COMMONWEALTH OF VIRGINIA

DEPARTMENT OF CONSERVATION
AND ECONOMIC DEVELOPMENT

DIVISION OF MINERAL RESOURCES

GEOLOGY AND MINERAL RESOURCES OF FREDERICK COUNTY

Charles Butts and
Raymond S. Edmundson

BULLETIN 80

VIRGINIA DIVISION OF MINERAL RESOURCES

James L. Calver
Commissioner of Mineral Resources and State Geologist

CHARLOTTESVILLE, VIRGINIA
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Commonwealth of Virginia
Department of Purchases and Supply
Richmond
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GEOLOGY AND MINERAL RESOURCES OF FREDERICK COUNTY

By

CHARLES BUTTS[1] AND RAYMOND S. EDMUNDSON[2]

ABSTRACT

Frederick County occupies about 433 square miles in northern Virginia and lies wholly within the Valley and Ridge province of the Appalachian Highlands. Southeast of Little North Mountain is a broad lowland, a segment of Shenandoah Valley, which is underlain by Cambrian and Ordovician limestone and shale. The northwestern part of the county is characterized by northeastward-trending ridges, some of large size, and intervening valleys. Here the exposed strata, ranging in age from Late Ordovician to Early Mississippian, consist mainly of sandstone and shale with minor amounts of limestone. The aggregate thickness of the sedimentary sequence is estimated at 22,000 feet.

The present attitude of the rocks is related to late Paleozoic orogeny. In the eastern part of the county the symmetry of the folds in response to the compressive forces from the east is shown by the oversteepened and locally overturned east limbs of synclines and west limbs of anticlines, and by the easterly dip of the thrust faults that cut some of the major folds. To the northwest faults are less common, and the folds are more open and less overturned. Minor folding, faulting, and cleavage are well displayed in a few exposures of incompetent soft shales and thin-bedded limestones and sandstones.

In the past, manganese ore and iron ore have been mined in Frederick County. Mineral resources of economic importance which are being produced and processed at the present time include limestone and dolomite, silica sand, and clay and shale.

INTRODUCTION

LOCATION AND SIZE OF AREA

Frederick County covers an area of about 433 square miles in the northern part of Virginia (Figure 1). Virginia counties bordering

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[2]Department of Geology, University of Virginia, Charlottesville.

Frederick are Clarke on the east and Warren and Shenandoah on the south. Adjoining West Virginia counties are Berkeley and Morgan on the northeast and Hampshire and Hardy on the northwest. The maximum length of the county, measured from Cacapon Mountain southward to U. S. Highway 11 at Cedar Creek, is 32 miles. The base map (Plate 1) used in this report is a composite of parts of the Capon Bridge, Gerrardstown, Middletown, Winchester and Wardensville topographic sheets of the U. S. Geological Survey. Winchester, the county seat, is located near the intersection of latitude 39° 10′ N. and longitude 78° 10′ W.

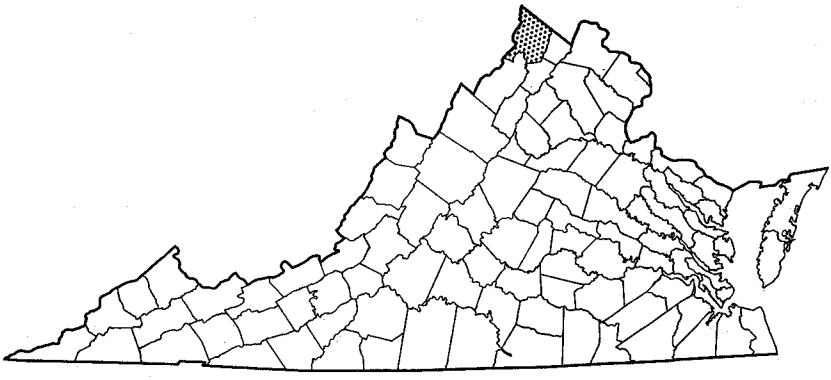

Figure 1. Index map showing location of Frederick County.

PRESENT INVESTIGATION

This report, prepared primarily for the residents of Frederick County, includes a discussion of the general geology, stratigraphy, geologic structure, and mineral resources. The geologic history that gave rise to the present land forms and the origin of the rocks and minerals are discussed briefly. The results of other investigations, including published maps and reports, have been drawn upon freely in preparing this report. The geologic map (Plate 1) shows the distribution of the various rock types (formations) and geologic structure. The use of this map, structure sections, and the accompanying descriptions in the text should give a better understanding of the natural resources and serve as a basis for more detailed exploration and testing.

OTHER INVESTIGATIONS

Roberts (1942) speaks of William Barton Rogers as being so closely identified with the foundations of geology in Virginia, his adopted State,

that he overshadows all other students during the period from 1835 to 1880. Butts refers specifically to Rogers' annual survey reports for the period 1835 to 1841, reprinted in 1884, and states that they were illustrated by a series of excellent geological cross sections of the Appalachian Valley in Virginia that have been improved only by refinement through later detailed work.

Significant contributions to the geology of Virginia were made with the publications of U. S. Geological Survey folios during the period from 1894 to 1899, but none of these geological maps included the area of this report. State geological maps that included Frederick County were published by the Virginia Geological Survey in 1911 and in 1928, and by the Virginia Division of Mineral Resources in 1963. Another geological map that covers the area of Frederick County is contained in the report by Stose and Miser (1922) on the manganese deposits of western Virginia.

Field surveys by Butts and assistants were begun in the Appalachian Valley in Virginia in 1926 and continued until 1931. The results of these investigations are included in Virginia Geological Survey Bulletin 42, "Geologic Map of the Appalachian Valley of Virginia with Explanatory Text," published in 1933, and in Bulletin 52, parts 1 and 2 (1940-41) which is complementary to the map and contains a discussion of the stratigraphy, structure, and paleontology. Many geologists have written about certain aspects of the geology of Frederick County, and others, who did not deal directly with the area, have formulated principles which are applicable here.

The iron industry in the county was reported on by Hotchkiss (1882), Holden (1907), and Bruce (1930). Manganese-ore deposits have been described, with geologic maps and charts, by Stose and Miser (1922) and by Monroe (1942). Nonmetallic resources which have been produced or investigated include raw materials for the manufacture of cement (Bassler, 1909); clay, shale, and related materials (Ries and Somers, 1920; Calver and others, 1961); silica sand (Lowry, 1954); and limestone and dolomite with respect to their chemical composition (Edmundson, 1945) and physical properties (Gooch and others, 1960). Ground-water resources have been described by Cady (1936, 1938).

The geology of Little North Mountain has been described by Giles (1927, 1942), Butts and Edmundson (1939), Edmundson (1940), and Brower (1961). Stratigraphic studies in the county include those by Swartz (1929), Cooper and Cooper (1946), Wilson (1952), Nicholas

(1954), Dennison (1961), Wood (1962), Rader (1962), and Rodgers (1964). A synthesis of stratigraphic information in the central Appalachians, including many references to Virginia, is contained in Woodward's reports on the Cambrian (1949), Ordovician (1951), Silurian (1941), and Devonian (1943) systems of West Virginia. Recent publications from neighboring states, which have proposed a revision in stratigraphic nomenclature, are cited in the text.

FIELD WORK AND ACKNOWLEDGMENTS

Most of the field work was done jointly by the writers, as a project for the Virginia Geological Survey, during the summers of 1936 to 1940. During this period the writers mapped 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. About 2 months of additional field work, including a study of industrial limestones, checking certain boundaries for the preparation of the final geologic map, and a re-examination of Little North Mountain, was done by the junior writer and assistants during the period from 1942 to 1963.

Acknowledgment is made to the late V. E. Shainin, then a student at Columbia University, who capably assisted with the study of industrial limestones in northern Virginia during the summer of 1942, and to employees of the Virginia Division of Mineral Resources, Eugene Rader who made many of the photographs and assisted with the final checking of the geologic map for a few weeks in 1963 and Richard Pharr who assisted in the measurement of a geologic section and photographed certain features in 1964. Credit is extended also to William Rodgers, then a student at the University of Virginia, who visited the area with the writer in 1964 and gave permission to use his detailed geologic section showing the rock sequence in the vicinity of Hayfield. Thanks are extended to Drs. W. B. Brent, R. L. Ellison, and R. S. Young who made field visits and gave helpful suggestions.

It was originally intended that Dr. Butts would write the stratigraphic section and the junior writer would prepare the other sections of the report. The final editing and the preparation of the geologic map were to be done jointly. The death of Dr. Butts in 1946 made it necessary for the junior writer to assume full responsibility for the preparation of the report for publication. Fortunately, his manuscript maps and a draft of the stratigraphic section were filed with the Virginia Geological Survey, thus every attempt is made in this report to carefully record the

interpretations of Dr. Butts or to document subsequent changes by the junior writer.

Much of the data presented in this report, particularly the section on economic resources, have been taken from published reports. Credit for this material is cited at appropriate places in the text. The writer wishes to thank Dr. James L. Calver, State Geologist, and other members of the Virginia Division of Mineral Resources for the editing and preparation of the manuscript for publication. Residents of the county and quarry operators have generously offered information which is incorporated in this report and which is here gratefully acknowledged.

GEOGRAPHY

TOPOGRAPHY AND DRAINAGE

Frederick County lies wholly within the Valley and Ridge province of the Appalachian Highlands and, on the basis of similar rock types and land forms, it is divided into two natural divisions. Southeast of Little North Mountain is a broad generally flat belt interspersed with low hills and ridges, whereas the northwestern part of the county is characterized by northeastward-trending mountains, some of large size, and intervening valleys. These divisions are referred to in the following discussion as the valley belt and the ridge belt.

Valley Belt

The valley belt, commonly known as Shenandoah Valley, is bounded on the northwest by Little North Mountain and on the southeast by the Blue Ridge which forms the eastern boundary of Clarke County. The total width of Shenandoah Valley is about 20 miles in northern Virginia, but only 8 to 10 miles of the belt (Figure 2) is represented in Frederick County.

West of a line passing southwestward through or near Stephenson, Winchester, and Middletown, the bedrock is predominantly limestone and dolomite, and the topography is characterized by low discontinuous ridges aligned in a northeasterly direction. Apple Pie Ridge in the vicinity of White Hall, Poplar Ridge east of Marlboro, and a prominent ridge in the western environs of Winchester are a few of the well-known examples. Profiles of the surface in this part of the county show a series of low rounded ridges and shallow valleys on a gently sloping surface that rises from an altitude of about 750 feet in the vicinity of Winchester to about 900 feet along the southeast base of Little North Mountain.

The eastern part of the valley belt which is underlain by shale and fine-grained sandstone has no conspicuous knobs or ridges. The altitude along Opequon Creek where it enters West Virginia is about 450 feet,

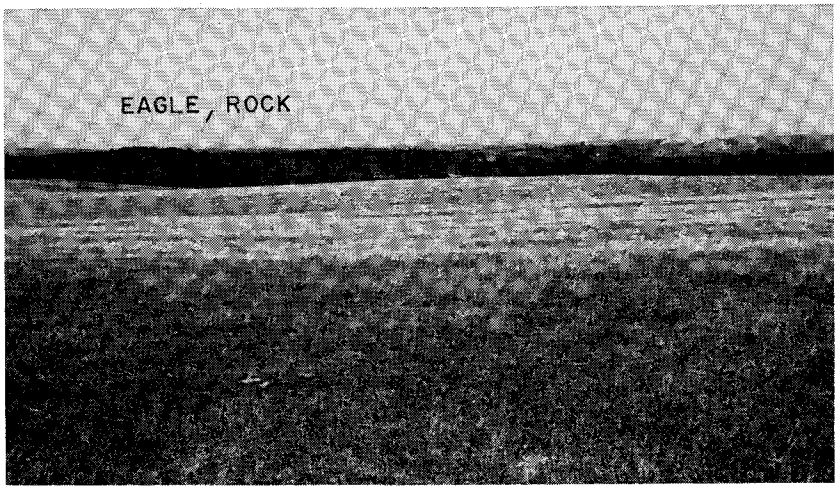

Figure 2. View from U. S. Highway 11 about 1 mile southwest of Middletown northwestward across a part of the valley belt to Great North Mountain. The first ridge on the left and a prominent knob on the right are discontinuous parts of Little North Mountain.

whereas in the southwestern part of the belt, altitudes ranging from 700 to 750 feet are common. Shallow drainage channels which cross the area become somewhat deeper and more numerous eastward, giving a branching or dendritic pattern. Interstream surfaces are flat or smoothly rounded.

Ridge Belt

Prominent features of the landscape west of Shenandoah Valley, occurring within or bordering Frederick County, are Little North, Great North (Figure 3), Cacapon, and Sleepy Creek mountains. Little North Mountain, the most easterly ridge, has an altitude of 1345 feet at the Virginia-West Virginia boundary at a point 3 miles north of White Hall. From Green Springs southwestward to Cedar Creek, it is characterized by numerous watergaps which break the continuity of the ridge. The remnants of the ridge between the gaps consist of short linear ridges (Figure 4) and isolated rounded hills (Figure 5), locally called mountains or knobs. Some of these interrupted parts of the mountain, with a height of 300 to 400 feet above the surrounding valleys, are Babbs Mountain, Round Hill, and Funkhouser Knob.

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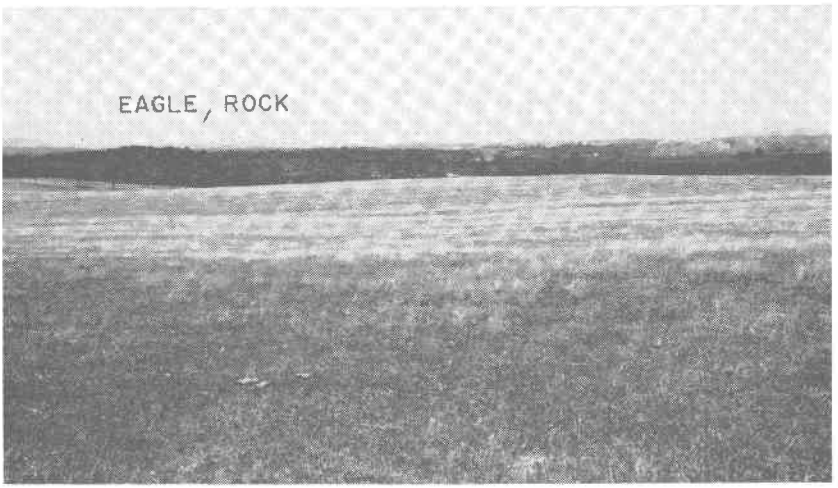

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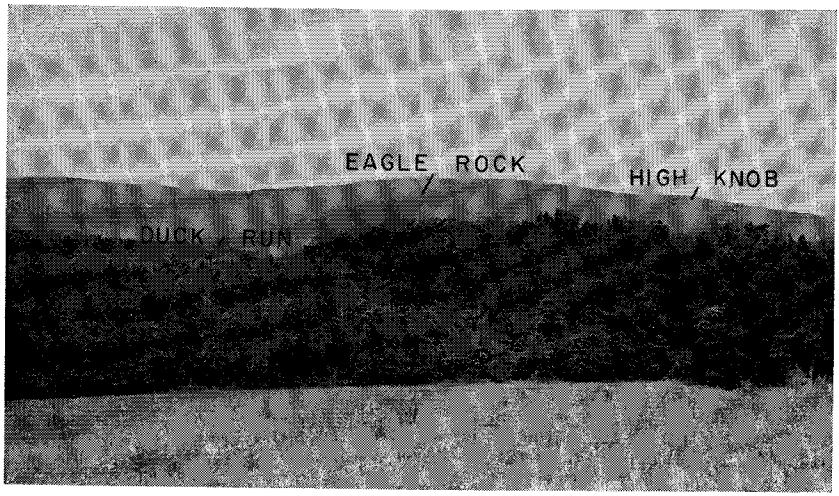
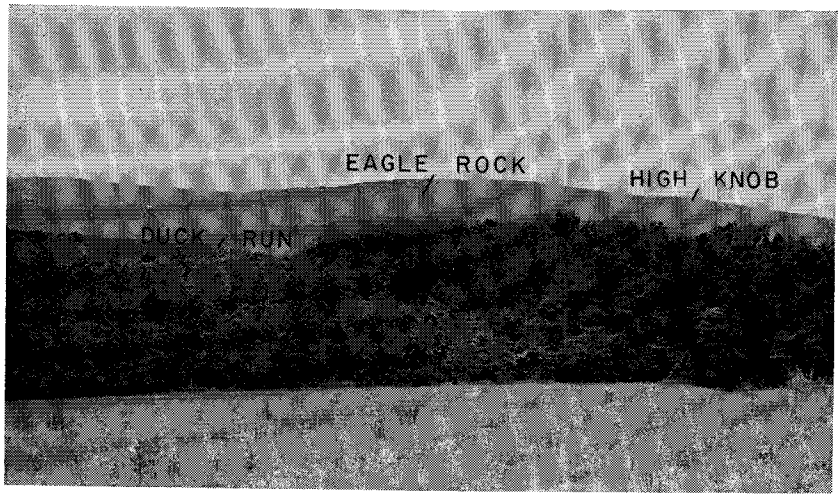


Figure 3. View of Great North Mountain from a point along State Road 600 northwest of Star Tannery. High Knob, elevation 2844 feet, is the highest point in Frederick County. South of Eagle Rock erosion has removed the resistant rocks from the crest of the Great North Mountain anticline, and the mountain splits into two distinct ridges. On the east the ridge is called Short Mountain north of Duck Run and Paddy Mountain south of the gap, and on the west along the Virginia-West Virginia boundary, the ridge is named North Mountain.

Figure 4. View of the even crest of Little North Mountain midway between Hoop Petticoat and Wisecarver gaps. The monoclinal ridge is underlain by 150-200 feet of Tuscarora sandstone. Looking westward from a point 1 mile south of Opequon.



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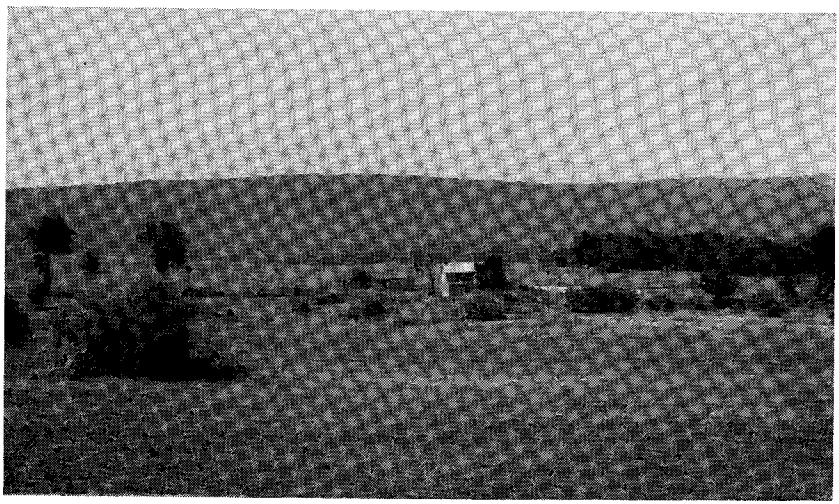

Figure 4. View of the even crest of Little North Mountain midway between Hoop Petticoat and Wisecarver gaps. The monoclinal ridge is underlain by 150-200 feet of Tuscarora sandstone. Looking westward from a point 1 mile south of Opequon.

Northwest of Little North Mountain, between Chambersville and Hayfield, are a series of low parallel ridges, such as Whisson and Hunting ridges, and narrow valleys which drain into Hogue Creek. The valley

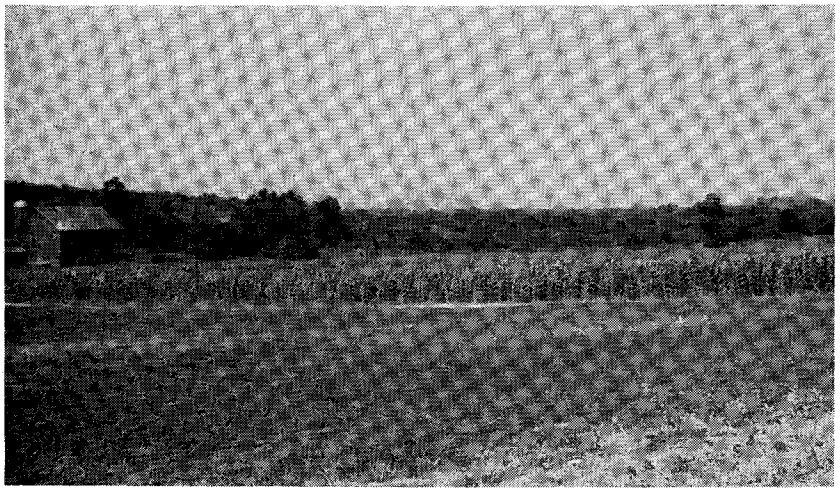

Figure 5. Round Hill just north of Hoop Petticoat Gap is one of the conspicuous knobs along the trend of Little North Mountain which is underlain by a thick lens of Tuscarora sandstone. Looking northward from a point 1 mile south of Opequon.

occupied by Hogue Creek is bounded on the northwest by Great North Mountain which is the most conspicuous landmark in western and southwestern Frederick County. Great North Mountain begins as a distinct ridge along U. S. Highway 50, midway between Gore and Hayfield, and persists with increasing prominence southwestward across the county. Altitudes range from about 800 feet at the northeast end to 2844 feet at High Knob (Figure 3) along the West Virginia boundary northwest of Mountain Falls. Farther southwest at a point about 1 mile northeast of Duck Run the mountain splits into two distinct ridges —Paddy Mountain on the east and North Mountain on the west. The crest of Great North Mountain, especially when viewed from a distance, is remarkably even. There are, however, small subordinate ridges and deep narrow valleys on the flanks and near the base of the mountain. Flint Ridge is one of the minor ridges that is prominent southwest of Hayfield. It continues around the northeast end of the mountain and connects with Sand Ridge southwest of Gore.

The area between Great North Mountain and Big Timber Ridge along the Virginia-West Virginia boundary west of Gore is somewhat similar to Hogue Creek valley in having a series of low, parallel

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The area between Great North Mountain and Big Timber Ridge along the Virginia-West Virginia boundary west of Gore is somewhat similar to Hogue Creek valley in having a series of low, parallel

northeastward-trending ridges and valleys. From east to west, along a line about 2 miles southwest of U. S. Highway 50, the ridges are named Sand, Cove, Gallows, Cappers, Little Timber, and Big Timber. Big Timber Ridge along the Virginia boundary has an average altitude of 1250 feet. The extreme northwest corner of the county includes parts of Cacapon and Bear Garden mountains. The highest altitude along Cacapon Mountain in Virginia is 2564 feet.

Between Bear Garden Mountain and Shockeysville, at the southwest base of Sleepy Creek Mountain, there are several ridges that rise 100 to about 300 feet above the intervening valleys. From west to east these are named Big Timber, Little Timber, Dick, Railroad, and Winding ridges. Sleepy Creek Mountain, a prominent ridge in West Virginia, ends rather abruptly at Shockeys Knob, which is located along the Virginia-West Virginia boundary about 1 mile northeast of Shockeysville. The altitude of Shockeys Knob is 1865 feet or approximately 1000 feet above the broad valley around the southwest base of the mountain.

Back, Cedar, and Sleepy creeks are the principal drainage systems in the ridge belt. Back Creek, Isaacs Creek northwest of Great North Mountain, and Hogue Creek on the southeast side unite at a point about 3 miles northeast of Gainesboro and flow thence northeastward across the county toward the Potomac River. A few tributary streams flow from the western part of the valley belt through gaps in Little North Mountain to connect with the drainage in the ridge belt. The extreme northwestern part of Frederick County, between Dick Ridge and Bear Garden Mountain, is drained by Sleepy Creek which flows northeastward into West Virginia.

The ridge belt southwest of a low divide extending northwest of Stephens City and east of Great North Mountain is a part of the Cedar Creek drainage area. Cedar Creek flows northeastward along the southeast side of Paddy Mountain, turns eastward through a gap in Little North Mountain west of Marlboro, and then continues in a southeasterly direction to Shenandoah River. It is a tortuous stream that forms a natural boundary between Frederick and Shenandoah counties for a distance of approximately 15 miles.

CLIMATE

Temperature and precipitation data (Rice, 1959, p. 6) from the U. S. Weather Bureau Station at Winchester for the period 1931-1955 are as follows:

Averages for the period	Temperature (°F)	Precipitation (inches)
January	35.4	2.45
February	36.1	1.97
March	43.6	3.23
April	53.8	3.02
May	64.3	4.29
June	72.3	3.83
July	76.3	4.00
August	74.4	4.30
September	68.0	3.01
October	57.5	3.44
November	46.0	2.82
December	36.2	2.53
Annual	55.3	38.89

The range in temperature between the average for January and July, the coldest and hottest months, is about 41°F, and the annual mean temperature is about 55°F. Average annual precipitation is 38.89 inches.

Distinct variations in temperature are recorded for the county. A climatic summary of 27 years of U. S. Weather Bureau records at Winchester and 12 years of records at Stephens City, prior to 1940, is given by the U. S. Department of Agriculture (1941, p. 1159). During this period the highest temperature recorded in the county was 107°F. at Winchester and the lowest was −17°F at Stephens City.

For the period 1921-1950, the freeze data from the Winchester station (Rice, 1959, p. 5) gives the mean date of the last spring freeze as April 19 and the mean date of the first fall freeze as October 22. These records show that the average growing season, between killing frosts in the spring and fall, at Winchester over a period of 30 years is 186 days.

LAND USE AND POPULATION

Frederick County, with an area of 433 square miles or approximately 279,040 acres, is an important agricultural district in the Commonwealth. According to the U. S. Bureau of the Census (1961, p. 165), about 63 percent of the total area, or 175,770 acres, was in farms in 1959. Of this amount 47,388 acres is cropland harvested. The total value (U. S. Bureau of the Census, 1961, p. 173) of all farm products sold in 1959 was $9,816,110, and the value of fruit included in this total was

$6,027,191. Frederick County, exclusive of Winchester, Middletown, and Stephens City, had a population of 21,941 in 1960 as reported by the U. S. Bureau of the Census (1962). This is an increase of about 25 percent in population over the 1950 census. Winchester with a population of 15,110 in 1960 represents a net gain of 1269 or 9.2 percent over the preceding census.

HISTORY AND EARLY SETTLEMENT

More than a hundred years elapsed after the founding of the Jamestown Colony before Governor Spotswood and his Knights of the Golden Horseshoe entered the Great Valley in 1716. As a matter of comparison, Virginia east of the Blue Ridge had begun regular and systematic administration of law as early as 1619. In 1720 the General Assembly passed an act for the erection of Spotsylvania County which, in addition to the territory east of the Blue Ridge, included the fertile region of the lower Shenandoah Valley. Subsequently, in 1734 Spotsylvania was divided, and its northern half became the County of Orange. Two counties were created by the Colonial Assembly of Virginia in 1738 and included within their boundaries all of the territory west of the Blue Ridge claimed by Virginia. The county on the north was called Frederick, after Frederick, the Prince of Wales, son of George II, and the other, Augusta, after the wife of Prince Frederick. A reduction in the area of Frederick County followed when Hampshire County was formed in 1752, Shenandoah and Berkeley counties in 1772, and Clarke and a part of Warren County in 1836.

The following quotations, as well as the preceding outline of the history of Frederick County, are from the pen of Judge Philip Williams (1930, p. 9-18) of Winchester.

> "The first permanent white settlement within the present boundaries of Frederick County was made in the spring of the year 1732. Hans Jost Heydt, a German and a native of Strassburg, but later a resident of Pennsylvania, purchased from John and Isaac Vanmeter, orders issued by the Governor and Council of Virginia, authorizing the settlement of forty thousand acres of land in the Shenandoah Valley, upon the condition that at least one family for each thousand acres should be settled upon the land within two years from the issuance of the orders.
>
> "Heydt collected a party of sixteen families.... They set out from Little York in Pennsylvania and traveled southward by way of the Cumberland Valley to the Potomac, which they crossed near the site of Shepherdstown, and continued their way into the valley of the Shenandoah. Heydt located his forty thousand acres largely in what is now

Frederick County, and there he erected his stone dwelling on the head-waters of the Opequon, about five miles south of where Winchester was afterward located.

* * * * *

"Though Frederick County was established by law in 1738, no organization of the County government took place until five years later, due probably to a lack of residents qualified to fill the required offices. On the eleventh day of November, 1743, at the residence of Colonel James Wood, situated in what is now the western suburbs of Winchester, the first court for Frederick County was convened.

* * * * *

"James Wood, the first clerk of Frederick County, was a native of Winchester, England. He was young, enterprising, well-educated, and a skillful surveyor.... He had evidently been attracted by the beauty and fertility of the Valley, and had selected as a site for his homestead, a picturesque glen through which meandered a stream of clear water from a group of fine springs. By virtue of an order obtained from the Governor and Council of Virginia, he had surveyed twelve hundred acres of land about this site. At the head of the glen, he had built his house, which he appropriately named 'Glen Burnie'....

"On this tract of land, about a mile eastwardly from his residence, James Wood laid off a site for a town.... This town became the county seat and was at first [1744] called Frederick Town.

* * * * *

"....By an act of the General Assembly of 1752, the county seat was chartered as a town by the name of Winchester, and 54 additional half-acre lots were annexed by Lord Fairfax to the 26 lots laid out by James Wood. Later, in 1758, James Wood added 106 acres to the Town, and in the following year it was still further enlarged by Lord Fairfax when he added 173 lots."

TRANSPORTATION FACILITIES

Frederick County has a good network of primary and secondary roads that are well maintained. U. S. Highway 11 enters Virginia near Rest and crosses the county in a southwesterly direction, passing through Clearbrook, Winchester, Stephens City, and Middletown. U. S. Highways 50 and 522 cross the county in a southeasterly direction and intersect U. S. Highway 11 in Winchester. Alternate U. S. Highway 340 coincides with State Highway 7 east of Winchester and with U. S. Highway 522 south-southeast of Winchester. Other State Highways are 277, connecting Stephens City with U. S. Highway 522, and 55 along Duck Run west of Star Tannery. Interstate Highway 81, now under construction, is parallel to U. S. Highway 11. Branch lines of the Baltimore and Ohio and Pennsylvania railroads provide freight service

in the eastern part of the county. Another branch line, the Winchester and Western Railroad, connects with the Baltimore and Ohio at Winchester and serves the glass-sand industry at Gore.

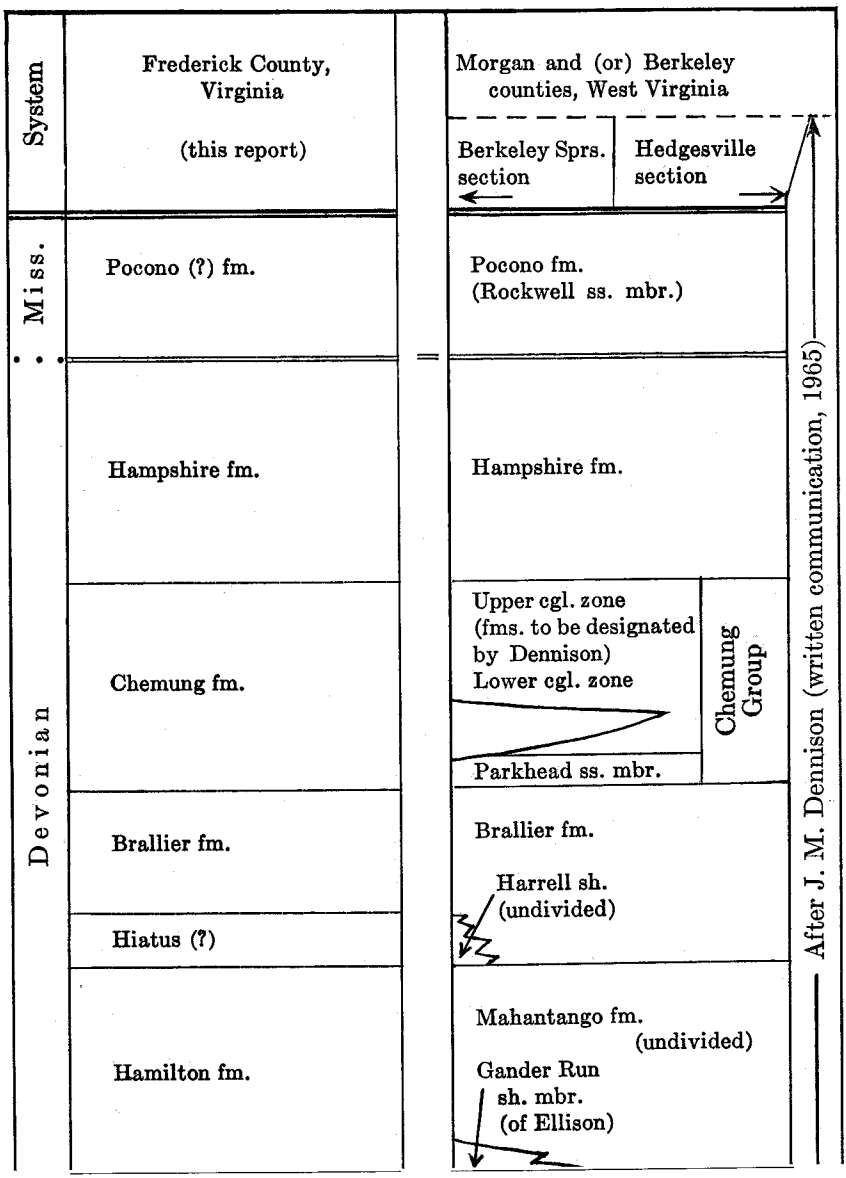
STRATIGRAPHY

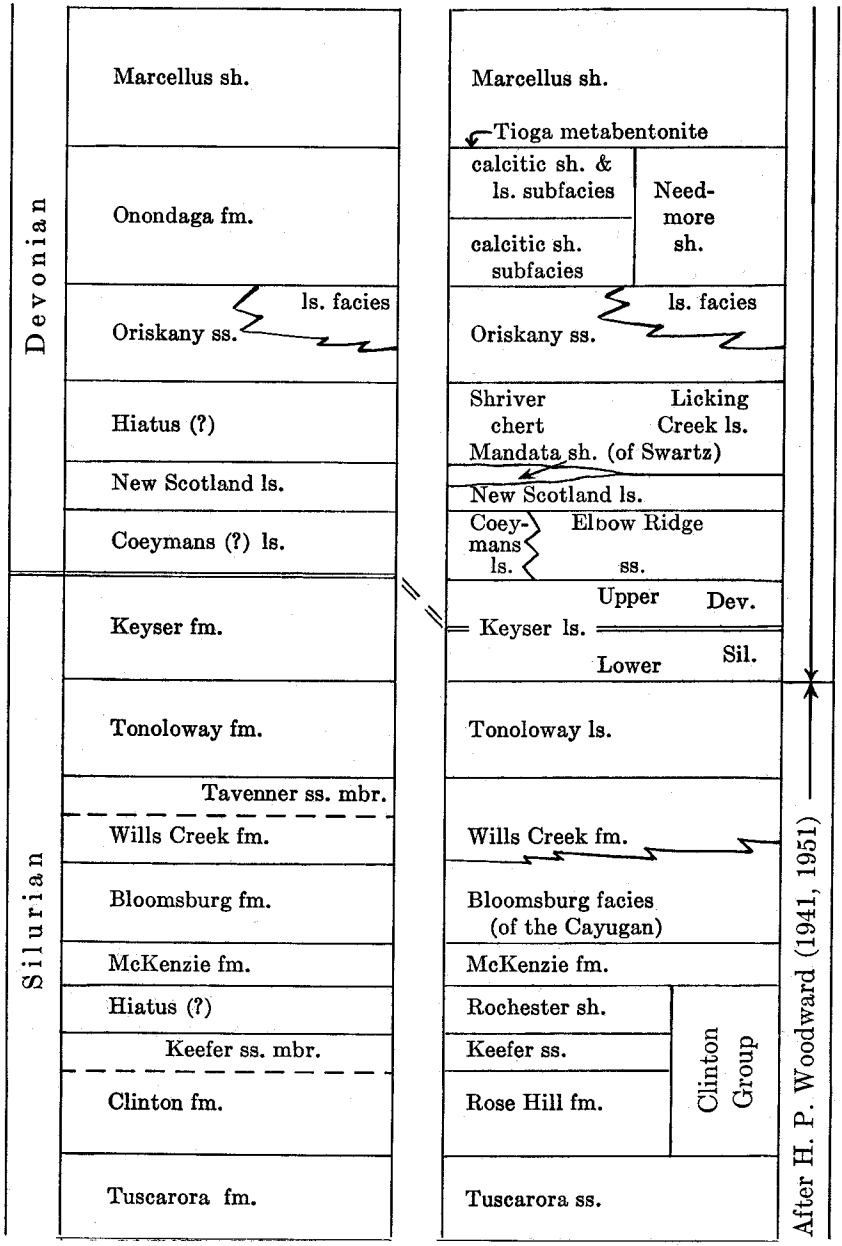
This section was prepared by the late Dr. Charles Butts in 1943. Some of his stratigraphic descriptions, supplemented by measured sections and chemical analyses of the rocks, and the geologic maps of the Shenandoah Valley part of Frederick County, were published in a report on the industrial limestones and dolomites (Edmundson, 1945).

