomerate; clasts up to 15 mm in diameter are enclosed in medium-gray, fine-grained, impure limestone	6
Rockdale Run Formation (upper 1202 feet)	
10 Limestone and dolomite repeated in cycles of 10 to 20 feet, from top down, typified by the following sequence: (a) medium- to bluish-gray, fine-grained limestone with interbeds of finely laminated, light-gray, fine-grained dolomite; (b) medium-grained limestone with anastomosing network of irregularly shaped rod-like bodies of light-gray, medium-grained dolomite; (c) the anastomosing rocks grade into ribbon-banded, medium-gray, medium- to fine-grained limestone with interbeds of well-defined layers of light-gray, medium-grained dolomite; beds are 6 inches to 4 feet thick	268
9 Limestone and dolomite, interbedded; limestone, medium-gray, fine-grained; weathers light gray; dolomite, light- to medium-gray, fine- to medium-grained, laminated; minor amounts of ribbon-banded limestone and dolomite; some anastomosing dolomite stringers in the fine-grained limestone; algal masses at base; beds 6 inches to 4 feet thick	128
8 Limestone and dolomite, interbedded; like unit 10, except increasingly more dolomitic towards base	73
7 Dolomite and limestone, interbedded; dolomite, light-gray, medium-grained, in part saccharoidal; weathers very light gray; few beds contain coarse sand grains and quartz geodes (maximum diameters of 4 cm); limestone, grayish-blue, fine-grained; contains minor amounts of dolomite-pebble conglomerate and thin chert stringers; limestone comprises about 20 percent of unit	196
6 Limestone and dolomite, interbedded; limestone, dark-gray, fine- to medium-grained; weathers grayish blue; dolomite, light-gray, fine- to medium-grained, laminated and massive; fossils include abundant algal heads and a few 3 to 6-inch thick beds of black stromatolitic chert; nodules of chert, up to 3 inches thick, are present throughout; beds 3 inches to 4 feet thick; limestone comprises about 65 percent of unit	132
5 Limestone, dark-gray, fine- to medium-grained, contains laminations of dolomite that weather yellowish-gray; magnesian content increases downward in section to a limy dolomite in the lower few feet	45
4 Limestone, dark- to medium-gray, fine to medium-grained; weathers light bluish-gray	150
3 Limestone, dark-gray, fine-grained; weathers light bluish gray; contains algal structures associated with abundant coarse sand grains; 2 foot thick bed of medium-grained, pale yellow-weathering dolomite at base	35

		Thickness Feet
2	Limestone, light- to dark-gray, fine- to medium-grained; weathers light bluish gray with orange laminae of dolomite; algal structures common in light bluish-gray limestones; 4 foot thick bed of pale orange-weathering dolomite at base	55
1	Limestone, dark-gray, fine- to medium-grained; weathers light bluish-gray; contains few interbeds of light-gray, medium-grained, laminated dolomite; section ends near hinge of Stone Bridge anticline	120

Section 12: Milldale

Begins 275 feet NW of the bridge on State Road 624 at the crossing of Borden Marsh Run and extends southeastward for about 900 feet, Warren County (Plate 3); measured by W. E. Nunan. (Top of unit 4 is about 600 feet beneath the base of the Big Spring Station Member of the Conococheague Formation, which at this locality has more sandy layers than in Section 3 along Craig Run.)

Elbrook Formation (middle 666 feet)

4	Dolomite, light- to dark-gray, fine- to medium-grained; weathers very light to medium gray and pale yellow; medium-grained rocks have saccharoidal texture and the darker beds are generally coarser grained; ribbon-banded dolomite and limestone beds are numerous; some dolomite layers are shaly; many of the lighter colored dolomites are laminated and show cross-bedding; algal structures are common with heads up to 3 feet in diameter; calcareous brown shales in beds up to 10 feet thick comprise about 20 percent of this unit	262
	Intersect State Road 624	
3	Like unit 4 except for a lower percentage of shale; light-gray, pink-banded, fine-grained dolomite at base; weathers pale yellow; minor folding in this interval	67
2	Dolomite, light- to dark-gray, fine- to medium-grained; weathers very light to medium gray and pale yellow; at base dolomite, green, sandy, 8 feet thick	183
1	Dolomite, very light to medium-gray, fine- to medium-grained; some layers saccharoidal; weathers light gray; base near minor anticlinal axis	154

Section 13: Wrights Branch

Begins in lower part of Antietam Formation, 500 feet SE of State Road 638, and continues upstream along Wrights Branch for about 0.7 mile, Clarke County (Plate 3); measured by W. E. Nunan.