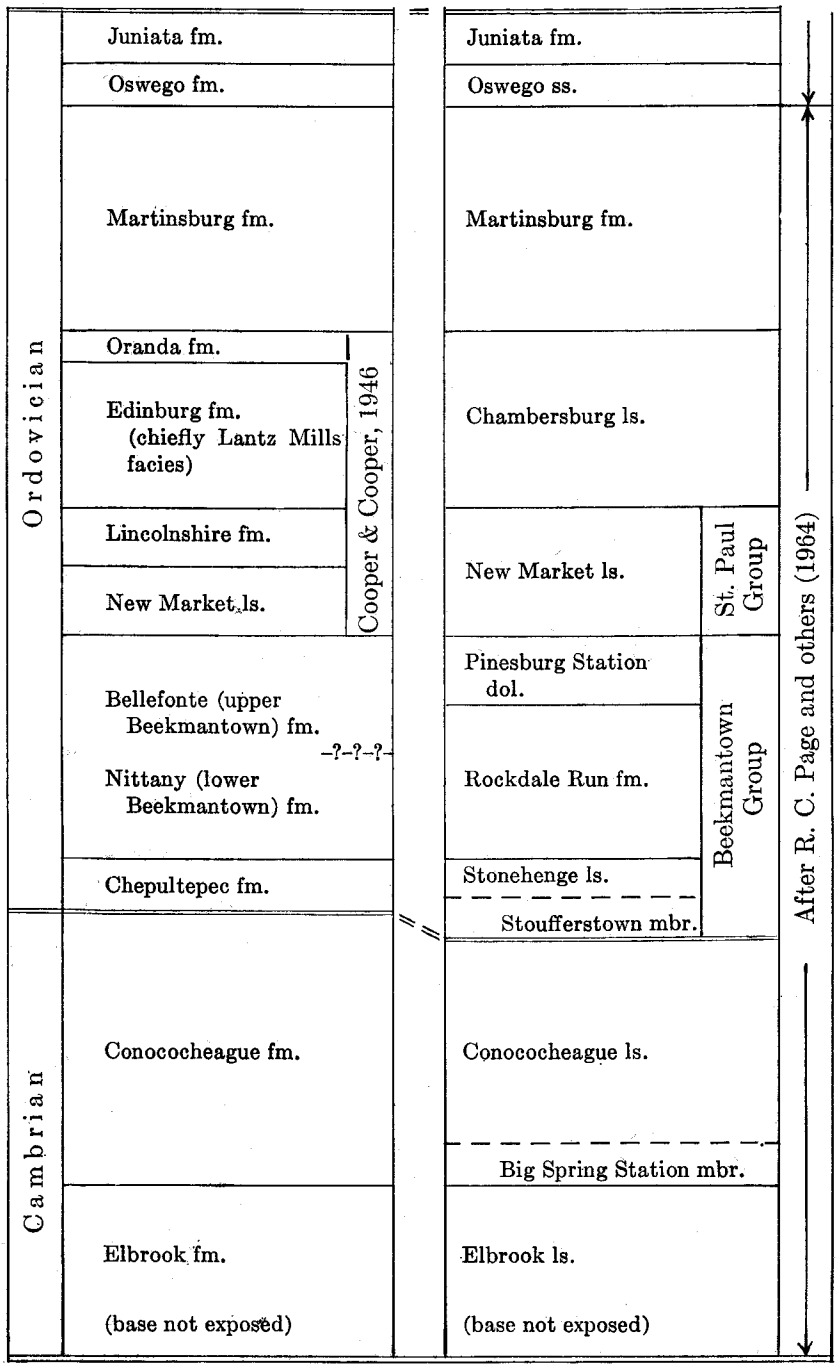
Stratigraphic nomenclature presents a problem in this report, because so much careful stratigraphic work has been done in Virginia and nearby states in recent years. After due consideration and with the approval of the State Geologist of Virginia, the nomenclature used by Butts, except for the lower Middle Ordovician, is retained. Other revisions proposed in the literature, some referring specifically to Frederick County, are cited in the text and, in the junior writer's opinion, should be considered by future workers in Shenandoah Valley, Virginia.

The rock strata cropping out in Frederick County are, on the basis of their lithologic character and fossils (Appendix II), subdivided into formations; the names of which are given in Table 1. These formations originated at the bottom of the sea as deposits of sediments discharged by the rivers throughout most of the Paleozoic era. The process still continues. For example, the Mississippi River discharges large quantities of sediment into the Gulf of Mexico each year, and these sediments settle to the bottom of the Gulf to form rock formations of the future. From this manner of origin the formations at the bottom are the oldest, and those at the top the youngest. In a discussion of stratigraphy, it is usual to begin with the oldest formation and then continue with the description of the successive younger units.

Table 1.—Stratigraphic nomenclature used in this report and in adjacent Morgan and (or) Berkeley counties, West Virginia. This is not a correlation chart and stratigraphic thickness is not portrayed.




Devonian
Silurian
Marcellus sh.
Onondaga fm.
ls. facies
Oriskany ss.
Hiatus (?)
New Scotland ls.
Coeymans (?) ls.
Keyser fm.
Tonoloway fm.
Tavenner ss. mbr.
Wills Creek fm.
Bloomsburg fm.
McKenzie fm.
Hiatus (?)
Keefer ss. mbr.
Clinton fm.
Tuscarora fm.
Marcellus sh.
Tioga metabentonite
calcitic sh. & ls. subfacies
calcitic sh. subfacies
Need-more sh.
ls. facies
Oriskany ss.
Shriver chert
Licking Creek ls.
Mandata sh. (of Swartz)
New Scotland ls.
Coey-mans ls.
Elbow Ridge ss.
Upper
Dev.
Keyser ls.
Lower
Sil.
Tonoloway ls.
Wills Creek fm.
Bloomsburg facies (of the Cayugan)
McKenzie fm.
Rochester sh.
Keefer ss.
Rose Hill fm.
Clinton Group
Tuscarora ss.
After H. P. Woodward (1941, 1951)


Ordovician
Juniata fm.
Oswego fm.
Martinsburg fm.
Oranda fm.
Edinburg fm. (chiefly Lantz Mills facies)
Lincolnshire fm.
New Market ls.
Cooper & Cooper, 1946
Bellefonte (upper Beekmantown) fm.
-?-?-?-
Nittany (lower Beekmantown) fm.
Chepultepec fm.
Cambrian
Conococheague fm.
Elbrook fm.
(base not exposed)
Juniata fm.
Oswego ss.
Martinsburg fm.
Chambersburg ls.
New Market ls.
St. Paul Group
Pinesburg Station dol.
Rockdale Run fm.
Beekmantown Group
Stonehenge ls.
Stoufferstown mbr.
Conococheague ls.
Big Spring Station mbr.
Elbrook ls.
(base not exposed)
After R. C. Page and others (1964)

CAMBRIAN SYSTEM

Elbrook Formation[1]

The Elbrook, which is the oldest bedrock exposed in Frederick County, derives its name from Elbrook, Franklin County, Pennsylvania, where it was named by Stose (1906, p. 209) as the Elbrook limestone. The main outcrop (Plate 1) of the formation is along the southeast slope of Little North Mountain, beginning on the north 1 mile south of Nain and extending thence southwestward to Shenandoah County. A second outcrop begins as a narrow wedge near the Cedar Creek Grade (State Road 622) about 2 miles southwest of Winchester, continues northward through White Hall into West Virginia, increasing to a width of 0.5 mile at White Hall. Apple Pie Ridge is on this belt north of U. S. Highway 522. A third smaller, lozenge-shaped area midway between the other two belts, crosses U. S. Highway 50 about 2.5 miles west of Winchester. Each of these belts of Elbrook is bounded on the northwest by a fault along which the Elbrook has been thrust over younger, and normally much higher, rocks in the stratigraphic section. West of Apple Pie Ridge and north of Cedar Grove the Elbrook is thrust over the Conococheague formation, whereas to the north it is in contact with the Chepultepec and lower part of the Beekmantown. The Elbrook belt along Little North Mountain is for most of its length in Frederick County thrust upon the Martinsburg formation.

An examination of several incomplete exposures of the Elbrook indicates that it is composed of limestone and argillaceous limestone with only minor amounts of dolomite. The purer limestone is rather thick bedded, whereas the argillaceous parts are thinner bedded and weather out as rusty-looking slabs and laminae. It has not been determined whether these lithologic units have any persistent stratigraphic arrangement. The argillaceous, rusty-weathering materials are the best criteria for the recognition of the Elbrook. Some areas lacking exposures of bedrock are strewn with fragments of rusty, crumbly rock suggesting shale. Such material is abundant on the ridge 0.5 mile west of Marlboro.

A complete section of the Elbrook is not exposed in Frederick County. The thickness, as determined from its widest outcrop and its dip west of St. Stephens Church, Shenandoah County, is 2000 feet. This thickness does not represent a full section because the lower contact is not exposed, but estimating from the width of outcrop in the vicinity

[1]Although terms such as limestone, shale, etc. were used by the senior writer for many of the mapped units, the less definitive term formation has been used in this discussion for units which have marked variations in lithology.

of Milldale in adjoining Warren County, the thickness cannot exceed 2500 feet.

The Elbrook is sparingly fossiliferous in this area as well as throughout the Appalachian Valley generally. Some pieces of limestone crowded with trilobite remains, mostly fragments, were found on the bluff of Cedar Creek 0.5 mile northwest of Marlboro (Plate 1) and probably were derived from the lowermost beds of the Elbrook. One imperfect head was tentatively referred by Resser to *Glyphaspis,* and two fairly complete tails to *Glossopleura.* Both genera are of Middle Cambrian age. Resser (1938, p. 79, pl. 7) reports that *Glossopleura bassleri* occurs near the bottom of the formation in the vicinity of Waynesboro, Pennsylvania. As Nolichucky fossils (Late Cambrian) occur in the upper part of the limestone included in the Elbrook east of Abingdon, Washington County, Virginia, there is a possibility that the upper part of the Elbrook in Frederick County may be of Late Cambrian age. However, there are no beds in Frederick County corresponding lithologically to the Nolichucky shale which, south of New River, occupies a position between the Honaker dolomite, equivalent to the lower part of the Elbrook, and the Conococheague limestone. No Nolichucky fossils have been found in the lower part of the Conococheague or in the upper part of the Elbrook. In the writer's opinion the Nolichucky is represented in the top of the Elbrook, or, if not, is absent in Frederick County, so that there is a hiatus between the Elbrook and the Conococheague. Resser and others, however, are inclined to think that the Nolichucky is represented in the lower part of the Conococheague. Wilson (1952, p. 304-305), who has made detailed stratigraphic and paleontologic studies of the Upper Cambrian formations in the Cumberland-Shenandoah valleys, reports that: "Several of the common Dresbachian [Upper Cambrian] genera range down into the Elbrook below the base of the Conococheague and are found about 800 feet below the top of the Elbrook at one locality."

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 Conococheague (Plate 1) occupies a wide strip of the county extending northeastward from Cedar Creek, 4 miles northwest of Middletown, to West Virginia, 2.5 miles northeast of White Hall. The width of this belt is about 1.5 miles along Cedar Creek but is increased by folding and faulting to double that width north of the

latitude of Stephens City. From the vicinity of Winchester northeastward to Green Springs, the Conococheague is repeated by faulting, with the Elbrook along Apple Pie Ridge separating the two belts.

The Conococheague is predominantly a limestone in Frederick County but, like most of the older limestones of the Appalachian Valley, it contains beds of dolomite of varying, but generally small, thickness scattered through it, and making perhaps 10 percent of the whole. The limestone is marked by two distinctive features, clayey or sandy crinkly laminae (Figure 6) and extensive beds of intercalated sandstone. When the limestone weathers, especially beneath the surface of the ground, the clayey or sandy laminae are left projecting from the surface of the beds. The thicker sandstone beds are generally composed of well-rounded grains of quartz cemented into a solid mass by interstitial limestone. On outcrop the limestone cement is dissolved out, leaving projecting layers or boulders of sandstone. Owing to their greater resistance to solution and erosion, these beds of sandstone lead to the formation of conspicious ridges which, in some instances, can be traced for several miles by the sandstone debris along their crests. These sandstones are helpful in the interpretation of geologic structure, since in many instances they can be traced by their debris around the axes of minor folds that otherwise could not be detected in a homogeneous thick mass of limestone. So far as known, the beds of sandstone are not confined to any stratigraphic horizon but occur sporadically throughout the full thickness of the formation. Nicholas (1954, viii) examined exposures of the Conococheague in Shenandoah Valley from Staunton to Winchester and reports that:

> "Two distinct sandy zones are recognized in the outcrop belts west of the Massanutten syncline but only one such zone east of the syncline, along the eastern edge of the valley. The lower sandy beds which occur generally near the base of the formation belong to the Big Spring Station member [name proposed by Wilson to emphasize its importance both in areal mapping and stratigraphic correlation]. A higher succession of arenaceous beds near the top of the formation is persistent throughout the area, but individual sandy beds lense out along the strike."

The strongly laminated beds of limestone and the ridge-making sandstones are criteria for the recognition of the Conococheague. The top of the Conococheague is marked by a distinctive bed of laminated limestone that is persistent throughout Frederick County. It weathers to a ragged "worm-eaten" surface and is resistant enough to make a rather conspicuous terrace at places along its outcrop. There are also a few impure beds which have distinctive mudcracks (Figure 7).

The width of the outcrop belt in Shenandoah County, 3 miles northwest of Strasburg, is 4000 feet. Here the average dip is about 40° SE., and an approximate thickness of about 2500 feet is computed.

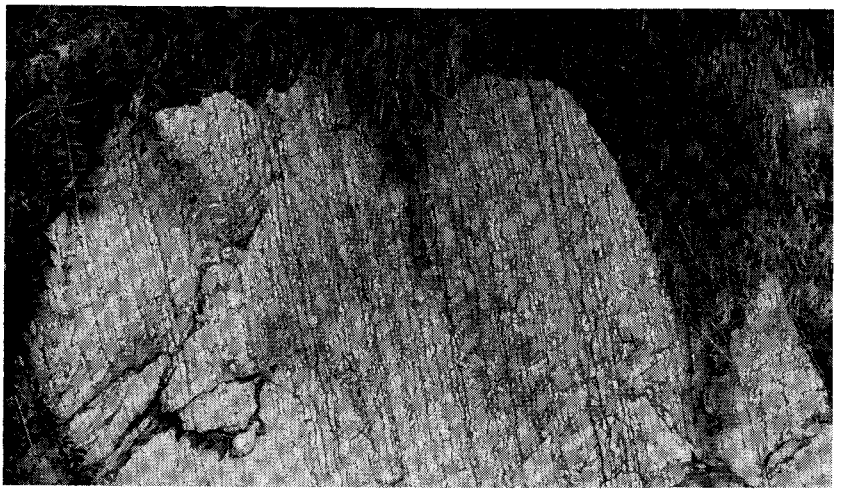


Figure 6. Crinkly siliceous laminae in the upper part of the Conococheague limestone exposed along State Road 631 about 1.5 miles northwest of Stephens City.

Another outcrop belt about 1 mile west of White Hall has a width of about 2500 feet; thus the thickness in the northern part of Frederick

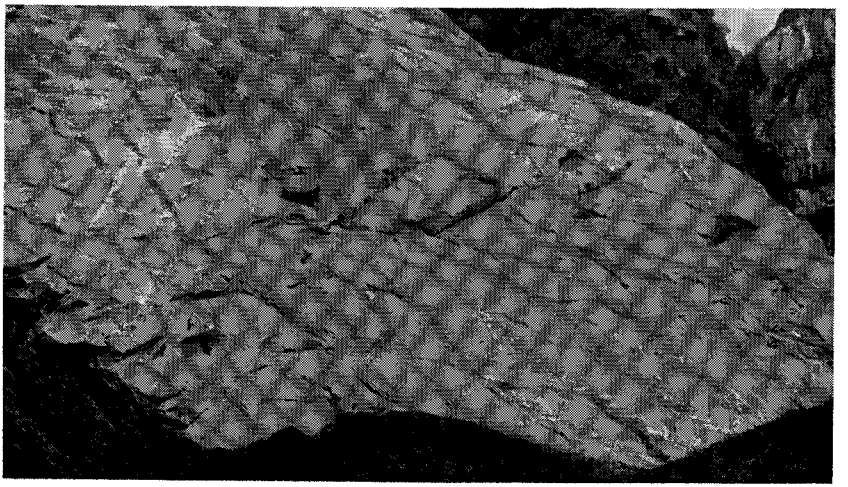
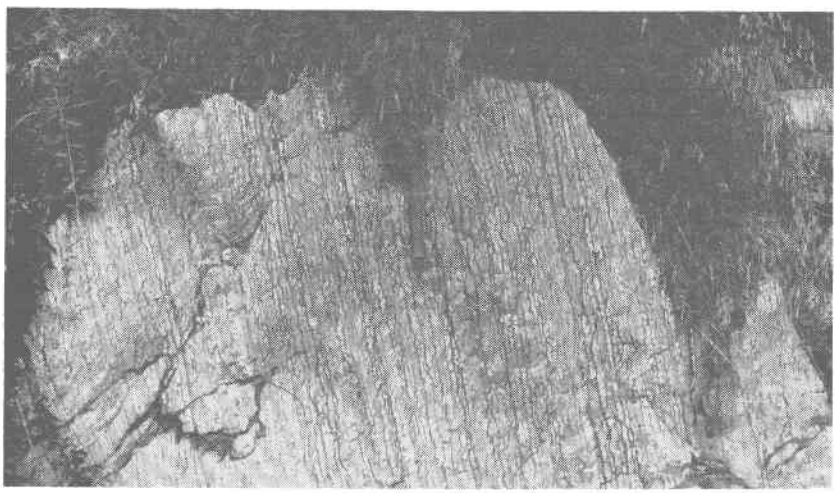


Figure 7. Mudcracks in the Conococheague formation. Block detached from the east wall of the Stuart M. Perry, Inc., quarry about 2.5 miles west of Winchester.

The width of the outcrop belt in Shenandoah County, 3 miles northwest of Strasburg, is 4000 feet. Here the average dip is about 40° SE., and an approximate thickness of about 2500 feet is computed.



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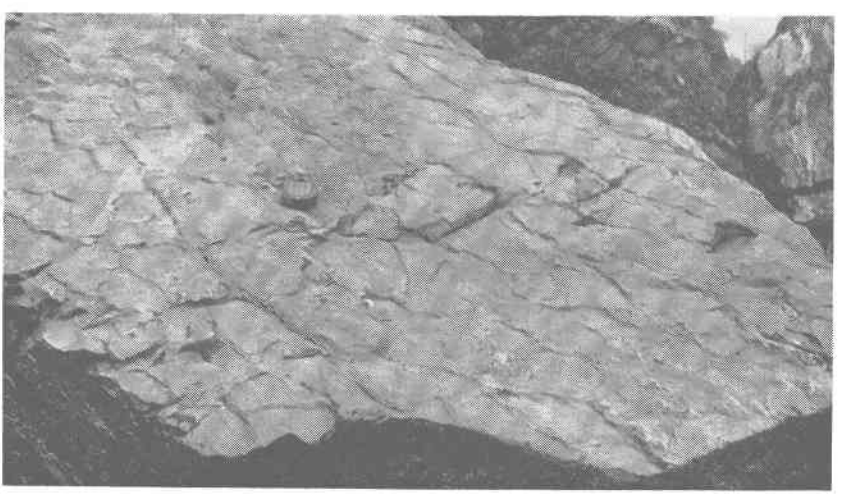

Figure 7. Mudcracks in the Conococheague formation. Block detached from the east wall of the Stuart M. Perry, Inc., quarry about 2.5 miles west of Winchester.

County is approximately 2000 feet. It appears that an average thickness of about 2250 feet is the best determination possible under the conditions observed in the field. The greater width of outcrop in most of Frederick County is plainly due to folding and faulting, both of which are apparent on the geologic map (Plate 1).

The Conococheague is sparingly fossiliferous. Trilobites, *Tellerina wardi,* have been collected in the western environs of Winchester and along a secondary road 3 miles northwest of the intersection of U. S. Highway 11 and State Highway 55 in Strasburg, and *Symphysurina* has been noted at a locality about 3.5 miles northwest of Marlboro. The fossils occur in a partially decalcified, calcareous sandstone. At Scotland, Franklin County, Pennsylvania, a species of *Tellerina* and *Saukia stosei* occur in the Conococheague. Both of these genera occur in the higher formations of the Upper Cambrian of Wisconsin which overlie formations corresponding to the Nolichucky of the southern Appalachian Valley. Since the Conococheague overlies the Nolichucky and also contains some genera of trilobites that occur in the higher formations of the Upper Cambrian of Wisconsin, most geologists regard the Conococheague as of Late Cambrian age.

Wilson's studies (1952, p. 308) of the Upper Cambrian formations in the Shenandoah-Cumberland Valley, including a section near Winchester, show that:

> "Trilobites of Dresbachian age are found always below in the Elbrook and in limestones interbedded with the orthoquartzite beds of the Big Spring Station member. Franconian trilobites occur about 300 feet above the top of the member. On the other hand, Trempealeauian trilobites and brachiopods occur associated with the upper sandy beds of the Conococheague when the latter are present. The section at Winchester, Virginia, demonstrates the complete stratigraphic relations, for here trilobites of all three Upper Cambrian stages are present, and both sequences of orthoquartzite beds are well developed, one about 1400 feet above the other."

Stratigraphic reference sections of Elbrook and Conococheague formations in Berkeley and Jefferson counties, West Virginia, have been described recently by Donaldson and Page (1963), and the units have been mapped by Page and others (1964) in the Martinsburg area.

ORDOVICIAN SYSTEM

Chepultepec Formation

This formation was named by Ulrich (1911, p. 638) as the

Chepultepec limestone from the village of Chepultepec, Blount County, Alabama, just west of which it is exposed and highly fossiliferous. In Frederick County, the Chepultepec crops out in a narrow strip, about 500 feet wide, from Cedar Creek, 3 miles northwest of Middletown, to West Virginia. The outcrop is sinuous due to offsetting by overlapping (*en echelon*) folds and minor faults. There is also a narrow strip 2.5 miles long, adjacent to a fault, 0.5 mile west of White Hall, and a small lozenge-shaped area, also adjacent to a fault, crossing U. S. Highway 50, 2.5 miles west of Winchester.

The Chepultepec is, as a rule, a thick-bedded limestone which differs from the Conococheague in the absence of sandstone and the absence or rare occurrence of siliceous laminae. Its lower boundary is marked by the siliceous, laminated, "worm-eaten" bed forming the top of the Conococheague, and its upper limit is marked by the occurrence of limestone with dolomite containing *Lecanospira* and forming the Nittany division of the next overlying formation, the Beekmantown. In places, such as along the belt of outcrop southwest of Stephens City, the limestone near the base of the Chepultepec is extremely massive and projects like great boulders or walls above the surface of the ground.

The Chepultepec is best exposed at the south end of a pitching anticline on the Wright farm about 3 miles slightly southwest of Stephens City. There are other good exposures on a characteristic bench about 1000 feet west of State Road 628 due west of Kernstown, and at a locality just west of U. S. Highway 11 in the southern environs of Winchester, about 0.5 mile southwest of the intersection of U. S. Highways 11 and 50. At the latter locality the siliceous bed at the top of the Conococheague is exposed, and the relations of the Chepultepec to the Conococheague can be seen. Probably one of the most accessible places to see a nearly complete section of the formation is on the east side of the ridge just north of Star Fort and about 1.5 miles north of Winchester. The thickness of the Chepultepec computed from the width of outcrop and average dip at a locality 0.8 mile due west of Minebank Ford, Shenandoah County, and nearly 4 miles west-northwest of Middletown is 350 feet. At Star Fort it is about 280 feet thick. Since precise measurements are hardly possible, 300 feet may be taken as the approximate thickness.

The Chepultepec is moderately fossiliferous. The most abundant forms are small, curved cephalopods with closely spaced septa belonging to the genera *Dakeoceras* and *Cyrtocerina*. Gastropods of the genera *Helicotoma, Ozarkina, Gasconadia,* and *Ophileta* and a few brachiopods,

such as *Finkelnburgia virginica* and *Tetralobula delicatula,* occur and are characteristic. In Frederick County the identification of the Chepultepec rests mainly upon the presence of the curved cephalopods. These forms are scarce and hard to find, but adequate search rarely fails to be rewarded by a few specimens. The brachiopod, *Tetralobula,* is very abundant in the massive limestone which crops out in the southern environs of Winchester and at the locality previously mentioned west of Kernstown. *Tetralobula* in the same belt has been noted as far south as the vicinity of Quicksburg, Shenandoah County. *Ophileta hunterensis,* occurring on the Wright farm, indicates the partial equivalence at least of the Chepultepec with the Tribes Hill limestone of New York that usually has been regarded as of basal Beekmantown age and to be represented in the Stonehenge limestone of central Pennsylvania. The curved cephalopods and some of the gastropods also indicate equivalence of the Chepultepec with the Gasconade limestone of Missouri and the Oneota limestone of Wisconsin.

The nomenclature of Lower and lower Middle Ordovician rocks used in this report and the revised nomenclature used in neighboring states are shown in Table 1. The basis for drawing the Cambrian-Ordovician boundary, considered by Butts to be the base of the Chepultepec in Frederick County, was the siliceous, laminated, "worm-eaten," easily recognizable bed forming the top of the Conococheague. In Maryland, Sando (1957) described the Stonehenge limestone, the basal formation of the Beekmantown group, as overlying conformably the Conococheague. With reference to the Cambrian-Ordovician boundary, Sando (1957, p. 16) stated: "The occurrence 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 Ordovician 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. Two sections of the Stonehenge limestone in Frederick County, described by Wood (1962, p. 36-48), show *Symphysurina* as occurring about 30 feet below the top of the Stoufferstown member. Five sections measured by Wood, between Winchester and Timberville, Rockingham County, show that the lower member of the Stonehenge ranges in thickness from about 30 to 100 feet.

Beekmantown Formation

The name Beekmantown was proposed by Clarke and Schuchert (1899, p. 874-878) from the small village of Beekmantown, Clinton County, New York. It thus happens that this small village has given a name to one of the most important formations in the Appalachian Valley. The Beekmantown crops out in a sinuous belt across the county from Cedar Creek northwest of Middletown to West Virginia, where it crosses the State line on both sides of U. S. Highway 11. The belt is widest northwest of Middletown, where, because of a number of subordinate folds and a fault, its width is increased to several times its narrowest part west of Stephens City. These minor folds, as well as others farther northeast, in addition to a fault west of Kernstown, cause conspicious offsets in the outcrop. Two other small belts with faulted relationships are located northwest of White Hall at the southeast base of Little North Mountain and at the southeast corner of Frederick County.

The Beekmantown in Frederick County (Edmundson, 1945) is composed of interbedded, fine-textured, bluish-gray limestone and finely crystalline gray dolomite. An estimate based on several incompletely exposed sections indicates that the ratio of limestone or magnesian limestone to dolomite for the full thickness of the formation is about 3 to 2, although dolomite predominates in the upper part. In Clarke County, adjoining Frederick County on the east, the Beekmantown is predominantly limestone with only minor amounts of dolomite. Some of the thin beds meet the specifications of high-calcium limestone.

There are no sandstones as in the Conococheague. Chert is also relatively scarce as compared with its abundance in the Beekmantown in the southern part of the Valley. However, locally, the uppermost part of the formation is characterized by a distinctive vuggy chert having the appearance of an encrustation on the surface of the rock or filling the recesses formed by solution along the bedding planes. Many well-preserved fossils have been obtained from this material.

At certain localities beds of compact, nongranular rock of a pearl-gray color are present. These layers look so much like the overlying New Market (Mosheim) limestone that, where they are both present, close observation is required to distinguish the formations and locate the boundary between them. As a general rule, however, the uppermost part of the Beekmantown contains a few finely crystalline, gray dolomite layers that are easily distinguishable.

The thickness of the Beekmantown along State Road 631 west of

Stephens City is about 2500 feet. Here the beds are largely exposed and vertical. The formation appears to be about 3500 feet thick in northern Frederick County (Edmundson, 1945, p. 36), but the measurements of exposures there may be inaccurate as a result of folding and faulting which were not evident in the field.

On the basis of fossils, two divisions of the Beekmantown are recognized; a lower division marked by *Lecanospira,* and an upper division containing *Ceratopea.* So far as known, these fossils have not been found at the same geologic horizon. In central Pennsylvania, where the Beekmantown is predominantly dolomite, the easily recognizable blue limestone, the Axemann, separates the lower division, the Nittany dolomite, from the upper division, the Bellefonte dolomite. In Frederick County the Axemann has not been recognized, so it is impossible to separate the two divisions on lithologic grounds. However, an approximate boundary (Plate 1) can be determined by fossils. For example, on the Chapel Road, (State Road 627) northwest of Middletown, *Ceratopea* occurs just south of Buffalo Marsh Run, whereas *Lecanospira* occurs on the slope 1000 feet northwest of the same stream. The boundary lies between these locations.

The *Lecanospira* zone includes other fossils, a few of which have been collected and identified as the following: *Ecculiomphalus triangulus, Hormotoma gracilens, Diaphelasma pennsylvanicum,* and *Finkelnburgia virginica.* In the *Ceratopea* zone are *Ecculiomphalus perkinsi, Ophileta canadensis, Pleurotomaria arabella, Pionoceras swartzi,* and *Centrotarphyceras macdonaldi. Calaurops lituiformis* has not been found in Frederick County, but it occurs in the vicinity of Front Royal, Warren County.

The occurrence of *Lecanospira* is evidence for the correlation of the lower division with the Roubidoux limestone of Missouri, the Longview limestone of Alabama, the Nittany dolomite of central Pennsylvania, and the lower part of the typical Beekmantown of New York and Vermont. *Ceratopea* connects the upper division of the Beekmantown of Frederick County with the Cotter dolomite of Missouri, the Newala limestone of Alabama, and the Bellefonte dolomite of Pennsylvania, whereas the other fossils of this division, especially the coiled cephalopods and *Calaurops,* show that the upper division is also to be correlated with the Fort Cassin limestone of the upper Beekmantown of New York and Vermont.

In the preparation of this report for publication, Edmundson noted that Butts' manuscript maps showed Nittany and Bellefonte as the

mapped units succeeding the Chepultepec, whereas in his manuscript these rocks were described under the heading Beekmantown limestone with a lower division, or *Lecanospira* zone, and an upper division, or *Ceratopea* zone. It is hoped that the explanation on the map (Plate 1) showing Nittany (lower Beekmantown) formation and Bellefonte (upper Beekmantown) formation represents the implied intent of Dr. Butts. According to Sando (1957), the Beekmantown group in Maryland includes the Stonehenge limestone and the units which he named the Rockdale Run formation and the Pinesburg Station dolomite. These formations comprising the Beekmantown group have been recognized and mapped by Page and others (1964) in the Martinsburg quadrangle which is located about 15 miles northeast of Frederick County.

Revision of Lower Middle Ordovician Nomenclature

The results of detailed study of lower Middle Ordovician stratigraphy of the Shenandoah Valley, Virginia, and an analysis of previous interpretations were published by Cooper and Cooper (1946). Their joint study revealed the need for a revision of the stratigraphic nomenclature since, in many instances, the generally accepted classification confused time-stratigraphic divisions with purely lithologic units transcending faunal zones. The new names employed by Edmundson in this report were proposed by Cooper and Cooper (1946) and are in accord with the current usage of the Virginia Division of Mineral Resources. The interested reader is referred to Appendix I for Butts' description and interpretation of the post-Beekmantown—pre-Martinsburg stratigraphy.

The following section, modified from Cooper and Cooper (1946, p. 76, 95-96), is not in Frederick County; however, the units included in their revision of the lower Middle Ordovician stratigraphy are well exposed and the location is only about 2 miles southwest of the county line.

Geologic Section 1.—Along Tumbling Run, 1.5 miles southwest of Strasburg, Shenandoah County, Virginia.

	Thickness Feet	Inches
ORANDA FORMATION (50 feet)		
27. Limestone, shale, and siltstone; exposed along U. S. Highway 11 about 300 yards north of Tumbling Run; very fossiliferous; contains *Lingulasma* sp., *Ptychoglyptus* sp., *"Sowerbyella" pisum, Bimuria, Oxoplecia simulatrix, Christiania trentonensis, Eoplectodonta alternata,* and *Reuschella "edsoni"*	50	

	Thickness Feet	Inches
EDINBURG LIMESTONE (530 feet)		
26. Limestone, buff-gray, crumbly, cobbly; contains *Camarocladia* (Lantz Mills facies)	40	
25. Limestone, dark-gray, dense, slabby to cobbly; contains *Nidulites* and *Lambeophyllum* (Lantz Mills facies)	200	
24. Limestone, black, dense, even-bedded; contains *Nidulites* and *Lambeophyllum* (Liberty Hall facies)	64	
23. Limestone, clayey, shaly, cobbly; contains *Nidulites* and *Lambeophyllum* (Lantz Mills facies)	26	
22. Limestone, black, medium-bedded, slabby (Liberty Hall facies)	22	
21. Limestone, very clayey, nodular (Lantz Mills facies)	9	
20. Limestone, black, dense; partings of black shale (Liberty Hall facies)	14	
19. Limestone, nodular to cobbly; contains *Nidulites* and *Lambeophyllum* (Lantz Mills facies)	26	
18. Limestone, black, dense, slabby; contains *Arthrorhachis, Robergia,* and *Bronteopsis; Nidulites* also plentiful but none below this unit (Liberty Hall facies)	45	
17. Limestone, argillaceous, cobbly; contains *Dinorthis* cf. *D. transversa, Resserella* cf. *R. rogata,* and a large *Corineorthis* (Lantz Mills facies)	20	
16. Limestone, buff, nodular, shaly; contains *Echinosphaerites aurantium, Chasmatopora "sublaxa," Opikina* cf. *O. "minnesotensis," Homotelus simplex, Oxoplecia* sp., *Resserella* cf. *R. rogata, Christiania* sp., *Sowerbyella* sp. (Lantz Mills facies)	33	
15. Limestone, granular, good ledge maker (Liberty Hall facies)	9	
14. Limestone, buff, cobbly; bright-buff shaly partings (Lantz Mills facies)	3	3
13. Siltstone, brownish-buff, shaly in lower part	2	9.5
12. Metabentonite, buff, sheared		10
11. Chert		1
10. Limestone, cobbly, several clayey partings which are probably metabentonitic (Lantz Mills facies)	7	
9. Limestone, irregularly bedded, medium- to coarse-grained (Liberty Hall facies	7	
8. Metabentonite, buff		8.5
LINCOLNSHIRE LIMESTONE (132 feet)		
7. Limestone, fine-grained, cobbly, sparsely cherty	27	
6. Limestone, black, dense, cherty; contains *Mimella* sp., *Sowerbyites triseptatus, Multicostella saffordi,* and *Dinorthis atavoides*	35	
5. Limestone, dark-gray, granular, cherty; contains intercalated beds and lenses of coarse-grained limestone crowded with *Girvanella*	32	

	Thickness Feet	Thickness Inches
4. Limestone, black, fine- to medium-grained, cherty	29	
3. Limestone, dark-gray, thin-bedded, platy, no chert	4	6
2. Limestone, medium-gray, coarse-grained, no chert	4	6
NEW MARKET LIMESTONE (55 feet)		
1. Calcilutite, dense, medium-bedded, crowded with *Tetradium syringoporoides;* base exposed in stream bed beneath bridge	55	
BEEKMANTOWN DOLOMITE		

New Market Limestone

The New Market limestone was named by Cooper and Cooper (1946, p. 71-72), and the name was taken from a town on U. S. Highway 11 in southern Shenandoah County, Virginia. It is above the Beekmantown and below the dark-gray, commonly cherty Lincolnshire limestone. The New Market crops out in a long, finger-like area along Middle Marsh Brook for 2.5 miles north of the Frederick-Shenandoah county line, and in a very narrow band extending northeastward across the county passing near Stephens City, Winchester, and Clearbrook, and thence northeastward to Martinsburg, West Virginia. This outcrop (Plate 1) is offset at several places by plunging folds and minor faults. Other incomplete exposures, associated with faulting, have been mapped southwest of Wisecarver Gap; near the West Virginia boundary about 2.5 miles north-northeast of White Hall; and at the southeast corner of the county.

The New Market is dominantly a compact or glassy-textured, thick-bedded, dove-gray limestone (Figure 8) with generally a lower zone containing a few impure layers that are thin bedded. Exclusive of the impure layers near the base, the formation is 97 to 98 percent calcium carbonate and is extensively quarried and mined as high-calcium limestone. The thickness of the New Market in the central part of the county, between Winchester and Kernstown, is estimated to be 50 feet or less, whereas the thickness along the strike to the northeast and southwest ranges from about 80 feet to a maximum of about 200 feet.

The New Market is sparsely fossiliferous. The fossils that have been observed in the county are sections of gastropods which occur on the weathered surface of the limestone. Fairly good and abundant specimens were noted on the west limb of the Marsh Brook syncline, about 0.3 mile northeast of Cedar Creek, occurring in about the middle

of the formation. The most abundant forms suggest *Trochonemella;* others seem to be *Lophospira grandis.* Another significant form, *Tetradium syringoporoides,* is present in outcrop along Tumbling Run in northern Shenandoah County. The New Market is essentially the same as the unit identified by Butts as the Mosheim limestone in Frederick County.

Figure 8. Sharp boundary between the New Market (light) and Lincolnshire (dark) limestones in the W. S. Frey Company quarry about 0.5 mile southeast of Clearbrook. Looking northeast (1964).

Lincolnshire Formation

This formation was named by Cooper and Prouty (1943, p. 863) as the Lincolnshire limestone from a creek about 2 miles northeast of North Tazewell, Virginia. In Frederick County and along Tumbling Run, Shenandoah County, the Lincolnshire extends from the New Market to near the base of the lower *Echinosphaerites* zone (Cooper and Cooper, 1946) of the Edinburg formation. In discussing the Lenoir, Butts (Appendix I) places the upper boundary about 20 feet below a prominent siltstone in the Tumbling Run section, whereas Cooper and Cooper (1946) place the Lincolnshire-Edinburg boundary about 15 feet below the siltstone. For the purpose of mapping, the two units are essentially the same in Frederick County.

The outcrop of the Lincolnshire is a narrow, sinuous band, contiguous with the New Market, that extends in a northeasterly direction across the county from Cedar Creek to West Virginia 0.5 mile south of Ridgeway. Other small outcrops, with faulted relations, occur at the

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southeast base of Little North Mountain near the West Virginia boundary and in the southeastern part of the county south of Wright Run.

The Lincolnshire is a dark, almost black, finely crystalline limestone (Figure 8). It is medium thick bedded, and the layers tend to be nodular or made of irregular, lenticular slabs of a few square inches in area. The formation is especially characterized and made identifiable by fairly abundant nodules, plates, and stringers of black chert. The chert commonly weathers out in cuboidal chunks on the surface and affords means of tracing the formation where there are no exposures of bedrock. At localities where chert is not prominently developed, or if the chert is omitted from the sample, available chemical analyses show 95 to 96 percent calcium carbonate. Generally the formation is high in silica and, for that reason, is not considered a high-calcium limestone.

The thickness of the Lincolnshire along Tumbling Run (Shenandoah County) is about 132 feet. A thickness of about 100 feet has been noted in the vicinity of Rest, southeast of Kernstown, and at Vaucluse; whereas in the vicinity of Winchester it appears to be much thinner, perhaps less than 50 feet.

The Lincolnshire is moderately fossiliferous, and many fine silicified specimens have been etched from slabs of limestone collected in the Strasburg area and are revealed also on weathered pieces of black chert. A few of the fossils are cited in Geologic Section 1 and in Appendix I.

According to Cooper and Cooper (1946, p. 75):

> "The name Strasburg limestone was introduced without definition by Ulrich (1939, p. 106) for a part of the succession herein identified as Lincolnshire. Later Ulrich and Cooper (1942, p. 622) used it as equivalent to the 'upper Lenoir' of Tennessee. Since the name had received no precise definition or description at the time Lincolnshire was introduced ([Cooper and Prouty,] 1943), Strasburg is considered invalid."

Edinburg Formation

The Edinburg was named by Cooper and Cooper (1946, p. 78) from a locality 1.5 miles northeast of Edinburg, Shenandoah County, Virginia. It includes about 500 feet of beds above the Lincolnshire formation and below the Oranda formation (*"Christiania"* bed of Butts) in Frederick County. The Edinburg formation crops out in a band about 800 feet wide extending from the vicinity of Strasburg, Shenandoah County, northeastward to West Virginia, crossing the State

boundary about 0.5 mile south of Ridgeway. Other small exposures occur along Opequon Creek east of Brucetown and Parkins Mills and at the southeast corner of the county. The main belt is widest at the south end of the Belle Grove anticline about 2.5 miles northeast of Strasburg. This belt to the northeast is offset by folds or faults at a number of places, as in the vicinity of Stephens City, southeast of Winchester, between Winchester and Clearbrook, and at the State line.