Antietam Formation (lower part)

13	Quartzite, very light-gray, medium-grained; contains reddish-brown streaks and specks, quartz, 85 to 95 percent; feldspar, 5 to 15 percent; dark minerals 2 percent; quartz cement	45

	Thickness Feet
Harpers Formation (2145+ feet)	
Upper member (1723± feet)	
12 Mostly covered; float consists of olive and light-gray; bronze-weathering phyllite and graywacke; beds of very light-gray quartzite, 2 to 4 feet thick, occur at 5- to 20-foot intervals	225±
11 Graywacke, olive, fine- to medium-grained; interbedded with olive phyllite; some light-gray, medium- to coarse-grained quartzite beds, 2 to 15 feet thick, occur at 20- to 100-foot intervals; muddy, very coarse-grained graywacke at base; about 65 percent covered	425±
10 Quartzite, very light-gray, fine- to medium-grained; contains black laminae; quartz, 95 percent; feldspar, 3 to 5 percent; heavy minerals, 1 to 2 percent; quartz cement; unit mapped separately on Plate 3 as unit "q"	79
9 Graywacke, olive, fine-grained, muddy; interbedded with quartzite beds, 2 to 4 feet thick, similar to unit 10; at base quartzite bed, 4 feet thick; about 15 percent covered	44±
8 Graywacke, olive, fine- to medium-grained; interbedded with olive to grayish-blue phyllite and pale-yellow, medium-grained quartzite; quartzite beds, 2 to 4 feet thick, are separated by 3 to 15 feet of graywacke and phyllite; about 55 percent covered	230±
7 Phyllite, grayish blue, sandy; interbedded with a few very light-gray, medium-grained quartzite beds; about 50 percent covered	300±
6 Graywacke, grayish-yellow to very light-gray, very fine-grained; interbedded with very light-gray, medium-grained quartzite; about 50 percent covered	325±
5 Graywacke, olive, grayish-green, and dusky-yellow, fine- to medium-grained; darker colors predominate; about 60 percent covered	95±
Middle member (upper 422 feet)	
4 Graywacke, grayish-green, fine-grained	10
3 Graywacke, olive to grayish-green; some layers with medium-grained, reddish-brown specks; interbedded with greenish-gray phyllite; about 60 percent covered	110±
2 Graywacke, grayish-green, fine-grained; forms falls in stream	27
1 Phyllite, greenish-yellow to grayish-blue, interbedded with olive, fine-grained graywacke and dusky-brown, ferruginous, medium-grained graywacke; about 75 percent covered	275+

Section 14: Poplartree Hollow

Begins in middle member of Harpers Formation in Poplartree Hollow approximately 2500 feet upstream from its junction with Wrights Branch, Clarke County (Plate 3); measured by W. E. Nunan. (Section begins on east limb of a syncline which is complementary to an anticline developed between this point and Section 13 along Wrights Branch.)

		Thickness Feet
	Harpers Formation (1235+ feet)	
	Middle member (lower 1125± feet)	
4	Phyllite, olive to grayish-green, silty; interbedded with grayish-green, fine- to medium-grained graywacke with reddish-brown specks; may be in part the same as unit 1 of Geologic Section 13; however, thought to be somewhat lower in the section; about 40 percent covered	725±
3	Graywacke, olive to grayish-green, fine- to medium-grained; few interbeds of grayish-blue to grayish-green phyllite; about 50 percent covered	400±
	Lower member (110+ feet)	
2	Phyllite, pale-green to pale-blue; some yellowish-gray; sandy lenses; about 15 percent covered	110+
1	Covered interval for about 700 feet to top of the Weverton Formation	?

Section 15: Lockes Landing

In north bluff of Shenandoah River beginning on the west about 0.8 mile south of Lockes Landing and extending easterly to the axis of the Slate Ridge anticline on the Ashby Gap 7.5-minute quadrangle, Clarke County; modified after Edmundson (1945, p. 182).

	Rome Formation (lower 275± feet)	
8	Dolomite, shaly, thin-bedded; contorted	75+
7	Mostly covered; a few exposures of bluish-gray, fine-grained dolomite and magnesian limestone; conspicuous black chert near base	200±
	Shady Formation (upper 528 feet)	
6	Dolomite, light- and dark-gray, fine-grained	94
5	Dolomite, white to light-gray, fine- to medium-grained; a few saccharoidal beds; brecciated zone at top contains a few crystals of galena	148
	Analysis of units 5 and 6, sampled thickness 242 feet: SiO_2, 1.50; Fe_2O_3, 0.44; Al_2O_3, 0.60; $CaCO_3$, 54.82; $MgCO_3$, 42.24; total, 99.60.	
4	Dolomite, light-gray, fine-grained	28

		Thickness Feet
3	Covered	27
2	Dolomite, dark-gray, medium-grained	31
1	Partly covered; exposed beds light- and dark-gray dolomite; SiO_2, 0.96; Fe_2O_3, 0.56; Al_2O_3, 0.64; $CaCO_3$, 54.92; $MgCO_3$, 42.44; total, 99.52	200

GENERAL INDEX

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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