Approximately 70 percent of the rocks exposed along Tumbling Run in northern Shenandoah County are nodular to cobbly, dark- to buff-gray limestone with shaly partings and have been assigned by Cooper and Cooper (1946, p. 95-96) to the Lantz Mills facies of the Edinburg. 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 which characterize the Liberty Hall facies. A layer of siltstone, approximately 3 feet thick, and several thin metabentonites occur near the base of the formation. The siltstone, here named the Tumbling Run, is easily distinguished from the enclosing rocks and is thus a valuable horizon marker for a considerable distance. Its outcrop forms a low ridge which can be traced southward to Maurertown and northward at least to Strasburg Junction, 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 main outcrop belt of the Edinburg near Vaucluse and Bartonville (Figure 9) is composed of about equal amounts of the Lantz Mills and Liberty Hall facies, whereas in the northern part of the county, near Rest, the rocks appear to be chiefly the Lantz Mills facies. The eastern outcrop belt which is mainly in Clarke County, but with a few exposures in Frederick County along Opequon Creek, is composed largely of the Liberty Hall facies. The thickness of the Edinburg in Frederick County, except for one section about 0.5 mile southeast of Kernstown which may be thinned by faulting, ranges from about 400 to 550 feet.

The Edinburg is highly fossiliferous, but the fossils are usually fragmentary, from which it would appear the limestone was deposited in water much affected by waves and currents. Some of the fossils are silicified, and good specimens can be etched from the limestone by acid. A few of the diagnostic fossils are cited in Geologic Section 1 and in Appendix I.

Along the west limb of the Massanutten syncline, the Edinburg is equivalent to beds mapped by Butts and Edmundson as the Chambersburg limestone, exclusive of the relatively thin *"Christiania"* bed at the

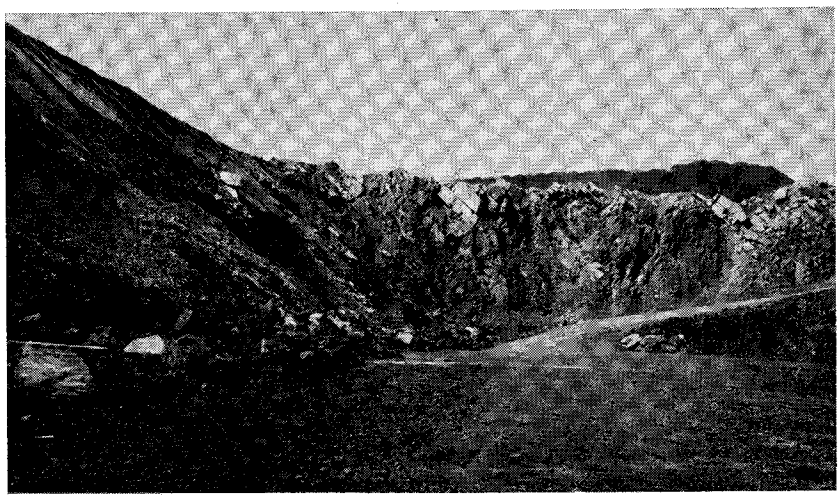

Figure 9. Edinburg limestone in the Salem Stone Corporation quarry at Bartonville. Looking northeast (1964).

top of the formation. The new name would include also the few limited exposures of the beds mapped as the Athens, east of the broad expanse of Martinsburg shale along Opequon Creek and in the southeast corner of Frederick County.

Oranda Formation[1]

The name Oranda formation was proposed by Cooper and Cooper (1946, p. 86) from a hamlet about 3.5 miles northeast of Strasburg, Shenandoah County, Virginia. This relatively thin zone overlies the Edinburg and directly underlies the *Sinuites* beds of the Martinsburg formation in Frederick County.

According to Cooper and Cooper (1946, p. 87):

> "The Oranda is composed mainly of very argillaceous limestone but contains metabentonitic clays, shales, and ledge-making siltstones. It forms the transition zone between the subjacent limestone and the succeeding sandy shales of the Martinsburg. Except in road cuts, the Oranda is almost nowhere fully exposed. Many of its metabentonites are unknown outside the type section."

[1]The explanation on the geologic map (Plate 1) does not include the Oranda formation. This is an error and the unit mapped as Edinburg formation should read "Edinburg and Oranda formations."

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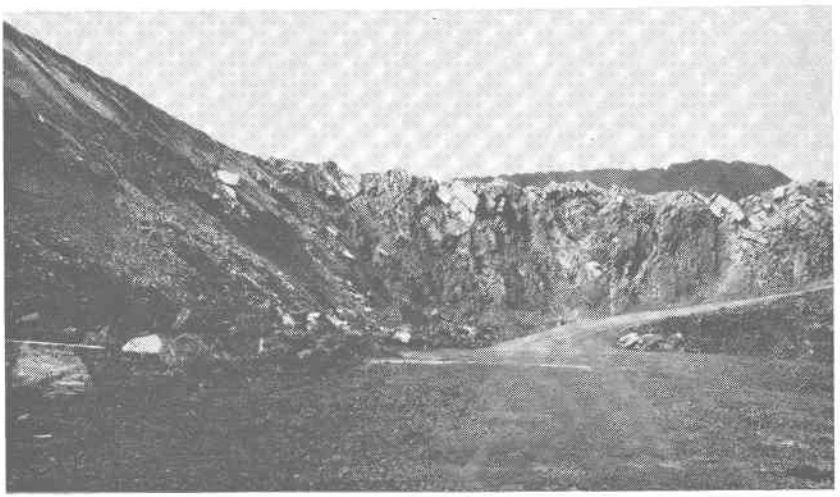

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The thickness of the Oranda (Cooper and Cooper, 1946, p. 87-95) is 56 feet at the type section, and in Frederick County it is reported to be 25 feet near Vaucluse and 30 feet near Rest. Perhaps 40 feet would be a reasonable average thickness in Frederick County.

Fossils occurring in the siltstone which is prominently exposed along U. S. Highway 11 about 300 yards north of Tumbling Run, have been identified (Cooper and Cooper, 1946, p. 95-96) as *Lingulasma* sp., *Ptychoglyptus* sp., *Bimuria* sp., *Oxoplecia simulatrix, Christiania trentonensis, Eoplectodonta alternata,* and *Reuschella "edsoni."* The Oranda formation is characterized by the occurrence of *Reuschella "edsoni"* and its associates. It is equivalent to the "*Christiania* bed," upper Chambersburg, of Butts (Appendix I).

Martinsburg Formation

The Martinsburg was named by Geiger and Keith (1891, p. 161) as the Martinsburg shale from Martinsburg, West Virginia. However, its first description was given by Darton (1892, p. 13). In Frederick County the lower boundary is defined as above calcareous siltstone (Oranda formation), and its top boundary is drawn at the base of the Oswego where it is recognized in the section. The Martinsburg occupies a wide belt along the medial part of the Massanutten syncline, lying in general between Winchester and Opequon Creek, but in places extending about 0.5 mile across the creek into Clarke County. Exposures are especially good where the belt is crossed by U. S. Highway 50 and State Highway 7 (Figure 10). Another belt, constricted by faulting except possibly at the northeast end, extends along the southeast base of Little North Mountain throughout the county. The Martinsburg also crops out in a wide area along the axis of the Great North Mountain anticline in the southwest corner of the county and in a small, oval-shaped inlier (Plate 1) along Paddy Run just south of The Half Moon.

In Frederick County the Martinsburg varies from a fissile clay-shale to a thinly laminated rock partly composed of exceedingly fine particles, and can properly be called a fine-grained sandstone. A very few massive layers, apparently without bedding lamination, and a few medium-thick layers of coarser grained sandstone have been observed in the Massanutten syncline. In this broad outcrop belt the Martinsburg is bluish gray but turns to brown on weathering, due to the oxidation of the ferruginous constituents in the shale. In other belts within the county the shale seems to be of a more purely clayey composition, is softer, and weathers to a yellowish color. A few calcareous beds, containing

Orthorhynchula linneyi, were observed near the top of the Martinsburg and within a few feet of the overlying Oswego along Paddy Run in the southwestern part of the county. Along U. S. Highway 11, 0.5 mile south of Tumbling Run, Shenandoah County, the basal few feet of the Martinsburg is crumbly shale, apparently slightly calcareous, which weathers yellowish gray, and contains *Cryptolithus* and *Dalmanella.* Above the gray shale at this locality is about 100 feet of very fissile, black, graptolitic shale.

Figure 10. Bedding in Martinsburg shale cut by cleavage, along State Highway 7 about 0.5 mile west of Opequon Creek.

No accurate determination of the thickness of the Martinsburg is possible in Frederick County. The top of the Martinsburg is not preserved in the Massanutten syncline within the limits of Frederick County. Near New Market, Shenandoah County, the top and bottom are defined and the width of outcrop is approximately 4000 feet. Thus, under the most favorable conditions, the maximum possible thickness cannot exceed 4000 feet.

Along the breached Great North Mountain anticline in Vances Cove, the top is exposed, but older rocks are not exposed on the surface. The belt along Little North Mountain, except possibly north of Green Springs, is bounded on the east by the North Mountain fault. Near the West Virginia boundary and north of Green Springs the width of outcrop is about 2800 feet. If the sequence is normal, as it appears to be, and an average dip of about 45 degrees is assumed, the calculated thickness would be 1800 feet. Near Chambersville on U. S. Highway 50, the Martinsburg

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is exposed through 1500 feet of steeply dipping beds. Here it is adjacent to the North Mountain fault on the east, and it is also interpreted by Edmundson as having faulted relationships at the top. Similar faulted relationships are indicated near Fawcett Gap about 4 miles to the southwest. At this locality the outcrop belt is only 800 or 900 feet wide and, according to Butts, apparently both top and bottom of the Martinsburg are represented in the section. If so, it is abnormally thin or has been partly squeezed out or compressed in folding. Woodward (1951, p. 340) reports a thickness of the Martinsburg on the order of 1400 to 1600 feet in the belts west of the Massanutten syncline in West Virginia. Recently, Page and others (1964) have listed the formation as 2000-3000 feet thick in the Martinsburg quadrangle.

The wide synclinal belt of the Martinsburg in Frederick County is apparently devoid of all fossils except graptolites. By persistent search these were found at various points across the belt but no other fossils were found. The graptolites are mostly poorly preserved, but all, so far as their condition permits identification, are *Diplograptus amplexicaulis.* East of Opequon Creek, Clarke County, in the very bottom of the Martinsburg, *Corynoides* cf. *C. gracilis* has been found in abundance at several localities. South of Frederick County, at the north end and on the east side of Massanutten Mountain and on Cub Run 0.5 mile southeast of Catherine Furnace, the following fossils, collected within 200 feet below the top of the formation, were found: *Dalmanella meeki, D. emacerata?, Rafinesquina alternata, Orthorhynchula* sp., *Byssonychia radiata, Orthodesma?, Modiodesma?, Cyclonema?, Calymene meeki,* and *Cryptolithus bellulus.*

On the west side of the syncline along U. S. Highway 11, 1.75 miles southwest of Strasburg, *Diplograptus amplexicaulis, Ctenobolbina ciliata?, Tetradella subquadrans,* and *Cryptolithus tessellatus* occur near the base of the Martinsburg. On the western belt, along the southeast slope of Little North Mountain, *Cryptolithus* sp. occurs near the top; and near Fawcett Gap *Cryptolithus tessellatus,* associated with many specimens of *Corynoides,* occurs in dark calcareous shale at the bottom of the formation. Several hundred feet below the top of the formation, *Cryptolithus bellulus, Ectenocrinus simplex,* and *Glyptocrinus pattersoni* occur in an outcrop in Page County along U. S. Highway 211, 0.5 mile southeast of New Market Gap. These fossils indicate the Eden age of the containing beds. On Paddy Run in the gap through Paddy Mountain in the southwest corner of Frederick County, *Orthorhynchula linneyi* occurs abundantly. The previously listed fossils prove that the Martinsburg formation in northern Virginia is Trenton to Maysville in age.

Oswego Formation

The Oswego was named from Oswego, New York, where it crops out and was described by Vanuxem (1842, p. 67) as the gray sandstone of Oswego. It was later specifically named by Prosser (1890, p. 205-206) as the Oswego sandstone. It is well developed along the crest of Great North Mountain at the State boundary, both north and south of State Highway 55 and on the west slope of Paddy Mountain which forms the eastern boundary of Vances Cove. Other small areas have been identified at the southeast base of High Knob, along the northwest slope of Great North Mountain 3 miles southwest of Rock Enon Springs, and in the deep ravine at the head of Sink Pond Hollow in the northwest corner of the county. The occurrence 3 miles south of Rock Enon Springs is a wedge-shaped belt which seems to be bounded by a fault on the west, for the Oswego apparently is in contact with the Clinton.

The Oswego is thicker and better exposed on the southeast slope of Little North Mountain along the road through Ponzer Gap in northern Shenandoah County. Recent reconnaissance work (1963) by the junior writer along Little North Mountain has shown a few feet of brownish, weathered, coarse-grained sandstone with small chert pebbles at the northeast end of Funkhouser Knob in southwestern Frederick County. Farther northeast along the mountain, gray and pink to maroon-colored sandstone float has been noted at a locality about 2 miles southwest of Chambersville, reddish sandstone float near the southeast base of Round Hill, and an abundance of gray impure sandstone float along the southeast slope of the mountain northeast of Nain. Butts' manuscript maps show the overlying red beds of the Juniata, without any Oswego, as present along the southeast slope of Little North Mountain north of Green Springs and in a very narrow strip from a locality 1.5 miles west of Albin northward to the vicinity of Nain. The area needs additional study; however, on the basis of the meager evidence now available, thin discontinuous belts of undifferentiated sandstone and shale, possibly Oswego-Juniata with faulted relationships, are shown on Plate 1.

The Oswego in Great North Mountain is a thick-bedded, coarse, gray or greenish sandstone, with well water-worn pebbles up to 4 inches in diameter, making a coarse conglomerate (Figure 11). The pebbles are mostly quartzite but include a few small ones of vein quartz and fewer of chert. Along Little North Mountain in northern Shenandoah County, it is a thick-bedded, gray sandstone apparently without pebbles. The thickness of the Oswego has not been accurately determined, but

such observations as have been made indicate a thickness of 100 to 200 feet.

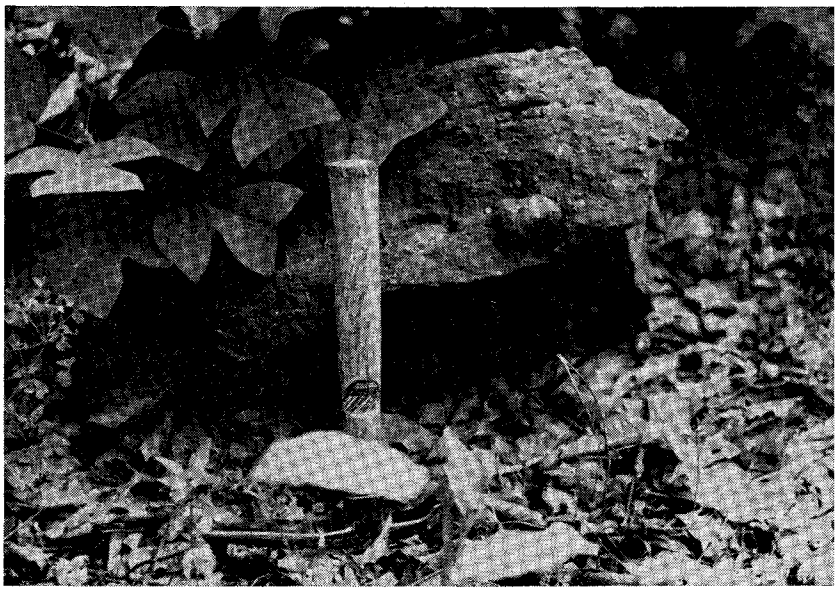

Figure 11. Oswego conglomerate along State Highway 55 in Duck Run gap about 2.5 miles northwest of Star Tannery.

The general character and thickness of the Oswego near the west end of Duck Run gap is as follows:

Geologic Section 2.—Near west end of Duck Run gap at the entrance to Vances Cove, Frederick County.

	Thickness Feet
OSWEGO FORMATION (100 + feet)	
2. Sandstone or grit, thick-bedded; small grains of quartz and brownish rock, 1 mm in diameter; contains many pebbles, mostly quartzite, up to 4 inches in diameter; the distinctly greenish color suggests glauconite	50
1. Sandstone, gray, thick-bedded, coarse; contains only a few pebbles; covered at base, but Martinsburg shale with *Orthorhynchula* close below	50+

The Oswego here, as in central Pennsylvania, is without fossils. It is tentatively identified as Oswego because it is in the same stratigraphic sequence as the Oswego of New York, where it underlies the Queenston shale which is correlated with the Juniata formation. The Oswego in

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Virginia underlies the Juniata as it does in central Pennsylvania. Many geologists prefer the name Bald Eagle sandstone. Beneath the Oswego in Pennsylvania is the *Orthorhynchula* zone of the Reedsville shale, which is the same as the *Orthorhynchula* zone of the Martinsburg formation immediately underlying the Oswego of Virginia. The Oswego sandstone is also believed to be represented in the upper part of the Maysville group, the McMillan formation of the Cincinnatti, Ohio region.

Juniata Formation

The Juniata was named by Darton (1896, p. 2) from Juniata River in Pennsylvania. It is present along the southeast slope of Little North Mountain north of Green Springs (shown as undifferentiated Oswego-Juniata on Plate 1) and in a very narrow strip from near the County Farm, 1.5 miles west of Albin, northward to the vicinity of Nain. In more recent work, however, fossils, tentatively identified as of Clinton age a few hundred feet north and south of Nain, suggest to the junior writer that the few feet of white and brown sandstone associated with red shale referred to by Butts as the Juniata in the vicinity of the County Farm may be a southwesterly continuation of the Clinton. Nevertheless, no fossils were noted in the County Farm area and the red shales are not typical of the Clinton.

The main body of the Juniata is in Great North Mountain. It crops out on both flanks of the anticline in the southwestern part of the county. Another outcrop which is wedge-shaped lies along the southeast slope of the mountain below High Knob. There are also two inliers, one in the deep ravine at the head of Laurel Run west of Mountain Falls and another on the southeast slope of Cacapon Mountain at the head of Sink Pond Hollow in the northwest corner of the county.

The Juniata is composed of red shale or red lumpy mudrock and thin-bedded, red, partly arkosic and cross-bedded (Figure 12) sandstone. It is nowhere fully exposed in Frederick County so that its detailed character cannot be determined. The thickness may be 50 to 100 feet in Little North Mountain north of Green Springs and as much as 200 feet in Great North Mountain.

The Juniata is unfossiliferous but is known through its stratigraphic relations to be the equivalent of the Queenston shale of New York, and the latter is known by its fossils to be partly equivalent to the highly fossiliferous Richmond of southern Indiana and southwestern Ohio. A considerable number of Richmond fossils occur in the Queenston in

Canada at the west end of Lake Ontario. The Juniata also persists to the southwest corner of Virginia, where it is known as the Sequatchie formation. At Cumberland Gap the Sequatchie formation contains Richmond fossils.

Albert Crenshaw

Figure 12. Cross-bedded Juniata sandstone exposed along Duck Run and State Highway 55 about 2.5 miles northwest of Star Tannery.

SILURIAN SYSTEM

Tuscarora Formation

The Tuscarora was named by Darton (1896, p. 2) from Tuscarora Mountain between Perry and Juniata counties, Pennsylvania. The same formation, cropping out along Clinch Mountain in Tennessee, has been named Clinch sandstone (Stafford, 1869, p. 292). The name Tuscarora is used in northern Virginia, although Clinch is an older name.

The Tuscarora in Frederick County crops out along Little North Mountain, on Great North Mountain (Figure 13), and on the southeast slope of Cacapon Mountain. Owing to the hardness and resistance to erosion of the Tuscarora, the areas underlain by it have been eroded less than the adjacent areas underlain by weaker rocks and have thus remained standing above the general level. Nearly all of the prominent linear ridges in the Appalachian Valley from Pennsylvania to Tennessee are due to the same cause.

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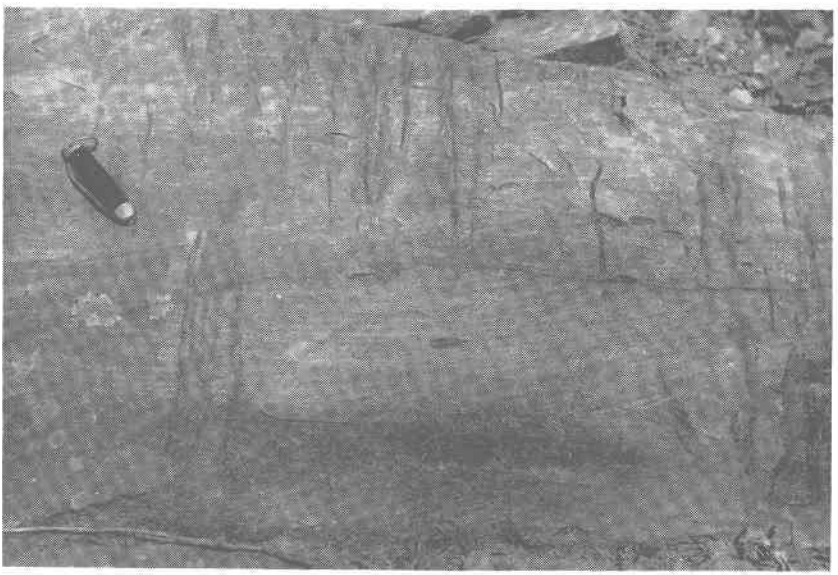

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The formation is a rather thick-bedded, hard, gray rock, predominantly an ordinary sandstone, but, locally at least, part of the formation is a conglomerate composed of quartz pebbles, usually about 0.25 inch in diameter. A well-developed conglomerate is on the crest of Paddy Mountain about 2 miles southwest of Paddy Run.

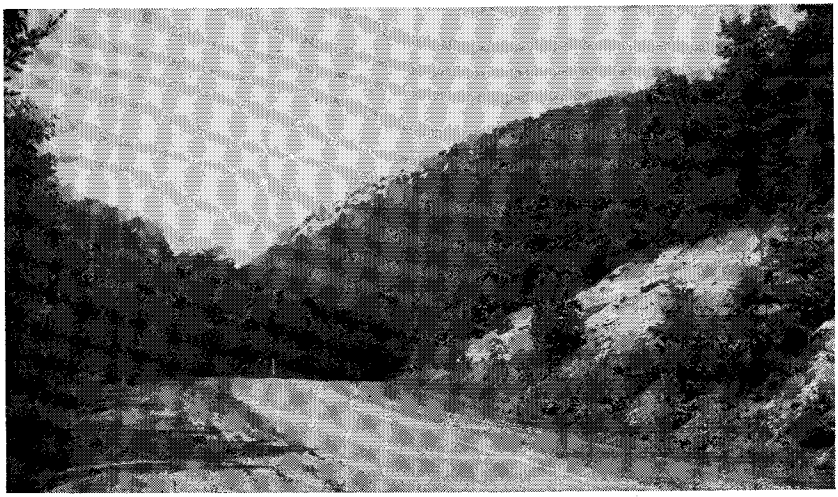

Figure 13. Short Mountain in the background underlain by steeply dipping Tuscarora sandstone which crosses Duck Run and State Highway 55 about 2.4 miles northwest of Star Tannery.

The varying width of outcrop and even the absence of the Tuscarora along Little North Mountain in Frederick County are worthy of notice. North of Green Springs and southward to Round Hill it is generally thin and locally absent, but with prominent exposures in Babbs Mountain, Flint Ridge north of Nain, and in Round Hill (Figure 5) where the thickness is estimated to be about 200 feet. The Tuscarora does not crop out along U. S. Highway 50 (old location) at Chambersville. Here the Martinsburg is interpreted as being in contact with the Wills Creek formation. In less than 0.5 mile south of Chambersville it thickens to perhaps 200 feet and continues southward as a prominent ridge-maker (Figure 4) for a distance of at least 3 miles, and from there the outcrop belt narrows as the crest of the mountain gradually descends to the valley level at Wisecarver Gap. There are no exposures in the floor of the gap, but immediately to the south and continuing for a short distance the Tuscarora appears to be about 150 feet thick. To the south in the Fawcett Gap area, except for a few thin lenses of white sandstone, the Martinsburg is in contact with the Marcellus shale. The most southerly prominent topographic feature along the trend of the

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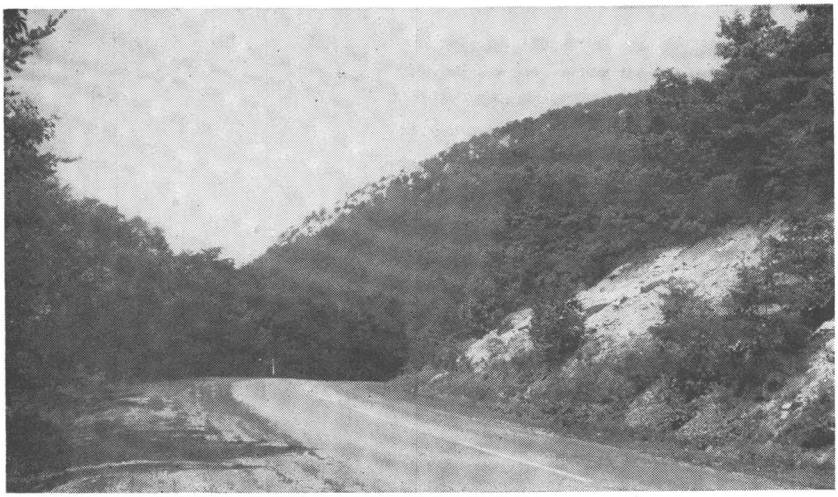

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mountain is Funkhouser Knob, which, like the knob south of Wisecarver Gap, probably contains 100 to 150 feet of Tuscarora. In Baldwin Gap, near the Frederick-Shenandoah county boundary, the exposed thickness of white to gray Tuscarora sandstone is 40 feet or less. These variations in distribution and thickness have been explained by faulting or as the result of original unequal deposition. A review of this question, with suggestions by the junior writer, are given in the section on geologic structure.

The thickness, as determined on Duck Run in the southwestern part of the county, is approximately 300 feet. Southwest of Wheatfield in Shenandoah County, however, the thickness is apparently about 500 feet which is greater than known elsewhere in Virginia, except in Massanutten Mountain. Perhaps 250 to 300 feet is about the normal thickness for Frederick County.

The typical Tuscarora is a nonmarine formation and destitute of fossils, except for *Scolithus* tubes (worm borings) and *Arthrophycus,* another genus of fossil worm. In western New York, south of Lake Ontario, the equivalent of the Tuscarora is the Albion sandstone ("White Medina" sandstone), which is fossiliferous. The equivalent of the Albion, undergoing various facies modifications, has been traced northwestward through Canada and has yielded satisfactory evidence of its equivalence, in part at least, with the Brassfield limestone of Ohio. At Cumberland Gap in the southwest corner of Virginia, the Tuscarora equivalent is a marine fossiliferous sandstone and limestone. A considerable number of fossils collected there are similar to the well-known fossils obtained from the Albion at Lockport, New York. Also, a number of the fossils from Cumberland Gap are identical with species occurring in the Brassfield limestone of Ohio. The Tuscarora is an example of the transition of a nonmarine formation without life (except for the traces of worms, presumably of terrestrial habitat) into a marine formation containing abundant remains of marine animals.

Clinton Formation

The Clinton formation was named by Conrad (1842, p. 229-230) from the town of Clinton, Oneida County, New York. The Keefer sandstone member, named by Stose and Swartz (1912, p. 5) as the Keefer sandstone, from Keefer Mountain, Pennsylvania, forms the top of the Clinton as used in this report. The Clinton crops out in Little North Mountain, on both slopes of Great North Mountain northward nearly to U. S. Highway 50 where it dips below the surface on the northward-

plunging anticline, and along the southeast base of Cacapon Mountain in the northwest corner of the county. Although there are no completely exposed sections in Frederick County, an accessible place to study the upper 100 feet of the formation, beneath a conspicuous ledge of Keefer sandstone, is along State Highway 55 at the east entrance to the gorge of Duck Run.

At the termination of joint field studies in 1940, the Clinton had been identified in the Little North Mountain belt only in the area north of Green Springs, Frederick County, and south of Wheatfield, Shenandoah County. Subsequent field work by the junior writer in 1946 resulted in the collection of diagnostic Clinton fossils, mainly from float material, on Babbs Mountain, Flint Ridge, Round Hill, and at three localities between U. S. Highway 50 and Fawcett Gap. On the basis of this evidence a thin belt of Clinton, but with uncertain boundaries, is shown on Plate 1.

The Clinton is composed largely of hard, gray, sandstone (Keefer sandstone member) at the top and fine-grained, thin-bedded sandstone with sandy shale layers in the lower division. The Keefer sandstone is particularly well exposed along the southeast slope of Great North Mountain as a persistent gray ledge halfway up the slope and strikingly visible in the early morning light from the highway and country to the southeast. The Falls, 1.7 miles north of the village of Mountain Falls, is a cascade about 50 feet high made by Fall Run flowing down over a steeply dipping surface of the Keefer sandstone (Figure 14). The Keefer is a sandstone or quartzite, in all respects like the Tuscarora, and its thickness appears to be 30 to 50 feet in the Great North Mountain area.

The rocks in the lower division of the Clinton are predominantly gray sandstone and sandy shale but include layers of cinnabar-red and purplish-red sandstone ("Cacapon type"). Even the predominantly gray sandstone, due to films of iron oxide on the bedding and cleavage surfaces, is mottled with brown or reddish blotches. The "Cacapon type" sandstone can be relied upon for identifying the Clinton, since no other formation in the Valley of Virginia contains beds of similar character. A close approximation of thickness has been made in a ravine just north of Duck Run, where the upper and lower limits are definitely marked by the Keefer and Tuscarora sandstones respectively. Here the thickness is about 350 feet.

The most notable paleontological feature of the Clinton is the great abundance of individuals and species of ostracodes, among which

Mastigobolbina, Bonnemaia, Zygosella, Zygobolba, and *Zygobolbina* are most abundant. These are all illustrated in the volume on the Silurian of Maryland (Maryland Geological Survey, 1923). Other common and strictly diagnostic Clinton fossils (Butts, 1940), which occur in nearly every fossiliferous layer, are *Liocalymene clintoni, Chonetes novascoticus,* and *Anoplotheca hemispherica.* In a full sequence, as in central Pennsylvania, the Keefer is overlain by about 50 feet of shale in which occur fossils of Rochester age. No such rocks or fossils have been found in Frederick County, which indicates a hiatus between the Keefer and the McKenzie formation.

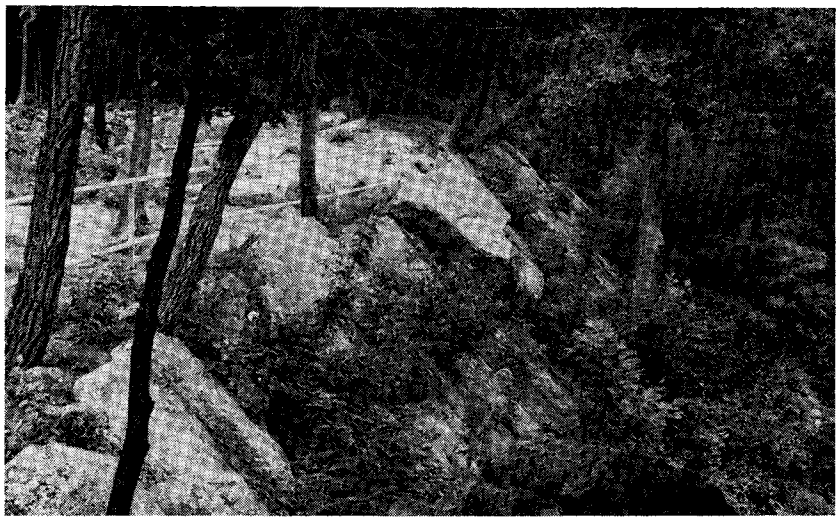

Figure 14. Fall Run, occupying a narrow channel in the Keefer sandstone, forms a cascade about 50 feet in height. The Falls is located about 1.7 miles northwest of the village of Mountain Falls.

McKenzie Formation

The McKenzie was named by Ulrich (1911) from McKenzie Station, 9 miles southwest of Cumberland, Maryland, and described by Stose and Swartz (1912, p. 5-6) in the Pawpaw-Hancock folio. Exposures of the McKenzie in Frederick County are generally poor and weathered, but it is known to occupy a narrow belt along the slopes of Great North and Cacapon mountains. No fossils have been noted in the stratigraphic position of the McKenzie along Little North Mountain. The few available exposures contain Bloomsburg-type rock or red sandstone with local intercalations of yellowish shale in the lower part almost in contact with the underlying gray sandstone. It is the junior writer's opinion that the

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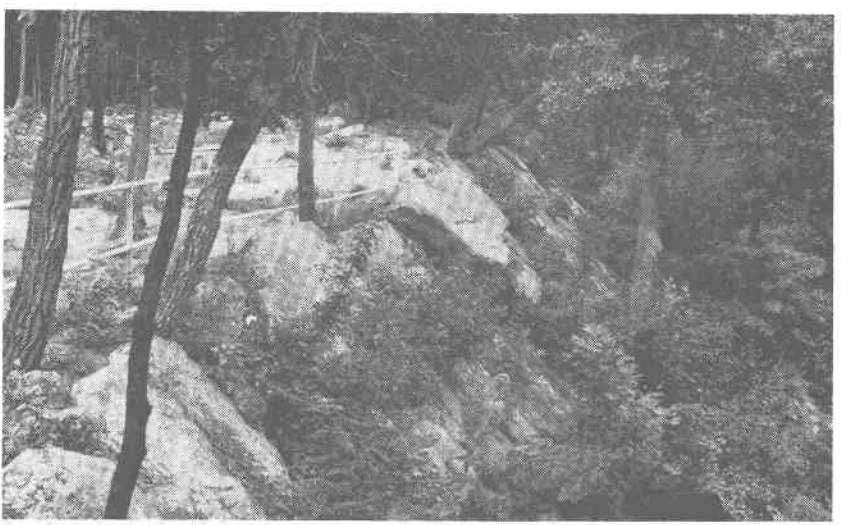

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yellow shale intercalations, such as exposed 0.1 mile north of Chambersville School, should be examined more thoroughly for the possible occurrence of diagnostic fossils.

The McKenzie is mainly a soft gray shale with some silky shale, yellowish in weathered condition, and a few layers of friable sandstone. Recent observations by the junior writer along the new location of U. S. Highway 50 about 1.3 miles east of Gore have shown that the upper 10 to 15 feet of the section which is exposed in a small anticline directly beneath the red Bloomsburg is mainly light olive-gray claystone but with thin dark-gray calcareous beds. A considerable thickness of weathered shale and float material derived from the upper part of the formation is exposed along U. S. Highway 50 about 0.4 mile east of the previously cited anticlinal structure. Other incomplete exposures, but having the adjacent formations exposed at the base and top, are on Poplar Spring Run 1 mile northwest of Clowser Gap and at the Falls 1.7 miles north of the village of Mountain Falls. On Poplar Spring Run there is a sandy layer containing many medium-sized brachiopods and a few specimens of ostracodes.

The true thickness of the McKenzie is unknown in Frederick County. The width of the outcrop belt along Fall Run and at the entrance to Duck Run gorge is 250 to 300 feet, thus, with the inferred steep dips, it is reasonable to assume that the average thickness of the McKenzie in Great North Mountain is about 200 feet.

Weathered yellowish shale and float material derived from the upper part of the McKenzie are exposed along U. S. Highway 50 about 1.7 miles southeast of Gore. Here many of the shale flakes contain abundant minute ostracodes, *Eukloedenella sinuata* and *Dizygopleura swartzi*. Also on Poplar Spring Run there is a sandy layer containing many *Camarotoechia* and a few specimens of *Eukloedenella sinuata*. The ostracodes cited were described by Ulrich and Bassler (1923) from material obtained at Flintstone and Cumberland, Maryland, and referred by them to the McKenzie. It is for this reason that the bed in Great North Mountain, containing these fossils, is identified as McKenzie. This identification is also in accord with the stratigraphic relations.

Bloomsburg Formation

The Bloomsburg was named by White (1883, p. 252) from Bloomsburg, Columbia County, Pennsylvania, where it is a prominent formation. In the Cumberland region of Maryland and in the Altoona region of

central Pennsylvania, where it is a thin formation, it has been included as a basal member of the Wills Creek shale. The Bloomsburg has been identified along both sides and around the north end of Great North Mountain (Figure 15) where the outcrop, due to minor folding, forms a number of salients and reentrants on the northward-plunging Great North Mountain anticline; in the northwest corner of the county where it is well exposed along a narrow ridge from the head of Bear Garden Creek southward into West Virginia; and along the west flank of Little North Mountain. A few localities along the Little North Mountain belt, where it is exposed or its presence is indicated by red soil and rock debris, are north of Green Springs, on the road from Paxton Chapel to Mt. Pleasant, and in Wisecarver and Baldwin gaps.

Figure 15. Small anticline in the Bloomsburg red beds at the northeast end of Great North Mountain along U. S. Highway 50 about 1.3 miles east of Gore.

The Bloomsburg in Frederick County is predominantly a thick-bedded, red sandstone with layers of compact, crumbly, red mudrock. Its color and composition are distinctive and serve as reliable criteria for its identification. The Wills Creek, overlying the Bloomsburg, has relatively thin beds of red shale, but no thick-bedded, red sandstone like that of the Bloomsburg. The thickness of the Bloomsburg ranges from about 80 to 150 feet, as determined from two localities on U. S. Highway 50 at the north end of Great North Mountain.

The Bloomsburg is without fossils. It evidently originated under conditions prohibitive to life, but just what those conditions were is

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The Bloomsburg is without fossils. It evidently originated under conditions prohibitive to life, but just what those conditions were is

unknown. The age and stratigraphic position of the Bloomsburg in Frederick County are fixed by its relations to the fossiliferous McKenzie below and the Wills Creek above.

Through the work of Swartz and Swartz (1931, p. 656-660) in Pennsylvania and Maryland, it was shown that the amount of red-colored rocks increases eastward so that in eastern Pennsylvania almost the entire Cayugan group is a red nonmarine facies. According to Woodward (1941, p. 172-174), because the red rocks of the Bloomsburg are gradually replaced westward by marine beds of varying ages, it is clear that the Bloomsburg must occupy a different horizon at each more westerly locality in Pennsylvania, Maryland, and West Virginia. He observed also that the disappearance of the red nonmarine phase leaves everywhere marine Cayugan beds at equivalent stratigraphic levels; thus from place to place the Bloomsburg cannot be assigned a definite horizon in the geologic column. In view of this interpretation Woodward prefers the phrase "Bloomsburg facies of the Cayugan."

Wills Creek Formation

The Wills Creek was named by Uhler (1905, p. 19-26) from Wills Creek in the vicinity of Cumberland, Maryland. The Wills Creek formation in Frederick County appears to be persistent in outcrop along Little North Mountain, except in the vicinity of Fawcett Gap; on both sides of Great North Mountain; and at the southeast base of Cacapon Mountain. It was not seen exposed along Cacapon Mountain, but there is a wide area with no exposures which it probably underlies. The Wills Creek is fully exposed in Baldwin Gap, at Chambersville, and at the north end of Great North Mountain on U. S. Highway 50 (new location) just west of the main anticlinal axis.

The Wills Creek is of heterogeneous composition. It seems to be mainly calcareous in the unweathered condition; but, losing its calcium carbonate on weathering, it becomes partly a nonfissile mudrock, partly a fissile clay-shale, and partly a fine-grained, friable sandstone. There is some nearly pure limestone, some of which, however, contains a small amount of very fine quartz sand. Lenses of red shale of undetermined extent are present which make it difficult to determine the boundary with the underlying Bloomsburg formation.

At the top of the Wills Creek is a hard sandstone about 10 feet thick, which, because of its usefulness as a horizon marker, is here named the Tavenner sandstone member from Tavenner Run in the vicinity of

Gainesboro. The Tavenner sandstone member crops out on both sides of a narrow anticlinal area of Wills Creek along Tavenner Run south of Gainesboro. What is believed to be the Tavenner is exposed in the area of folded structure at the north end of Great North Mountain, and along Little North Mountain in Baldwin Gap and north of Round Hill.

Although the boundaries are indefinite, the thickness of the Wills Creek is about 180 feet in Baldwin Gap and probably ranges from 300 to 400 feet in the Great North Mountain area. The general character and thickness of the Wills Creek are shown in Geologic Sections 3 and 5.

The Wills Creek is scantily fossiliferous. In a few layers, two medium-sized species of *Camarotoechia* are plentiful. Ostracodes are abundant in some layers, but they are difficult to find and hard to identify. *Leperditia elongata willsensis* is the most common and probably the most widely distributed. Species of *Eukloedenella, Dizygopleura,* and *Kloedenia* can be recognized. *Leperditia alta,* reported from the Wills Creek in Maryland, has not been seen in the Wills Creek in Frederick County.

Geologic Section 3.—Along U. S. Highway 50 (new location) about 1.3 miles east of Gore, Frederick County. (Section by Edmundson and Pharr).

	Approximate Thickness Feet
WILLS CREEK FORMATION (382 ± feet)	
26. Sandstone, medium-grained; lower 6 feet gray, upper 4 feet green to reddish; interpreted as Tavenner sandstone member	10
25. Siltstone and limestone, thin- to medium-bedded	32
24. Largely covered; few layers of bluish limestone and yellow shale	39
23. Limestone, thin-bedded; partly covered	38
22. Siltstone, greenish-gray, thick-bedded	8
21. Limestone, thin-bedded, impure	3
20. Shale, greenish	4
19. Limestone, bluish-gray, thin-bedded	4
18. Mudstone and siltstone, greenish; 1 foot of red mudstone at top (due to minor folding it is thought that this red bed is repeated about 20 feet to the west; section continued on this assumption)	5
17. Mudstone and siltstone, greenish	8
16. Siltstone and fine-grained sandstone, thick-bedded	10
15. Mudstone, reddish	2
14. Limestone, dark-gray, thin-bedded; contains intercalated green to buff, shaly-weathering mudstone	52

	Approximate Thickness Feet
13. Limestone, thin-bedded, impure	6
12. Mudstone and shale; weathers yellowish	22
11. Covered; abundant shale fragments	11
10. Mudstone, greenish-gray; some shale partings	10
9. Mudstone, reddish	4
8. Limestone, bluish-gray, few intercalated layers of greenish calcareous siltstone	59
7. Limestone, dark-gray, shaly; 1 foot of reddish siltstone at top	20
6. Sandstone, dark-reddish, fine-grained	3
5. Mudstone, bluish-gray to green; weathers shaly	14
4. Mudstone, reddish	4
3. Mudstone, greenish; weathers shaly	14
BLOOMSBURG FORMATION (80 ± feet)	
2. Sandstone and claystone, grayish-red; some layers marked by irregular green blotches	80±
MCKENZIE FORMATION (upper part)	
1. Claystone, light olive-gray; well-developed cleavage results in shoepeg fragments when weathered; contains a few thin dark-gray calcareous beds; thickness estimated across axis of anticline	10-15

Tonoloway Formation

The Tonoloway was named by Ulrich (1911, p. 128) from Tonoloway Ridge west of Hancock, Washington County, Maryland. The formation crops out along the northwest base of Little North Mountain as shown in Baldwin Gap, along the northwest base of Flint Ridge, and in several synclinal areas between Flint Ridge and Great North Mountain. Only a few exposures have been noted along Cacapon Mountain, but it is believed to be continuous in this area since it is well known farther north and west. The Tonoloway is not well exposed as a general rule in Frederick County. The best exposures are on the road south from Sand Ridge 2 miles south of Gore and at the southwest end of Hayfield Ridge 1.5 miles northwest of Hayfield.

The Tonoloway is mostly a thin-bedded limestone but contains a few layers that become sandstone on the leaching out of the carbonate. Some of the layers are finely laminated or straticulate, with many thin, light-gray, or almost white laminae, and on weathering they have a characteristic marking that can be compared to the marbled edges of the pages of a book. As this feature is strictly characteristic of the Tonoloway, it serves well for the identification of the formation.

The Tonoloway is 175 to 200 feet thick in Baldwin Gap. In Hayfield Ridge, at Pembroke Springs, and along U. S. Highway 50 just west of Great North Mountain a thickness of 400 to 500 feet is indicated. The thickness and character of the Tonoloway at Hayfield Ridge, as described by Rodgers (1964) with only slight changes by Edmundson to conform with the style of this report, are shown in Geologic Section 4.

The Tonoloway is moderately fossiliferous as a whole and some layers are highly fossiliferous. The preservation is usually not the best, and identifications are, therefore, not certain in all instances. The following list gives the more common forms: *Stromatopora concentrica, Favosites niagarensis, Favosites helderbergiae, Cladopora?* sp., *Syringopora* sp., *Rhombotrypa ramulosa, Camarotoechia litchfieldensis, C. litchfieldensis* var. *marylandica, Hindella congregata, Spirifer vanuxemi, Stropheodonta bipartita, Pterinea* sp., *Hormotoma rowei, Tentaculites gyracanthus, Bythocypris phaseolina, Kloedenia normalis?, Kyammodes* sp., *Leperditia alta, L. altoides, L. mathewsi,* and *Zygobeyrichia?* The most significant of these fossils for correlation are *Hindella congregata* and the three species of *Leperditia,* although *L. alta* is also cited from the Wills Creek in Maryland. It was not, however, found in the Wills Creek in Virginia. Taken altogether the fossil evidence is adequate for the correlation of the limestone here described with the Tonoloway of Maryland. The Tonoloway is also correlated with the Bossardville limestone of eastern Pennsylvania and New Jersey.

Geologic Section 4.—Along U. S. Highway 50 and in Stodler quarry about 1.5 miles west of Hayfield, Frederick County (modified after Rodgers, 1964).

	Thickness Feet
KEYSER FORMATION (lower part)	
25. Calcarenite, medium dark-gray, coarse-grained, very fossiliferous; crinoid stems abundant	3
TONOLOWAY FORMATION (417 ± feet)	
24. Calcilutite, medium dark-gray, weathers dusky-yellow, laminated to very thinly bedded	2
23. Covered	88
22. Calcilutite, dark-gray, argillaceous, weathers pale-olive, laminated to very thinly bedded; bottom 3 feet contains black chert	18
21. Calcilutite, grayish-black, argillaceous, weathers dusky-yellow to pale-olive, laminated to thinly bedded; chert 1.5 and 1 foot from bottom; celestite geodes containing pyramidal crystals	9.5

	Thickness Feet
20. Calcarenite, medium-gray, fine-grained, argillaceous, weathers medium light-gray, very fossiliferous	2
19. Calcilutite, dark-gray, argillaceous, weathers dusky-yellow to medium-gray, thinly laminated to very thinly bedded	24.5
18. Calcilutite, dark-gray, dense, weathers medium-gray; contains fibrous celestite vein (0.25 inch thick) parallel to bedding at the top	0.5
17. Calcisiltite, dark-gray, argillaceous, dolomitic, weathers dusky-yellow, thinly laminated; contains vugs lined with celestite	0.5
16. Calcilutite, dark-gray, argillaceous, dolomitic, weathers pale-olive, laminated; appears massive on fresh break; contains vugs lined with celestite	13.75
15. Calcilutite, dark-gray, dolomitic, weathers dusky-yellow, massive; nodular and displaying good rock cleavage 2.25 feet from bottom	6.5
14. Calcisiltite, medium-gray, argillaceous, dolomitic, weathers medium light-gray, laminated; intraformational conglomerate in top 4 inches; contains vugs lined with celestite	8.5
13. Calcisiltite, grayish-black, argillaceous, dolomitic, weathers medium light-gray; *Collenia undosa* and celestite crystals associated with the algae 5 feet from the bottom	7
12. Calcilutite, grayish-black, argillaceous, weathers medium-gray, laminated to very thinly bedded; silicified *Hindella congregata* 14 feet from bottom	21.25
11. Calcisiltite, dark-gray, cherty, dolomitic, weathers medium light-gray, very thinly to thinly bedded, mainly 2-inch beds; numerous ostracodes; bluish celestite in small vugs	18
10. Calcilutite, dark-gray, argillaceous, dolomitic, weathers pale-olive, laminated to very thinly bedded; numerous stylolites; abundant ripple marks	28.25
9. Calcarenite-calcisiltite, dark-gray, algal, somewhat siliceous, dolomitic, weathers pale-olive and in cylindrical fragments; celestite masses 3 to 6 inches in diameter	2
8. Calcilutite, dark-gray, argillaceous, weathers pale-olive, laminated	1
7. Calcarenite-calcisiltite, dark-gray, algal, somewhat siliceous, dolomitic, weathers pale-olive	0.75
6. Calcilutite, dark-gray, argillaceous, weathers medium light-gray, laminated; numerous ostracodes	45
5. Calcilutite, dark-gray, argillaceous, dolomitic, weathers medium-light gray; 5-inch, thinly laminated beds; numerous ostracodes; abundant mud cracks; contains vugs lined with celestite	12
4. Calcilutite, dark-gray to grayish-black, argillaceous, weathers pale-olive to grayish-orange, laminated to thinly bedded, mainly 0.5-inch beds; numerous ostracodes; abundant mudcracks in lower 21 feet	77.5
3. Covered	28

	Thickness Feet
2. Calcilutite, medium-gray, argillaceous, dolomitic, weathers pale-olive, laminated to very thinly bedded; numerous mudcracks	3

WILLS CREEK FORMATION (upper part)

1. Siltstone and sandstone; siltstone, grayish blue-green, calcareous, weathers pale-olive, thinly bedded, mostly 6-inch beds; sandstone, lower 4 feet, grayish-red, ferruginous, fine-grained, massive, blocky, jointed	20

Keyser Formation

The Keyser was named by Swartz (1913, p. 98-102) as the Keyser limestone from Keyser, West Virginia, where it is thick and well exposed in a large quarry. The Keyser is believed to be present all along the northwest slope of Little North Mountain, although certainly seen only in Baldwin Gap, 1 mile northwest of Marlboro. Exposures of bedrock are very few along that belt. Adequate exposures show that it is present all along Flint Ridge east of Great North Mountain, and it is well exposed on Sand Ridge west of Great North Mountain and probably persists southwestward to and beyond the county boundary. Good exposures along the bluff of Bear Garden Mountain reveal its presence there. The best exposures of the Keyser are on Richards Run 4000 feet west-northwest of Mountain Falls; along a secondary road 2500 feet west of Gainesboro; and at the north end of Bear Garden Mountain 2 miles south of the State boundary.

The Keyser is all limestone in Frederick County. The basal part is distinctly nodular, being largely made up of rather thick layers of nodular structure. These layers weather to small, roughly lenticular pieces that accumulate on weathered outcrops like gravel. There are, however, coherent layers a few inches thick. The upper part of the formation seems to be composed of thin-bedded limestone, some layers of which are finely granular and light gray. Some layers contain much fine quartz sand. Such a layer, about 2 feet thick, at the south end of Hayfield Ridge contains abundant shells of *Chonetes jerseyensis*. Chert, although not abundant, was observed along Richards Run and as float on Hayfield Ridge. The best estimates for the Keyser in the county, exclusive of the Little North Mountain belt (Geologic Section 5), indicate a thickness of 200 to 250 feet.

Geologic Section 5.—Baldwin Gap through Little North Mountain about 1 mile northwest of Marlboro. (Units 1-15 measured along State Road 623; units 16-20 about 150 feet north of road; and units 21-24 offset about 600 feet along the strike to the northeast. Upper two units scaled from Butts' columnar section.)

	Thickness Feet
NEW SCOTLAND AND KEYSER LIMESTONES (148 + feet); covered at top	
26. Limestone, cherty	80+
25. Limestone	30±
24. Limestone, gray, medium-grained	10
23. Limestone, medium-grained, nodular-weathering	28
TONOLOWAY FORMATION (192 ± feet)	
22. Limestone, fine-grained, laminated, shaly	26
21. Covered	12
20. Limestone, impure	53
19. Limestone, impure; scattered chert; some beds weather cobbly	32
18. Limestone, cherty	2
17. Limestone, gray, fine-grained; some impure partings	42
16. Limestone, shaly, laminated	25
WILLS CREEK FORMATION (181 ± feet)	
15. Sandstone, massive, thick-bedded (Tavenner sandstone member)	9
14. Limestone, shaly	57
13. Limestone, shaly; partly covered	51
12. Sandstone, brown	4
11. Shale, red	5
10. Sandstone, brown	5
9. Shale and intercalated thin-bedded limestone	24
8. Shale and sandstone	20
7. Shale, red	6
BLOOMSBURG FORMATION (160 feet); may include some Clinton in lower part	
6. Sandstone and shale; partly covered; red float	25
5. Largely covered; some red float	26
4. Sandstone and shale, red; some sandstones are thick bedded	62
3. Covered	47
TUSCARORA FORMATION; tentatively interpreted as having fault contacts	
2. Sandstone, gray, medium- to thick-bedded	40
MARTINSBURG FORMATION	
1. Covered; shale noted along strike north and south of State Road 623	76
ELBROOK FORMATION, in upper plate of North Mountain fault	

The Keyser is moderately fossiliferous. The following named species have been identified: *Stromatopora concentrica, Favosites helderbergiae, Lepocrinities manlius* (stems), *Monotrypella? arbusculus, Atrypa reticularis, Camarotoechia litchfieldensis, Chonetes jerseyensis, Meristella praenuntia, Nanothyris mutabilis, Nucleospira swartzi, Rhipidomella emarginata, Schuchertella prolifica, Spirifer modestus, Spirifer vanuxemi, Strophodonta bipartita, Unicinulus keyserensis, Calymene camerata,* and *Kloedenia nearpassi?*. For their bearing on the question of correlation and systemic position of the Keyser, *Chonetes jerseyensis, Strophodonta bipartita, Camaratoechia litchfieldensis,* and *Monotrypella? arbusculus* are the most important of the foregoing list. *Chonetes jerseyensis* is abundant in the lower part of the Keyser and in the lower part of the Decker Ferry limestone of New Jersey and, because of this occurrence, the lower part of these formations has been designated as the *Chonetes jerseyensis* zone. *Strophodonta bipartita, Camaratoechia litchfieldensis,* and *Monotrypella? arbusculus* occur in the Cobbleskill limestone of New York, which is universally recognized as of Silurian age. It seems evident, therefore, that the *Chonetes jerseyensis* zone of the Keyser and the Decker Ferry include the equivalent of the Cobbleskill and is therefore Silurian. *Monotrypella? arbusculus* occurs in the upper part of the Keyser at the south end of Hayfield Ridge not far below the Coeymans limestone, and also in the same relative position in the Manlius limestone of New York, which justifies the correlation of the upper beds of the Keyser with the Manlius. For a number of years the Keyser had been regarded as Devonian, but the facts just set forth seem to justify its classification as Silurian. This conclusion has been reached by Dr. Charles K. Swartz through many years of careful investigation and is fully accepted here. According to this interpretation, the Keyser includes in its lower part representatives of the Cobbleskill limestone of New York, and the Decker Ferry limestone of New Jersey and in its upper part representatives of the Rondout and Manlius limestones of New Jersey and New York. Recent study (Bowen, 1963) of Keyser fauna, mainly new collections from the Keyser-Cumberland region, shows that the Silurian-Devonian boundary may occur within the Keyser limestone.

DEVONIAN SYSTEM

Coeymans (?) Limestone

The Coeymans limestone was named by Clarke and Schuchert (1899, p. 874-878) from the village of Coeymans, Albany County, New York. In Frederick County the Coeymans limestone has been tentatively

identified at the south end of Hayfield Ridge, where it lies between the Keyser and New Scotland limestones. In Hayfield Ridge the Coeymans is a massive bed, approximately 10 feet thick, of coarse-grained, light-gray, crinoidal limestone. No bed of similar lithology has been recognized elsewhere in the county. However, a bed of sandstone with quartz pebbles, apparently similar to what has been described by Woodward (1943, p. 71-72) on Wilson Ridge in the Panhandle of West Virginia and referred by him to the Coeymans sandstone, has been noted by Edmundson (Geologic Section 6, unit 23) along Richards Run about 0.7 mile northwest of Mountain Falls. Monroe (1942, p. 115) also reports the presence of a persistent layer of more or less phosphatic sandstone, from 2 to 5 feet thick, which occurs from 5 to 15 feet above the base of the New Scotland limestone in the Cedar Creek Valley area. Recently Dennison (1965, written communication) has suggested that the sandstone of Coeymans age in Berkeley County, West Virginia, and extending perhaps westward and southward, should be formally recognized as the Elbow Ridge sandstone—a name proposed by Swartz (1939, p. 86) from a section near Elbow Ridge in Franklin County, Pennsylvania. The limestone in Hayfield Ridge is in the stratigraphic position of the Coeymans and contains many large crinoid stems, similar to the Coeymans elsewhere in Virginia, and a meristelloid brachiopod that externally resembles *Gypidula* but is probably *Meristella*.

New Scotland Limestone

The New Scotland was named by Clarke and Schuchert (1899, p. 874-878) from the village of New Scotland, Albany County, New York. The formation is present along the northwest slope of Little North Mountain, except in the vicinity of Fawcett Gap; all along Flint Ridge and on Mineral Ridge, where it yields manganese ore; and in the complexly folded area around the north end of Great North Mountain, thence southward, via Sand, Cove, and Bear ridges, to West Virginia. In the northwest corner of the county the New Scotland follows the crest of Bear Garden Ridge and that of Warm Spring Ridge at the northern boundary of the State.

The New Scotland is a blue-gray, finely crystalline limestone. Its most characteristic lithologic feature in Frederick County is an abundance of dense, brittle chert. The chert occurs throughout the formation in large and small, irregular masses, plates, and stringers and, being very resistant to weathering, accumulates in great quantities on the weathered outcrop of the limestone (Figure 16). This chert is a certain indicator

of the presence of the New Scotland below the surface, even where it is not exposed in place. The chert is naturally dark gray but, on weathering, bleaches to light gray or white. On longer weathering it becomes a mealy-textured rock with a rusty-brown color, the latter being due to oxidation of the small iron content. The approximate thickness along Fall

Figure 16. Cherty New Scotland limestone and typical cuboidal chert float exposed in the bluff of Back Creek about 0.7 mile northwest of Gainesboro.

and Richards runs through Flint Ridge is 100 to 140 feet, the difference probably being caused by uncertainty as to the exact lower limit of the formation.

The best fossil collections were obtained at the south end of Hayfield Ridge; near Cedar Grove at the northwest base of Little North Mountain; and in the old manganese pits located on Mineral Ridge near the Frederick-Shenandoah county line. The following list of species is small, but it includes the most diagnostic of the New Scotland fossils that have been collected in the county: *Edriocrinus pocilliformis, Costellirostra peculiaris, Delthyris perlamellosus, Eatonia medialis, Spirifer concinnus, Spirifer macropleurus, Schellwienella woolworthana?,* and *Platyceras trilobatum.*

According to Butts, the Shriver chert and Becraft limestone are absent in Frederick County, and the Oriskany sandstone immediately succeeds the New Scotland limestone with an intervening stratigraphic gap or hiatus.

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In discussing the Early Devonian nomenclature in the Eastern Panhandle of West Virginia, Woodward (1943) suggests that the interval between the Coeymans and Ridgeley includes the New Scotland, Port Ewen, and Port Jervis formations. According to Woodward (1943, p. 83), the New Scotland in this part of West Virginia consists of a lower cherty member, 20 to 25 feet thick, and an upper shale, which may also contain some representation of the Becraft limestone of New York. The upper shale thins from 11 feet at Cherry Run, eastern Morgan County, to about 1 foot at Wilson Ridge, western Berkeley County, and is not known to continue southward in this belt across the West Virginia-Virginia boundary. The Port Ewen (Woodward, 1943, p. 99) in this region consists of about 25 feet of black limestone with augen-like nodules of black chert which thins southward and disappears near the Virginia boundary. The succeeding Port Jervis (Woodward, 1943, p. 115) is well exposed at Cherry Run along the Potomac River, near Tomahawk, and on Wilson Ridge, western Berkeley County. The thickness is reported as approximately 80 feet, and the rock is mainly light-gray and dark-gray, fairly pure limestone with only sparse chert. Swartz (1929), after studying the Helderberg group in parts of West Virginia and Virginia, considered that the limestones in the upper part of the Helderberg, containing certain diagnostic fossils, were Becraft, but suggested that the beds may range higher than the true Becraft of the type locality. Subsequent work (Swartz, 1939, p. 69-70) led him to the conclusion that the usage of Becraft in the Appalachian region was incorrect; thus the new name Licking Creek limestone was proposed from exposures in Pennsylvania. A tentative correlation chart recently prepared by Dennison (1965, written communication) portrays the interval between the rock of Coeymans age and the Oriskany sandstone as consisting of the New Scotland and Licking Creek formations in the vicinity of Hedgesville, Berkeley County, whereas in the Berkeley Springs area, Morgan County, this interval includes the Shriver chert and a thin Mandata shale rather than the Licking Creek. In light of these suggestions, it is the junior writer's opinion that more detailed work needs to be done in Frederick County to establish what is present in the stratigraphic interval referred to as New Scotland in this report.

Geologic Section 6.—Along Richards Run beginning at the top about 0.7 mile N. 45° W. of Mountain Falls.

	Approximate Thickness Feet
ORISKANY SANDSTONE	
29. Sandstone, light-gray to brown, coarse-grained; contains some pebble zones	65

	Approximate Thickness Feet
NEW SCOTLAND LIMESTONE (98 feet)	
28. Limestone, dark bluish-gray, medium-grained	2
27. Covered	21
26. Limestone, dark bluish-gray, medium-grained; lower 5 feet has irregular impure laminations on weathered surfaces	24
25. Covered	3
24. Limestone, dark-gray to black, nodular, cherty; irregular black chert zones with shaly laminations which tend to wrap around chert nodules are spaced at intervals ranging from about 2 to 18 inches; on weathering the naturally dark-gray chert bleaches to light gray or white, and some develops a mealy texture with a rusty-brown color	42
23. Sandstone, dark-gray to brown; few pebble zones	6
KEYSER FORMATION (187 feet)	
22. Limestone, impure; abundant fossils	3
21. Limestone, cherty; poorly exposed	15
20. Limestone, gray, medium-grained	3
19. Covered; limestone float	105
18. Limestone, coarse-grained, thick-bedded; few argillaceous partings; abundant fossils	15
17. Limestone, dark-gray, medium-grained	36
16. Limestone, dark-gray, coarse-grained	10
TONOLOWAY FORMATION (295 feet)	
15. Limestone, dark-blue to black, fine-grained, thinly laminated	40
14. Covered	9
13. Limestone, dark-blue to black, fine-grained, thinly laminated	9
12. Covered	57
11. Limestone, dark-gray, fine-grained, thinly laminated	4
10. Covered	18
9. Limestone, medium-grained, irregularly banded	3
8. Covered	18
7. Limestone, medium-grained, irregularly bedded; contains nodules of chert	6
6. Limestone, mainly thin-bedded but some massive nodular-bedded; nodular beds have crinkly clay partings; few beds contain abundant fossils	69
5. Covered	42
4. Shale and sandy mudrock; exact lower limit of formation is uncertain	20
WILLS CREEK FORMATION (upper 76 feet)	
3. Sandstone; although relatively thin, this unit may represent the Tavenner sandstone member at the top of the Wills Creek formation which was named from Tavenner Run about 12 miles to the northeast	2
2. Shale and sandy mudrock	14
1. Shale, yellow and red; 12-foot red shale occurs in the upper part	60

Oriskany Sandstone

The Oriskany was named by Hall (1839, p. 308-309) from Oriskany Fall, Oneida County, New York. The formation is present in outcrop along the northwest base of Little North Mountain, except in the vicinity of Fawcett Gap; along the crest of Flint Ridge; on the crest and northwest slope of Sand Ridge south of Gore; and along Cove and Bear ridges via Rock Enon Springs into West Virginia. It is also well exposed on the crest and southeast slopes of Bear Garden Mountain and Warm Spring Ridge in the northwest corner of the county.

The best exposure is in the quarry at Sand Ridge (Figure 17), 1 mile south of Gore, and on the long slope at the north end of the ridge. Other good exposures are 0.25 mile southwest of Nain; in the creek flat 0.25 mile northwest of the County Farm; at the west end of an inactive roadside quarry 0.7 mile northwest of Gainesboro; and along the railroad on Back Creek 0.5 to 1 mile northwest of U. S. Highway 50. There are also excellent exposures on the roads crossing Bear Garden Mountain in the northwest corner of the county.

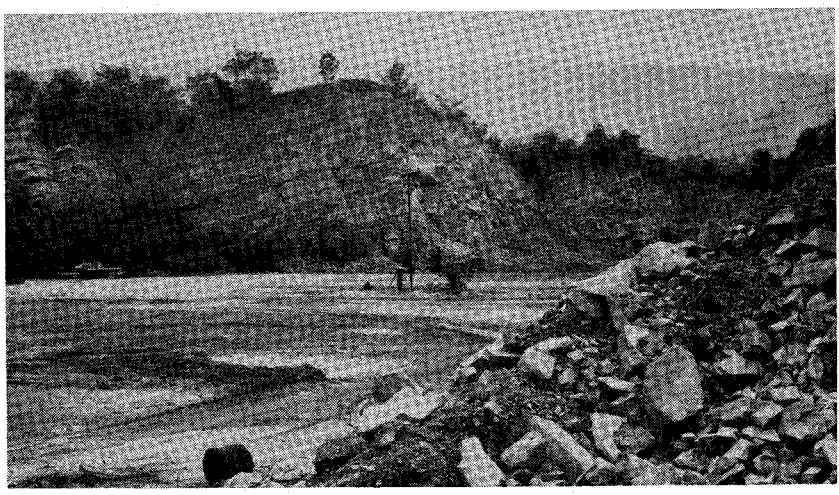

Figure 17. View southwestward along the strike of the Oriskany sandstone on the east limb of the Sand Ridge anticline at the Virginia Glass Sand Corporation quarry about 1 mile south-southwest of Gore (1962).

The Oriskany is predominantly a coarse-grained, thick-bedded sandstone, but in some localities it is so calcareous that it looks like a limestone on freshly exposed surfaces (Figure 18). It is constitutionally friable wherever the calcareous cement is leached out on weathering, so that it

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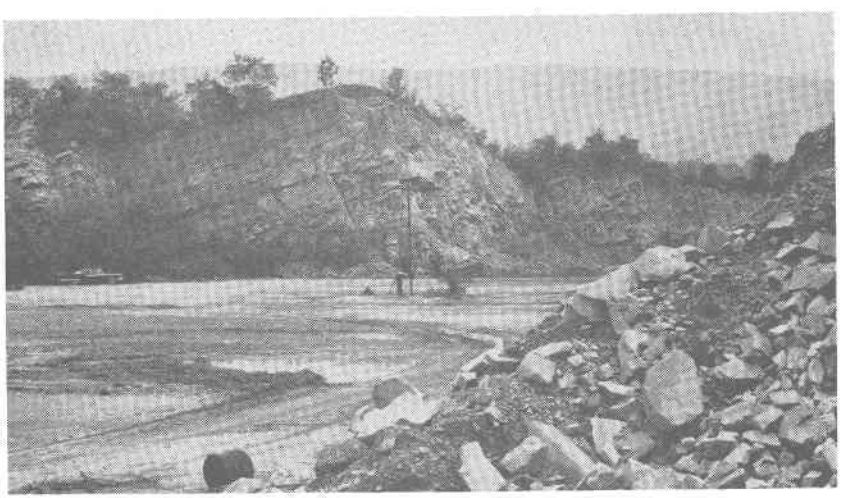

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readily disintegrates or can easily be crushed to sand. Where it is nearly free of iron, as it is in many localities, it is highly suitable for glass sand and is extensively used for glass manufacture. The large quarry for glass sand in Sand Ridge, about 1 mile south of Gore, is in the Oriskany.

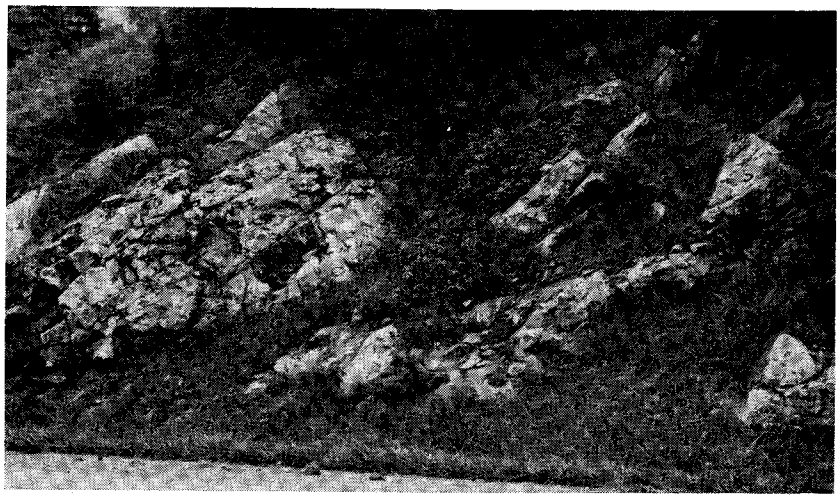

Figure 18. Calcareous facies of the Oriskany with several beds of quartz-pebble conglomerate exposed along U. S. Highway 522 about 0.7 mile northwest of Gainesboro. Contact with the Onondaga shale, shown in Figure 20, is near the left margin of photograph.

At the locality 0.25 mile northwest of the County Farm, it appears to be an unusual lenticular mass of conglomerate a few hundred feet long and has an estimated thickness of 200 feet. Here the rock contains quartz pebbles 1.5 inches in diameter. In the synclinal area south of Tunnel Ridge another unusual phase of the Oriskany is developed. In this area it is a coarse, massive, cavernous, iron-impregnated rock, 20 feet or more thick, which in places projects above the surface. On the top of Tunnel Ridge some limonitic-looking iron ore occurs in pockets and impregnated areas of the rock, and old diggings indicate that efforts have been made to exploit the ore, presumably for the old Taylor furnace on Furnace Run 0.75 mile east of Tunnel Ridge.

The thickness of the Oriskany is about 100 feet at Rock Enon Springs as measured across the vertical beds in an exposed cliff. It is 65 feet in the gorge of Richards Run west of Mountain Falls, and about 60 feet is exposed at the west end of the inactive quarry northwest of Gainesboro. The Oriskany appears to be abnormally thick in the Virginia Glass Sand Corporation quarry 1 mile southwest of Gore. The distance across the strike, extending from a small anticline in weathered cherty

readily disintegrates or can easily be crushed to sand. Where it is nearly free of iron, as it is in many localities, it is highly suitable for glass sand and is extensively used for glass manufacture. The large quarry for glass sand in Sand Ridge, about 1 mile south of Gore, is in the Oriskany.

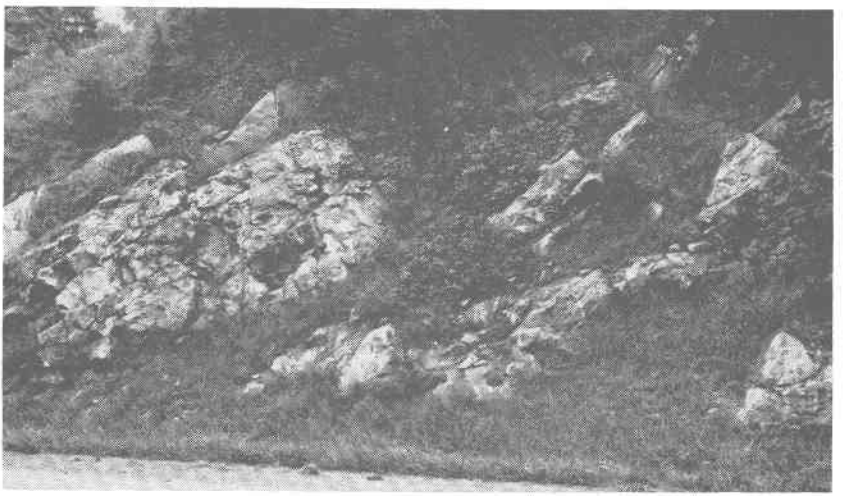

Figure 18. Calcareous facies of the Oriskany with several beds of quartz-pebble conglomerate exposed along U. S. Highway 522 about 0.7 mile northwest of Gainesboro. Contact with the Onondaga shale, shown in Figure 20, is near the left margin of photograph.

At the locality 0.25 mile northwest of the County Farm, it appears to be an unusual lenticular mass of conglomerate a few hundred feet long and has an estimated thickness of 200 feet. Here the rock contains quartz pebbles 1.5 inches in diameter. In the synclinal area south of Tunnel Ridge another unusual phase of the Oriskany is developed. In this area it is a coarse, massive, cavernous, iron-impregnated rock, 20 feet or more thick, which in places projects above the surface. On the top of Tunnel Ridge some limonitic-looking iron ore occurs in pockets and impregnated areas of the rock, and old diggings indicate that efforts have been made to exploit the ore, presumably for the old Taylor furnace on Furnace Run 0.75 mile east of Tunnel Ridge.

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limestone (Figure 19) along the west face of the quarry to the top of the Oriskany, is about 450 feet and the dip at the Oriskany-Onondaga contact is about 45° SE. If an average dip of only 25 degrees is assumed. the thickness is not less than 200 feet at this locality. Lowry (1954, p. 23-26) recognized the same difficulty in accurate determination of thickness at this locality and suggested that the Oriskany appeared to have a thickness of several hundred feet. Woodward (1943, p. 130, 135, 148), who preferred the use of Ridgeley sandstone instead of Oriskany as a lithologic unit for mapping purposes, suggested that thicknesses of 200 to more than 300 feet in the Great North-Cacapon mountain region may represent an overthickened sandstone facies that descends into some portion of the underlying Helderberg.

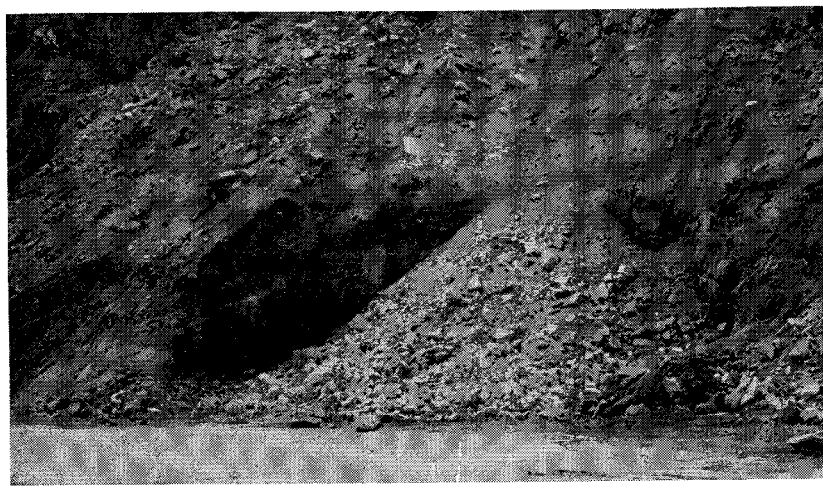

Figure 19. Weathered cherty limestone, beneath the Oriskany sandstone, is exposed along the axis of the Sand Ridge anticline near the west face of the Virginia Glass Sand Corporation quarry (1962).

The Oriskany is sparsely fossiliferous. The largest number of fossils was noted on the knob of Flint Ridge where it is crossed by the road to Richards Run west of Mountain Falls. Here *Spirifer arenosus* is very abundant and *Spirifer murchisoni* was noted. The most fossils were collected by the workmen at the Virginia Glass Sand Corporation quarry south of Gore, and were donated by Mr. Sawyer, the Superintendent. These include the unique and rare crinoids, *Technocrinus andrewsi* and *T. lepidus,* and the more common *Spirifer arenosus, Rensselaeria marylandica, Platyceras gebhardi,* and *P. subfalcatum. Spirifer arenosus* is considered the main guide fossil.

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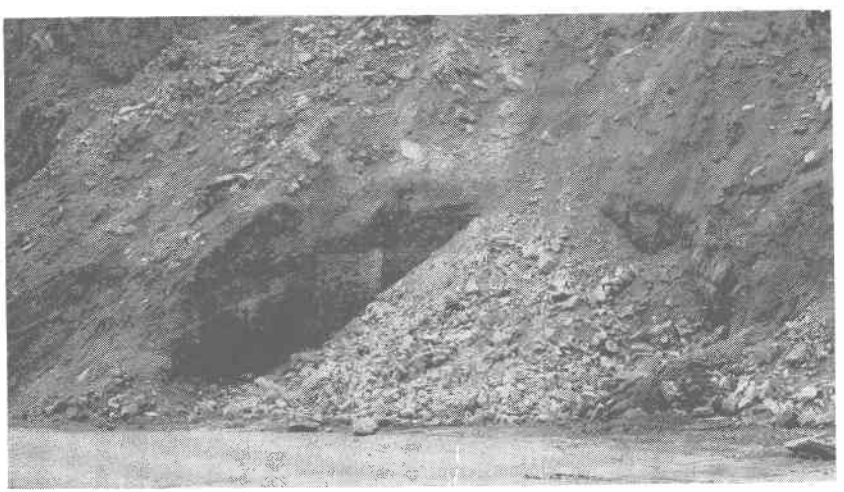

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Onondaga Formation

The Onondaga was named by Hall (1839, p. 293-309) from Onondaga County, New York, where the formation is largely a cherty limestone and at one time was known as the Corniferous limestone. In Virginia it has been included in the "Romney" shale as a basal member (Kindle, 1912). The Onondaga is present in outcrop all along the northwest slope of Little North Mountain, except in the vicinity of Fawcett Gap; along the southeast flank of Flint Ridge; on the northwest slope of Great North Mountain; and along the southeast side of Bear Garden Mountain. It also crops out on a narrow anticline in an area of Marcellus shale 0.5 mile west of Mountain Falls and in a long syncline southwest of Beans Hill. There are especially good exposures of the Onondaga in the folded areas in the vicinity of Hayfield; south of Gravel Springs; in the wide outcrop belt 0.5 mile west of Fremont Church, about 3 miles south of Hayfield; and in a narrow anticline west of Mountain Falls.