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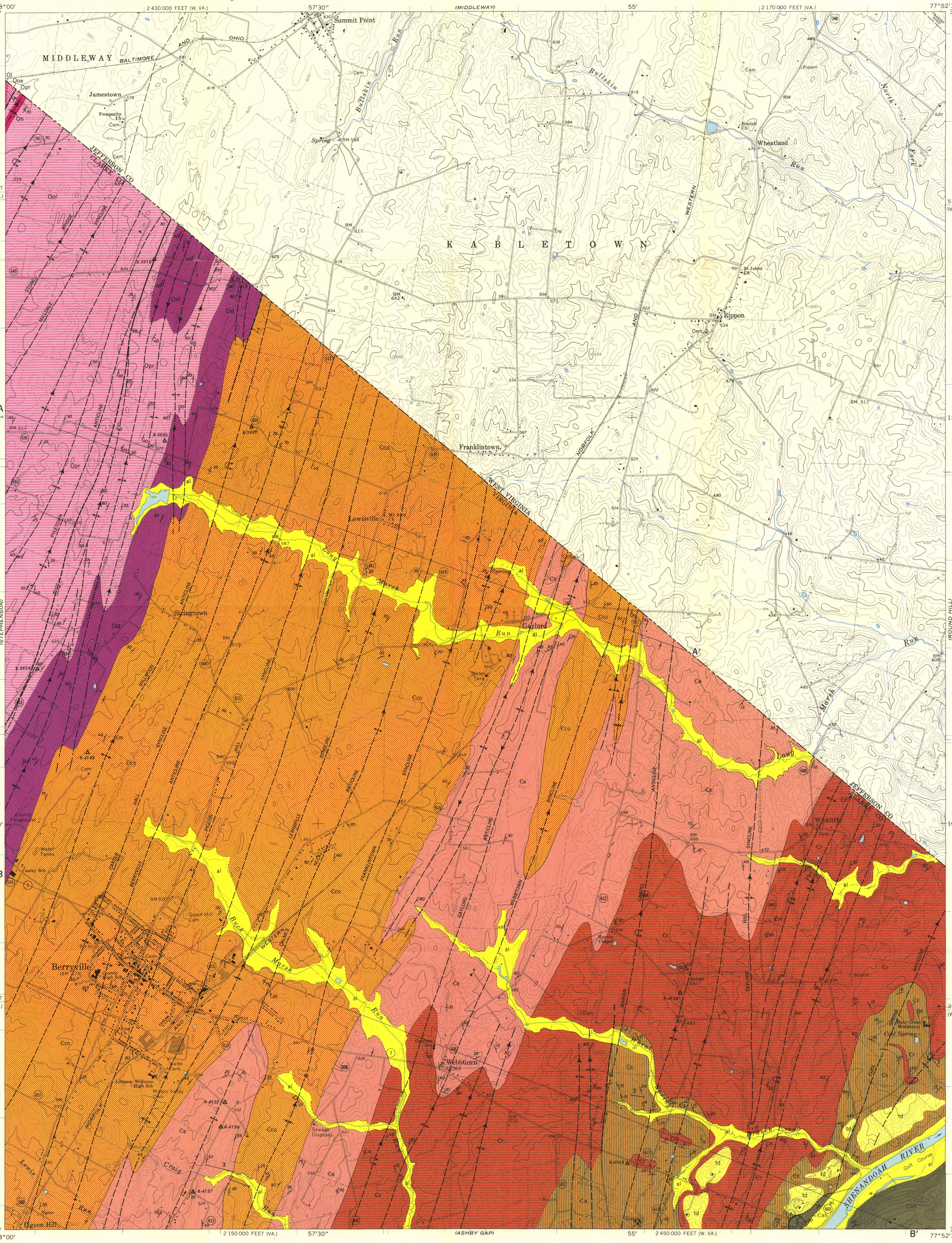
PLATE 1

Berryville



Base map from U. S. Geological Survey, Berryville Quadrangle, 7½ Minute Series

UTM GRID AND 1968 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

MN GN 6½° 116 MILS 1°51' 33 MILS

GEOLOGIC MAP OF THE BERRYVILLE QUADRANGLE, VIRGINIA

Geology by Raymond S. Edmundson and W. Edward Nunan

SCALE 1:24 000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

VIRGINIA
QUADRANGLE LOCATION

1972

Williams & Heintz Map Corporation

EXPLANATION

CENOZOIC

al

Alluvium (HOLOCENE)
Dark-gray sandy clay, silt, and clay containing gravel; calcareous with some massive beds of travertine along many tributary streams.

td

Terrace deposits
Rounded gravels and cobbles in sand, silt, and clay matrix; colluvial blocks intermixed with roundstones along base of Blue Ridge.

PALEOZOIC

ORDOVICIAN

Ooe

Oranda Formation and Edinburg Formation
Oranda: dark-gray, argillaceous limestone with intercalated siltstones and micaceous metabentonite. Edinburg: dark-gray to black, dense limestone with nodular layers, siltstones, and variable amounts of black shale.

Ol

Lincolnshire Formation
Dark-gray, fine- to medium-grained limestone with stringers and nodules of black chert common; locally, contains pinkish partings along irregular bedding surfaces.

On

New Market Limestone
Bluish- to dove-gray, dense, thick-bedded limestone with a lower impure zone that is thinly bedded; locally, a few feet of pebble conglomerate at base.

Opr

Pinesburg Station Dolomite and Rockdale Run Formation
Pinesburg Station: predominantly light-gray, fine-grained dolomite; weathers yellowish to drab-gray. Rockdale Run: interbedded bluish-gray limestone and gray dolomite; several distinctive chert zones; algal structures associated with clastic limestone common.