In Frederick County the Onondaga, in weathered exposures, is a dark clay rock that possibly should be best designated as shale, although it is not fissile, but breaks up into small chips and lumps. Possibly the unweathered rock is calcareous, but the weathered material shows no trace of calcium carbonate on treatment with acid. A very few small, thin pieces of fossiliferous limestone have been found. Also a little lumpy, coarse, gray rock occurs, and in places the shale is pale green on weathered outcrops.

Recent studies by Rader (1962, p. 68-71) show that the Needmore shale (Onondaga of this report) is about 115 feet thick in an inactive quarry along U. S. Highway 522, 0.7 mile northwest of Gainesboro (Figure 20); and at Hayfield, about 3.5 miles to the southwest, he reports a thickness of 140 feet but with the contact between the Needmore and Oriskany not exposed. According to Butts, there are a number of places along Flint Ridge where the width of outcrop and the dip suggest a thickness of about 175 feet.

The Onondaga is moderately fossiliferous. The following named species have been collected in Frederick County: *Trachypora elegantula?*, *Cystodictya ovatipora*, Fenestellids, *Ambocoelia umbonata*, *Anoplotheca acutiplicata*, *Chonetes buttsi*, *Acidaspis callicera*, *Lichas contusus*, *Odontocephalus aegeria*, *Phacops rana*, *Bollia ungula*, *Favulella favulosa*, *Kloedenia* sp., and *Octonaria stigmata*. The trilobites, except *Phacops rana*, are present in the Onondaga from New York to the James River

in Virginia and, so far as reported, occur only in the Onondaga. The ostracodes, *Bollia ungula, Favulella favulosa,* and *Octonaria stigmata,* are likewise known in the Onondaga, but in no other formations. One or

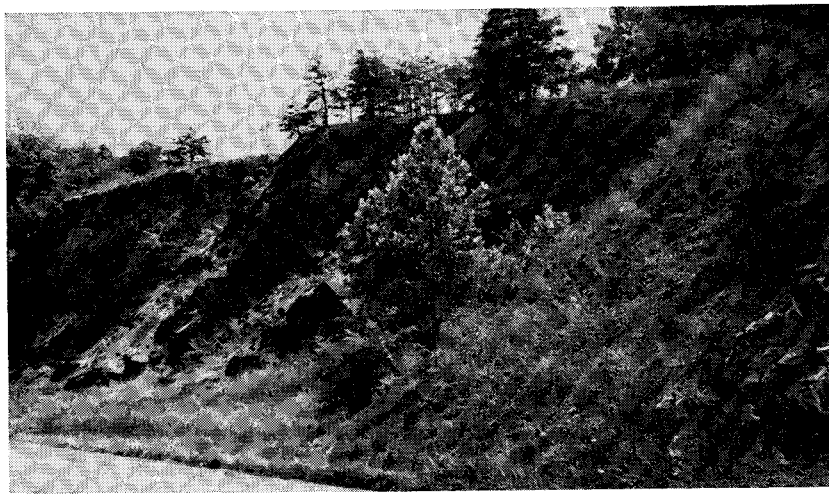

Figure 20. Onondaga shale completely exposed in inactive roadside quarry along U. S. Highway 522 about 0.7 mile northwest of Gainesboro. Contact with Oriskany is in lower right of photograph.

more of these species can be found in every exposure of the Onondaga; in some instances, all on the same slab. The brachiopod, *Anoplotheca acutiplicata,* is also constant in occurrence and equally diagnostic of the Onondaga.

After detailed study of many sections in West Virginia and bordering states, including three localities in Frederick County, Virginia, Dennison (1961, p. 10) proposed that the top of the Onesquethaw stage be defined as the top of the Tioga metabentonite (or at a stratigraphic postion of equivalent age if the metabentonite is absent) and that the base be drawn at the top of the Deerpark stage (top of the Oriskany sandstone and its equivalents). The Tioga metabentonite has not been identified in Frederick County. However, Rader (1962, p. 68-71) who has measured two sections in the county suggests that it may be represented in the covered interval at the base of the Marcellus. According to Dennison (1961, p. 15-16), the marine strata of the Onesquethaw stage are composed of three major lithologies, namely shale, chert, and limestone with subordinate amounts of sandstone and dolomite. Where dominantly shale, as it is in Frederick County, it constitutes the Needmore shale—a name proposed by Willard (1939, p. 149) from Needmore,

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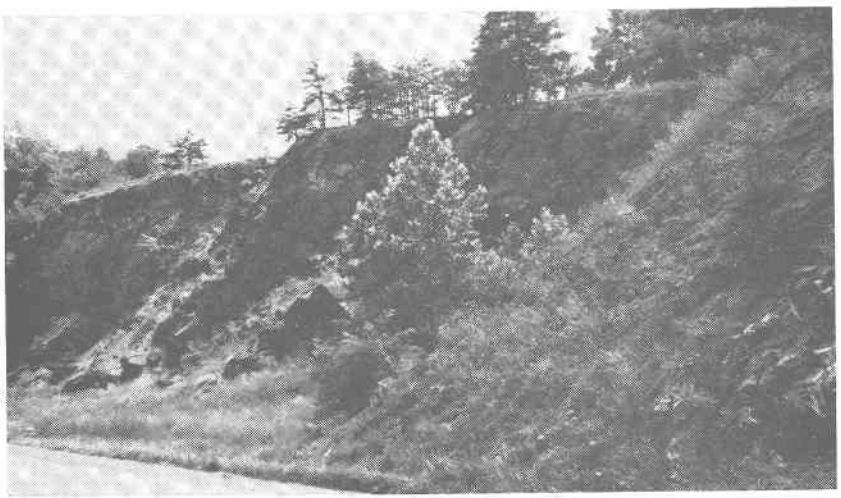

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Fulton County, Pennsylvania. Subfacies of the Needmore (Beaver Dam black shale, calcitic shale, and calcitic shale and limestone) have been recognized by both Dennison and Rader in Frederick County. In Edmundson's opinion, to accept this change in Frederick County would bring the stratigraphic nomenclature more into conformity with current usage.

Marcellus Shale

The Marcellus was named by Hall (1839, p. 295-296) from the village of Marcellus, Onondaga County, New York. The Marcellus is constant in occurrence throughout the county. It has the same distribution as the Onondaga and the Osiskany, with the exception that it crops out at Fawcett Gap where these other formations are absent, at least in outcrop.

There are good exposures in the Little North Mountain belt at Green Springs; at Fawcett Gap where the bleached-gray aspect is particularly well developed; and at Coal Mine School northeast of Wheatfield, Shenandoah County. The greatest exposure is along the wide belt southwest of Hayfield to the southern boundary of the county where the shale is exposed in many road cuts. In places this belt is nearly a mile wide. The shale is extensively exposed also at and just east of Gainesboro and in places along the North Fork of Sleepy Creek in the northwest quarter of the county.

The Marcellus in Frederick County is a dark-gray to black, more or less fissile (in places highly fissile) shale. On outcrop the mass effect is black, on which is based the common designation "black shale." But on close examination, these apparently black parts of the shale can be seen to be dark gray. Some layers are siliceous and micaceous and yield more rigid and tougher laminae. The dark color is due to the presence of carbonaceous material, which may be leached out on weathering so that the leached rock becomes a yellowish gray.

On the North Fork of Sleepy Creek in the northwest part of the county, there is included in the Marcellus, above a few hundred feet of very black, fissile shale, 500 feet of gray nonfissile, unfossiliferous shale which is exposed along U. S. Highway 522 at the State boundary. This upper shale might, with equal probability, be included in the Hamilton. The junior writer, when compiling the geologic map for this report, shifted the Marcellus-Hamilton boundary westward in this part of the county so that the nonfissile gray shale is included in the lower part of the unit mapped as the Hamilton.

The Marcellus apparently has a wide range in thickness. Along the northwest base of Little North Mountain, where the Marcellus is vertical, the width of outcrop does not permit a thickness of more than about 200 feet. In the wide belt from Gainesboro southwestward to the boundary of the county, the steep dip gives the impression of a thickness of thousands of feet. However, regardless of impressions, the dip cannot be constant across the outcrop. That is evident from the structural conditions existing at Hayfield at the north, and south of Gravel Springs on the south, where the axes of several folds can be seen to pass into the Marcellus. Possibly more minute folding or plications exist but are not revealed in the exposure. Still it is probable that the thickness here is considerably greater than it is at the northwest base of Little North Mountain, and a thickness of at least 500 feet might be a conservative estimate.

The Marcellus is almost destitute of fossils. The only species at all common, except *Styliolina fissurella,* are *Leiorhynchus limitare* and a small *Chonetes* cf. *C. lepidus.* Rare forms, usually badly preserved, are *Paleschara* and *Plumalina plumaria?.* The *Leiorhynchus* is widely distributed in the Marcellus of New York, Pennsylvania, and Virginia, and may be regarded as a guide fossil for that formation. The *Paleschara,* although rare in occurrence, is also widely distributed, and, so far as observed by the writer, is in association with *Leiorhynchus limitare.*

Hamilton Formation

The Hamilton was named by Vanuxem (1840, p. 380) from exposures at West Hamilton, Madison County, New York. In that region the beds have been subdivided into several parts, variously called formations or members. In Frederick County, however, no basis for such a subdivision has been recognized. Here the Hamilton succeeds the Marcellus and is overlain unconformably by the Brallier, because the Naples or lowermost Portage beds which normally lie between the Hamilton and Brallier have not been recognized in the county.

Based on recent studies in West Virginia and Maryland, Dennison (1963, p. 220) prefers to recognize the Marcellus and Mahantango (unit mapped as Hamilton in this report) formations in West Virginia, and to consider them collectively as the Hamilton Group. In Edmundson's opinion, to accept this change in Frederick County would bring the stratigraphic nomenclature of Virginia more into conformity with that of other states.

The most easterly belt of Hamilton parallels Little North Mountain on the west side and is continuous throughout its extent in Frederick County. Another broad belt enters Frederick County from West Virginia north of De Haven, extends southward for 6 miles, and splits north of Gainesboro, on the axis of the Great North Mountain anticline, into two branches which continue southward on both sides of Great North Mountain. The most westerly belt crosses the northwest corner of Frederick County about 2 miles southeast of Cacapon Mountain.

The formation is predominantly a fine-grained, blue-gray sandstone or siltstone interbedded with layers of dark-colored, crumbly, nonfissile, clayey rock or shale. On weathering, parts of the formation develop a spheroidal structure (Figure 21) and in mass effect the color becomes very dark gray. The color seems to be due to the oxidation of iron or manganese. Layers of highly fossiliferous calcareous sandstone occur. These on extreme weathering are reduced to a cavernous or porous, rotten, friable, blackish rock. A few beds of sandstone are coherent. They seem to be penetrated by innumerable, closely spaced fissures subparallel to the bedding, so that the rock breaks down to thin flakes at the lightest blows of the hammer. It is almost impossible to trim a fossiliferous slab down to portable dimensions without shattering it into pieces and destroying the fossils. The only exception to this general character of the Hamilton is a coherent, massive sandstone about 100 feet thick at the top. This sandstone is exposed on Cedar Creek about 0.5 mile west of Baldwin Gap and on U. S. Highway 50 about 0.5 mile west of Chambersville. It is probable that the same sandstone, containing large specimens of *Taonurus velus,* is exposed along U. S. Highway 522 just west of Isaacs Creek (Figure 22). The best determination of the thickness was made at the continuous, vertical exposure along U. S. Highway 50 about 0.5 mile west of Chambersville. Here the thickness is about 1100 feet.

The Hamilton is in part highly fossiliferous, but the list of identified species is small. It includes the following: *Microcyclus intermedius, Favosites hamiltoniae?, Ancyrocrinus bulbosus,* Fenestellids, *Ambocoelia umbonata, Chonetes vicinus?, C. mucronatus?, Cranaena lincklaeni, Cyrtina hamiltonensis, Orthotetes arctostriata, Rhipidomella vanuxemi, Spirifer audaculus, S. granulosus, S. mucronatus, S. tullius, Strophodonta concava, S. demissa, S. inequistriata?, S. perplana, Tropidoleptus carinatus, Actinopteria decussata?, Aviculopecten* (fragments), *Glyptodesma erectum, Modiomorpha alta, M. concentrica, Nucula corbuliformis, Palaeneilo maxima, Paracyclas lirata, Pleurotomaria ella?, Pterinea flabel-*

lum, Bactrites, and *Dipleura* (*Homalonotus*) *dekayi.* Most of the fossils included are well-known and diagnostic Hamilton species and prove the Hamilton age of the formation.

Figure 21. Spheroidal weathering in the Hamilton formation exposed along U. S. Highway 50 (new location) about 0.5 mile west of Chambersville.

Figure 22. Thick-bedded sandstone near the top of the Hamilton formation exposed along U. S. Highway 522 about 1.2 miles southeast of Cross Junction.

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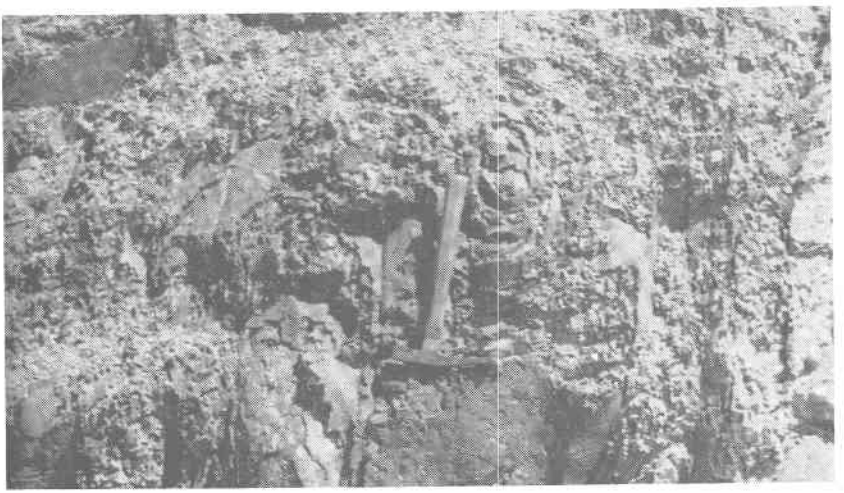

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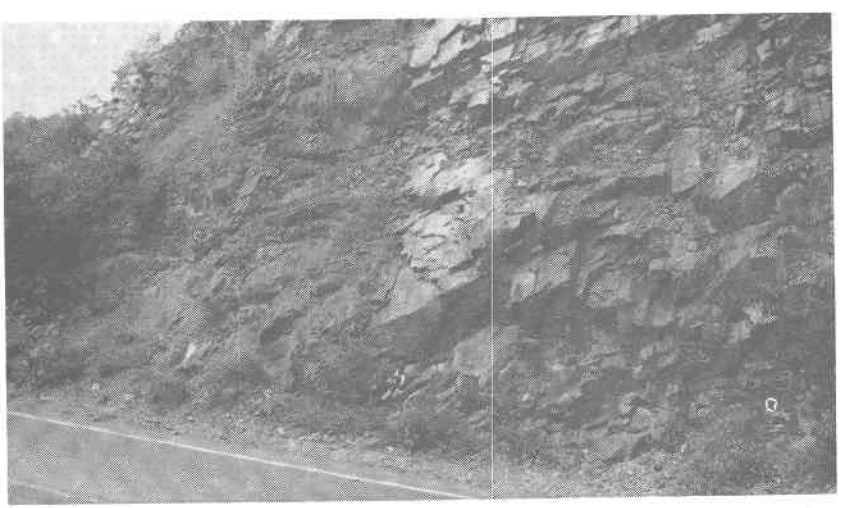

Figure 22. Thick-bedded sandstone near the top of the Hamilton formation exposed along U. S. Highway 522 about 1.2 miles southeast of Cross Junction.

Brallier Formation

The Brallier was named by Butts (1918, p. 523-537) from Brallier Station on the Huntingdon and Broadtop Mountain Railroad, Bedford County, Pennsylvania. In Frederick County, it succeeds the Hamilton and crops out in belts parallel to those of the Hamilton throughout the area. It crops out also in a narrow anticlinal strip along Brush Creek in the northwestern part of the county. The best and most accessible exposures of the Brallier are those extending along U. S. Highway 50, 0.5 mile west of Chambersville; crossing the highway 1.5 miles southeast of Hayfield; and beginning at the Hamilton contact about 600 feet west of Gore.

The formation is composed of siliceous and micaceous shale and sandstone (Figure 23). The shale is so called because of its thinly laminated structure, but it is not an indurated fissile clay rock, which is the common definition of shale. The laminae are commonly stiff or rigid and resistant to breakage, and their surfaces are commonly undulating or dimpled. The sandstone is very fined grained and mostly in even layers, 2 to 6 inches thick, which form blocks due to the presence of joints. The color of the sandstone is gray, and the shale is greenish gray. The best estimates of thickness indicate about 1250 feet in the belt immediately northwest of Little North Mountain, and approximately 1800 feet in the belts southeast of Hayfield and northwest of Gore. Some uncertainty exists with respect to the upper boundary of the Brallier, because there appears to be a transition of Brallier types into the overlying Chemung. The lower boundary is reported (Woodward, 1943, p. 391-394) as gradational with the Harrell shale in parts of the Eastern Panhandle of West Virginia, and in other sections of this district the Harrell is absent. Because the Harrell has not been recognized in Frederick County, there is a distinctive boundary between the Brallier and the underlying fossiliferous beds of Hamilton.

The Brallier is generally nearly unfossiliferous, but the following fossils are present in Frederick County: *Arthroacantha ithacensis, Pteridichnites biseriatus, Chonetes* aff. *C. coronatus, Leiorhynchus globuliforme, Productella exanthemata?, P. speciosa?, Pugnax altus, Reticularia laevis, Schizophoria impressa?, Spirifer mesastrialis, Spirifer mucronatus posterus, Lyriopecten tricostatus.* All of these fossils except *Chonetes* and *Productella exanthemata* are cited by Williams and Kindle (1905) as occurring in the Portage formation (Ithaca and Enfield members) in the region around Watkins Glen and Ithaca, New York. Thus, the Brallier of Frederick County is thought to include the equivalent of the Ithaca

and Enfield, and through them the Hatch and Gardeau members of the Portage in the gorge of Genesee River, Livingston County, New York. The reason for using Brallier instead of Portage or Gardeau is that the Brallier does not include all of the Portage group and is believed to in-

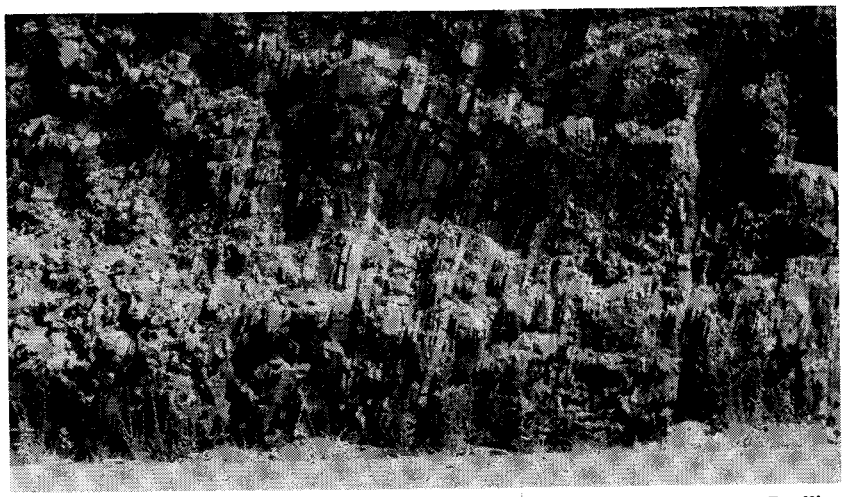

Figure 23. Shale and very fine-grained, thin-bedded sandstone of the Brallier formation exposed along U. S. Highway 50 (new location) about 0.6 mile west of Chambersville.

clude the Hatch, as well as the Gardeau, flags and shales. In other words, the Brallier includes more than the Gardeau and less than the Portage. In addition, the Brallier corresponds to about the lower half of the Jennings shale and Kimberling shale as described in the Staunton (Darton, 1894) and Pocohontas (Campbell, 1896) folios of the U. S. Geological Survey.

Chemung Formation

The Chemung was named by Hall (1839, p. 322-326) from Chemung Narrows of Chemung River, 10 miles southeast of Elmira, New York. The main areas of the Chemung in Frederick County are in the Mt. Pleasant syncline, divided for part of its extent into two belts by a long, narrow outcrop of the Hampshire formation; around the south end of the wide area of Hampshire in the Sleepy Creek Mountain (Meadow Branch) syncline; and along the southeast side of Cacapon Mountain in the northwest corner of the county. The best exposures of the Chemung are in the four belts that are crossed by U. S. Highway 50. The belt west of the Mt. Pleasant syncline and the first belt northwest of Gore are especially instructive because red rock is interbedded with fossiliferous gray beds.

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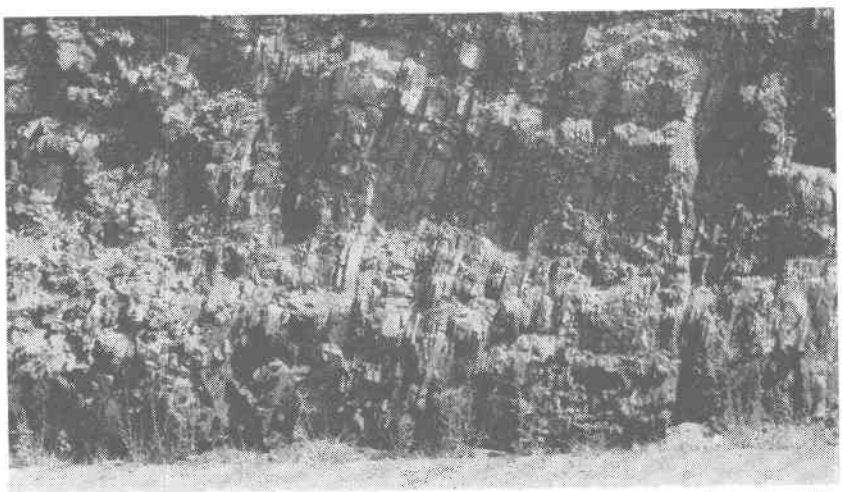

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The Chemung is composed almost entirely of clastic rocks, sandstone, conglomerate, and shale. A rare bed is made up largely of fossil shells, and such beds are commonly called "shell limestone." The sandstone is generally coarse grained, loosely cemented, and rusty or blotched with manganese stains, especially where weathered at or near the surface. Such beds of sandstone generally contain many molds of fossil shells, mainly brachiopods and pelecypods. The shale interbeds are generally nonfissile, yellowish or greenish clay rock or mudstone. A distinctive feature is quartz-pebble conglomerate, which is absent or very rare in any of the adjacent formations. The pebbles are of vein quartz, generally 0.5 inch or less in diameter, but a few are as much as 1 inch in diameter. At least four such beds, 1 inch to 5 feet thick, are exposed in the belt of Chemung on U. S. Highway 50 west of Gore.

Another feature which distinguishes the Chemung from the Brallier is the occurrence of red shale and sandstone interspersed throughout the Chemung, especially in the upper half. These red beds are interbedded with gray sandstone and shale containing Chemung fossils. Regarding the lower boundary, there is no sharp and easily recognizable surface between the Chemung and Brallier, but at some distance above or below the boundary, as located, a difference can be seen. The Chemung contains thicker and more coherent beds of sandstone, thicker bedded than in the Brallier and interbedded with greenish or yellowish shale or nonfissile "mudrock"; in the Brallier thin, evenly bedded sandstone and stiff, greenish, micaceous shale predominate. These types of rock grade into one another without a prominent lithologic change at any horizon. The boundary is placed where fossils of the Chemung appear in the general succession. Where fossils are not found, the boundary is placed, as nearly as can be judged, at the horizon of their appearance at other localities. The thickness of the Chemung as measured across the belt crossed by U. S. Highway 50 northwest of Gore, where the road is at right angles to the strike, and the dip is substantially vertical, is about 2500 feet.

The Chemung is only moderately fossiliferous, and the fossils are generally badly preserved, so that in many instances, specific or even generic determinations are uncertain. The following list includes the names of the best identified fossils: *Protolepidodendron, Atrypa reticularis, Bucanopsis maera, Camarotoechia eximia, C. congregata?, Cyclonema crenulistriata, C. multistriata, Cystodictya* sp., *Delthyris mesacostalis, Ectenodesma birostratum, Glossites?* sp., *Goniophora chemungensis?, Leiopteria* cf. *L. bigsbyi, Leptodesma potens, Loxonema*

terebrum?, Nuculites oblongatus, Productella lachrymosa, Pterinea dispanda?, Pugnax?, Schizodus chemungensis?, Schizophoria impressa, Sphenotus sp., *Spirifer disjunctus, S. mesastrialis, Tropidoleptus carinatus,* and *Acantholepis* (fish spines).

The most significant fossil in this list is *Spirifer disjunctus* which ranges through nearly the full thickness of the formation and is regarded as a diagnostic Chemung fossil. In fact, the entire assemblage is known to occur in the Chemung and proves the Chemung age of the formation here described. The Chemung corresponds to approximately the upper half of the Jennings shale and of the Kimberling shale as described in the Staunton (Darton, 1894) and Pocohontas (Campbell, 1896) folios of the U. S. Geological Survey.

The reader is referred to Woodward's (1943, p. 446-468) discussion of the Chemung and particularly those belts in the Eastern Panhandle of West Virginia which are parts of a continuous outcrop that extends southwestward from Pennsylvania into northern Virginia. Dennison (1963) has also discussed the Chemung along the Allegheny Front in northern West Virginia and Maryland and, more recently (1965, written communication), has proposed that for the present in West Virginia the Chemung group can be mapped, and distinct lithologic zones within the group indicated; then, after distinct formations are named to comprise the entire interval of the Chemung Group, the name Chemung should be dropped from the lithostratigraphic nomenclature of West Virginia and adjacent states.

Hampshire Formation

The Hampshire was named by Darton (1892, p. 13-18) from Hampshire County, West Virginia. It has been called the Catskill formation from the Catskill Mountains in New York, but subsequent detailed investigations have led to the conclusion that it is not Catskill in this part of the Appalachians but a younger formation not present in the Catskill Mountains. A discussion and sketch section showing the relations of the Hampshire and Catskill formations are presented by Butts (1940, p. 333). The Hampshire is the youngest formation in Frederick County, except for sandstone and conglomerate of Mississippian age on Shockeys Knob along the State boundary at the southwest end of Sleepy Creek Mountain. The Hampshire occupies the deeper synclines, namely the Mt. Pleasant, Sleepy Creek Mountain (Meadow Branch), and Whitacre synclines.

The Hampshire is mainly a thick mass of red shale or mudrock and sandstone. The mudrock is nonfissile and tends to break into irregular lumps like a piece of dry mud. The sandstone is medium grained, compactly cemented, and medium to thick bedded; some of it is arkosic. It is estimated that 80 percent of the mass is commonly designated red shale or red sandstone; in reality it is not red, but rather some shade of brown. In addition to the distinctive "red" beds, there are gray or greenish-gray sandstones up to 100 feet thick.

Only in the Sleepy Creek Mountain (Meadow Branch) syncline is the full thickness of the Hampshire present. Based on the assumption that the top of the Hampshire is at the base of Shockeys Knob and the bottom along Little Mountain Run 5500 feet to the west, and that the average dip is 30° SE., the calculated thickness is about 2700 feet. After the difference in elevation, 900 feet, is added to this figure, the total calculated thickness is about 3600 feet. This determination agrees closely with that of 3800 feet made in the Pawpaw-Hancock area (Stose and Swartz, 1912) and with the thickness of 3000 to 4700 feet reported in Pendleton and Hardy counties, West Virginia.

The Hampshire in Frederick County is nonmarine and composed largely of red beds; however, some red beds occur in the general sequence below the Hampshire where they are interbedded with gray sandstone and shale carrying Chemung fossils. Tongues of gray sandstone with marine fossils of Chemung types occur in the red Hampshire beds along the Allegheny Front a few miles west of Altoona, Pennsylvania. From the Allegheny Front at Lock Haven, Pennsylvania, the Hampshire can be traced westward along the Susquehanna River and Sinnamahoning Creek into the Oswayo and Cattaraugus formations in the region of Olean, New York, and farther west, into the Conewango formation in the vicinity of Warren, Pennsylvania. In this distance the "red" beds disappear, except for a single bed 10 feet thick at Warren, and the full thickness is replaced by fossiliferous, gray, marine beds containing a modified Chemung fauna. These beds are directly overlain near Olean and Warren by the Knapp sandstone containing such Lower Mississippian fossils as *Parapharhynchus, Shumardella,* and *Eumetria.* On the basis of this evidence the Hampshire is considered as uppermost Upper Devonian.

MISSISSIPPIAN SYSTEM

Pocono (?) Formation

Sleepy Creek Mountain, a prominent ridge in West Virginia, terminates rather abruptly to the south at Shockeys Knob along the

Virginia boundary. The rocks at this locality have been identified by Grimsley (1916) as the Rockwell formation and the Purslane sandstone—the latter forming the crest of the mountain. Butts refers to the sandstone on Shockeys Knob as possibly representing the basal member of the Rockwell formation as described in the Pawpaw-Hancock folio (Stose and Swartz, 1912).

In compiling the geologic map for this report, Edmundson used the name Pocono (?) formation to include the thick-bedded clastic rocks which occur above the Hampshire red beds and extend for about 700 feet south of Shockeys Knob into Frederick County. No reference to the Pocono was made in Butts' manuscript; however, he (1940, p. 347) had applied the name to rocks of Mississippian age known to occur as far northeast as Rockingham County, Virginia.

STRUCTURE

The sedimentary rocks in Frederick County are generally inclined at angles to the almost horizontal position in which they were deposited. The present attitude of the rocks is related to late Paleozoic orogeny when compressive forces from the east folded the bedrock into a series of synclines and anticlines. Most of the axes of these folds and the truncated edges of the strata which crop out along the limbs of the structures are approximately parallel and trend northeastward. In places the normal geologic sequence of the formations is disrupted by faults.

The symmetry of the folds produced in response to the compressive forces from the east is shown by the oversteepened and locally overturned east limbs of synclines and west limbs of anticlines, and by the easterly dip of the thrust faults which cut the major folds. Minor folding (Figures 24, 25), faulting (Figure 26), and cleavage (Figure 10) are well exposed in the incompetent soft shales and thin-bedded limestones and sandstones. Other characteristic features, formed during the course of the deposition of the sediment, are ripple marks, mudcracks (Figure 7), and cross bedding (Figure 12). The major geologic structures in Frederick County are described briefly by Edmundson in the order of their occurrence from Opequon Creek northwestward to the West Virginia boundary (Plates 1, 2).

MASSANUTTEN SYNCLINORIUM

One of the major structures of the Valley of Virginia is the Massanutten synclinorium (Massanutten syncline of Butts)—a synclinal complex that includes the bedrock structures underlying Shenandoah

Valley. This subprovince is bounded on the southeast by the Blue Ridge in eastern Clarke County and on the northwest by Little North Mountain. The total width of Shenandoah Valley is about 20 miles in northern Virginia, but only 8 to 10 miles of the belt is represented in Frederick County.

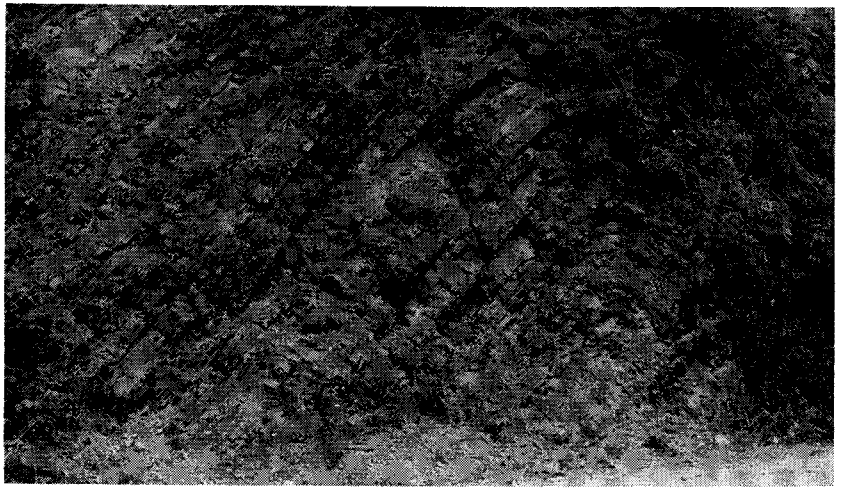

Figure 24. Small anticline in the lower part of the Brallier formation about 0.3 mile northwest of Gore along U. S. Highway 50.

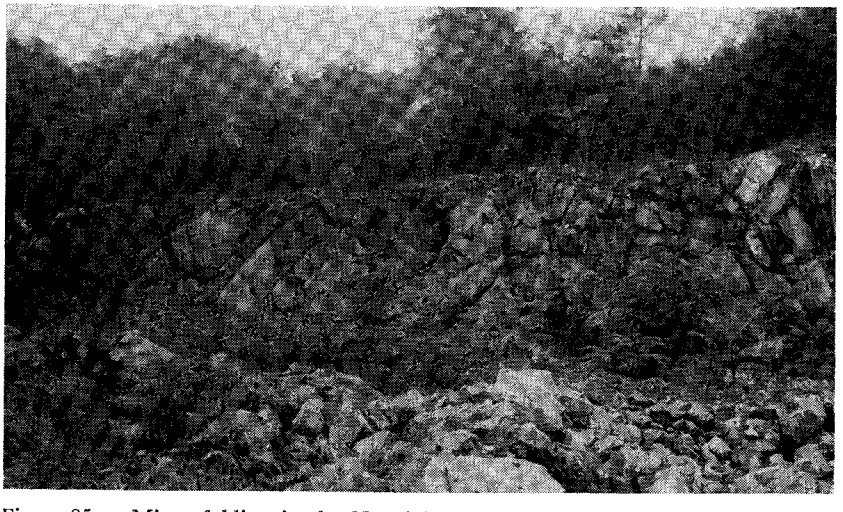

Figure 25. Minor folding in the New Market and Lincolnshire limestones at the southwest end of the M. J. Grove Company quarry about 1.3 miles northwest of Middletown.

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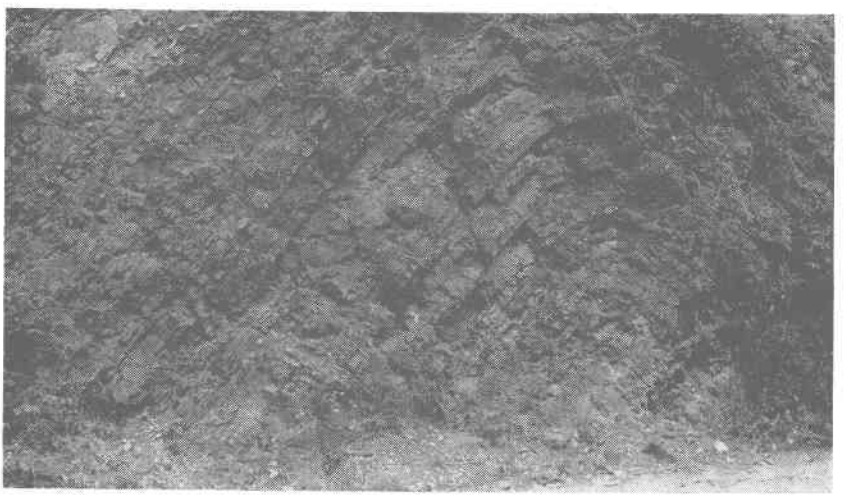

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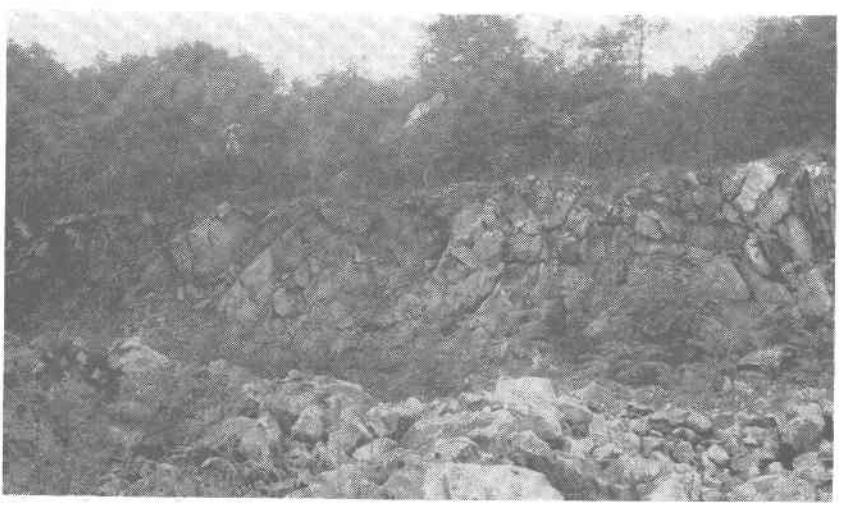

Figure 25. Minor folding in the New Market and Lincolnshire limestones at the southwest end of the M. J. Grove Company quarry about 1.3 miles northwest of Middletown.

From the vicinity of Strasburg, Shenandoah County, to "The Peak" east 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.

Figure 26. About 5 feet of Silurian sandstone in Fawcett Gap showing faulted contact with the Martinsburg shale on the right and with the Marcellus shale on the left. The exposure is along the trend of Little North Mountain.

In Frederick County the belt of Martinsburg shale, marking the trough of the synclinorium is from 2.5 to 4.5 miles wide, and the valley floor rises from about 475 feet along Opequon Creek at the West Virginia boundary to about 700 feet in the vicinity of Winchester. The eastern boundary of the shale belt follows closely Opequon Creek which defines the eastern boundary of Frederick County. The northwest boundary of the Martinsburg formation, although sinuous due to minor folding and faulting, roughly parallels U. S. Highway 11 and passes southwestward through Winchester, Stephens City, and Middletown.

West of the shale belt and extending to near the southeast base of Little North Mountain, the bedrock is predominantly limestone and dolomite, and the topography is characterized by low discontinuous ridges aligned in a northeasterly direction. Altitudes on this gently sloping surface range from about 700 feet in the vicinity of Winchester to about 900 feet along the southeast base of Little North Mountain. As in the shale belt to the east, the normal sequence of bedrock has been repeated

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by folding and locally disarranged by faulting. Although some of these minor structures are discussed in this report, the writer is aware that additional structures may be identified in the course of more detailed investigations.

Two traverses along U. S. Highway 50 and State Highway 7, which cross the shale belt, indicate that most of the dips are 30° to 75° SE. This observation indicates that the southeast limb of the structure is overturned, but it has not been possible in any of the traverses to locate an axis, even approximately. To compute thickness from the generally steep dips and width of outcrop would greatly exceed other estimates for the Martinsburg in Virginia; thus the apparent extra thickness is believed to be due to repetition of the beds by minor structures which do not appear in any section open to inspection.

Lower Middle Ordovician limestones (New Market, Lincolnshire, Edinburg, and Oranda) crop out as a narrow belt, averaging about 1000 feet in width, on both sides of the Martinsburg shale. These formations on the eastern limb of the synclinorium are mainly in Clarke County, except for small areas east of Brucetown and Parkins Mills, and southwest of Armel. The general southwesterly trend of the limestones along the west margin of the Martinsburg shale in Frederick County is interrupted at many places by minor folds and faults. Examples of the minor folds are well shown east of Clearbrook and Bartonville and west of Stephens City and Middletown. Small faults which have disturbed the limestones may be noted along the West Virginia boundary east of Rest, southwest of Stephenson, south of Winchester, east of Bartonville, and west of Middletown at the southern boundary of Frederick County. These faults are assumed to be high-angle types, although no exposures of the fault surfaces were noted which would permit dip measurements.

The Lower Ordovician formations (Chepultepec and Beekmantown), occupying a broad belt east and west of U. S. Highway 11 at the Virginia-West Virginia boundary, extend in a southwesterly direction across the county. The narrow belt of Chepultepec enters Virginia about 1.3 miles northwest of Rest and trends southwestward for a distance of about 5 miles to where it wraps around the axis of an anticline plunging to the southwest. From this locality it may be traced in a northerly direction to the vicinity of Grimes, where it wraps around a synclinal fold and then continues southwestward through Winchester (Plate 1). The broad belt of the older Conococheague on the west and the younger Beekmantown belt on the east clearly reflect these folds. South of

Winchester, in the vicinity of Kernstown and at a locality west of Vaucluse, the outcrop belt of the Chepultepec is offset by faulting.

A series of four folds, plunging to the southwest, are of special interest and may be seen along a traverse extending northwestward from Middletown. They are named here as the Belle Grove anticline, Marsh Brook syncline, Watson Run anticline, and the Marsh Run syncline. In this area Beekmantown rocks are involved in the folding at the surface, except for the Marsh Brook syncline which has lower Middle Ordovician limestones exposed along the axis.

The oldest rocks exposed at the surface in Frederick County are the Elbrook and Conococheague formations of Cambrian age. The main outcrop of the Elbrook is at the southeast base of Little North Mountain, beginning on the north at the North Mountain fault 1 mile south of Nain and extending thence southwestward to Shenandoah County. A second outcrop begins as a narrow wedge near the Cedar Creek Grade about 2 miles southwest of Winchester and continues northward along Apple Pie Ridge into West Virginia, increasing to a width of 0.5 mile at White Hall. A third, smaller, lozenge-shaped area midway between the other two belts, crosses U. S. Highway 50 about 2.5 miles west of Winchester. Each of these belts of Elbrook (Plate 1) is bounded on the northwest by an overthrust fault.

The Conococheague formation, in normal geologic sequence above the Elbrook, occupies a wide strip of the county extending northeastward from Cedar Creek to West Virginia, 2.5 miles northeast of White Hall. The width of this belt is about 1.5 miles along Cedar Creek but is increased by folding and faulting to double that width north of the latitude of Stephens City. From the vicinity of Winchester northeastward to West Virginia, the Conococheague is repeated by faulting, with the Elbrook along Apple Pie Ridge separating the two belts.

LITTLE NORTH MOUNTAIN AND ASSOCIATED STRUCTURES

Little North Mountain, the western boundary of Shenandoah Valley in northern Virginia, originates in a complex of unoriented ridges about 10 miles northwest of Lexington, Virginia. It extends northeastward for about 150 miles across Rockbridge, Augusta, Rockingham, Shenandoah, and Frederick counties, Virginia, and Berkeley County, West Virginia, to end in Bear Pond Mountains, Washington County, Maryland. Approximately 20 miles of the ridge is in Frederick County (Plates 1, 2).

The first detailed description of the mountain to include Frederick County was by Giles, who reported on the geology of Little North Mountain in northern Virginia and West Virginia in 1927 and on the structure of the mountain in the north-central Appalachians in 1942. In 1927 (p. 53) he interpreted the structure in northern Virginia as follows:

> "Structurally Little North Mountain may be considered a faulted monocline of overturned beds with steep southeastward dip bounded on the east by closely compressed generally overturned folds affecting the Cambrian and Ordovician formations underlying the Valley, and on the west by a broad syncline developed in Devonian rocks. The faults are overthrusts from the southeast with southeastward inclination. The major overthrust presents a continuous trace on the west side of the mountain. The other faults are distributive from the major overthrust and consequently are discontinuous, merging with the major overthrust at infrequent intervals. Their traces in general lie east of the mountain crest and locally may depart some distance beyond the foot of the mountain. Rarely are more than three faults with significant displacement present, and for much of the distance the displacement is limited to two fault surfaces."

In a later paper Giles (1942, p. 965) reported as follows:

> "This interpretation of the structure of Little North Mountain agrees with the interpretation of its structure in West Virginia by Grimsley and by Stose and Swartz and in Maryland by Swartz and by Bassler, except that they regard the major overthrust as lying east of the mountain, the others being distributive from it."

Regarding the fault west of the mountain, Giles (1942, p. 979) states:

> "Throughout much of the distance from Maryland into Rockingham County, Virginia, the western auxiliary of the North Mountain fault is recognized and mapped on the west side of Little North Mountain. The numerous gaps in Little North Mountain throughout this distance strongly suggest that the Tuscarora sandstone which forms the mountain range has been repeatedly thinned or deleted by this subsidiary fault, permitting the formation of the gaps in the less resistant formations flanking the sandstone."

The structure of Little North Mountain in northern Virginia was described by Butts and Edmundson (1939) and by Edmundson (1940). Edmundson (1940, p. 544) interpreted the structure of Little North Mountain as an overturned monocline with steep southeasterly dips, bounded on the east by the Little North Mountain fault and on the west by a broad syncline of Devonian rocks. The Little North Mountain fault, the trace of which now lies east of the ridge, was thought to have

extended above the present summit of the mountain in a tightly compressed overturned fold. Subsequently much of the thrust block was removed by erosion, and at the present time only the overturned northwest limb of the anticline is preserved.

Unequal sedimentation during Silurian and Early Devonian times, in conjunction with some local minor faulting, were proposed by Butts and Edmundson (1939) to explain the pronounced variations in thickness and the absence of one or more units at certain localities along the trend of the ridge. It was further postulated by the writers (Butts and Edmundson, 1939, p. 179) that a low shore, fringed with islands, peninsulas, and lagoons, in conjunction with oscillations of the seas and fluctuations in sedimentation may have been the sedimentary environment responsible for the stratigraphic discontinuities. Another suggestion by Edmundson (1940, p. 532) was that the discontinuous distribution of the sediments, especially the ridge-making Tuscarora sandstone, may have acted as a weakened zone during the orogeny which determined the locus of the fault and the uplifting and overturning of the formations.

In regard to the sedimentary environment postulated by Butts and Edmundson (1939) to explain the local stratigraphic discontinuities, Woodward (1951, p. 392):

> "... feels that too much is demanded of littoral coincidence to explain the lensing of so many different formations at the same place. He [Woodward] recalls that the line of this mountain was noted as the probable site of the Mid-Ordovician Adirondack (or Tazewell) axis of uplift, and wonders if there may not be some structural control of post-Ordovician deposition by the ancient Ordovician axis. In the event that this control is not regarded adequate, he can fall back upon no better explanation than strike faulting, in which the displacement and planes of dislocation have not been detected save by the absence of expectable formations. As this situation seems very likely at Hedgesville [West Virginia], the presence of faults elsewhere along North Mountain and Little North Mountain is no less probable."

Woodward (1955, p. 36) also suggests that it "... seems probable that the concealed arch is responsible for the location and perhaps for the formation of the long North Mountain fault, which may represent slicing directed upward along the east flank of the arch."

Brower (1961, p. 63-66), with reference to Massanutten Mountain on the east and Great North Mountain on the west, has portrayed an interpretation of the structural development of Little North Mountain as it appeared in Tuscarora, Clinton, Cayugan, Helderberg-Romney, Brallier-Chemung, and Hampshire times and postulated that back-limb

thrusting could have occurred during the latter stage. In summary, Brower (1961, p. 81) states:

> "Contemporaneous deformation of the Little North Mountain anticline was occurring during Tuscarora time. When the initial deformation began cannot be stated at the present time but the author would suggest that it may have begun during deposition of the Martinsburg subgreywacke. If this is true, two main periods of contemporaneous deformation are present (the first during Martinsburg-Cayugan time, and the second beginning in Brallier time . . .)."

Pre-Onesquethaw geology in West Virginia and bordering states has been depicted by Dennison (1961, Fig. 3). According to Dennison (1961, p. 15): "The paleogeologic map shows unconformities in the Silurian and early Devonian of Virginia. During this time between the Taconic and Acadian orogenies, the Valley and Ridge area of Virginia and West Virginia behaved more as a cratonic region than as a typical geosyncline." Dennison (1961, p. 14) refers specifically to a section of Little North Mountain, about 2 miles long and centered at Fawcett Gap, where the Needmore shale does not crop out and the Marcellus shale occurs adjacent to the Cayugan or Tuscarora formations. He suggests that the Needmore shale was probably deposited unconformably over a thin sequence of Cayuga strata at Fawcett Gap and is absent from the section because of a local thrust fault, probably a branch of the North Mountain fault which is exposed at the surface a few hundred feet southeast of the Tuscarora outcrop. This is the same structural interpretation favored by Giles (1942, p. 976).

In the following revised interpretation of the structure, the junior writer now favors the suggestion made by Giles (1927) that the gaps in Little North Mountain occur where the ridge-making sandstones have been thinned or removed from outcrop by faulting. However, the evidence throughout Frederick County is not conclusive that a western auxiliary fault presents a continuous trace along the west side of the mountain, unless the narrow outcrop belts and the absence of the McKenzie, which has not been positively identified in any of the sections, can be best explained by faulting. A continuous fault along the west side of Little North Mountain has been recognized by Stose and Swartz (1912, p. 17, Fig. 7) and Grimsley (1916, Fig. 16) in West Virginia and by Giles (1927) in northern Virginia and West Virginia. At a locality about 2.5 miles southwest of Hedgesville Gap, West Virginia, Stose and Swartz (1912, Section F-F′) show the Clinton faulted against the Oriskany on the west side of the mountain. Similar faulted relationships of Clinton against Oriskany are also shown by Grimsley (1916) in

his structure sections at a locality about 5 miles southwest of Hedgesville Gap and at a locality about 2.5 miles north of the Virginia-West Virginia boundary.

The southwestward extension of this fault into Virginia is possible, but, if so, the beds deleted from the section would appear to be greatly reduced and the exact location of the fault, based on available exposures, would remain uncertain. It is the junior writer's suggestion that, except for faulting west of Funkhouser Knob and Wisecarver Gap, where the ridge is prominently developed, such as south of Chambersville, Round Hill, Flint Ridge, Babbs Mountain, and north of Green Springs, the section may be complete along the west slope. The evidence, although subject to question and possible revision, includes scattered exposures of bedrock at various stratigraphic levels along the strike, and in each section examined, the intervening covered intervals are thought to be of sufficient width to accommodate a complete geologic section.

An alternate interpretation of the minor faulting, but not necessarily excluding the presence of other subsidiary faults west of the ridge, such as occur between Funkhouser Knob and Wisecarver Gap, is to locate an auxiliary fault along the west margin of the Martinsburg shale which crops out along the east side of Little North Mountain. Such faulting, either continuous or discontinuous, could explain the rapid thinning and omission of certain units in the gaps that break the continuity of Little North Mountain. Brent (1960, p. 98-99) has described northwestward-dipping reverse faults at a similar stratigraphic horizon along the east side of Little North Mountain in Rockingham County, Virginia. However, the exposures in Frederick County are not adequate for evaluation of the nature of the faulting, and, lacking this evidence, the writer has assumed that the fault is of the thrust type, dipping to the southeast and possibly representing a minor branch of the North Mountain fault.

In the available exposures all of the rock units along Little North Mountain are characterized by narrow outcrop belts, as compared with contemporaneous deposits in more westerly belts. For example, the thickness of the Wills Creek in Baldwin Gap is about 180 feet as compared with 300 to 400 feet in the Great North Mountain area. Similarly, the thickness of the overlying Tonoloway in Baldwin Gap is only 190 feet, and probably less than 70 feet for the Keyser, or about half of the thickness determined for these units in the western belts. Other examples are the Oriskany sandstone and the Marcellus shale. Along the northwest base of Little North Mountain, where the Marcellus beds are vertical, the width of outcrop indicates a thickness of no more than 200

feet, whereas in the western belts a thickness of 500 feet might be a conservative estimate. The Oriskany sandstone, except for a locality 0.25 mile northwest of the County Farm, has the same general thickening in a westerly direction and is estimated to have a thickness of more than 200 feet southwest of Gore. At an early date Stose and Swartz (1912, p. 17) reported in the Hancock-Pawpaw folio, which contains a segment of the Little North Mountain structure that: "All the formation outcrops are very narrow, owing to the great compression and probably to distributed faulting."

In addition to the narrow outcrop belts, some of the units have marked variations in thickness from section to section along their strike. For example, the Oriskany northwest of the County Farm appears to be an unusual lenticular mass of conglomerate, estimated by Butts to be 200 feet thick, which thins markedly to an estimated 50 feet or less in a distance of about 1 mile to the north and to the south along strike. It is also notable that the outcrop belt of the Tuscarora seems to vary in width along the strike in areas where the sequence appears to be normal. Generally, this outcrop belt is wider in those positions along the ridge which represent the higher altitudes.

Where faulting is not recognized, it is the writer's opinion that the possible occurrence of unconformities and the demonstrated variations in thickness, both on a regional basis and locally along the strike, reflect the history attending or following sedimentation, but it is not to be denied that some changes in thickness may have resulted from extreme compression during folding. The writer favors Woodward's (1951, p. 392) reference to the line of Little North Mountain as the probable site of the Mid-Ordovician Adirondack (or Tazewell) axis of uplift, and the possibility that it may have had some structural control of post-Ordovician deposition.

The following discussion deals with the field data used in compiling the structure sections (Plate 2) beginning at the north in the vicinity of Green Springs. Structure Section 1, located about 0.5 mile north of Green Springs, begins near the intersection of State Road 671 with a farm road and extends in an easterly direction across Little North Mountain. On the west are good exposures of the Hamilton, Marcellus, and Onondaga which are overturned with steep southeasterly dips. The section continues as a normal sequence with abundant float of the Oriskany sandstone and New Scotland chert, the latter exposed southwest of the farmhouse. Between the New Scotland and Bloomsburg is a covered interval of about 500 feet which is interpreted as including the

Keyser, Tonoloway, and Wills Creek, since these units have been identified at other localities along the trend of the mountain to the southwest. Structure Section 1 is resumed near the crest of the mountain with adequate exposures for mapping the Bloomsburg, Clinton, Tuscarora, Juniata, and Martinsburg. At Green Springs, mainly along State Road 671 for a distance of approximately 600 feet, there are incomplete exposures of the Hamilton, Marcellus, Onondaga, Oriskany, New Scotland, and a few feet of dark-gray limestone tentatively identified as the Keyser. Immediately to the east and extending for about 1800 feet east of the foot of the mountain is a partially exposed section of Martinsburg shale. Along the eastern margin of the shale, near the west end of the mill dam, the Conococheague is faulted against the Martinsburg, whereas the western boundary is interpreted as an auxiliary fault which brings the Martinsburg in contact with the Helderberg limestone.

Little North Mountain is not expressed topographically between Green Springs gap and Babbs Mountain, except for a rounded hill at Old Stone Church and a low ridge north of Cattail Run (Plate 2, Section 2) which owe their origin to disconnected slices of Tuscarora sandstone. Between these slices the Martinsburg appears to be faulted against the Onondaga, whereas along the rest of the trend of the mountain in this sector the Martinsburg is in contact with the Helderberg.

Beginning at State Road 730 and traversing the crest of Babbs Mountain to the gap along State Road 672 east of Cedar Grove, there are satisfactory exposures of the Tuscarora, the Clinton with diagnostic fossils, and, following closely on the west, the Bloomsburg red beds. Of interest here and to the southwest are a few feet of gray sandstone which may represent the Keefer sandstone member of the Clinton. Although the section is largely covered east of Cedar Grove, there are a few exposures of New Scotland chert, Bloomsburg red beds, and Tuscarora sandstone at the east end of the gap. The covered intervals east and west of the Bloomsburg are adequate to accommodate a full sequence of the formations (Plate 2, Section 3).

The next sector of the mountain, Flint Ridge, extends from Babbs Run southwestward to the gap traversed by State Road 630, a distance of about 3.5 miles. The crest of this narrow ridge, except for the wind gap along U. S. Highway 522 at Nain, slopes gradually southwestward. Structure Section 4, located about 1 mile northeast of Nain, is interpreted as containing a normal sequence of formations. However, this interpretation is based upon the assumption that the covered interval, estimated to be about 500 feet, along the west flank of the ridge would

include the Keyser, Tonoloway, and Wills Creek formations. Near the crest of Flint Ridge there are exposures of the Bloomsburg, Clinton, and Tuscarora, and an abundance of gray impure sandstone float along the southeast slope of the mountain which is tentatively identified as undifferentiated Juniata-Oswego.

In the gap at Nain (Plate 2, Section 5) the available exposures suggest that the ridge-making sandstones may be Clinton, since a few diagnostic fossils have been identified from float material north and south of U. S. Highway 522. These badly fractured sandstones are followed on the west by typical Bloomsburg red beds and on the east, beyond a narrow covered interval, by the Martinsburg. Unless the sandstones in the gap have been misidentified, minor faulting is indicated here to explain the absence in outcrop of the Tuscarora and Juniata-Oswego. The North Mountain fault, which brings the Conococheague in contact with the Martinsburg, is located about 700 feet east of the gap near the southeast foot of the mountain. Flint Ridge gradually descends to the level of the valley floor where it loses its identity in the gap along State Road 630. Here the Martinsburg appears to have been faulted against the Bloomsburg. This would suggest that the auxiliary fault along the western boundary of the Martinsburg has changed its course to a more westerly direction so that the Clinton has been cut out in a distance of not more than 1 mile south of U. S. Highway 522.

The area north and west of the County Farm, and extending from State Road 630 southwestward to Round Hill, contains exposures of bedrock which permit a better understanding of the stratigraphy between the Marcellus and Bloomsburg. Structure Section 6 is a composite section in this area along the trend of Little North Mountain. Along and just north of a farm road at the northeast end of Round Hill are good exposures of the Marcellus, Onondaga, Oriskany, and New Scotland; along and south of State Road 679 are scattered exposures of the Keyser, and of special significance is the occurrence of the Tavenner sandstone member at the top of the Wills Creek. To the east the section includes scattered exposures of the lower part of the Wills Creek and red shales and sandstones of the Bloomsburg, the latter cropping out along State Road 654 west and southwest of the County Farm. The low ridge, which is a continuation of Little North Mountain, crosses State Road 679 and extends southwestward, passing just west of the County Farm. Here the Martinsburg is succeeded on the west by a few feet of red shale and sandstone, a thin bed of gray sandstone, and

a thick section of the Bloomsburg. The easterly exposure of red shales was mapped by Butts and Edmundson as Juniata and the gray sandstones as a thin development of the Tuscarora; however, the junior writer now favors the assignment of these beds to the Clinton with the Martinsburg contact on the east having faulted relationships.

Round Hill, rising about 500 feet above the surrounding valleys, is one of the conspicuous landmarks along the trend of Little North Mountain. Scattered exposures of bedrock on the west slope and at the southwest and northeast ends of the knob indicate that a full sequence of Upper Silurian and Lower Devonian may be present at this locality (Plate 2, Section 7). Along U. S. Highway 50 (old location) through Hoop Petticoat Gap, the Martinsburg is faulted against the Wills Creek or possibly against a few feet of Bloomsburg in the lower part of the section. North of this locality, especially along a secondary road which serves a housing development at the southwest end of Round Hill, the section includes a full thickness of the Bloomsburg and, to the east, fractured gray and mottled sandstones which are tentatively identified as Clinton. The distribution of the rocks (Plate 1) between Structure Sections 7 and 8 suggests that they are eliminated from outcrop in a southwesterly direction by progressively impinging against a fault trending in a more westerly direction than the strike of the beds. Butts' manuscript maps show that he favored faulting to explain the Martinsburg-Wills Creek boundary west of Chambersville, but he interpreted the fault as a diagonal type which caused an offset in the ridge north and south of the gap. There is a strong suggestion that the discontinuous parts of the ridge do not match across the gap, but it is thought that this apparent anomaly may be explained by a bend in the structure accompanied by strike faulting such as outlined above.

The ridge-making sandstones are present just south of the gap at Chambersville, and produce an even crest which is maintained for 3 miles to the southwest. Abundant gray and pink to maroon sandstone has been noted at a locality along the east slope of the ridge about 2 miles southwest of Chambersville. On the basis of this meager evidence, a narrow belt of undifferentiated Oswego-Juniata has been mapped along this part of the ridge. Of interest along the line of Structure Section 9 are several iron-ore prospect pits in the Clinton that crops out near the crest on the west side of the ridge. Farther down the slope, but with intervening covered intervals, are partial exposures of the Bloomsburg, Keyser, New Scotland, Onondaga, Marcellus, and Hamilton.

Beginning near Structure Section 9, the ridge gradually diminishes

in height from 1400 feet to about 900 feet in Wisecarver Gap. Along this longitudinal profile the higher altitudes correspond to a normal thickness of the Tuscarora and possibly the Juniata-Oswego, whereas in a southwesterly direction the ridge-making sandstones appear to thin gradually (Plate 2, Section 10) and are terminated by faulting in Wisecarver Gap. Structure Section 11 through Wisecarver Gap shows Martinsburg faulted against Clinton and the overlying Bloomsburg faulted against the Onondaga. This interpretation, which apparently satisfies the structural conditions, differs in detail from the geologic map (Plate 1) which shows a complete section of the Cayugan and the basal part of the Helderberg thrust upon the Marcellus. Wisecarver Gap is bounded on the southwest by an elongate hill, underlain by the Tuscarora and Clinton, which rises steeply from the gap and gradually descends to Fawcett Gap, 1.5 miles to the southwest. The altitude of the summit of the hill is 1106 feet, whereas Fawcett Gap, with an average altitude of 820 feet, is a broad flat area along the trend of the mountain that connects with the adjacent valleys.

Along State Road 629 in Fawcett Gap (Plate 2, Section 12), about 5 feet of Silurian sandstone is in contact with the Martinsburg on the east and with the Marcellus on the west (Figure 26). This lens-like mass of sandstone is interpreted as a faulted segment along a branch of the North Mountain fault which is located about 900 feet east of this detached block. The North Mountain fault, except for highly deformed Ordovician limestone in the fault zone, brings the Elbrook in contact with the Martinsburg.

The most conspicuous topographic expression of Little North Mountain in southern Frederick County is Funkhouser Knob with an altitude of 1282 feet. At the northeast end, about 0.4 mile southwest of Fawcett Gap, the Martinsburg is faulted against the Marcellus, which is persistent in outcrop throughout the length of the ridge. Near the summit of the ridge (Plate 2, Section 13), the Tuscarora is prominently developed. It is followed on the east slope by brownish-colored conglomerate (Oswego?) containing chert pebbles, and on the west it is faulted against the Marcellus. All of the beds, in conformity with the general structure along the mountain, are overturned and dip steeply southeastward.

The most complete exposure of the rocks involved in the Little North Mountain structure is in Baldwin Gap (Plate 2, Section 14) about 1 mile northwest of Marlboro. The Elbrook is in the upper plate of the North Mountain fault. To the west is a thin exposure of Martinsburg

and about 40 feet of the Tuscarora, interpreted as having fault contacts. Immediately west of the Tuscarora is a partly covered interval which could accommodate about 160 feet of steeply dipping beds. Based on the scattered exposures of red sandstones in this interval, the rocks are tentatively referred to the Bloomsburg. However, another interpretation would be to assign some of the red thick-bedded sandstones (Geologic Section 5, unit 4) and the lower covered interval of 47 feet to the Clinton.

West of the main body of red beds are good exposures of the Wills Creek, with the Tavenner sandstone member at the top, Tonoloway, Keyser, and a part of the New Scotland. The line of section is offset along strike, first about 150 feet north of State Road 623 and again along the farm road at the west end of the gap. Of special interest in this section is the fact that the combined thickness of the formations is only about half of the thickness determined for the same units in the Great North Mountain area.

MT. PLEASANT SYNCLINE

Between Little North and Great North mountains is a broad syncline occupied by Devonian shales and sandstones. Prior to the survey for this report, this structure, although not named in Virginia, was referred to as: "... a well-defined syncline marked by Mt. Williams, Frederick County . . . a southern extension of the great syncline in West Virginia occupied by the Sleepy Creek synclinal mountain. . . ." (Butts, 1940, p. 454). Manuscript maps used in compiling the geologic map for this report show that the better reference for this structure in Frederick County is Mt. Pleasant, because this hamlet is astride the axis. Mt. Williams is approximately 1 mile to the northwest. It is also evident from the geologic map (Plate 1) that the Mt. Pleasant syncline at the Virginia-West Virginia boundary is separated from the Sleepy Creek Mountain (Meadow Branch) syncline on the west by an anticline, here named the Baileys Ford for one of the minor folds at the northeast end of the Great North Mountain anticlinorium. The Baileys Ford anticline is on strike with and appears to be a southwestward continuation of the Ferrel Ridge anticline which was mapped and described by Grimsley (1916, p. 127) in Berkeley County, West Virginia.

The axis of the Mt. Pleasant syncline, indicated by opposing dips in red sandstones of the Hampshire formation, is fully exposed along U. S. Highway 50 about 1.3 miles northwest of Chambersville. The width of the Devonian shales and sandstones (Onondaga, Marcellus,

Hamilton, Brallier, Chemung, and Hampshire), in the syncline along a line extending northwestward through Mt. Pleasant, is approximately 3.5 miles. Between Baileys Ford and Green Springs the Brallier, Chemung, and Hampshire boundaries converge gradually toward the axis which is plunging to the southwest. The northern extent of the Chemung in this belt is near the Virginia-West Virginia boundary, and the Hampshire is terminated in the syncline at a point about 1 mile east of Baileys Ford. To the southwest in Frederick County the Hampshire continues along the axial position of the fold, except for a distance of about 2 miles west-southwest of Cedar Grove. In northern Shenandoah County, within the large reentrant formed by Cedar Creek, the Hampshire also is eroded from the structure.

Of special interest are ridges which develop on massive thick-bedded sandstones in the Chemung. Examples in the Mt. Pleasant syncline are Hunting Ridge on the west limb, and Whisson Ridge and its extensions to the northeast and southwest on the east limb. Similar ridges occur in the Whitacre syncline along the northwest side of Great North Mountain. A comparison of the width of the mapped units on the limbs of the structure, mainly southwest of U. S. Highway 50, shows marked differences. Most of the dips on the east limb are steep in a westerly direction, except along the northwest base of Little North Mountain where they are overturned and dip to the southeast. Dips recorded in the Brallier and Chemung along the west limb range from 10° to 60° SE. and probably average about 30°.

GREAT NORTH MOUNTAIN ANTICLINORIUM

Great North Mountain is essentially an anticlinal structure but has minor folds occurring near the crest, on the southeast and northwest sides mainly near the base, and particularly at the northeast end along and north of U. S. Highway 50 (Plates 1, 2). The principal axis of the anticlinorium, pitching strongly to the northeast, crosses U. S. Highway 50 at Point of Rocks about 1.7 miles east of Gore. From this locality, at an altitude of about 850 feet, the mountain increases in prominence in a southwesterly direction to an altitude of 2844 feet (High Knob). In the southwest corner of the county, the axis passes into West Virginia. In this part of Frederick County, the resistant Oswego, Juniata, and Tuscarora formations have been eroded from the crest of the anticline and a deep intermontane valley, occupied by the headwaters of Paddy Run, occurs in the relatively soft Martinsburg shale. On both sides of this valley are high ridges made by the resistant sandstones. The ridge

on the west coincides with the Virginia-West Virginia boundary, and the ridge on the southeast limb is Paddy Mountain.

Minor faulting, with the Juniata and Oswego formations in contact with the Clinton, has been recognized (Plate 1) along the northwest side of Pinnacle Ridge and extends from a point about 2 miles northeast of the State boundary southwestward into West Virginia. Another fault is identified tentatively as crossing Duck Run about 1 mile southeast of Eagle Rock. To the northeast this fault apparently dies out within a broad belt of Wills Creek shales and sandstones about 0.5 mile northwest of Pembroke Springs. The southern limit is uncertain, but faulted relations between the Clinton and Tuscarora formations are thought to extend at least to Dog Cliff about 1 mile southwest of Duck Run.

The trace of the main axis of the Great North Mountain anticline is shown on the geologic map (Plate 1) as trending northeastward through Vances Cove and continuing without interruption along the crest of Fall Ridge for a distance of about 4 miles. However, since the Fall Ridge structure is a minor anticline along the southeast side of Great North Mountain, its axis should be shown only as a branch of the main axis at the northeast end of the cove. To correct this omission on the map, the trace of the main axis should be shown as crossing the Virginia-West Virginia boundary near the Capon Springs road, and extending in a southerly direction to connect with the axis as mapped in the general vicinity of Cold Spring Gap (Plate 2). To the northeast the axis reenters Frederick County about 0.5 mile south of High Knob, where the Oswego formation occupies the medial position of the fold. In less than 1 mile the Oswego plunges beneath the surface, and the younger Juniata in normal sequence continues for about 3 miles. The Tuscarora, the principal ridge-making sandstone, occupies the axial position of the structure for the remaining distance of about 7 miles to where it plunges beneath the surface 0.7 mile southwest of U. S. Highway 50. The Tuscarora sandstone occupies the crest of Great North Mountain throughout its extent in Frederick County, but the axis of the structure, between the latitude of Rock Enon Springs and High Knob along the West Virginia boundary, is locally as much as 0.5 mile east of the crest. Along this belt the Tuscarora occupies a minor synclinal flexure near the crest of the mountain, and is interpreted as a southwestward extension of the syncline along Laurel Run.

On the northwest side of Great North Mountain is Pinnacle Ridge, a structure similar in geologic detail to Fall Ridge. This prominent spur has an elevation of 2360 feet about 1 mile south of Rock Enon Springs.

From this locality it slopes gradually in a northeasterly direction to Laurel Run, where the elevation is only about 1200 feet. For the next 1.5 miles the anticlinal structure is expressed topographically as a narrow valley which, near its northeast end, is flanked on the west by Cove Ridge and on the east by Sand Ridge. These ridges, due to the convergence of the Oriskany sandstone as it wraps around the axis of the plunging fold, join at a locality about 1.4 miles southwest of Gore. This single ridge, capped with sandstone, persists with diminishing height for a distance of 1 mile and finally loses its identity just south of Gore, where the sandstone plunges beneath the surface. The Virginia Glass Sand Corporation quarry is located near the northeast end of this belt.

Traverses along U. S. Highway 50 from Gore to Hayfield, and along the Winchester and Western Railroad from Gore to Gainesboro show that the Great North Mountain anticlinorium is affected by many superimposed minor folds. It is thought that the location of the minor structural axes (Plate 1) in this area are reasonably accurate, because they are controlled by formations (McKenzie-Marcellus) that are relatively thin and have diagnostic lithologies. However, northeast of U.S. Highway 522, most of the minor structures lose their identity within a broad expanse of Middle and Upper Devonian shales and sandstones. Three exceptions are the Besor Ridge anticline which is an extension of the structure that is well exposed in Bowling Green Ridge along U. S. Highway 50, the Third Hill Mountain syncline northwest of Gainesboro School, and the Baileys Ford anticline along which the Hamilton formation extends northeastward into West Virginia.

Other minor structures, which are well defined at the northeast end of Great North Mountain and can be traced southwestward along the southeast foothills of the mountain, are the Hayfield Ridge syncline, the Tavenner Ridge anticline, and the complex of folds in the vicinity of Gainesboro which includes two synclines and two anticlines. The axis of the syncline in Hayfield Ridge extends southwestward to the vicinity of Yellow Spring Hollow, a distance of about 6 miles. Along U. S. Highway 50, about 1 mile northwest of Hayfield, the axis is within the Tonoloway limestone, whereas to the north the crest of the ridge is underlain by the Oriskany sandstone. A similar sequence of rocks (Tonoloway-Oriskany) occurs along the axis of the structure north of Yellow Spring Hollow for a distance of about 1.5 miles.

The Tavenner Ridge anticline closely parallels the Hayfield Ridge syncline on the southeast, and extends from the vicinity of Isaacs Creek southwestward to a locality about 1.5 miles southwest of Mountain View

School. Near the northeast end of this structure, west of Gainesboro, the rocks plunge northeastward and, within a distance of about 1 mile along the trend of the fold, a full sequence of Wills Creek to Marcellus is partly exposed. In an inactive roadside quarry, 0.7 mile northwest of Gainesboro, the upper part of the New Scotland, Oriskany, and Onondaga and the lower part of the Marcellus are fully exposed. Except for a narrow belt, about 2 miles in length, west of Mountain View School which exposes the Bloomsburg, the full length of the structure is occupied by the Wills Creek formation.

Beginning near the headwaters of Furnace Run and extending southwestward across Duck Run is a broad belt of complicated structure. A traverse extending from the village of Mountain Falls northwestward to High Knob near the West Virginia boundary crosses the axes of seven minor folds. On the west is the main axis of the Great North Mountain anticline and its prominent spur previously described as the Fall Ridge anticline. At the northeast end and along the southeast side of Fall Ridge is the Tunnel Ridge syncline which includes rocks ranging from the Tonoloway limestone around the base to the Onondaga shale along the crest of the ridge. Immediately east of Tunnel Ridge is a narrow, northeastward-plunging anticline which extends from Laurel Run northeastward to the vicinity of Beans Hill, a distance of about 5 miles. Rocks involved in this structure range from the Clinton in the vicinity of Duck Run to the Tonoloway at a locality about 0.5 mile northwest of Richards Run. Farther northeast the continuity of the Tonoloway along the axial line is interrupted by a narrow inlier of the Wills Creek.[1]

Paddy Run flows in an easterly direction across several minor folds near the Frederick-Shenandoah county line. Vances Cove on the west is eroded deeply into the relatively soft Martinsburg shale which underlies the resistant Ordovician and Silurian sandstones along the axis of the Great North Mountain anticline. The east rim of Vances Cove is Paddy Mountain which has an altitude of 2624 feet at Johnnies Knob, or approximately 1200 feet above the watergap along Paddy Run. The Tuscarora along the crest of Paddy Mountain dips steeply to the southeast, whereas along the east flank there are at least two minor folds. The western structure is a minor syncline in which the Juniata occupies the axial position where it crosses Paddy Run. Approximately 1000 feet to the east is the axis of an anticline which, due to erosion, exposes an oval-shaped area of the Martinsburg that contains abundant specimens

[1]On the geologic map (Plate 1) the symbol "Swc" is correct, but the color pattern is incorrectly shown as the Clinton formation.

of the brachiopod, *Orthorhynchula*. The steep-sided valley walls in this area have a full sequence of Oswego, Juniata, and Tuscarora above the Martinsburg. Where these resistant sandstones arch over the anticlinal axis, the structure is expressed topographically and designated The Half Moon. The eastern exit from Paddy Gap, where the land surface flattens, coincides with the crossing of the Tuscarora sandstone.

One of the most persistent small ridges in Frederick County begins about 0.5 mile west of Gainesboro and extends in a southwesterly direction to the southwest end of Limestone Ridge, about 1 mile north of the Frederick-Shenandoah county line. It is appropriately named Flint Ridge, because the New Scotland cherty limestone, or the chert float derived from the formation, can be observed in every traverse across the narrow belt. The overlying Oriskany sandstone together with the New Scotland are responsible for this low ridge, which averages 100 to 150 feet above the valley floor along the southeast side. To the northeast this narrow linear ridge loses its identity where the bedrocks become involved in minor folding as they wrap around the end of the plunging Great North Mountain anticline. However, southwest of Gore it reappears as a conspicuous ridge and continues in a southwesterly direction into Hampshire County, West Virginia.

SLEEPY CREEK MOUNTAIN (MEADOW BRANCH) SYNCLINE

Grimsley (1916, p. 124-126) has described the Meadow Branch syncline in Berkeley and Morgan counties, West Virginia, as a broad synclinal fold in Upper Devonian shales and sandstones and enclosing Mississippian strata which, due to their resistance to erosion, have resulted in the formation of two mountain ridges—Sleepy Creek Mountain on the west and Third Hill Mountain on the east—separated by the shale valley of Meadow Branch.

The resistant Mississippian rocks which cap Third Hill Mountain terminate about 2 miles north of the State boundary, and the ridge loses its prominence because of the softer shales and sandstones. However, it can be recognized to the south by rounded hills and short linear ridges to Little Mountain about 1 mile south of the State boundary. The western ridge, Sleepy Creek Mountain, is a bold ridge southward to its termination in Shockeys Knob along the Virginia-West Virginia boundary. Here the fold rises and the ridge-making Mississippian rocks, after extending for a few hundred feet into Virginia, are eroded.

Structure section A-A′ (Plate 1), between the Baileys Ford anticline on the east and the Acorn Hill anticline on the west, shows a broad

synclinal structure that has been modified by three minor folds. On the west the Sleepy Creek Mountain syncline is on strike with the mountain at the State boundary; Besor Ridge anticline, next to the east, is along Little Brush Creek; and Third Hill Mountain syncline has a well-defined axis that passes east of Siler and through Third Hill Mountain northwest of Howard Chapel.

The Besor Ridge and Third Hill Mountain structures lose their identity in a complex of folds at the northeast end of Great North Mountain, whereas the deeper fold, Sleepy Creek Mountain syncline, apparently dies out within a thick section of the Chemung at a locality about 2 miles southwest of Cross Junction.

WHITACRE SYNCLINE

Between Great North Mountain and Cacapon Mountain is a broad syncline developed in Devonian shales and sandstones. The axis of this trough passes through Whitacre, Frederick County, and the name Whitacre syncline is suggested for this structure. The northeasterly extension of this fold across Morgan County, West Virginia, although not named, has been mapped by Grimsley (1916). The principal structures described by Grimsley (1916, p. 122-126) in the central part of Morgan County are the Cacapon Mountain anticline on the west and the Meadow Branch syncline on the east. However, his mapping shows that the broad belt between these major structures is modified by two well-defined folds—a syncline on the west and an equally well-defined anticline that is occupied by the Portage (Brallier) formation on the east. Southward into Frederick County, the anticline has been traced to the vicinity of Acorn Hill and this name is suggested (Plate 1) for the structure. From the West Virginia boundary to the vicinity of Mt. Hebron Church, the Brallier formation occupies the medial position of the fold, but in a short distance to the southwest it wraps around the axis of the fold and is covered by a broad expanse of the Chemung formation.