Ost

Stonehenge Formation
Laminated, dark-gray limestone; siliceously banded zones contain intraformational conglomerate; algal structures common (upper part). Light- to dark-gray limestone; few thinly bedded layers with minor amounts of black chert (middle part). Stoufferstown Member: fine- to medium-grained limestone with distinctive crinkly siliceous laminae; scour fillings of "fossil hash" common (lower part).

CAMBRIAN

Ꞓco

Conococheague Formation
Gray to dark-gray limestone with interbeds of light- to dark-gray dolomite; friable sandstone and sandy chert widespread; grades down into siliceously banded limestone with intraformational conglomerate common; few beds, containing well-rounded quartz sand, weather to blocks of friable sandstone (upper part). Ribbon-banded limestone with minor siliceous laminae; light-gray bands are dolomitic; few thicker beds of dolomite (middle part). Big Spring Station Member: Interbedded dolomite, magnesian limestone, and limestone; few thin beds of sandy dolomite; brownish-weathering shale, quartzose sandstone, and stringers and nodules of black chert (lower part).

Ꞓe

Elbrook Formation
Predominantly limestone with interbeds of dolomite, shale, and siltstone, and an occasional bed of sandstone; much of the limestone and dolomite is banded with argillaceous material and on weathering yields ocherous slabs and thin plates; the more massively bedded, impure rocks weather to a dun color, except for a thin zone near middle of section which is green to maroon limestone, shale, and fine-grained sandstone.

Ꞓr

Rome Formation
Argillaceous limestone and dolomite which weather to a yellowish ocherous rock and thicker beds, apparently of purer dolomite; variable amounts of purer limestone, siltstone, mudstone, sandstone, and varicolored fissile shale; many beds contain stringers and nodules of black chert; most distinctive feature is maroon or reddish-brown shale and siltstone occurring at several horizons.

Ꞓs

Shady Formation
White to bluish-gray, fine- to medium-grained in part saccharoidal, dolomite (upper part). Bluish-gray limestone with shale partings and interbeds of dolomite; sandstone float near base (lower part); nowhere in mapped area is contact with underlying quartzite exposed.

Ꞓah

Antietam Formation and Harpers Formation
Fine- to coarse-grained, silica cemented quartzite underlain by graywacke, metasubarkose, and phyllite; quartzites, ranging from 2 to 15 feet thick, associated with phyllites and graywacke.

CONTACTS

Dashed where approximate; dotted where covered

FOLDS

Anticline — trace of fold and direction of plunge

Syncline — trace of fold and direction of plunge

Overturned anticline — trace of fold and direction of plunge

Overturned syncline — trace of fold and direction of plunge

FAULTS

Dashed where approximate; dotted where covered

T on upper plate; arrows indicate relative movement

ATTITUDE OF ROCKS

15 Strike and dip of beds

70 Strike and dip of overturned beds

Strike of vertical beds

Horizontal beds

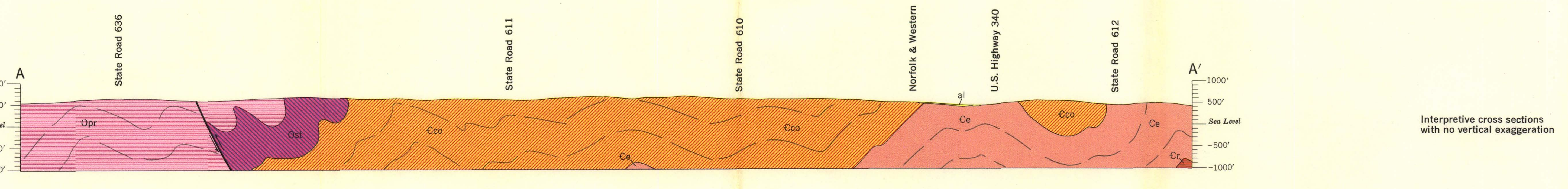
INDUSTRIAL MATERIAL EXTRACTION SITE

Active quarry
Stuart M. Perry, Inc. - dolomite (crushed stone)

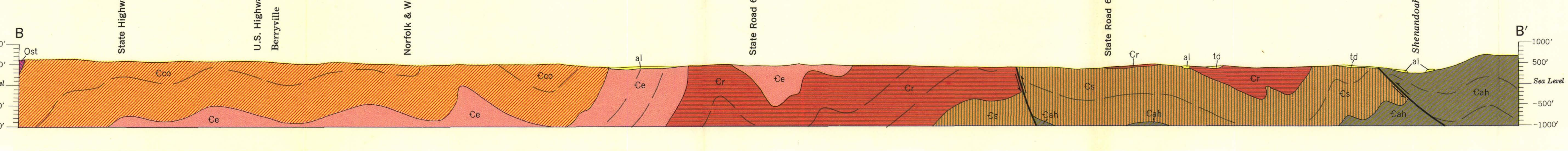
SAMPLE LOCATIONS

R-3918 Location and repository number of sampled lithology

2 3 Location of measured stratigraphic section



Interpretive cross sections with no vertical exaggeration



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

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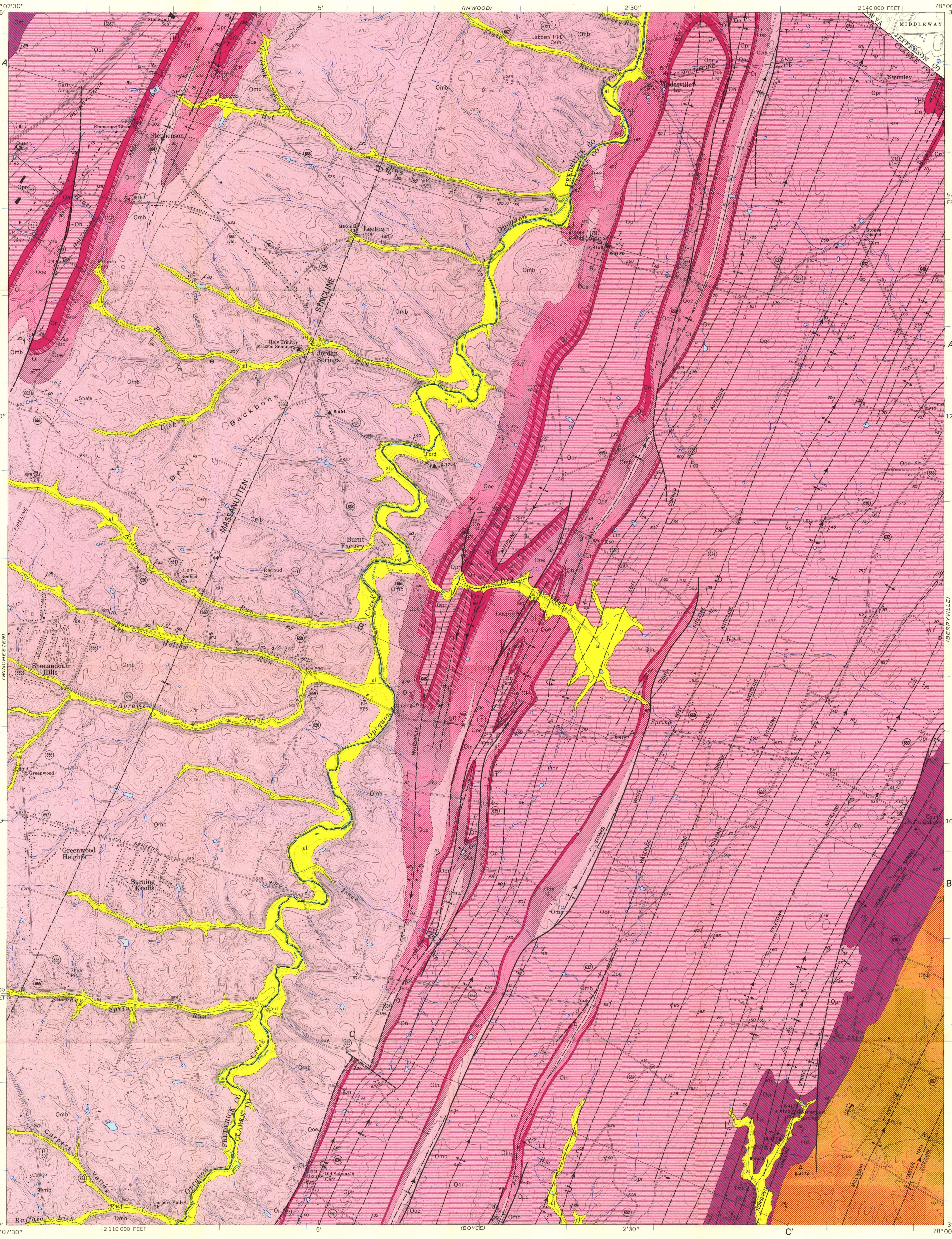
PLATE 2

Stephenson



Base map from U. S. Geological Survey, 1966
Stephenson Quadrangle, 7½ Minute Series

Williams & Heintz Map Corporation

GEOLOGIC MAP OF THE STEPHENSON QUADRANGLE, VIRGINIA

Geology by Raymond S. Edmundson and W. Edward Nunan

MN GN 6° 107 MILS 1°51' 33 MILS

UTM GRID AND 1966 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

1972

VIRGINIA
QUADRANGLE LOCATION

EXPLANATION

CENOZOIC — HOLOCENE

al — **Alluvium**
Dark-gray sandy clay, silt, and clay containing gravel; calcareous with some massive beds of travertine along many tributary streams.

PALEOZOIC — ORDOVICIAN

Omb — **Martinsburg Formation**
Bluish-gray to yellowish-brown, fissile clay shale and dark-brown, thinly laminated siltstone; black, calcareous shale with occasional thin metabentonites near base.

Ooe — **Oranda Formation and Edinburg Formation**
Oranda: dark-gray, argillaceous limestone with intercalated siltstones and micaceous metabentonite. Edinburg: dark-gray to black, dense limestone with nodular layers, siltstones, and variable amounts of black shale.

Ol — **Lincolnshire Formation**
Dark-gray, fine- to medium-grained limestone with stringers and nodules of black chert common; locally, contains pinkish partings along irregular bedding surfaces.