The Whitacre syncline enters Hampshire County, West Virginia, on the southwest because of a distinct offset or jog in the State line. Tilton and others (1927, p. 110, 232) employed the name Meadow Branch syncline for the southwesterly continuation of the fold in Hampshire and Hardy counties. According to Tilton and others (1927, p. 110):

> "The area from Cacapon River in the southeastern part of Hampshire County is a part of a large synclinal area which extends across the northwestern part of Virginia into Berkeley County. The continua-

tion of this synclinal area includes a minor fold known as the Ferrel Ridge Anticline in Berkeley County. This faulted anticline dies out in that county."

It is conceivable that the synclinal belt along the northwest side of Great North Mountain may be a southern extension of the Meadow Branch syncline but, if so, a regular structural sequence toward the main axis is interrupted by minor folds. For example, the Acorn Hill anticline separates the Whitacre syncline on the west from the main syncline in the northwestern part of Frederick County and in Morgan County, West Virginia. East of Great North Mountain and extending to Little North Mountain is the Mt. Pleasant syncline which is separated from the Meadow Branch syncline on the west by the Besor Ridge anticline in Virginia and its northeastward extension, Ferrel Ridge anticline, in Berkeley County, West Virginia.

The width of the Whitacre syncline, as arbitrarily measured from the top of the Marcellus shale in the vicinity of Gore northwestward to where the formation again comes to the surface in Hampshire County, West Virginia, is about 4.5 miles. The general distribution of the formations, except for a few minor wrinkles (Figure 22) noted in roadside exposures, indicates that the fold is relatively simple, but that the southeast limb is oversteepened in response to compressive forces from the east.

CACAPON MOUNTAIN ANTICLINORIUM

Since only a few square miles of the Cacapon Mountain anticline, here referred to as the Cacapon Mountain anticlinorium (Plate 2) because of its multiple character, occurs in Frederick County, the following summary of the structure is taken from the report on Hampshire and Hardy counties (Tilton and others, 1927) which was published by the West Virginia Geological Survey. According to Tilton and others (1927, p. 111), the Cacapon Mountain anticline is described as follows:

"In Morgan County to the northeast the Cacapon Mountain Anticline is recognized, extending at least to Potomac River, which it reaches between the towns of Great Cacapon and Hancock. The multiple character of the anticline is noticeable at the northward end near the Potomac.

"This anticlinal mountain capped by White Medina Sandstone extends for four miles along the Virginia-West Virginia State line of Hampshire County, then, as it plunges southwest, the multiple character of it is evident in the . . . cross-section through Bloomery Gap, where the Keefer Sandstone is at the surface along the road. To the west of the mountain is a parallel fold that becomes Ice Mountain farther south.

To the east are two other folds extending as far as Good, southwest of which town the Oriskany ridge along the anticline is recognized as Bear Garden Mountain. Between Bear Garden and Ice Mountains, there is a continuous alternation of anticlines and synclines, as revealed in the... cross-section through Springfield and across Bear Garden Mountain.... Similar anticlines and synclines are to be noted from Cacapon Mountain along the west side of Cacapon River to Hanging Rock Gap close to North River. The same is true clear to the Hardy-Hampshire County line. Where the Oriskany Sandstone is brought to the surface it resists erosion; thus the entire region consists of mountains of Oriskany Sandstone arranged in echelon parallel to the strike. Where shale is brought to the surface erosion has cut deep valleys. The entire region is very rugged."

GEOLOGIC HISTORY

To outline the factors that control the origin and distribution of rocks and minerals and the features of the landscape, it is necessary to have some understanding of the succession of geologic events. These events have been mentioned from time to time in the text, but they have not been grouped in any systematic order. Time is one of the most important factors in geologic history. Most of the recorded geologic history represents millions of years. To facilitate better understanding of the long history of the earth and for convenience of reference, geologic time has been divided into several major divisions called eras, and the eras are subdivided into smaller time units called periods. For example, bedrock now exposed at the surface in Frederick County was formed during the Cambrian, Ordovician, Silurian, Devonian, and Early Mississippian periods of the Paleozoic Era.

Since Frederick County is a part of the vast Appalachian Valley, its geologic history is included in the following outline of the broader province. The history of the Appalachian Valley began when eastern North America was an extensive lowland underlain by granites, schists, gneisses, and other related rock types. This lowland was formed from pre-existing uplands by the action of weathering and erosion throughout a long period of time. At the beginning of the Cambrian Period, about 500 million years ago, this lowland began to subside along a belt extending roughly from Newfoundland on the northeast to Alabama on the southwest. This subsidence resulted in the formation of a trough which was flooded by the sea from time to time throughout most of the Paleozoic Era. Although the development of this trough is a relatively late event in the history of the earth, it marks the beginning of the geologic record in the Appalachian Valley.

Some distance east of the present valley, during the cycle of Paleozoic sedimentation, was a landmass which was drained westward by streams flowing into the valley trough. Perhaps some sediment was also supplied from other sources. As these streams, laden with sediment, entered the shallow interior sea, they deposited their load just as modern rivers do, and the currents and waves of the sea distributed the material over the bottom. These sediments were spread out as essentially horizontal layers. It must be inferred that, with deposition continuing, the trough progressively sank to accommodate the new layers of sediment, which for the most part have shallow-water characteristics. The existing rock record suggests that the trough was not completely flooded at all times nor was deposition continuous, but the general processes were more or less active throughout most of the Paleozoic Era.

Sediments derived from the bordering highlands included mud, sand, and gravel. Most of the limy material was carried in solution, whereas the other material was carried in suspension or transported along the bottom by currents. Upon consolidation, the muds became stratified or layered shales, the sands became sandstone, and the coarser material formed conglomerates. The limy material, as the name suggests, formed the carbonate rocks, chiefly limestones and dolomites. It has been estimated that the aggregate thickness of sedimentary rocks in the Appalachians is about 50,000 feet. Such a thickness is not present at a single locality because sedimentation was not continuous everywhere in the trough, and also subsequent erosion of bedrock has not been uniform throughout the province. The total thickness of the formations in Frederick County is approximately 22,000 feet.

Toward the end of the Paleozoic Era, downwarping of the Appalachian trough ended and upward movements began, which were accompanied by enormous lateral pressure 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 overthrust to the northwest. Generally speaking, the magnitude of deformation decreases in a northwesterly direction. The profound geologic change which took place in the Eastern United States during late Paleozoic time is known as the "Appalachian Revolution." The mechanics of mountain building is a most complex and fascinating subject; thus the interested reader is referred to textbooks and other reports dealing with structural geology for a better comprehension of the birth and development of mountains.

The post-Paleozoic geologic history, beginning with the first dry land

in the Appalachians and continuing to the present time, has been chiefly land sculpture by the agents of erosion. This long period of denudation, perhaps including 200 million years, is not one of ordinary simplicity, because there is evidence of periodic uplifts and variable rates of erosion. The region has not remained in a stable condition. What we see today in the form of mountains and valleys is simply a stage in the ever-changing configuration of the earth's surface, and future geologic time will certainly witness additional profound changes. Bedrocks, their attitude, and composition play an important role in determining the features of the landscape. Resistant rocks such as dense hard sandstones generally are ridge-makers, whereas the softer and more soluble types are the sites of valleys.

The origin of minerals is important in earth history. They may originate at the same time as the associated bedrock or they may form at a later date. Minerals that form later than the bedrock commonly occur in fractures which were filled by the deposition of material carried in solution. Another way by which minerals may form is by weathering of the solid rock. That is, the parent rock may contain disseminated particles of a mineral which are not sufficiently concentrated to be of economic importance. However, when large masses of rock weather, the ore minerals may be carried in solution to a deeper horizon which is favorable for deposition, or the ore minerals may become concentrated in the residual soil overlying bedrock. For example, the manganese and iron ores in Frederick County have been described as occurring in residual materials (cherty and sandy clay) derived from limestone. Study of the occurrence and origin of minerals represents a highly specialized branch of geology which is beyond the scope of this outline.

MINERAL RESOURCES

INDUSTRIAL LIMESTONES AND DOLOMITES

The Shenandoah Valley portion of Frederick County was described by Edmundson (1945, p. 20-40). Most of the following geological data and analyses, exclusive of the section dealing with the physical properties of aggregate, are taken from that report.

High-Calcium Limestone

High-calcium limestone, containing more than 95 percent calcium carbonate, includes the New Market (Mosheim) limestone and locally a part of the Lincolnshire (Lenoir) limestone in areas where it is

relatively free of chert. Names in parentheses are those used by the writers at the time of the survey of Frederick County and by Edmundson (1945).

The thickness of the New Market limestone in the central part of the county, between Winchester and Kernstown, is estimated to be 50 feet or less, whereas the thickness along the strike to the northeast and southwest ranges from about 80 feet to a maximum of about 200 feet. Exclusive of impure layers near the base, the rock is 97 to 98 percent calcium carbonate. The overlying Lincolnshire is 50 to 100 feet thick, and analyses at a few localities where chert is not prominently developed show 95 to 96 percent calcium carbonate. Generally, the formation is high in silica, and for that reason it is included with the discussion of impure limestones.

The principal deposits of high-calcium limestone occur within a narrow belt (Plate 1) that enters Virginia about 0.5 mile southeast of Rest and continues southwestward across the county, passing near Clearbrook, Winchester, Stephens City, and Middletown. It is sinuous due to minor folding, and locally offset by faulting. One of these minor folds, having large reserves of limestone, extends from Cedar Creek at the southern boundary of Frederick County northeastward along the Marsh Brook syncline for about 3 miles. Data for selected localities from the report on industrial limestones and dolomites in Frederick County (Edmundson, 1945, p. 22-29) are shown on Table 2 to illustrate the general thickness and chemical composition of the New Market (Mosheim) limestone.

Impure Limestone

In the Shenandoah Valley part of Frederick County, impure limestones include the Chepultepec, the Lincolnshire at most localities, and the Edinburg (Chambersburg). Another unit, the Conococheague, is predominantly a limestone, but, like most of the older limestones of Shenandoah Valley, it contains variable amounts of magnesian limestone and dolomite. Formations west of Shenandoah Valley which are dominantly limestone are the Tonoloway, Keyser, and New Scotland. Only the lower 250 feet of the Tonoloway limestone at a locality about 1 mile northwest of Hayfield was sampled from the western part of the county.

The Chepultepec, with an average thickness of about 300 feet, crops out in a narrow sinuous belt (Plate 1) that extends northeastward across the county, passing about 1 mile west of Bartonville, Kernstown, and

Table 2.—Chemical composition of the New Market limestone at selected localities in Frederick County. (Analysts: Froehling and Robertson, Inc., Nos. 1-8; J. H. Yoe, No. 9)

Location	Formation	Thickness (feet)	Chemical Composition					
			$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	Total
1. Near Virginia-West Virginia line, 0.5 mile east of Rest	New Market	80	98.32	0.80	0.10	0.08	0.34	99.64
		30	97.72	1.05	0.06	0.04	0.62	99.49
2. Along Ross Run, 0.4 mile southeast of Clearbrook	New Market	130	98.02	0.97	0.04	0.04	0.52	99.59
		89						
3. About 100 yards northeast of above location	New Market	100	98.06	1.53	0.50	0.12	0.16	100.37
		22	93.22	4.27	1.89	0.17	0.35	99.90
4. About 0.4 mile northeast of Stephenson	New Market	88	97.44	1.24	0.22	0.08	0.82	99.80
		30						
5. About 1 mile east of U. S. Highway 11 and 0.5 mile northeast of Winchester	New Market	73	96.09	2.33	0.40	0.12	0.72	99.66
		9						
6. Along U. S. Highway 11 at Vaucluse	New Market	80	97.52	0.92	0.18	0.08	0.44	99.14
		57						

Table 2.—*Continued.*

Location	Formation	Thickness (feet)	Chemical Composition					
			$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	Total
7. Along State Road 627 about 1.5 miles northwest of Middletown	New Market	100	98.02	1.26	0.14	0.08	0.34	99.84
8. M. J. Grove Lime Company quarry, 1.5 miles west of Middletown	New Market	100	97.72	0.94	0.08	0.12	0.48	99.34
		54						
9. Along State Road 652, 0.5 mile southeast of Kernstown	New Market	82*	95.33	2.53	0.46	R_2O_3 1.47		99.79

*Includes impure beds in lower part.

Clearbrook. There is also a narrow belt about 4 miles west of Rest, and a small lozenge-shaped exposure extending across U. S. Highway 50, about 2.5 miles west of Winchester. The Lincolnshire and Edinburg limestones, in normal sequence above the New Market, have the same general distribution (Plate 1) as the unit described as high-calcium limestone. The thickness and chemical composition of the impure limestones described by Edmundson (1945, p. 29-32) and the analyses of the Tonoloway northwest of Hayfield are shown in Table 3.

High-Magnesium Dolomite

The term high-magnesium dolomite (Edmundson, 1945, p. 5) is defined as a rock "containing more than 40 percent magnesium carbonate and generally less than 4 percent noncarbonates." The chemical composition of the upper part of the Beekmantown at three localities is summarized in Table 4. The analyses in Table 4, except for location 3, contain more than 5 percent noncarbonates; thus the units sampled by the writer do not meet the specifications as set forth arbitrarily in the definition of high-magnesium dolomite. However, since most of the analyses contain more than 40 percent magnesium carbonate, it is the writer's suggestion that a detailed study should be extended to other localities to determine the chemical composition of the upper part of the Beekmantown dolomite throughout Frederick County.

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. Excerpts from a recent report on sources of aggregate used in Virginia highway construction (Gooch and others, 1960 p. 2-3) are as follows:

> "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 Grade B aggregate are utilized for aggregate base course, soil aggregate surface course, bituminous concrete, Portland cement concrete, 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 and others (1960, p. 3): "Any aggregate that

Table 3.—Analyses of impure limestones at selected localities in Frederick County. (Analysts: John H. Yoe, Nos. 1-5; Froehling and Robertson, Inc., Nos. 6, 7)

Location	Formation	Thickness (feet)	Chemical Composition					
			$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3 | Al_2O_3	R_2O_3	Total
1. Along the southwest slope of Star Fort Hill, 0.5 mile north of Winchester.	Chepultepec	35±	92.84	1.92	4.57		0.76	99.88
		35±	86.38	6.60	6.64		0.91	100.53
		35±	86.86	3.68	5.55		2.54	98.63
		35±	85.75	5.39	5.15		1.87	98.16
		35±	90.57	3.57	4.31		1.87	100.32
		35±	87.04	2.34	5.59		2.60	97.57
		35±	94.32	2.87	4.85		0.59	102.68
		35±	93.80	1.48	3.91		0.69	100.09
	Conococheague (upper)	50±	80.97	7.69	8.67		2.77	98.40
		50±	89.43	4.85	5.98		0.69	100.95
		50±	79.47	8.24	7.23		3.46	100.10
2. One mile southwest of junction of State Roads 631 and 625, 2.5 miles east of Marlboro.	Chepultepec	35±	88.62	5.01	6.36		0.96	100.95
		35±	83.86	3.97	8.69		2.27	98.79
		35±	90.54	8.47	2.65		0.91	102.57
		35±	88.93	5.77	6.96		1.38	103.04
		35±	84.59	5.12	6.78		1.24	97.73
		35±	91.72	3.59	3.83		0.90	100.94
		35±	89.90	3.66	4.85		1.04	99.45
		35±	91.45	3.05	4.31		0.49	99.30

Table 3.—*Continued.*

Location	Formation	Thickness (feet)	Chemical Composition					
			$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3 | Al_2O_3	R_2O_3	Total
3. Along U. S. Highway 11, 0.5 mile southwest of Winchester.	Chepultepec (lower)	100	90.24	1.41	8.04		1.47	101.16
	Conococheague (upper)	50	72.76	2.00	22.30		2.35	99.41
4. Along State Road 652, 0.5 mile southeast of Kernstown.	Edinburg	268	87.70	2.75	6.92		2.84	100.21
	Lincolnshire (exclusive of chert)	94	95.77	2.29	1.09		0.98	100.13
5. North of U. S. Highway 50 at southwest end of Hayfield Ridge, 1 mile northwest of Hayfield.	Tonoloway (lower)	50	55.99	1.75	16.86		24.51	99.11
		50	65.17	1.72	20.65		11.14	98.68
		50	54.07	11.89	31.48		4.84	102.28
		50	85.74	3.54	8.53		1.89	99.70
		50	67.29	13.61	12.49		6.22	99.61

Table 3.—*Continued.*

Location	Formation	Thickness (feet)	Chemical Composition					
			$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	Total
6. Near State Road 669, 0.75 mile southeast of Rest.	Edinburg	391	90.89	2.58	5.18	0.34	1.26	100.25
7. Stuart M. Perry Company quarry south of U. S. Highway 50, 2.5 miles west of Winchester.	Conococheague (near middle)	200	68.36	16.10	14.10	1.30	1.40	101.26

Table 4.—Analyses of dolomite at selected localities in Frederick County. (Analyst: Froehling and Robertson, Inc., Nos. 1, 2).

Location	Formation	Thickness (feet)	Chemical Composition					
			$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	Total
1. Along State Road 624 near Cedar Creek.	Beekmantown (upper)	100	51.62	40.91	5.88	0.49	0 56	99.46
2. About 0.5 mile southwest of the intersection of U. S. Highways 50 and 522, 0.5 mile south of Winchester. Partly covered in open field.	Beekmantown (upper)	350±	53.23	41.14	5.30	0.54	0.58	100.79
		350±	54.58	40.59	5.71	0.44	0.63	101.95
		350±	55.41	38.42	5.01	0.50	0.86	100.20
3. M. J. Grove Lime Company quarry, about 1.5 miles west of Middletown. Average analysis (letter August 5, 1964) which represents a rather large tonnage of dolomite.	Beekmantown (upper)		55.72	42.48	1.08	R_2O_3 1.04		100.32

absorbs over 1 to 1½ 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). Aggregate produced from 38 quarries in limestone and dolomite located in the Valley and Ridge province (Gooch and others, 1960, p. 5-28) shows a range in bulk specific gravity from 2.69 to 2.90 with an average of about 2.77.

Carbonate rocks in Shenandoah Valley have been widely used as aggregate in Virginia highway construction. It is significant that the rocks (Elbrook, Conococheague, Beekmantown, New Market, Lincolnshire, and Edinburg formations) tested from 13 quarries (Gooch and others, 1960, p. 5-28), although varying in lithologic character from place to place, have Grade A classification. Physical test data cited (Gooch and others, 1960, p. 11, 20) for two producers in Frederick County are given in Table 5.

Table 5.—Physical test data at two selected localities in Frederick County, modified after Gooch and others (1960, p. 11, 20).

	Location	Formation	Los Angeles Loss (500 rev.)	Absorption	Specific Gravity
1.	M. J. Grove Lime Company mine, about 0.5 mile northwest of Stephens City.	New Market	22.9 - 30.8	0.84	2.72
2.	Stuart M. Perry Company quarry just south of U. S. Highway 50 and about 2.5 miles west of Winchester.	Conococheague	18.1	0.33	2.73

Quarries and Mines

Producers of limestone or dolomite in Frederick County, when visited in July 1964, were the W. S. Frey Company, the M. J. Grove Lime Company Division of the Flintkote Company, Stuart M. Perry, Inc., and the Salem Stone Corporation. The W. S. Frey Company operations (Plate 1, No. 1) are located about 0.4 mile east of Clearbrook.

The high-calcium New Market limestone, exposed in and along the lower east face of the quarry (Figure 8), crops out along the east limb of a small anticline that is plunging gently to the southwest. The company began underground development of the New Market limestone in the quarry during 1964. The Lincolnshire limestone serves as the hanging wall for the mine which consisted, during July 1964, of four tunnels being developed down dip in the east side of the quarry. The company was also developing a new quarry in the New Market limestone just north of State Road 672. Stone from the underground mine and the new quarry is trucked to a crusher just east of the mine site. Company plans called for the development of a tunnel under State Road 672 to connect the new quarry with the underground mine and thereby shorten the trucking distance to the crusher. The high-calcium limestone is marketed chiefly for use as fluxstone for blast and open-hearth furnaces, concrete aggregate, and roadstone. A small quantity of the stone was sold during 1964 for railroad ballast and for use in cement manufacture.

Although the rocks in the quarry were not sampled for this report, limestone from the same belt in the vicinity of Ross Run, a few hundred feet to the southwest, was sampled and analyzed during the earlier survey of the industrial limestones and dolomites in Shenandoah Valley (Edmundson, 1945). The chemical composition of this limestone is shown in Table 2.

The M. J. Grove Lime Company operations are located about 0.5 mile west of Stephens City (Plate 1, No. 2) and about 1.5 miles northwest of Middletown (Plate 1, No. 3). The company produces crushed limestone at each location for use as metallurgical flux, agstone, and in cement, lime, and glass manufacture. West of Stephens City, the general northeasterly trend of the belt of high-calcium New Market limestone is modified by close folding, including a small anticline and syncline which are pitching gently southwestward. The mine of the M. J. Grove Lime Company, in which the high-calcium New Market limestone is produced is located near the southwest end of the anticline. In 1964, work was in progress to supplement the mining operations by developing a quarry in the New Market limestone near the axis of the anticline a few hundred feet southwest of the present operations and at another locality along the west limb of the syncline about 0.7 mile southwest of the mine.

The company also established a quarry during the first half of 1964 in the Lincolnshire formation just southwest of their mine to produce crushed stone for use primarily as road aggregate. The Middletown quarry (Plate 1, No. 3) which began producing high-calcium limestone

in 1939 is located within the Marsh Brook syncline. This narrow structure can be followed by tracing the New Market limestone from a point north of State Road 627 southwestward into Shenandoah County. Because of its gentle plunge to the southwest the syncline deepens and the New Market is separated into two belts with the Lincolnshire retained along the axis of the fold southwest of Nieswanders Fort. Another quarry of the M. J. Grove Lime Company (Plate 1, No. 4) is located about 500 feet west of the Marsh Brook syncline. This quarry, although not operating in 1964, is reported to have produced a large amount of dolomite from the upper part of the Beekmantown formation. The chemical compositions of the New Market limestone and the upper part of the Beekmantown dolomite are shown in Tables 2 and 4.

The Stuart M. Perry, Inc. quarry is located approximately 2.5 miles west of Winchester (Plate 1, No. 5) and a few hundred feet south of U. S. Highway 50. Part of the Conococheague formation, consisting of banded limestone, magnesian limestone, and lesser amounts of dolomite with a few thin layers of sandstone, is well exposed in the quarry. The stone is crushed for use as concrete aggregate, roadstone, agstone, stone sand, and other uses. An average of two samples obtained from the quarry in 1942, each representing about 100 feet of rock, shows 68.36 percent calcium carbonate, 16.10 percent magnesium carbonate, and 14.10 percent silica. The physical properties determined from one sample of rock are shown in Table 5.

The Salem Stone Corporation operations in July 1964 consisted of a new quarry in the Beekmantown limestone and dolomite which is located north of State Road 663 and about 1 mile west of Stephenson; a quarry, temporarily inactive (Figure 9), in the Edinburg limestone located just east of U. S. Highway 11 at Bartonville (Plate 1, No. 10); and another quarry which was being developed in the Edinburg at a locality east of U. S. Highway 11 and about 0.5 mile southwest of Vaucluse. Portable plants were being utilized at each of the quarry sites to produce crushed stone for local road construction. The chemical composition of the Edinburg was not determined for the Salem Stone Corporation sites, but along the same belt of rocks to the northeast in the vicinity of Kernstown, 268 feet of the Edinburg shows 87.70 percent calcium carbonate, 2.75 percent magnesium carbonate, and 6.92 percent silica. For a more detailed account of the industrial limestones and dolomites in Frederick County the reader is referred to Edmundson (1945) and Gooch and others (1960).

CEMENT MATERIALS

Modern 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 5 percent. 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.

None of the rocks analyzed appear to be suitable for the manufacture of natural-rock cement. However, it is probable that several formations in Frederick County could be used as raw materials for the manufacture of portland cement. Among the materials which should receive additional detailed field study and trial runs in a furnace are the New Market (Mosheim), Lincolnshire (Lenoir), and Edinburg (Chambersburg) limestones, and the Martinsburg shale.

The interested reader is referred to a report on the cement resources of Virginia west of the Blue Ridge (Bassler, 1909) for a detailed discussion of the cement industry and an evaluation of the raw materials. For example, the following analysis (Bassler, 1909, p. 69) indicates that the impure Chambersburg (Edinburg of this report) limestone east of Winchester, with a proper admixture of Martinsburg shale which lies immediately above, could be used as raw materials for the manufacture of portland cement:

(*J. H. Gibboney, Analyst*)	*Percent*
Insoluble	14.78
Alumina and iron oxide	2.72
Calcium carbonate	80.25
Magnesium carbonate	0.71
Total	98.46

CLAY, SHALE, AND RELATED MATERIALS

In an early report on the clay and shale resources of Virginia west of the Blue Ridge by Ries and Somers (1920), physical properties were cited for altered Martinsburg shale at a locality about 2.75 miles east of Winchester, and for whitish residual clay, probably derived from Devonian shale, located on the southeast side of Great North Mountain,

a short distance west of Mountain Falls. Firing tests on the Martinsburg shale produce a brick which has a good red color and an excellent ring, whereas the tests of residual clay suggest that it could be used in the manufacture of stoneware. Other whitish residual clays were reported (Ries and Somers, 1920, p. 78) as occurring in several test pits dug for Oriskany brown iron ore on the northwest slope of Great North Mountain near Rock Enon Springs.

A recent comprehensive report (Calver and others, 1961) contains tests and determinations of properties required to evaluate the potential ceramic and nonceramic uses of 15 samples of raw materials collected in Frederick County from the Martinsburg, Marcellus, Hamilton, Brallier, and Chemung formations. Calver and others (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." Potential uses for the raw material sampled at selected localities and from five different formations are shown on Table 6. The interested reader is referred to the report cited above for additional localities sampled and for detailed analyses of the clay materials. At the present time the Shenandoah Brick and Tile Corporation, located about 0.5 mile northeast of Winchester (Plate 1, Nos. 6, 7), is producing raw materials from the basal part of the Martinsburg formation.

MANGANESE ORE

A resurvey of the manganese deposits in southwestern Frederick and northwestern Shenandoah counties (Cedar Creek valley) was begun by the U. S. Geological Survey in 1940, and the results of these studies were published in 1942 (Monroe, 1942, p. 111-141). The results of earlier investigations of this district were published by the Virginia Geological Survey (Stose and Miser, 1922, p. 57-73). The following summary of the Mineral Ridge mine and prospects in southwestern Frederick County is based entirely on these reports.

The Mineral Ridge mine is located on Mineral Ridge, near the Frederick-Shenandoah county line, about 2.1 miles north of Zepp and 8 miles west-northwest of Strasburg. According to Stose and Miser (1922, p. 43):

> "The manganese deposits of western Virginia have been worked at times since 1834 and have yielded both manganese and manganiferous iron ores. The earliest mine to be worked was the Mineral Ridge mine

Table 6.—Potential use of clay materials from Frederick County.
(Data compiled from Calver and others, 1961, p. 55-73).

Location	Formation	Sampled Interval	Potential Use
1. Junction of State Roads 696 and 698, about 1.5 miles north of Whitacre.	Chemung	Composite sample across 240 feet of shale.	Common brick at about 2150°F; probably quarry tile.
2. East side of U. S. Highway 522, about 1 mile south of West Virginia line.	Hamilton	Composite sample across 140 feet of shale.	Common brick at about 2150°F; probably quarry tile.
3. Junction of U. S. Highway 522 and State Road 698, about 1.5 miles northwest of Cross Junction.	Chemung	Composite sample across 130 feet of shale and siltstone.	Common brick at about 2150°F; probably quarry tile.
4. Junction of U. S. Highway 522 and State Road 681, about 3 miles northwest of Nain.	Hamilton	Composite sample across 60 feet of shale.	Common brick at about 2150°F; probably quarry tile.
5. North side of State Road 671, about 0.75 mile west of De Haven.	Brallier	Composite sample across 230 feet of shale and siltstone.	None
6. East side of State Road 600, about 2.25 miles southwest of Hayfield.	Marcellus	Sample of shale from outcrop 10 feet in height.	Common brick and probably quarry tile.
7. Junction of State Roads 667 and 668, about 2 miles northeast of Clearbrook.	Martinsburg	Composite sample across 185 feet of shale.	Common brick and probably quarry tile.

Table 6.—*Continued.*

Location	Formation	Sampled Interval	Potential Use
8. Junction of State Roads 660 and 664, about 2.5 miles southeast of Stephenson.	Martinsburg	Composite sample across 245 feet of shale and mudstone.	Common brick and tile.
9. West side of U. S. Highway 522, just south of Parkins Mills.	Martinsburg	Composite sample across 30 feet of unweathered shale.	Brick, tile, and lightweight aggregate.
		Sample of 10 feet of weathered shale.	Common brick, tile, and lightweight aggregate.
10. Northeast side of State Road 668, about 1.5 miles northwest of the Frederick-Clarke county line.	Martinsburg	Composite sample across 200 feet of unweathered shale and siltstone.	Lightweight aggregate.
		Sample of 7 feet of weathered shale and siltstone.	Brick and tile.
11. West side of U. S. Highway 50, about 4 miles southeast of Winchester.	Martinsburg	Composite sample across 90 feet of unweathered shale and siltstone.	Excellent lightweight aggregate material; might make common brick.
		Sample of 6 feet of weathered shale.	Common brick.

in Frederick County. It is said to have been worked for many years before the Civil War, beginning in 1834, and for many years after the war, and the total production of this mine during the period ending in 1885 is reported to have been about 2,000 tons."

There is no record of any production of manganese ore between 1885 and 1915, although some prospecting (Stose and Miser, 1922, p. 59) was done after the mine was acquired by Charles F. Nelson and associates in 1893. From 1915 to 1920, mining on a small scale by several different operators produced about 1500 tons of ore.

The Mineral Ridge mine was leased by N. H. Mannakee and associates in April 1920, and they worked the mine under the name Hy-Grade Manganese Company. According to Monroe (1942, p. 123-124):

"This company continued ... until January 16, 1929. In October 1929 the property was leased by the Hy-Grade Manganese Production & Sales Corporation, which operated it until December 1932. The mine remained idle from 1932 until September 1940, when it was bought from Mr. Nelson by the American Alloy Corporation. During the period of operation by the Hy-Grade Manganese Co. beginning in 1920 it shipped about 6,440 tons of ore, according to the owner, Charles F. Nelson. The successor company, the Hy-Grade Manganese Production & Sales Corporation, is said by Mr. Nelson to have shipped about 3,545 tons. Thus the total production of the mine before July 1941, the date of the first shipment by the American Alloy Corporation, was about 13,500 tons of ore."

The following information on the mine, from 1941 through 1957, was assembled from records of the Virginia Division of Mineral Resources and from the United States Bureau of Mines "Minerals Yearbook" for those years. The American Alloy Corporation produced about 150 tons of metallurgical-grade manganese ore during 1941. The mine remained idle from 1942 through 1952. The Old Dominion Manganese Company, Inc., produced manganese ore from the Mineral Ridge mine during 1953 and 1954. In 1956 the mine was leased by that company to Hott and Miller, Wardensville, West Virginia, and was operated intermittently until the lease expired in March 1957. The last reported production was by the Old Dominion Manganese Company, Inc., during the months of October and November 1957. A total of 35,000 tons of manganese ore was reported to have been produced from the Mineral Ridge mine during the period 1941 through 1957. The total reported production of manganese ore from the mine from 1920 to 1957 is about 48,500 tons.

The New Scotland limestone, weathered to cherty clay, occupies

the crest of Mineral Ridge and dips in a southeasterly direction. In sequence it is overlain by the Oriskany sandstone on the southeast slope of the ridge and underlain by the Keyser and Tonoloway limestones on the northwest side.

Monroe (1942) refers to a section of rocks exposed in a tunnel and measured by M. I. Goldman in 1928. According to Monroe (1942, p. 125-126), Goldman's notes indicate that:

> "...40 feet of shattered Oriskany sandstone, veined with red clay, is underlain by 82 feet of more or less sandy chert and clay, residual from the New Scotland limestone. This material is underlain by a 2½-foot bed of sandstone containing phosphatic nodules and manganese stains. The sandstone is underlain by 13 feet of cherty clay, which merges downward into 20 to 40 feet of clay derived from limestone, probably the Keyser.
>
> "The New Scotland limestone on the ridge is weathered to cherty clay to the depth of the lowest tunnel, which is at an altitude of 1,233 feet, or more than 200 feet below the crest of the ridge.
>
> * * * * *
>
> "The deposit of manganese ore occurs in the lower part of the sandy and cherty clay that is residual from the New Scotland limestone. Most of the ore is immediately above the phosphatic sandstone bed near the base of the New Scotland, but some is found just below this bed. The ore is irregularly distributed through a zone from about 15 to 30 feet thick."

Manganese prospects (Stose and Miser, 1922, p. 70-73) have been described along the northeasterly extension of Mineral Ridge (Stave Mill and Sarah Orndorff ridges) and at the southwest end of Limestone Ridge, structurally a syncline that plunges northeastward. These test pits and tunnels did not encounter commercial quantities of manganese. Since the proven occurrence of manganese in southwestern Frederick County occurs within the decomposed New Scotland limestone immediately under the Oriskany sandstone, any additional search or prospecting for manganese should first be restricted to areas where these rocks are present (Plate 1).

IRON ORE

The iron industry in Frederick County began at an early date but never experienced any large-scale operation. So far as known to the writer, there has been no production in this area since 1864, and it is not likely that the known local deposits can be operated successfully in the future.

The following historical statement of an early iron furnace in

Frederick County is taken from a placard displayed at the Taylor furnace (Figure 27) which is located along Furnace Run about 2 miles southwest of Mt. Williams:

> "Land: In 1767 Mordecai Bean obtained this land and in 1777 leased the mineral rights to Paddy Mountain from Lord Fairfax. It was here that the first furnace was built by Isaac Zane, Jr. in 1768-'70.
>
> "Taylor Furnace: Built by a Mr. Pennington in 1844—Was operated until 1864."

Holden (1907, p. 429) refers to Zane's furnace on Cedar Creek as being active in Jefferson's time. Evidence of the ruins, presumably the site referred to by Holden, may be seen east of the crossing of Cedar Creek by State Road 628 and about 0.4 mile southwest of Marlboro. Another mention of Zane's charcoal furnace is in *The Virginias* (1882, p. 62). According to this source the Zane furnace, which had a forge, was the earliest iron works in this region; it was abandoned in about 1828. Bruce (1930, p. 21) reports that the iron industry in northern Virginia was begun by Vestal, an immigrant from Pennsylvania, in 1742 and that this operation preceded Zane's Marlborough works by several years. Another furnace, the Paddy hot-blast charcoal furnace, is described in *The Virginias* (1882, p. 62). It was situated on the border of Shenandoah County, 7 miles west of Strasburg and was built in 1833.

The chief source of iron ore in the Great North Mountain area is the Oriskany limonite or brown ore. The name Oriskany is used by Holden (1907, p. 408) for those ores which have a similar origin and occur either in the Helderberg limestone, the Oriskany sandstone, or the lower part of the overlying Devonian shale. Most of the Oriskany limonite is associated with the limestone that immediately underlies the Oriskany sandstone and not in the sandstone itself. This occurrence is similar to that described for manganese on Mineral Ridge.

Extensive workings in the Oriskany, interpreted as the source of the ore for Taylor furnace, were noted along Tunnel Ridge. Other formations which have produced iron ore in western Virginia, south of Frederick County, are the Clinton formation (fossil hematite) and ores associated with the residual decay of Cambrian and Ordovician limestones (limestone limonite). Diggings, now largely overgrown, were noted within the belt mapped as Clinton, north of State Highway 55 and Duck Run and along Little North Mountain, but no fossil hematite was observed by the writer in Frederick County. Holden reports (1907, p. 416) that Clinton ore was little used in charcoal furnaces and was

Figure 27. Taylor furnace along Furnace Run about 2 miles west of Mt. Williams. Sketch of flow sheet and brief history of furnace are displayed on the placard.

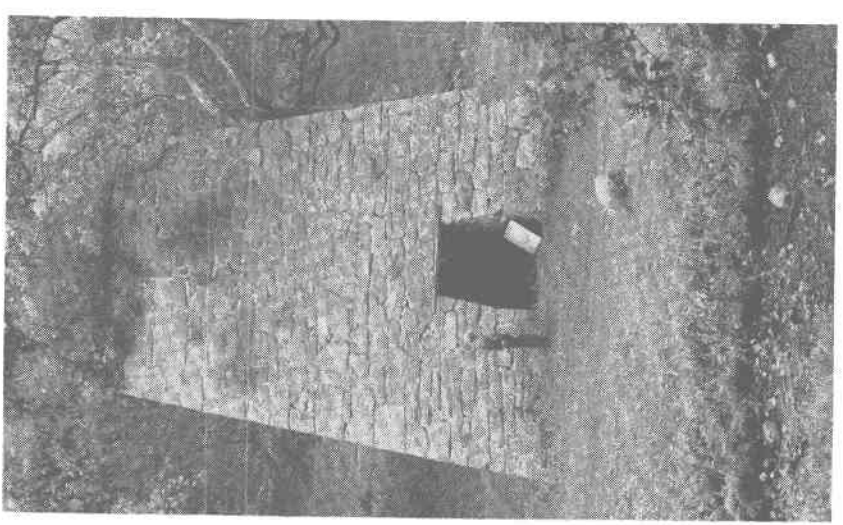

Figure 27. Taylor furnace along Furnace Run about 2 miles west of Mt. Williams. Sketch of flow sheet and brief history of furnace are displayed on the placard.

first mined for shipment in Virginia about 1880. Scattered fragments of limonite or brown iron ore, associated with older limestones, were observed at a few localities but not in quantities to suggest any possible economic importance.

SILICA SAND

According to Lowry (1954, p. 9), the most important sources of silica sand deposits of western Virginia are: (1) Erwin quartzite-Antietam sandstone of Early Cambrian age; (2) Clinch-Tuscarora, Keefer, and Massanutten sandstones of Silurian age; (3) Oriskany sandstone of Devonian age; and (4) Pocono and Price (approximate equivalents) sandstones of Mississippian age. In Frederick County the Tuscarora, Keefer (upper Clinton), and Oriskany sandstones have extensive areas of exposure, whereas the Pocono is restricted to a small area along the crest of Sleepy Creek Mountain at the Virginia-West Virginia boundary (Plate 1).