Oln — **Lincolnshire Formation and New Market Limestone**
Lincolnshire: dark-gray, fine- to medium-grained limestone with stringers and nodules of black chert common. New Market: bluish- to dove-gray, dense thick-bedded limestone.

On — **New Market Limestone**
Bluish- to dove-gray, dense, thick-bedded limestone with a lower impure zone that is thinly bedded; locally, a few feet of pebble conglomerate at base.

Opr — **Pinesburg Station Dolomite and Rockdale Run Formation**
Pinesburg Station: predominantly light-gray, fine-grained dolomite; weathers yellowish to drab-gray. Rockdale Run: interbedded bluish-gray limestone and gray dolomite; several distinctive chert zones; algal structures associated with clastic limestone common.

Ost — **Stonehenge Formation**
Laminated, dark-gray limestone; siliceously banded zones contain intraformational conglomerate; algal structures common (upper part). Light- to dark-gray limestone; few thinly bedded layers with minor amounts of black chert (middle part). Stoufferstown Member: fine- to medium-grained limestone with distinctive crinkly siliceous laminae; scour fillings of "fossil hash" common (lower part).

PALEOZOIC — CAMBRIAN

Ꞓco — **Conococheague Formation**
Gray to dark-gray limestone with interbeds of light- to dark-gray dolomite; friable sandstone and sandy chert widespread; grades down into siliceously banded limestone with intraformational conglomerate common; few beds, containing well-rounded quartz sand, weather to blocks of friable sandstone (upper part). Ribbon-banded limestone with minor siliceous laminae; light-gray bands are dolomitic; few thicker beds of dolomite (middle part). Big Spring Station Member: Interbedded dolomite, magnesian limestone, and limestone; few thin beds of sandy dolomite; brownish-weathering shale, quartzose sandstone, and stringers and nodules of black chert (lower part).

CONTACTS

Dashed where approximate; dotted where covered

FOLDS

Anticline-trace of fold and direction of plunge

Syncline-trace of fold and direction of plunge

Overturned anticline-trace of fold and direction of plunge

Overturned syncline-trace of fold and direction of plunge

FAULTS

Dashed where approximate; dotted where covered

T U D — T on upper plate; U on upthrown side and D on downthrown side; arrows indicate relative movement

ATTITUDE OF ROCKS

35 — Strike and dip of beds

85 — Strike and dip of overturned beds

Strike of vertical beds

⊕ Horizontal beds

INDUSTRIAL MATERIAL EXTRACTION SITE

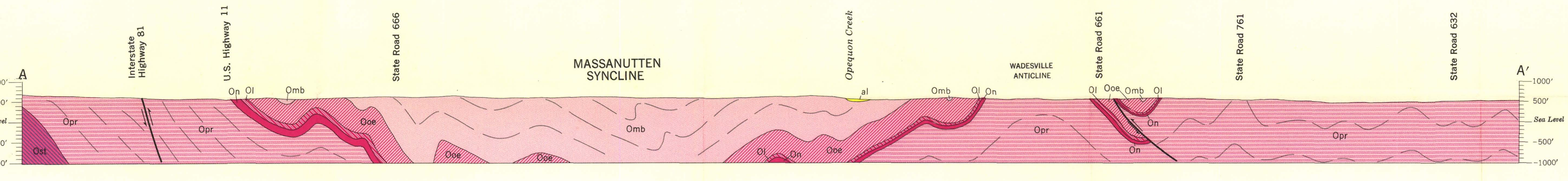
Inactive quarry
Limestone and dolomite

SAMPLE LOCATIONS

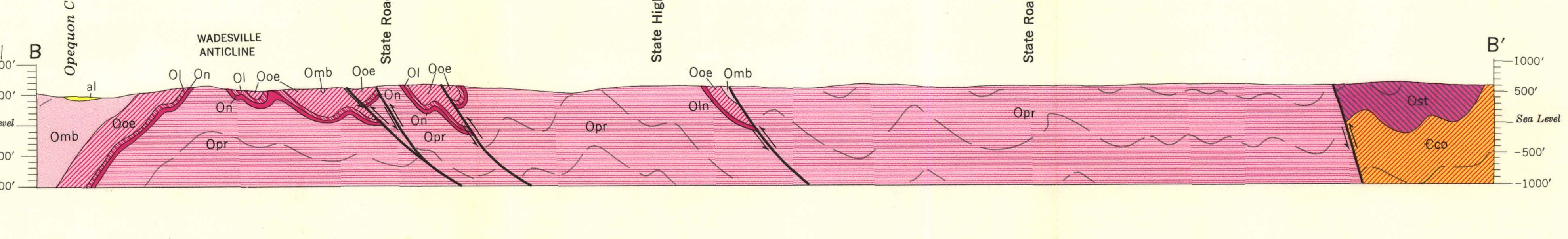
△ R-4170 — Location and repository number of sampled lithology