The Tuscarora crops out along Little North Mountain, on Great North Mountain, and on the southeast slope of Cacapon Mountain. Owing to its hardness and resistance to erosion, it is the dominant ridge-maker in the county. The Tuscarora is overlain by the Clinton formation which is composed of hard, gray sandstone (Keefer) at the top, and fine-grained, thin-bedded sandstone with sandy shale layers in the lower part. The Clinton crops out in Little North Mountain; on both slopes of Great North Mountain northward nearly to U. S. Highway 50 where it dips below the surface on the northward-plunging Great North Mountain anticline; and along the southeast base of Cacapon Mountain in the northwest corner of the county. The Keefer sandstone is particularly well exposed along and about halfway up the southeast slope of Great North Mountain northwest of the village of Mountain Falls. So far as known to the writer, the Tuscarora and Keefer sandstones have not been sampled and analyzed from Frederick County. However, the reader is referred to Lowry's report (1954) for a description of these sandstones, including chemical analyses, from other localities in western Virginia.

The Oriskany sandstone is being quarried by the Virginia Glass Sand Corporation whose quarry (Figure 17) and plant are located near the northeast end of Sand Ridge about 1 mile south of Gore (Plate 1, No. 8). Lowry (1954, p. 26) reports that production began in 1931. Most of the sand recovered is used in the manufacture of glass. The Shenandoah Silica Company, Inc. operates an adjacent processing plant

(Plate 1, No. 9) utilizing sand quarried by the Virginia Glass Sand Corporation to produce silica flour.

The Oriskany sandstone is widely distributed in Frederick County. It crops out along the southeast base of Great North Mountain, swings around the northeast end, and continues southwestward through Rock Enon Springs. Other conspicuous outcrops are on the crest and southeast slopes of Bear Garden and Warm Spring ridges in the northwest corner of the county. The most easterly belt in Frederick County is along the northwest base of Little North Mountain.

Generally, the Oriskany is a coarse-grained, thick-bedded sandstone, but at some localities it contains prominent beds of coarse conglomerate. Some unweathered outcrops are so calcareous that the rock looks like a limestone as, for example, at the west end of an inactive roadside quarry about 0.75 mile northwest of Gainesboro. In contrast, much of the rock exposed in the quarry on Sand Ridge is a quartzose sandstone. According to Lowry (1954, p. 23-25), "A few limy interbeds are present in the west wall of the quarry."

The Oriskany appears to vary widely in composition and thickness within the county. For example, in Tunnel Ridge the Oriskany is a coarse, massive, cavernous, iron-impregnated rock; along Richards Run, about 0.75 mile northwest of Mountain Falls, it consists of approximately 65 feet of light-gray to brown, coarse-grained sandstone with a few pebble zones; and at Rock Enon Springs the exposed thickness of about 100 feet is a light-gray sandstone. The average iron content of samples collected as chips across the exposure at Rock Enon Springs is 0.03 percent of Fe_2O_3. The maximum thickness of the Oriskany appears to be on Sand Ridge and in the belts that are exposed in the northwest section of the county. An attempt was made to determine the thickness in the quarry on Sand Ridge but, due to fractures, the measurements are not conclusive. The distance across the strike, extending from a small anticline in weathered cherty limestone along the west face of the quarry to the top of the Oriskany, is about 450 feet, and the dip at the Oriskany-Onondaga contact is about 45° SE. If an average dip of only 25 degrees is assumed, the thickness is not less than 200 feet at this locality.

The chemical analysis, made by Sharp-Schurtz Co., of grab samples from 5 or 6 carloads of silica sand produced by the Virginia Glass Sand Corporation (Lowry, 1954, p. 25) is as follows:

	Percent
SiO_2 (silica)	99.16
Fe_2O_3 (iron oxide)	0.029
Al_2O_3 (alumina)	0.43
TiO_2 (titania)	0.034
CaO (lime)	0.08
MgO (magnesia)	trace
Loss on ignition	0.18

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APPENDIX I

DISCUSSION OF LOWER MIDDLE ORDOVICIAN LIMESTONES IN SHENANDOAH VALLEY, VIRGINIA

By
CHARLES BUTTS

The following descriptions dealing with age and correlation, and the geologic section are modified from Butts' manuscript (1943). The lithologic descriptions of the formations and their distribution in Frederick County have been used by the junior writer in this report but included under the newer nomenclature—New Market, Lincolnshire, Edinburg, and Oranda.

Geologic section of the Chambersburg and associated formations along Tumbling Run, 1.5 miles southwest of Strasburg, Shenandoah County.

	Thickness Feet
MARTINSBURG FORMATION (lower part of Trenton exposed along U. S. Highway 11, 0.5 mile south of Tumbling Run)	
9. Shale, black, slaty; weathers gray; thin limestones; contains *Dalmanella* cf. *D. fertilis, Cryptolithus tessellatus, Tetradella subquadrans, Diplograptus amplexicaulis?*	20
CHAMBERSBURG LIMESTONE	
8. *Christiania* bed—Mudrock, calcareous, massive, argillaceous, non-splittable, tough, ragged fracture; mottled yellowish and grayish as weathered; contains *Christiania trentonensis, Bimuria lamellosa, Eoplectodonta, Leptellina, Multicostella, Ptychoglyptus sculpturatus, Reuschella edsoni, Resserella*	40±
7. *Nidulites* bed—Limestone, medium thick-bedded, 2- to 6-inch layers; some blocky, jointed to nodular, some compact; dark-gray to black, conchoidal fracture; identical with layers in the Athens; weathers bluish-gray. *Nidulites pyriformis* abundant in some layers in the middle and upper parts. *Corinorthis, Dinorthis, Ampyx hastata, Homotelus simplex,* and *Echinosphaerites* near bottom	400
6. Tumbling Run bed—Sandstone, laminated; brownish as weathered. A good horizon marker	3+
5. Bentonite bed—Limestone, top 5 feet, raggedly nodular, more evenly bedded below with thin layers of bentonite	20±
HIATUS: Holston, Whitesburg, and Athens absent	
LENOIR LIMESTONE	
4. Limestone, rather thin bedded, dark, finely crystalline; scattered nodules of black chert. *Rhinidictya* cf. *R. trentonensis, Cyrtono-*	

	Thickness Feet
tella, Dinorthis atavoides, Multicostella platys?, Sowerbyites, Homotelus, Leperditella cf. *L. sulcata* abundant locally, just above *Girvanella* bed. Etched material source of abundant microfossils	60±
3. Limestone, dark, rather thick-bedded, crystalline; layers commonly split into irregular lenticles, nodules, or slabs; stringers and plates of black chert throughout. *Girvanella* abundant in top 10 feet (*Girvanella* bed). *Rhinidictya* cf. *R. trentonensis, Multicostella platys?, Oxoplecia, Strophomena, Illaenus, Leperditia*	100±
MOSHEIM LIMESTONE	
2. Limestone, thick-bedded, compact, high-purity, quarry rock of the region. *Tetradium syringoporoides* in top (The Mosheim and the rock below the *Girvanella* bed in unit 3 are the Stones River of Bassler)	50
BEEKMANTOWN FORMATION	
1. Dolomite	

MOSHEIM LIMESTONE

Throughout the northern part of the Appalachian Valley in Virginia the Beekmantown is directly overlain by the Mosheim limestone. In the southern part of the Valley a formation identified as the Murfreesboro lies between the Beekmantown and the Mosheim.

The Mosheim is sparsely fossiliferous. All the fossils that have been observed in the county are sections of gastropods, which occur on the weathered surface of the limestone. The most abundant forms suggest *Trochonemella.* Other sections seem to be *Lophospira grandis.* These forms, together with characteristic lithology and stratigraphic relations, give convincing evidence that the formation containing them here is Mosheim. Another significant form is *Tetradium syringoporoides,* which has been collected in the vicinity of Strasburg, Shenandoah County.

LENOIR LIMESTONE

Locally at least, as on the Southern Railroad a few hundred feet northeast of Strasburg Junction, Shenandoah County, the Lenoir is firmly cemented to the Mosheim, the change from the dove-colored limestone of the Mosheim to the dark crystalline limestone of the Lenoir being abrupt and conspicuous. In Frederick County the Lenoir is terminated at the top by a hiatus, since the Holston, Whitesburg, and Athens are absent.

The Lenoir is moderately fossiliferous. The fossils are mostly revealed on weathered pieces of black chert, but many fine silicified examples have been etched from slabs of limestone derived from that part of the formation above the *Girvanella* bed shown in the Tumbling Run section. The etched material includes many fine examples of rhinidictoid Bryozoa, such as *Rhinidictya, Graptodictya,* and other forms as *Arthroclema, Nematopora,* and *Bythopora(?)*. The rhinidictoid types, however, range through the full thickness of the formation. A list of more than 50 fossils, mainly identified by Ulrich, have been collected along the outcrops from Toms Brook, Shenandoah County, through Frederick and Clarke counties. It is evident from this list,[1] mainly of generic determinations, that the correlative value is small. It will serve as a starting point for future comparative studies, including precise specific determinations which must be made for reliable stratigraphic correlation. As it stands at present (1943), the identification of this limestone as Lenoir rests mainly upon its stratigraphic relations. The sequence of Lenoir, Mosheim, and Beekmantown is persistent the full length of the Valley in Virginia. In Washington and Smyth counties in southern Virginia, the Lenoir, as determined by stratigraphy, contains *Maclurites magnus,* which is also so common in the typical Lenoir limestone at Lenoir City, Tennessee. What has always been identified as *Maclurites* (*Maclurea*) *magnus* is very abundant in the Crown Point (Chazy) limestone. There may be some significance in the fact that the earliest occurrence of *Rhinidictya* (*Stictopora*) *fasciata* (Hall, 1847), is in the Chazy limestone at Chazy, New York, and so far as known, the earliest occurrence of *Rhinidictya* in the Appalachian Valley is in the Lenoir. Owing to uncertainty as to the identity of this limestone with the type Lenoir, Ulrich (1939, p. 106) has proposed the name Strasburg for it because of a good exposure near Strasburg Junction, Shenandoah County.

CHAMBERSBURG LIMESTONE

The Chambersburg limestone was named by Stose (1906, p. 211) and applied by Bassler (1909, p. 56) to a thick body of limestone at Strasburg, Shenandoah County, which lies between the Lenoir (Stones River) limestone and the Martinsburg shale. The same correlation is given in the Tumbling Run section, except that the *Girvanella* bed is here included in the Lenoir rather than in the Chambersburg as shown by Bassler. As interpreted by the writer, the Chambersburg begins at a

[1]Manuscript on file at the Virginia Division of Mineral Resources, Charlottesville.

position which is believed to be about 20 feet below a laminated sandstone, about 3 feet thick, here named the Tumbling Run sandstone. The boundary is placed here because of the occurrence of bentonite which is especially common in rocks of Black River age. Another reason for this interpretation is the occurrence of a great hiatus between the Lenoir and Chambersburg, as here defined, as far south as the vicinity of Edinburg, at least, and probably to the vicinity of Mount Jackson. By continuous tracing in the summer of 1943, the continuity of Beekmantown, Mosheim, and Lenoir, in upward sequence, southwest of Lacy Springs, was established. Likewise the continuity of the Chambersburg with *Nidulites* and the immediately overlying *Christiania* bed was established. The Chambersburg and Lenoir continue in contact to the vicinity of Edinburg, but 4 miles south of Mount Jackson the Lenoir is separated from the Chambersburg by a space 700 feet wide and at Lacy Springs by a space 3000 feet or more wide. This space is occupied by limestone bearing such Athens (Normanskill) fossils as *Nemagraptus gracilis, Dicranograptus, Dicellograptus, Robergia major,* and *Ampyxina scarabeaus.* Because the Athens is absent at Strasburg and as far south as Edinburg, there is a hiatus between the Chambersburg and the Lenoir which is tentatively placed at the base of unit 5 in the Tumbling Run section.

The Tumbling Run sandstone makes a low ridge which can be followed north of Tumbling Run toward the railroad track 0.25 mile east of Strasburg-Junction, and, in the fields south of Tumbling Run to the vicinity of Maurertown. A similar bed, supposed to be the same, crops out on a low ridge 0.25 mile northwest of the quarry at Stephens City, also just north of Town Run northwest of the big spring at Winchester (Edmundson, 1939, p. 99-104), and in three places, close together, about 1 mile east of Glendale School, Clarke County. The character and thickness of the rock at all of these places indicate that it is the same bed throughout, which, if true, shows that the bed has a wide distribution which could greatly extend its servicability as a horizon marker.

The *Nidulites* bed, immediately overlying the Tumbling Run sandstone on Tumbling Run, is about 400 feet thick and, in general, consists of dark to black, compact limestone which can be easily distinguished from crystalline limestone of the Lenoir. In color and texture it closely resembles the Athens limestone. However, it differs in structure, being commonly blocky jointed or nodular instead of in continuous thin even layers as is the Athens.

The *Nidulites* bed is highly fossiliferous, but the fossils are usually

fragmentary. Some of the fossils are silicified and good specimens can be etched from the limestone by acid. As in the case of the Lenoir fossils, most of the identifications (36 types) are generic only and were made by Ulrich from material collected from the Strasburg section. The most significant fossil for determination of age for regional correlation is *Nidulites pyriformis* which is widely distributed from the Chambersburg region of Pennsylvania to the vicinity of Lexington, Virginia. Another fossil indicating the Chambersburg is an undescribed brachiopod identified by G. A. Cooper as possibly a species of *Corinorthis*. This form occurs at the base of the Chambersburg 2 miles southwest of Marion, Pennsylvania; it occurs in the same position 0.5 mile north of Glendale School, Clarke County, and at a point 0.5 mile north of Toms Brook, Shenandoah County.

The paleontological data in hand do not afford conclusive evidence of the Chambersburg and of its position in the general time scale. Ulrich, in his original description of the Chambersburg in the Mercersburg-Chambersburg folio, placed the *Nidulites* zone above the equivalent of the Lowville limestone, but it has not been possible to verify the correctness of that assignment. Nowhere has *Nidulites* been found in beds definitely overlying the Lowville in the same section. Tested by this decisive criterion of superposition, the proposition that the Chambersburg overlies the Lowville fails.

The Lowville is not present in recognizable form in Frederick County, nor has it been found anywhere along the southeast side of the Valley northeast of Roanoke. On the other hand, the occurrence of *Nidulites pyriformis* in the Ottosee limestone in southern Virginia south of Tazewell has been discovered. This occurrence could be held to indicate the equivalence of the Chambersburg with the Ottosee. The Ottosee is definitely below the Lowville. That fact is attested by the occurrence of a diagnostic Lowville fossil, *Cryptophragmus antiquatus,* above the Ottosee in southern Virginia. The pre-Lowville age of the Chambersburg is further indicated by such fossils as *Arthrorachis, Brontopsis,* and *Cybelloides* which do not occur in the Lowville but which are fairly common in pre-Lowville formations, a fact that indicates that the Chambersburg is older than the Lowville.

The *Nidulites* bed is overlain by about 40 feet of dark argillaceous-calcareous rock which is named the *Christiania* bed because of the occurrence of *Christiania trentonensis.* Although the *Christiania* bed has been noted at several localities in Frederick County, the best exposures are along U. S. Highway 11 about 1 mile southwest of Strasburg, and in a steep roadcut about 0.25 mile south of Tumbling Run.

The *Christiania* bed is moderately fossiliferous, but few of the fossils have precise correlative value in the present stage of specific identification and comparison with fossils from other localities. *Bimuria lamellosa* and *Christiania trentonensis* occur in the *Christiania* or Greencastle bed at the top of the type Chambersburg of Pennsylvania. The *Bimuria* occurs in shale, probably decalcified shale much like the same bed in Virginia, at the top of the *Nidulites* bed 1 mile northwest of Guilford Springs, Pennsylvania. *Aparchites granilabiatus* is an upper Black River, Decorah shale, fossil while *Leperditella tumida* is referred to the lower Black River, specifically, Lowville limestone. It is to be noted, however, that Ulrich identified *A. granilabiatus* from the Lenoir. *Reuschella edsoni* and *Cryptolithus tessellata,* which occur with *Reuschella* east of Willow Grove, Shenandoah County, and west of Linville, Rockingham County, are regarded as basal Martinsburg or Trenton fossils.

From the meager evidence afforded by the fossils, it may be justifiable to assume that both Lowville and Trenton are represented in the *Christiania* bed. This would be consistent with correlating the *Nidulites* bed with the Ottosee, and would explain the practical disappearance of the Lowville from this part of Virginia.

APPENDIX II

LIST OF FOSSIL NAMES

Fossil Names Used in Text	Updated Generic Names
PORIFERA	
Nidulites pyriformis Bassler	
COELENTERATES	
Cladopora? sp.	
Cryptophragmus antiquatus Raymond	
Favosites hamiltoniae? Hall	
F. helderbergiae Hall	
F. niagarensis Hall	
Microcyclus intermedius Bassler	
M. sp.	
Plumalina plumaria? Hall	
Stromatopora concentrica Goldfuss	
Syringopora sp.	
Tetradium syringoporoides Ulrich	
Trachypora elegantula? Billings	
BRYOZOANS	
Arthroclema sp.	
Bythopora? sp.	
Cystodictya ovatipora (Hall)	
C. sp.	
Fenestellids, several species	
Graptodictya sp.	
Monotrypella? arbusculas (Hall and Simpson)	
Nematopora sp.	
Paleschara sp.	
Rhombotrypa ramulosa Bassler	
Rhinidictya fasciata (Hall)	
R. sp.	
R. cf. *trentonensis* Ulrich	
BRACHIOPODS	
Ambocoelia umbonata (Conrad)	
Anoplotheca acutiplicata (Conrad)	
A. hemispherica (Sowerby)	*Coelospira hemispherica* (Sowerby)
Atrypa reticularis (Linné)	
Bimuria lamellosa (Bassler)	
B. sp.	
Camarotoechia congregata? (Conrad)	

C. eximia (Hall)	*"Camarotoechia" eximia* (Hall)
C. litchfieldensis (Schuchert)	*Cupularostrum litchfieldensis* (Schuchert)
C. litchfieldensis var. *marylandica* Swartz	*"Camarotoechia" litchfieldensis* var. *marylandica* Swartz
C. sp.	
Chonetes buttsi Kindle	*"Chonetes" buttsi* Kindle
C. aff. *coronatus* (Conrad)	*Devonochonetes* aff. *coronatus* (Hall)
C. jerseyensis Weller	*Eccentricosta jerseyensis* (Weller)
C. cf. *lepidus* Hall	*"Chonetes"* cf. *lepidus* Hall
C. novascoticus Hall	*"Chonetes" novascoticus* Hall
C. mucronatus? (Hall)	
C. vicinus? (Castelnau)	*"Chonetes" vicinus?* (Castelnau)
Christiania trentonensis Ruedemann	
Corinorthis sp.	
Costellirostra peculiaris (Conrad)	
Cranaena lincklaeni (Hall)	
Cyrtina hamiltonensis (Hall)	
Cyrtonotella sp.	
Dalmanella emacerata? (Hall)	
D. cf. *fertilis* Bassler	
D. meeki (Miller)	
D. sp.	
Delthyris mesacostalis (Hall)	*Tylothyris mesacostalis* (Hall)
D. perlamellosus (Hall)	*Kozlowskiellina perlamellosa* (Hall)
Diaphelasma pennsylvanicum Ulrich and Cooper	
Dinorthis atavoides Willard	
D. sp.	
Eatonia medialis (Vanuxem)	
Eoplectodonta alternata	
Finkelnburgia virginica Ulrich and Cooper	
Gypidula sp.	
Hindella? congregata Swartz	
Leiorhynchus globuliforme (Vanuxem)	
L. limitare (Vanuxem)	
Leptellina sp.	
Lingulasma sp.	
Meristella praenuntia Schuchert and Maynard	
M. sp.	
Multicostella platys? (Billings)	
M. sp.	
Nanothyris mutabilis (Hall)	
Nucleospira swartzi Maynard	
Orthorhynchula linneyi (James)	
Orthotetes arctostriata (Hall)	*"Orthotetes" arctostriata* (Hall)

Oxoplecia simulatrix (Bassler)	
O. sp.	
Productella exanthemata? (Hall)	
P. lachrymosa (Conrad)	
P. speciosa? Hall	
Ptychoglyptus sculpturatus (Bassler)	
Pugnax altus (Calvin)	
P. sp.	
Rafinesquina alternata (Emmons)	
Rensselaeria marylandica Hall	
Reticularia laevis (Hall)	*"Reticularia" laevis* (Hall)
Reuschella edsoni (Bassler)	
Rhipidomella emarginata (Hall)	
R. vanuxemi (Hall)	
Schellwienella woolworthana? (Hall)	*"Schellwienella" woolworthana?* (Hall)
Schizophoria impressa (Hall)	
Schuchertella prolifica Schuchert and Maynard	*"Schuchertella" prolifica* Schuchert and Maynard
Sowerbyites sp.	
Spirifer arenosus (Conrad)	*Costispirifer arenosus* (Conrad)
S. audaculus (Conrad)	*Brachyspirifer audaculus* (Conrad)
S. concinnus Hall	*"Spirifer" concinnus* Hall
S. disjunctus (Sowerby)	*Cyrtospirifer disjunctus* (Sowerby)
S. granulosus (Conrad)	*Spinocyrtia granulosa* (Conrad)
S. macropleurus (Conrad)	*Macropleura macropleura* (Conrad)
S. mesastrialis (Hall)	*Platyrachella mesastrialis* (Hall)
S. modestus Hall	*Howellella modesta* (Hall)
S. mucronatus (Conrad)	*Mucrospirifer mucronatus* (Conrad)
S. mucronatus posterus Hall and Clarke	*"Spirifer" mucronatus posterus* Hall and Clarke
S. murchisoni Castelnau	*Acrospirifer murchisoni* (Castelnau)
S. tullius Hall	*"Spirifer" tullius* Hall
S. vanuxemi Hall	*Howellella vanuxemi* (Hall)
Strophodonta bipartita (Hall)	*Leptostrophia bipartita* (Hall)
S. concava (Hall)	*Megastrophia concava* (Hall)
S. demissa (Conrad)	
S. inequistriata? (Conrad)	*"Strophodonta" inequistriata* (Conrad)
S. perplana (Conrad)	*Protoleptostrophia perplana* (Conrad)
Strophomena sp.	
Tetralobula delicatula Ulrich and Cooper	
Tropidoleptus carinatus (Conrad)	
Uncinulus keyserensis Schuchert and Maynard	*"Uncinulus" keyserensis* Schuchert and Maynard

PELECYPODS

Actinopteria decussata? (Hall)
Aviculopecten sp.

Byssonychia radiata (Hall)	*Ambonychia radiata* Hall
Ectenodesma birostratum Hall	
Glossites? sp.	
Glyptodesma erectum (Conrad)	
Goniophora chemungensis? (Vanuxem)	
Leiopteria cf. *bigsbyi* Hall	
Leptodesma potens Hall	
Lyriopecten tricostatus (Vanuxem)	
Modiodesma? sp.	
Modiomorpha alta (Conrad)	
M. concentrica (Conrad)	
Nucula corbuliformis Hall	
Nuculites oblongatus Conrad	
Orthodesma? sp.	
Palaeneilo maxima	
Paracyclas lirata (Conrad)	
Pterinea dispanda? (Hall)	*Cornellites dispanda?* (Hall)
P. flabella (Conrad)	*C. flabella* (Conrad)
Schizodus chemungensis? (Conrad)	
Sphenotus sp.	

GASTROPODS

Bucanopsis maera (Hall)	*Aglaoglypta maera* (Hall)
Calaurops lituiformi Whitfield	
Ceratopea sp.	
Cyclonema crenulistriata (Clarke and Swartz)	
C. multistriata (Clarke and Swartz)	
C. sp.	
Ecculiomphalus perkinsi (Whitfield)	
E. triangulus (Whitfield)	
Gasconadia sp.	
Helicotoma sp.	
Hormotoma gracilens (Whitfield)	
H. rowei Swartz	
Lecanospira sp.	
Lophospira grandis Butts	
Loxonema terebrum? Hall	
Maclurites magnus Lesueur	
Ophileta canadensis (Billings)	
O. hunterensis (Cleland)	
Ozarkina sp.	
Platyceras gebhardi Conrad	
P. subfalcatum Ohern	
P. trilobatum Hall	
Pleurotomaria arabella Billings	*"Pleurotomaria" arabella* Billings
P. ella? Hall	*"P." ella?* Hall
Trochonemella sp.	

CEPHALOPODS

Bactrites sp.
Centrotarphyceras macdonaldi (Hyatt)
Cyrtocerina sp.
Dakeoceras sp.
Pionoceras swartzi (Ulrich and Foerste)

CRICOCONARIDS

Styliolina fissurella (Hall)
Tentaculites gyracanthus (Eaton)

ECHINODERMS

Ancyrocrinus bulbosus Hall
Arthroacantha ithacensis Williams
Echinosphaerites sp.
Ectenocrinus simplex (Hall)
Edriocrinus pocilliformis Hall
Glyptocrinus pattersoni Miller
Lepocrinites manlius Schuchert
Technocrinus andrewsi (Hall)
T. lepidus Ohern

TRILOBITES

Acidaspis callicera Hall and Clarke
Ampyx hastata Ruedemann
Ampyxina scarabeaus Butts
Arthrorachis sp.
Bronteopsis sp.
Calymene camerata Conrad
C. meeki Foerste
Cryptolithus bellulus (Ulrich)
C. tessellatus Green
Cybeloides sp.
Dipleura (*Homalonotus*) *dekayi* Green
Glossopleura bassleri Resser
Glyphaspis sp.
Homotelus simplex (Raymond and Narraway)
H. sp.
Illaenus sp.
Lichas contusus Hall and Clarke
Liocalymene clintoni (Vanuxem)
Odontocephalus aegeria Hall
Phacops rana (Green)
Robergia major Raymond
Saukia stosei Walcott
Symphysurina sp.
Tellerina wardi (Walcott)

OSTRACODES

Aparchites granilabiatus
Bollia ungula Jones
Bonnemaia sp.
Bythocypris phaseolina Ulrich and Bassler
Ctenobolbina ciliata? (Emmons)
Dizygopleura swartzi Ulrich and Bassler
D. sp.
Eukloedenella sinuata Ulrich and Bassler
E. sp.
Favulella favulosa (Jones)
Kloedenia nearpassi? (Weller)
K. normalis? Ulrich and Bassler
K. sp.
Kyammodes sp.
Leperditia alta (Conrad)
L. altoides Weller
L. elongata willsensis Ulrich and Bassler
L. mathewsi Ulrich and Bassler
Leperditella cf. *sulcata* (Ulrich)
L. tumida (Ulrich)
Mastigobolbina sp.
Octonaria stigmata Ulrich
Tetradella subquadrans Ulrich
Zygobeyrichia? sp.
Zygobolba sp.
Zygobolbina sp.
Zygosella sp.
Zygobeyrichia nearpassi? (Weller)
"Kloedenia" normalis? Ulrich and Bassler
Pintopsis sp.

TRACE FOSSILS

Arthrophycus sp.
Pteridichnites biseriatus Clarke and Swartz
Scolithus sp.
Taonurus velus (Vanuxem)
Skolithos sp.

STOMOCHORDATES

Corynoides cf. *gracilis* Hopkinson
Dicellograptus sp.
Dicranograptus sp.
Diplograptus amplexicaulis (Hall)
Nemagraptus gracilis (Hall)

VERTEBRATES

Acantholepis (fish spine)

PLANTS

Collenia undosa Walcott
Girvanella sp.
Protolepidodendron sp.

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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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Geologic Map

FREDERICK COUNTY, VIRGINIA

Geology by Charles Butts and Raymond S. Edmundson

SCALE 1:62500

1963

EXPLANATION

MISSISSIPPIAN

- Mpo — Pocono (?) formation. *Shale, sandstone, and conglomerate. Noted only in Shockeys Knob along the Virginia - West Virginia boundary.*

DEVONIAN

- Dhs — Hampshire formation. *Chiefly red shale, mudrock, and sandstone.*
- Dch — Chemung formation. *Chiefly gray shale and sandstone with thin conglomerates and a few red zones.*
- Db — Brallier formation. *Greenish to brown micaceous shale with thin intercalated layers of fine-grained gray sandstone.*
- Dha — Hamilton formation. *Dark-gray to olive-green fine-grained sandstone with interbedded dark-colored shale.*
- Dmr — Marcellus shale. *Dark-gray to black, fissile shale; weathers gray.*
- Don — Onondaga formation. *Dark-green, non-fissile shale; in part calcareous.*
- Do — Oriskany sandstone. *Gray to white, coarse-grained, thick-bedded sandstone.*
- Dns — New Scotland limestone. *Bluish-gray, fine-grained, cherty limestone; locally includes a few feet of coarsely crystalline Coeymans type limestone at base.*
- Sk — Keyser formation. *Dark-gray, medium-grained, nodular weathering limestone.*
- St — Tonoloway formation. *Blue-gray, thin-bedded limestone with sandy layers.*
- Swc — Wills Creek formation. *Calcareous mudrock, fine-grained sandstone, and lenses of red shale.*
- Sb — Bloomsburg formation. *Red, thick-bedded sandstone with layers of compact, red mudrock.*
- Smk — McKenzie formation. *Gray, fissile shale with thin layers of sandstone.*
- Scl — Clinton formation. *Gray, medium-bedded, Keefer Sse sandstone at top; lower division, thin-bedded, gray sandstone and shale with some red "Cacapon" type sandstone.*
- Stu — Tuscarora formation. *Gray to white, thick-bedded sandstone with a few beds of conglomerate.*

DSoh — Oriskany sandstone and Helderberg limestones

Scy — Formations of Cayuga age

ORDOVICIAN

- Oj — Juniata formation. *Chiefly red shale or red, lumpy mudrock, and thin-bedded, red, arkosic sandstone.*
- Oos — Oswego formation. *Gray and greenish, thick-bedded, coarse-grained sandstone and coarse conglomerate.*
- Omb — Martinsburg formation. *Brownish, fissile shale and thinly laminated, fine-grained sandstone.*
- Oe — Edinburg (Chambersburg, Athens) formation. *Dark-gray to black, compact limestone with nodular layers, thin siltstones and variable amounts of black shale.*
- Ol — Lincolnshire (Lenoir) formation. *Dark-gray, finely crystalline limestone with stringers and nodules of black chert.*
- On — New Market (Mosheim) limestone. *Dove-colored, compact, thick-bedded limestone.*
- Obe — Bellefonte (Upper Beekmantown) formation. *Light to dark-colored limestone with finely crystalline gray dolomite.*
- Oni — Nittany (Lower Beekmantown) formation. *Bluish-gray limestone with minor amounts of gray dolomite.*
- Och — Chepultepec formation. *Bluish-gray, thick-bedded limestone with thin layers of magnesian limestone.*

Ojos — Juniata and Oswego formations

CAMBRIAN

- Cco — Conococheague formation. *Bluish-gray limestone with minor amounts of interbedded gray dolomite. Distinctive features are thin laminae, containing siliceous material, which weathers out on the surface as crinkly ribs, and a few beds of coarse-grained friable sandstone.*
- Ce — Elbrook formation. *Predominantly thin-bedded impure limestone and dolomite which commonly weathers on the surface to rusty-looking slabs and thin plates.*

SILURIAN

CONTACTS

Dashed where approximately located.

FAULTS

HIGH-ANGLE — Dashed where approximately located; arrows indicate relative movement.

THRUST — Dashed where approximately located; T indicates overthrust side.

Existence uncertain.

FOLDS

Anticline - trace of axial plane; arrow indicates plunge

Syncline - trace of axial plane; arrow indicates plunge

ATTITUDE OF ROCKS

Strike and dip of beds

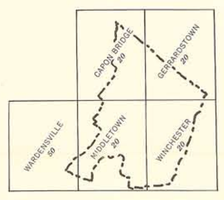
Strike and dip of overturned beds

Strike of vertical beds

Horizontal beds

ACTIVE MINES, QUARRIES, PLANTS

1. W. S. Frey, limestone quarry, Clearbrook
2. M. J. Grove Lime Company, mine, Stephens City
3. M. J. Grove Lime Company, limestone quarry, Middletown
4. M. J. Grove Lime Company, dolomite quarry, Middletown
5. Stuart M. Perry, Inc., limestone quarry, Winchester
6. Shenandoah Brick and Tile Corporation, quarry, Winchester
7. Shenandoah Brick and Tile Corporation, plant
8. Virginia Glass Sand Corporation, glass sand quarry, Gore
9. Shenandoah Silica Company, Inc., processing plant, Gore
10. Salem Stone Corporation, Bartonville



Topographic map from United States Geological Survey 15 - minute series. Contour intervals designated on index of quadrangles.

Geology compiled from manuscript maps by Charles Butts and Raymond S. Edmundson and prepared jointly, 1936-1940; additional mapping by R.S.E. on industrial limestones and Little North Mountain in 1942, 1946, 1961 and 1962.

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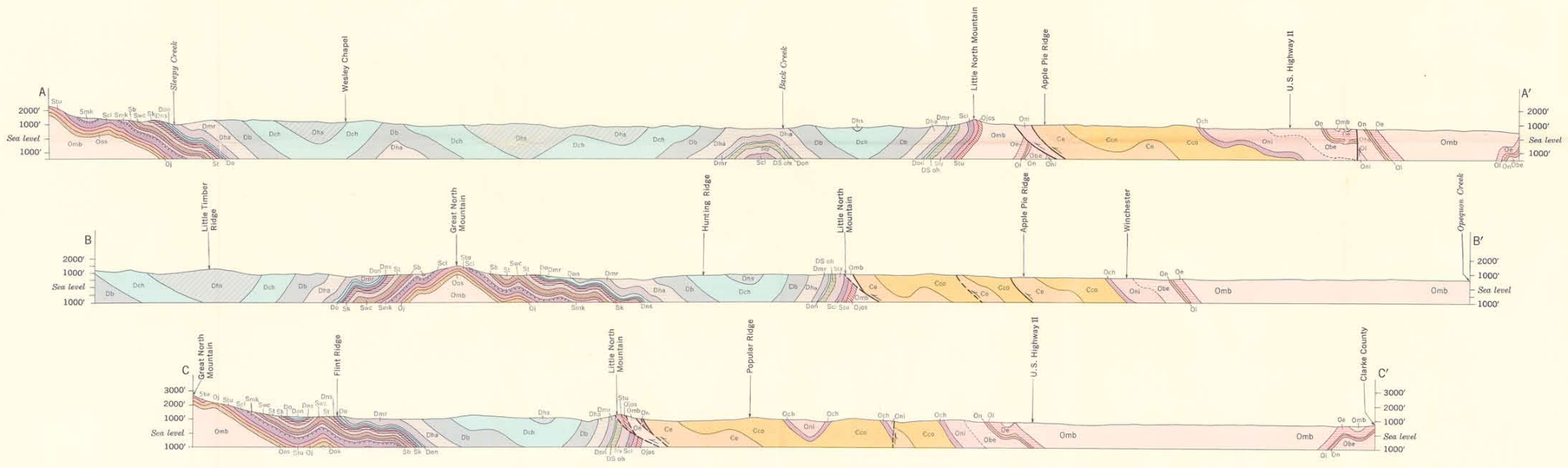


No Vertical Exaggeration

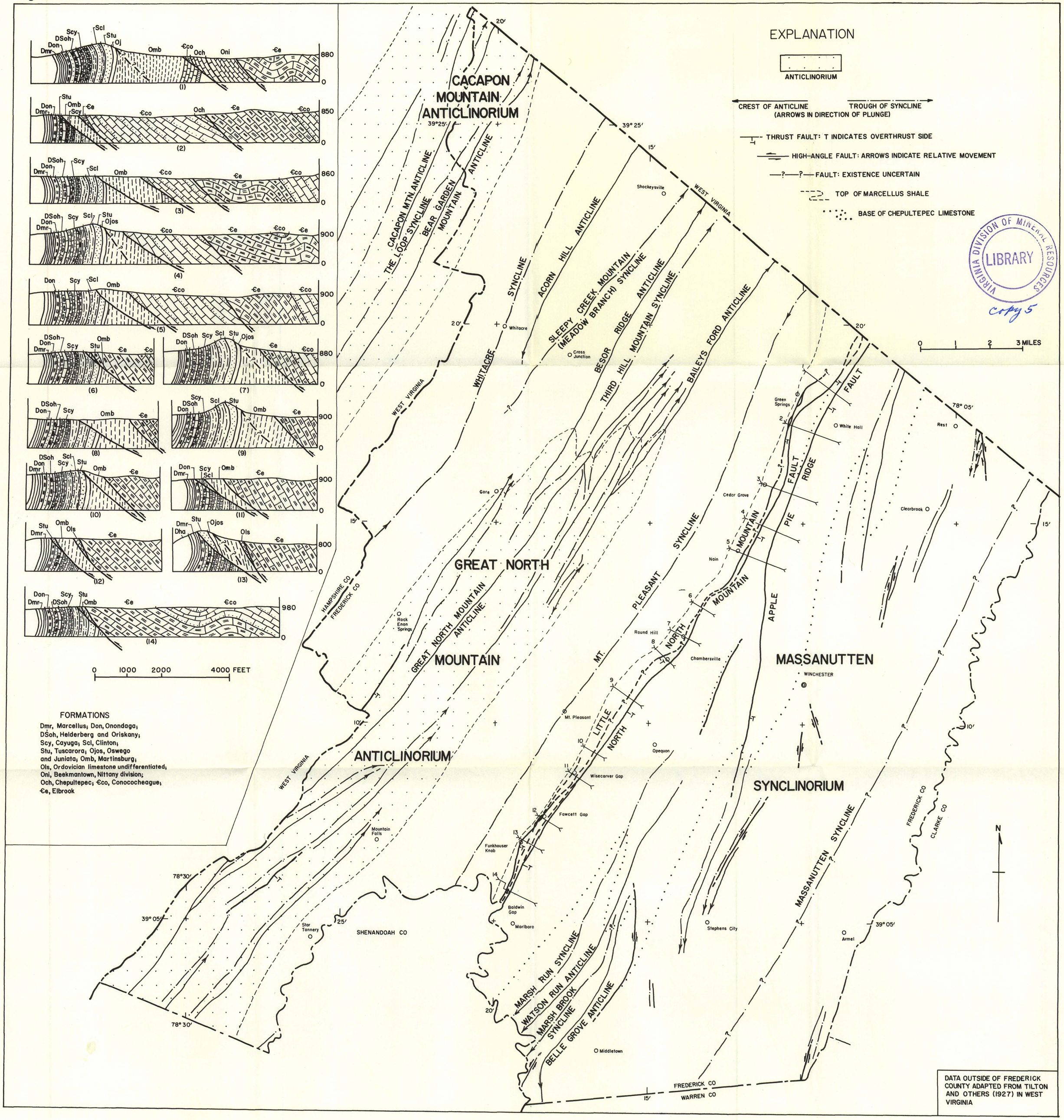
Structure Sections by Raymond S. Edmundson

ERRATA ON GEOLOGIC MAP

1. In the Explanation, Edinburg formation should read Edinburg and Oranda formations.

2. The color pattern for the small inlier between Tunnel Ridge and St. Johns Church should be that of Swc, as the letter symbol shows.

3. The structure designated as North Mountain anticline should read Great North Mountain anticline and the axis should be extended southwestward from High Knob into Vances Cove (see Plate 2).



Map of structural elements in Frederick County, and generalized structure sections of Little North Mountain