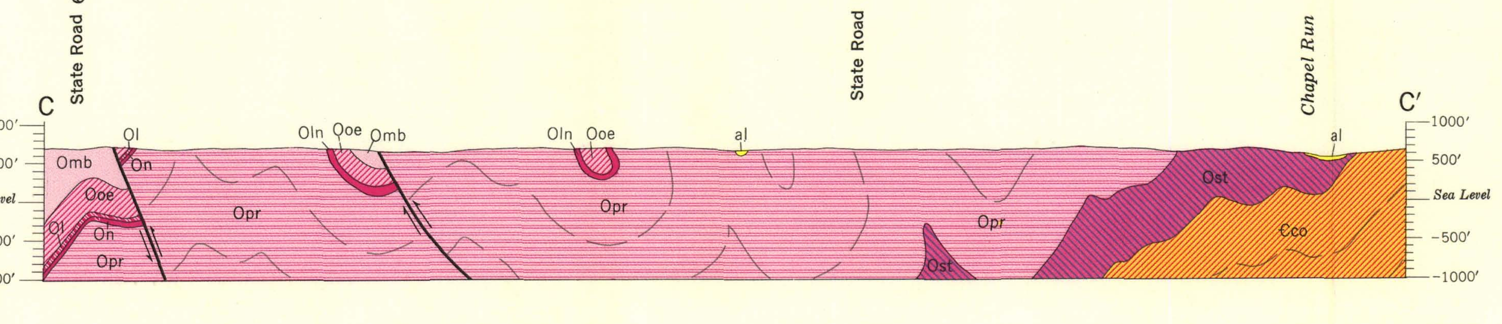
▲ R-1704 — Location of sample with potential use

10 11 — Location of measured stratigraphic section



Interpretive cross sections with no vertical exaggeration





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

Base map from U. S. Geological Survey, 1966
Boyce Quadrangle, 7½ Minute Series

UTM GRID AND 1966 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
MN GN 6° 107 MILS 1°51' 33 MILS

GEOLOGIC MAP OF THE BOYCE QUADRANGLE, VIRGINIA

Geology by Raymond S. Edmundson and W. Edward Nunan

SCALE 1:24 000
1 ½ 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

1972

VIRGINIA
QUADRANGLE LOCATION

Williams & Heintz Map Corporation

EXPLANATION

CENOZOIC — HOLOCENE

al — Alluvium
Dark-gray sandy clay, silt, and clay containing gravel; calcareous with some massive beds of travertine along many tributary streams.

td — Terrace deposits
Rounded gravels and cobbles in sand, silt, and clay matrix; colluvial blocks intermixed with roundstones along base of Blue Ridge.

PALEOZOIC — ORDOVICIAN

Omb — Martinsburg Formation
Bluish-gray to yellowish-brown, fissile clay shale and dark-brown, thinly laminated siltstone; black, calcareous shale with occasional thin metabentonites near base.

Ooe — Oranda Formation and Edinburg Formation
Oranda: dark-gray, argillaceous limestone with intercalated siltstones and micaceous metabentonite. Edinburg: dark-gray to black, dense limestone with nodular layers, siltstones, and variable amounts of black shale.

Ol — Lincolnshire Formation
Dark-gray, fine- to medium-grained limestone with stringers and nodules of black chert common; locally, contains pinkish partings along irregular bedding surfaces.

Oln — Lincolnshire Formation and New Market Limestone
Lincolnshire: dark-gray, fine- to medium-grained limestone with stringers and nodules of black chert common. New Market: bluish- to dove-gray, dense thick-bedded limestone.

On — New Market Limestone
Bluish- to dove-gray, dense, thick-bedded limestone with a lower impure zone that is thinly bedded; locally, a few feet of pebble conglomerate at base.

Orr — Rockdale Run Formation
Rockdale Run: interbedded bluish-gray limestone and gray dolomite; several distinctive chert zones; algal structures associated with clastic limestone common.

Ost — Stonehenge Formation
Laminated, dark-gray limestone; siliceously banded zones contain intraformational conglomerate; algal structures common (upper part). Light- to dark-gray limestone; few thinly bedded layers with minor amounts of black chert (middle part). Stoufferstown Member: fine- to medium-grained limestone with distinctive crinkly siliceous laminae; scour fillings of "fossil hash" common (lower part).

PALEOZOIC — CAMBRIAN

Ꞓco — Conococheague Formation
Gray to dark-gray limestone with interbeds of light- to dark-gray dolomite; friable sandstone and sandy chert widespread; grades down into siliceously banded limestone with intraformational conglomerate common; few beds, containing well-rounded quartz sand, weather to blocks of friable sandstone (upper part). Ribbon-banded limestone with minor siliceous laminae; light-gray bands are dolomitic; few thicker beds of dolomite (middle part). Big Spring Station Member: Interbedded dolomite, magnesian limestone, and limestone; few thin beds of sandy dolomite; brownish-weathering shale, quartzose sandstone, and stringers and nodules of black chert (lower part).

Ꞓe — Elbrook Formation
Predominantly limestone with interbeds of dolomite, shale, and siltstone, and an occasional bed of sandstone; much of the limestone and dolomite is banded with argillaceous material and on weathering yields ocherous slabs and thin plates; the more massively bedded, impure rocks weather to a dun color, except for a thin zone near middle of section which is green to maroon limestone, shale, and fine-grained sandstone.

Ꞓr — Rome Formation
Argillaceous limestone and dolomite which weather to a yellowish ocherous rock and thicker beds, apparently of purer dolomite; variable amounts of purer limestone, siltstone, mudstone, sandstone, and varicolored fissile shale; many beds contain stringers and nodules of black chert; most distinctive feature is maroon or reddish-brown shale and siltstone occurring at several horizons.

Ꞓs — Shady Formation
White to bluish-gray, fine- to medium-grained in part saccharoidal, dolomite (upper part). Bluish-gray limestone with shale partings and interbeds of dolomite; sandstone float near base (lower part); nowhere in mapped area is contact with underlying quartzite exposed.

Ꞓa — Antietam Formation
Predominantly silica-cemented, fine- to coarse-grained quartzite and metasubarkose; phyllite partings common; minor sericitic matrix in some beds; many layers stained with iron oxide.

Ꞓh, **q / Ꞓh** — Harpers Formation
Graywacke, metasubarkose, phyllite, and quartzite; quartzites, ranging from 2 to 15 feet thick, occur at several intervals and one unit, q, nearly 80 feet thick, is mapped (upper part). Phyllite and graywacke; rocks weather various shades of grayish-green and bluish-gray (middle part). Light bluish-gray, sandy phyllite with minor interbeds of fine- to medium-grained, ferruginous quartzite (lower part).

Ꞓw — Weverton Formation
Light-gray, massively bedded, quartz conglomerate and quartzite; well-defined cross bedding marked by purple ferruginous bands (upper part). Graywacke with pebble size quartz grains; bronze-weathering phyllite (middle part). Light-gray, medium- to coarse-grained, thick-bedded metasubarkose with dark streaks of heavy minerals (lower part).

PRECAMBRIAN

t / ꞒpꞒc — Catoctin Formation
Fine-grained, even-textured, green metabasalt; many layers contain amygdules filled with quartz and epidote; chrysotile and partially replaced quartz-chrysotile veins common; fewer epidote veins; much of the greenstone is epidotized; t, metamorphosed tuffs that occur at the top of the Catoctin Formation consist of dusky-purple phyllite with oval, pale-green splotches of muscovite.

CONTACTS

Dashed where approximate; dotted where covered

FOLDS

Anticline — trace of fold and direction of plunge
Syncline — trace of fold and direction of plunge
Overturned anticline — trace of fold and direction of plunge
Overturned syncline — trace of fold and direction of plunge

FAULTS

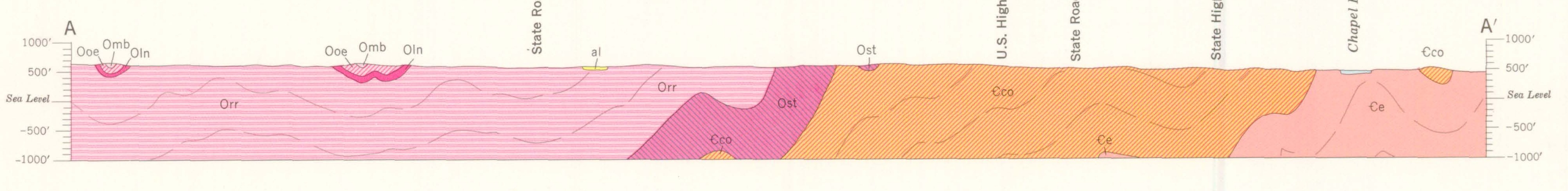
Dashed where approximate; dotted where covered
T on upper plate; U on upthrown side and D on downthrown side

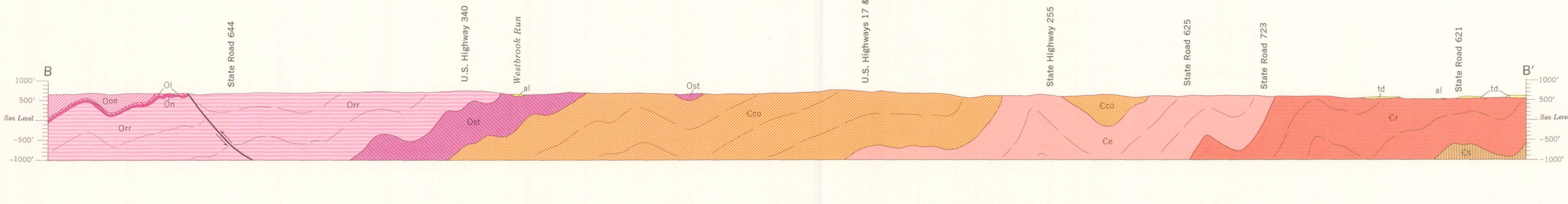
ATTITUDE OF ROCKS

15 — Strike and dip of beds
70 — Strike and dip of overturned beds
Strike of vertical beds
Horizontal beds

INDUSTRIAL MATERIAL EXTRACTION SITE

Active pit
J. C. Digges and Sons - marl (argricultural purposes)





Interpretive cross sections with no vertical exaggeration

SAMPLE LOCATIONS

R-4705 — Location and repository number of sampled lithology
13 — Location of measured stratigraphic section